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Solar Thermal Utility-Scale Joint Venture Program (USJVP) Final Report

SAIC Energy Products Division

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Solar Thermal Utility- Scale Joint Venture Program (USJVP) Final Report

26 January 2001

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1.0 Introduction

1.1. The Utility-Scale Joint Venture Program

The Utility-Scale Joint Venture Program (USJVP) is a joint effort between Science Applications International Corporation (SAIC), STM Corporation, and Sandia National Laboratories to develop and test a utility-scale dish/Stirling solar power system. The program consisted of two phases. In the first phase, a single prototype dish/Stirling system was designed, constructed, and operated at a test site near Golden, Colorado. In the second phase, the design of the dish/Stirling system was improved and systems installed and operated at four sites:

- National Renewable Energy Laboratory (NREL) Mesa Test Site, Golden, Colorado
- Arizona Public Service Co. Solar Test and Research (STAR) Facility, Tempe, Arizona
- Salt River Project (SRP), Mesa, Arizona
- Pentagon Utility Plant, Washington, D.C.

Although funded by another source, the Washington, D.C. installation is included in this report for completeness because its design was that of a Phase 2 system. The Washington, D.C. unit was moved after six months to become the APS West unit.

The Phase 1 dish/Stirling system was a solar-only system employing a radial truss/hub design for the dish and a Gen. 2 STM Stirling engine. The dish controls employed conventional off-the-shelf hardware and required operator intervention for normal operation. Installation of the prototype system started in late 1994 and it operated from June 1995 until July 1996, accumulating approximately 300 hours of on-sun operation.

Throughout the second phase of the USJVP, many improvements were made to the Phase 1 system design, including modifications to dish structure to reduce weight, wind loading, and parts count; implementation of face-down stow with an articulating engine support arm; control re-design to reduce costs and allow for autonomous operation; increased mirror facet size to boost power output; and design changes to the Stirling engine for simplification, improved performance, and hybrid operation with gaseous fuel.

In the second phase of the program, we operated the Phase 1 prototype system and four Phase 2 systems for more than 1,300 hours on-sun and 370 hours on gas. Most of the gas operation was conducted on the Washington, D.C. system because of limitations in solar operation and other operational constraints at that site.

In the course of building and operating the four Phase 2 dish/Stirling systems, we resolved many system integration and design issues while gaining much practical operational experience. The second phase of the program resulted in the development of a dish/Stirling system far superior to the Phase 1 system. It is simpler to install, more robust, and more capable (e.g., hybrid gas operation, autonomous operation, and facedown stow). The Phase 2 design has the potential for reliable, autonomous operation in a commercial utility setting.

1.2. Report Highlights

This report details the results of the Phase 1 program and each of the Phase 2 USJVP tasks. Phase 2 tasks were:

Task 1: Stirling Engine Development

Task 2: Solar Power Conversion System (PCS) Development

Task 3: Solar Dish Concentrator Development

Task 4: System Integration

Task 5: System Installation and Testing

Task 6: Business Development

Appendices that follow this report provide supplemental information. The following subsections highlight program results.

1.3. System Improvements

1.3.1. Phase 1 System Design

We designed the Phase 1 system to take advantage of the stretched-membrane mirror design. We installed 16 round facets on a radial truss structure with a central focus blower to provide focusing vacuum. The drive system used was a pedestal-mounted Flenders azimuth/elevation drive located in a hub at the vertex of the radial trusses. The Stirling engine was supported on a truss-like arm, counterbalancing the dish structure. While the system stowed in an upward-facing configuration, the engine could be brought to ground level for maintenance by stooping the dish downward below the horizon. A pneumatically actuated shutter was used to interrupt solar flux to the engine in emergencies or during focus/defocus. Figure 1 shows the Phase 1 prototype system in operation on sun.

Figure 1. Phase 1 SAIC/STM Prototype Dish/Stirling System

1.3.2. Phase 2 System Design

Changes and new features of the Phase 2 dish/Stirling system included the following:

- Increased facet diameter
- Staggered facet mounting on front and back of dish structure to reduce wind loading
- Hybrid (i.e., solar/fuel-gas burner) receiver in the Stirling Power Conversion System (PCS)
- Revised dish structure and hub designs
- Face-down stow capability with articulating PCS support arm
- Simplified, autonomous dish control system
- Gear drive to reduce 2200 RPM engine speed to 1800 RPM at the generator
- Simplified wiring harness for the dish control system components
- Sun tracker and peak-power tracking capabilities
- Electrically-actuated PCS shutter/plug with spring-powered, fail-safe closure
- Improved focus control valves
- Streamlined power wiring design and uninterruptible power supply for PCS
- National Electric Code (NEC)-compliant power wiring system.

Figure 2 illustrates the Phase 2 system (SRP dish in Mesa, Arizona).

Figure 2. Phase 2 Dish/Stirling System

1.4. Operational Results

We operated the Phase 1 prototype between June 1995 and July 1996, accumulating approximately 300 hours of on-sun operation during the first phase of the program. In addition we operated the Phase 1 prototype system from September 1997 through March 1998 for a total of 76.7 hours during the testing and development of Phase 2 components and systems. After a final drive failure on the system in early March 1998, we mothballed the Phase 1 prototype system and continued system testing and operation on Phase 2 systems.

The four Phase 2 systems were installed between January 1998 and August 1999. Because of problems encountered in debugging some of the changes to the system design, we were unable to operate the systems as much as projected at the beginning of the program. However, the following operational milestones were achieved with the Phase 2 systems:

- Net power delivered of 21.6 kW at ~1,000 W/sq.m direct normal insolation (APS-West system, 4/16/99)
- 30 days of uninterrupted solar operation at near 10kW output without an outage (Washington, D.C. system, 10/9/98-11/8/98)
- 180 kWh of solar energy in one day (APS-West system, 4/10/99)
- 159 kWh of fuel-powered energy delivery in one day (APS-West system, 3/26/99)
- Demonstration of hybrid system operation on propane, natural gas, and hydrogen fuels (NREL system (propane), Washington, D.C. system (natural gas), APS-East (natural gas), and APS-West system (natural gas & hydrogen))
- Total of 1,592 hours of solar operation on all four systems (575 hours on a single system)
- Total of 398 hours of gas operation on all four systems (346 hours on a single system)
- 11,243 kWh delivered on solar, 2,803 kWh delivered on gas operation
- 2959 Hours accumulated on three Solar/Hybrid PCS's, 969 hours at STM on hybrid operation.

1.5. Future Activities

Operation of the three Phase 2 systems in Arizona helped SAIC and STM identify further areas for improvement to the system. Continuing operational testing of the systems and development of further improvements to the system design are proposed for the future. Evaluation of additional structural changes is planned, to eliminate movement of the structure that led to focus and alignment changes. Development of an improved shutter/plug system is planned to improve its seal and to better protect its components from the solar flux that is encountered at the front of the PCS. The actuator and blower controls will be ruggedized. Additional engineering development for future systems is also being pursued, including development of advanced drive systems, an on-board hydrogen replenishment system, and improved focus controls for the dish. All of these activities are aimed at increasing the performance, reliability, and functionality of the SAIC/STM dish/Stirling system for future commercial implementation.

The next step was to continue operation of the Phase 2 systems and accumulate performance and operational data. These data will be used to drive design upgrades and modifications for the next-build of production systems. A particular need for future deployments is the development of an advanced drive system for future systems, since the number of Flenders drives is limited and they are not presently in production. Another significant area of effort is to so develop the dish that it can be used with other engine/converter systems, to provide more flexibility and open additional markets for system deployment.

2.0 STM Engine Development

2.1. Background

At the start of the USJVP program in 1993, the U.S. Department of Energy (DOE) policy was that STM engine development be funded by industry. STM raised private capital to fund engine development while DOE funded the application of the engine to solar power generation. Since 1993 STM and its industry partners have invested $47 million in private funds toward the development of the STM 4-120 engine (Figure 3). During the same period, DOE invested $6 million toward the solarization of the engine (Figure 4). Information in the public domain (i.e., funded by the government through cost share under this contract) is reported on fully.

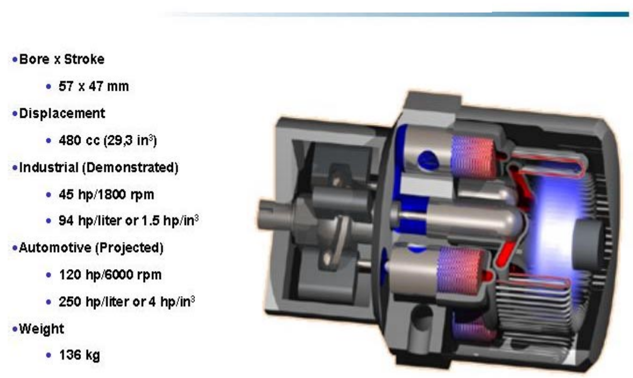


Figure 3. STM 4-120 Engine

Figure 4. Solarization of the Engine

STM is partnering with a major U.S. automotive supplier to establish a production manufacturing capability for the STM 4-120 engine and STM's distributed generation system called the STM PowerCell (Figures 5 and 6). To meet the forecast market requirements, STM's manufacturing partner will establish a manufacturing capability of 10,000 STM PowerCells per year from the fourth quarter of 2002. A major U.S. energy company will become STM's marketing partner of the STM PowerCell for DG markets worldwide except Asia.

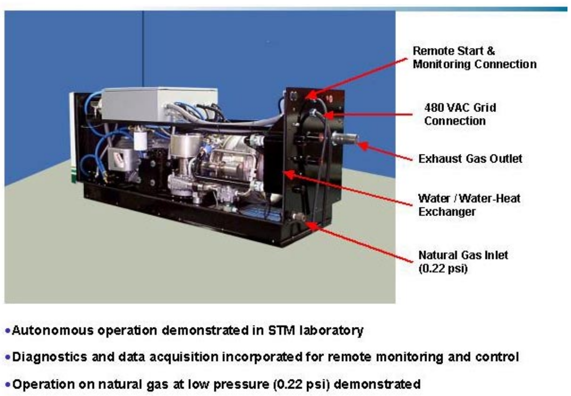


Figure 5. Operation and Grid Connection

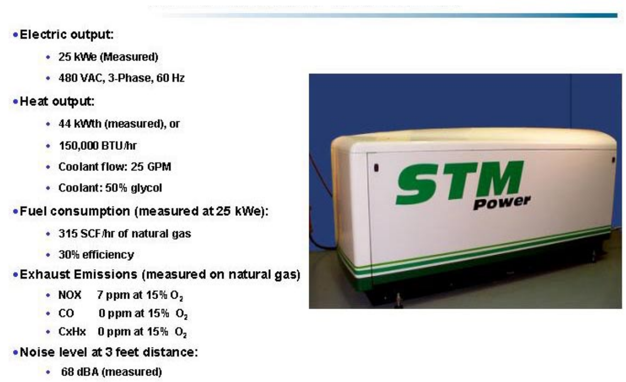


Figure 6. STM Power Cell Demonstrated Performance

2.2. Engine Validation

In 1998 STM engaged Price Waterhouse Coopers Securities, LLC, Washington DC (PWC) to find strategic partners and investors to manufacture and market STM engines. STM engaged third parties to perform independent validations as part of the development of the Private Placement Memorandum. These parties validated the STM technology, test procedures, performance, endurance, and manufacturing cost.

2.2.1. Engine Design, Performance and Testing

The majority of the initial applications for the STM engine will use natural gas as the primary fuel. The Institute of Gas Technology (IGT) was engaged to perform the validation of engine performance and testing procedures. Their findings are documented in a report dated September 1999. (See Section 2.6.3.)

2.2.2. Engine Manufacturing Costs

The goal of STM and its investors was to develop a new advanced engine using the Stirling (or near Carnot) cycle that could be manufactured at competitive costs to equivalent piston engines without sacrificing performance and reliability.

STM developed a double-acting engine with a variable swash plate for speed and power control. The cylinders of the STM engine are located parallel to and concentrically around the drive shaft. This configuration provides a very compact and uniform (symmetric) design (Figure 7).

Figure 7. STM 4-120 Engine

In the STM engine the pressure of the working fluid (hydrogen) is a function of the temperature. Heated gas in the cylinder above a piston increases the gas pressure, while cooled gas in the adjacent cylinder below the piston provides the pressure differential and power output. Speed and power are regulated by varying the piston stroke and energy supply. The ability to vary the stroke makes it possible to change speed rapidly. Early Stirling engines with fixed stroke required either changing speed or changing the working fluid pressure to change power. Changing the working fluid pressure requires a complex system of valves, pumps, hydrogen storage means and controls and, as a result, is expensive to manufacture and would require extensive service and maintenance. The STM engine concept provides a cost effective approach to different applications by using a common power section design for solar and non-solar applications.

STM also engaged Manufacturing Innovation & Technology for Industry LLC (MITI) to perform an independent study of manufacturing cost for both the solar-only and solar-hybrid versions of the STM engine. They found that the manufacturing costs would be very competitive once the engine is produced in reasonable quantities. MITI estimated the costs for 1 system, 100 system, 1000 system, 5,000 system, and 15,000 system, per year. The costs were $180,000; $119,000; $80,000; $18,000; and $10,000. A coalition of U.S. manufacturers is supplying everything from standard components to specially designed and fabricated components for the STM 4-120 engine.

2.2.3. Solar System Manufacturing Cost

In 1999, STM acquired a license from SAIC to manufacture and market the SAIC concentrator developed under this contract. STM intends to commercialize the complete system called the SunDish worldwide. In order to determine the manufacturing cost of the SunDish STM engaged Black & Veach (B&V) and MITI to estimate the cost to manufacture and install 1, 40, 80, 100, 200 and 1,000 systems. The system costs were $350,000, $250,000, $200,000, $200,000, $180,000, and $150,000. As a part of the B&V effort, the Bill of Material was reviewed and manufacturing sources were identified as well as the cost drivers in the system that need to be addressed.

2.3. Engine Configuration

Earlier versions of Stirling engines (for example Kockums 4-95 engine and the Solo V160 engine) have demonstrated their ability to operate on concentrated solar energy as well as on conventional fuels. The senior key management of STM led the development of the V160 engine until the engine was licensed to Schlaich Und Partner/Solo in Germany. The same management was a part of the Kockums/McDonnell Douglas effort to develop the 4-95 dish Stirling system in the 1980's until the project was terminated due to high manufacturing costs in volume production. The lessons learned form these older Stirling engines have been used in the development of the new advanced STM 4-120 engine.

2.4. Engine Generations

STM developed the STM 4-120 engine in three different generations, Gen I, II and III (Figure 7.).

2.4.1. Generation I STM 4-120 Engine

The first generation engine (Gen I) demonstrated the proof of concept. The test experience from the Gen I engine was used to design and build a small series of Gen II engines that were tested in laboratory and field.

2.4.2. Generation II STM 4-120 Engine

In the first phase of the USJVP program the engineering prototype 25 kW STM 4-120 engines (Identified as *Generation II*) were used. The use of Generation II STM 4-120 engineering prototype engines expedited the program. Even though they were not designed to meet cost targets they were available at the start of phase one. Several engines of this generation were built and tested.

The objective was to verify the function, performance and durability of the Generation II STM 4-120 engines in a solar energy application. The engines functioned as predicted and the measured performance (efficiency and power) was within five percent of the predicted performance. More than 5,000 hours of engine testing were accumulated. Testing consisted of laboratory and field testing (direct insolation receiver and heat pipe receiver running on sun).

Several of the components and subsystems were not designed to meet the cost targets. For example, the engine crankcase was pressurized with helium to reduce pressure differences and decrease working fluid leakage. The swashplate actuation system used a hydraulic actuator that had high parasitics for the hydraulic pump. Likewise, the mechanical oil pump only began to pressurize the oil once the engine drive shaft was rotating and stopped when the motor stopped.

2.4.3. Generation III STM 4-120 Engine

Following the promising result from the testing of the Gen II, STM decided, supported by its investors, to increase the engineering effort to develop production prototype version of the STM 4-120 engine (Gen III). As a result of a major engineering and manufacturing effort a small series of engines was designed, manufactured, and tested. The Gen III engine is currently used in the second phase of the USJVP program.

STM accumulated approximately 30,000 hours of laboratory and field testing. In total, 18 Gen III engine drive rigs, complete engines and generator sets have operated on natural gas, propane, gasoline, diesel, hydrogen, biomass (wood products), simulated landfill gas.

The generation III STM 4-120 engines incorporated changes, which addressed the problems encountered during Phase I demonstrations. The Generation III STM 4-120 engine improvements included an electrical motor driven actuator control, an electric water pump, an electrical oil pump and an un-pressurized crankcase. The motor driven actuator provides precise and rapid actuation. An automatic brake system holds the actuator in place when the motor is de-energized. The electrical actuator design eliminates the parasitic losses associated with the hydraulic actuator used in the Generation II STM 4-120 engines. The water pump is thermostatically operated to reduce parasitic loads. It only operates when cooling is needed. The electric oil pump reduces wear on the engine by pressurizing the lubrication system before the engine start. Actuator improvements have been made in the worm gear drive that controls the angle of the swashplate. Other improvements have been made in the electrical controls for the engine and related equipment.

The Gen III engine has half as many components and subsystems as the Gen II engine, which will reduce both the manufacturing costs and improve the reliability. The measured performance is within two percent of predicted performance and slightly higher compared to the Gen II engine. The projected manufacturing costs are lower than projected. The performance is 22kW at a cost of $180,000.

The Gen III engine was designed to operate on gaseous as well as liquid fossil fuels as the baseline. During Phase II, STM developed a solar hybrid system that demonstrated the ability to operate on a combination of solar-natural gas, solar-hydrogen, and solar-landfill gas.

STM developed the analytical tools required to adapt this engine concept to other solar applications and to project the probable life of the engine. These studies indicate that the commercial versions of the STM 4-120 engine used in this demonstration should, when commercialized, achieve the U.S. DOE life objective of 50,000 hours before overhaul.

STM is proceeding, to pursue commercialization of the SunDish concept and identified a large number of potential applications. These demonstrations have identified opportunities for improvement in performance or reductions in cost, which will be pursued by STM and its partners including SAIC.

2.5. STM Laboratories Overview

STM invested in extensive laboratory capability spanning from forced component testing of critical components and sub systems, engine performance mapping and testing in dynamometers; complete system testing of the STM PCS systems; and solar simulation of the engine in elevated operating positions. The emission collection setup provides opportunities to collect emission data from each test cell. The STM Laboratories consists of 5 test cells, rated for gasoline usage.

Most of the applications of the STM engine are in the area of electric power generation. Therefore, STM invested in equipment to become an Independent Power Producer ("IPP") and the STM facility is classified as an IPP with a total generating capability of 1MWe. Therefore, with the exception of the dynamometer and hybrid vehicle application, engines are tested an engine-generator assemblies. STM has an agreement with Detroit Edison to sell electricity back to the grid. In addition to accumulation of durability hours and reliability, electricity is being put back into the grid.

As can be seen in Figure 8, five test cells are the STM testing laboratory facility. Four out of the five are used for engine/generators, dynamometer (Figure 9) and rig testing. The fifth is dedicated to combustion development. All emissions measured at STM are done with a Horiba combustion gas analyzer (Figure 10.)

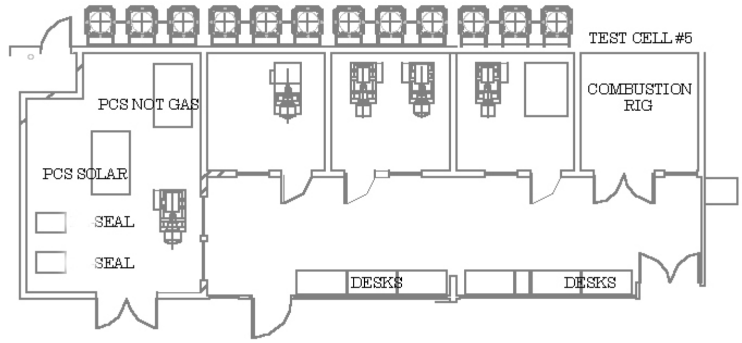


Figure 8. Test Cells at the STM Testing Laboratory

Figure 9. Dynamometer

Figure 10. Horiba Combustion Gas

2.6. Testing

Testing of the Gen III engines and engine components continues at STM (Figure 11) and in the field. A total of 29,613 hours have been accumulated on engine-generator systems (solar hybrid PCS, natural gas PCS, cogen power cells), full engine rigs, drive rigs and component durability rigs.

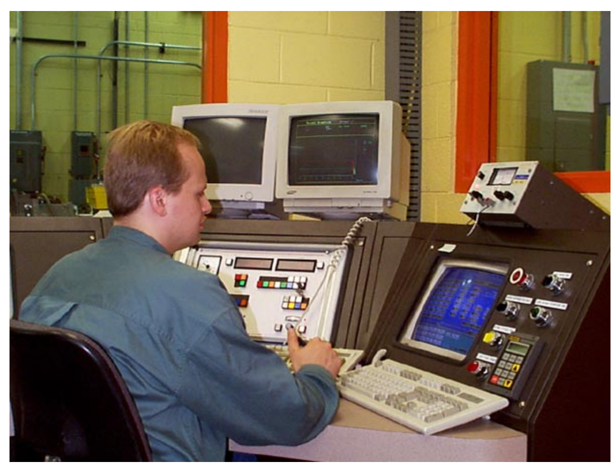


Figure 11. Phase I Testing

2.6.1. Engine and Systems Testing

During Phase I of the USJVP Project the Solar thermal system demonstrated its ability to produce over 20 kW of electrical energy peak. While the engine demonstrated the ability to produce 25 kW net electric output using natural gas, the electric output operating on sun was limited to 20 kWe. The reason was that the concentrator in phase I did not deliver enough heat into the receiver.

The correction to this in Phase II of the program was to design the concentrator with increased reflective surface area. However, the specification requirement was to increase the reflective area enough to produce 104 kWth in to the hybrid receiver in order to produce 25-kWe net electric. In reality, the phase II concentrator delivers only 95 kWth into the receiver, which still limits the engine to produce 22 kW of net electricity. The reflective area concentrator is not enough too produce 56,000 kW hrs from solar power alone during a full yearly cycle including allowances for the changes in effective insolation during the day, and season. During phase II the peak electrical output has been 21.6 kWe. At the same time, the solar hybrid system demonstrated 25-kWe net operating on natural gas as well as hydrogen. Phase II confirmed that the STM 4-120 engine and related technology was sufficiently well developed that commercialization for solar energy applications could be initiated within the next few years.

2.6.2. Component Test Rigs

The seal rigs shown in Figures 12 and 13 were instrumental in the design and testing of individual components without being affected by other components or systems. These tests resulted in improvements in the engine design, which increased reliability and reduced costs. The majority of these improvements focused on the dynamic seals, swashplate actuator and piston rings.

Figure 12. Seal Rigs

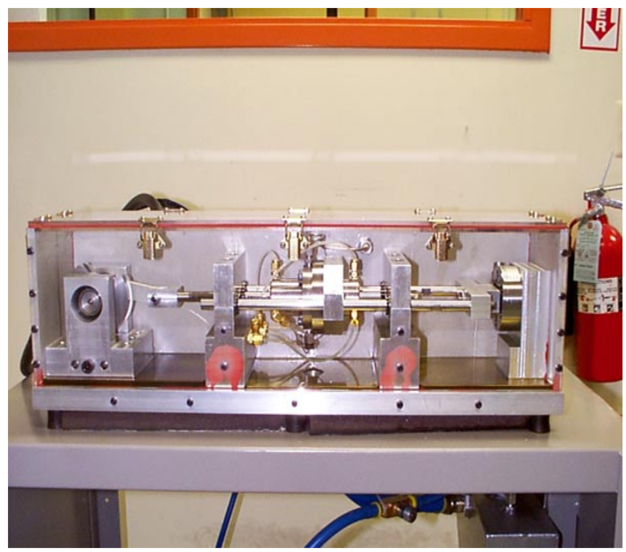


Figure 13. Seal Rig

The improvements to the dynamic rod seal were on the seal support and spring loading, allowing the seal to move with the rod accommodating slight rod deflections. The seals are clamped between elements with low friction support surfaces allowing them to float with the small radial motion of the piston rods. The single coil spring used initially had been replaced with a different design that reduces the radial constraint and provides a more uniform seal loading. This configuration is now used in all engines and had been tested in a rig (Figure 12) to over 7,000 hours with gas leakage within acceptable limits. These improvements were incorporated into the Solar PCS engines.

Actuator improvements have been in the housing, worm gear drive and in the electrical control drivers. All of which have been incorporated into Solar PCS engines. Field testing in Arizona on sun helped in building more robust electrical controls for the actuator.

2.6.3. Laboratory Testing Results (Validated by IGT)

2.6.3.1. Test Description

Configuration

- STM4-120 # 2005 with "low-NOx" natural gas EHS, operational swashplate actuator and steel reciprocating components with a balancing flywheel
- Dynamometer load
- Insulated External Heating System
- Controllable facility cooling system using water at constant 1.67 liter/sec.
- Hydrogen working gas supplied by a controllable facility charging system

Instrumentation and Data

- Temperatures: 4 cylinder tubes (CT), 4 regenerator tubes (RT), coolant in, coolant out, exhaust, oil sump, air inlet and ambient
- Pressures: 4 mean cycle pressures (to be kept constant at all data points), inlet air, oil
- Swashplate angle or actuator position
- Torque, speed and shaft power from dynamometer
- Fuel mass flow (or fuel pressure, temperature and volume flow)
- Combustion air mass flow

Nominal Operating Conditions

- Heater control temperature 800 °C
- Coolant inlet temperature: 45 °C (it was not possible to maintain a constant coolant inlet temperature; Fluctuation occurred within ±7 °C of nominal)
- Mean cycle pressure: 15 MPa (adjusted manually for each data point)
- Air/fuel ratio: 29:1 (corresponding to $\lambda = 1.75$)

Operational Variables

- Speed: 1000 rpm to 2400 rpm in 200 rpm increments
- Stroke: 27 percent, 36 percent, 45 percent, 64 percent, 82 percent and 100 percent

2.6.3.2. Test Results

Figures 14 and 15 show the gross shaft power and gross shaft-fuel efficiency, respectively, as functions of the speed at different stroke values. Gross shaft power is the mechanical power at the engine shaft. A portion of the gross shaft power is consumed by the external auxiliaries (combustion air blower and coolant pump). The gross shaft-fuel efficiency is the ratio of the gross shaft power and the fuel heat rate (based on the lower heat value).

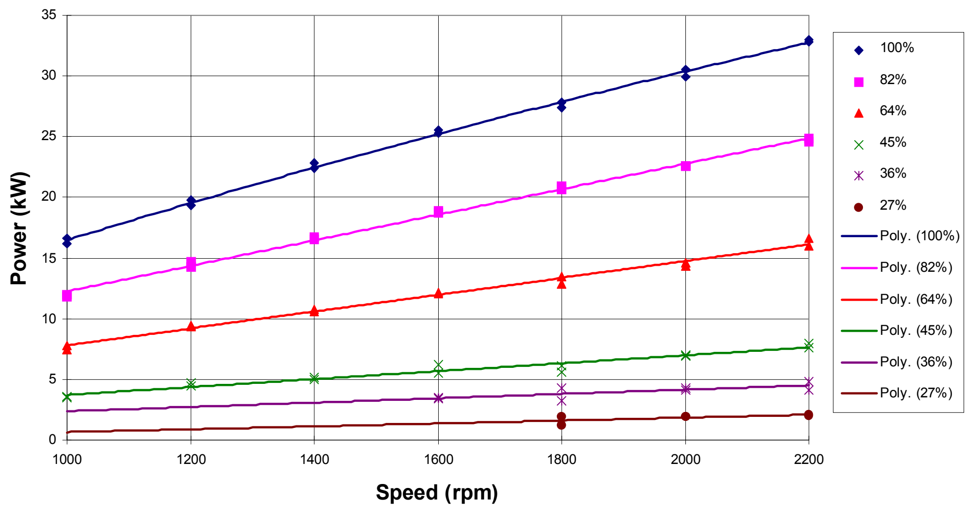


Figure 14. Shaft Power at 15 MPa and Various % Stroke (Test runs 3 and 4)

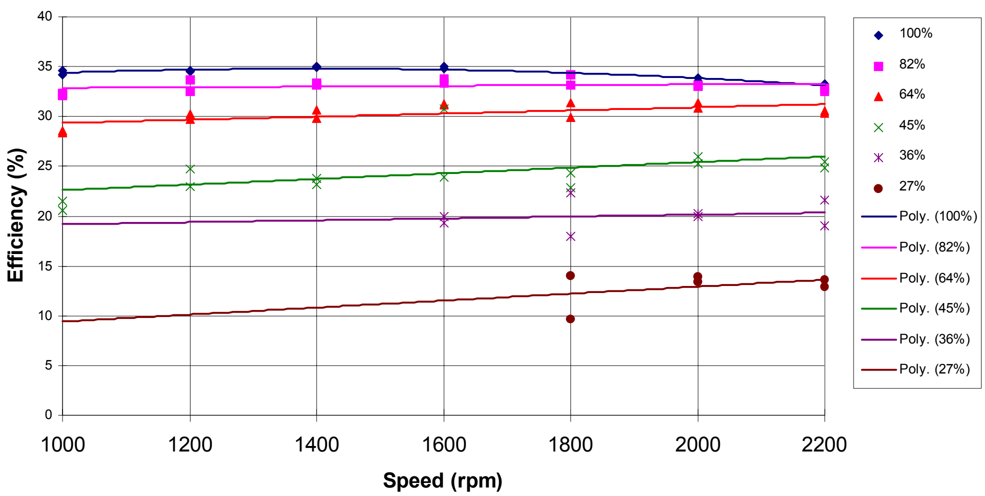


Figure 15. Shaft Fuel Efficiency at Various % Stroke (Test runs 3 and 4)

Power

Over the speed range of the tests (1,000 to 2,400 rpm) power increases roughly linearly with speed with slopes that increase with the stroke thus demonstrating the expected qualitative behavior.

Brake Fuel to Shaft Efficiency

At low stroke, the efficiency increases with speed (and power). As the stroke increases, the efficiency vs. speed curves becomes flatter. At full stroke, the efficiency is almost independent of the speed over the entire speed range. Qualitatively, this behavior is expected. Quantitatively, the peak gross shaft-fuel efficiency measured is 35 percent at 1,400 rpm and 34 percent at nominal speed.

External Heating System (EHS) Efficiency

The external heating system efficiency (based on the exhaust temperature) is shown in Figure 16 as a function of the airflow. Data from all four passes is combined in Figure 16 also. It appears that the EHS efficiency for test runs 3 and 4 is marginally lower than for test runs 1 and 2.

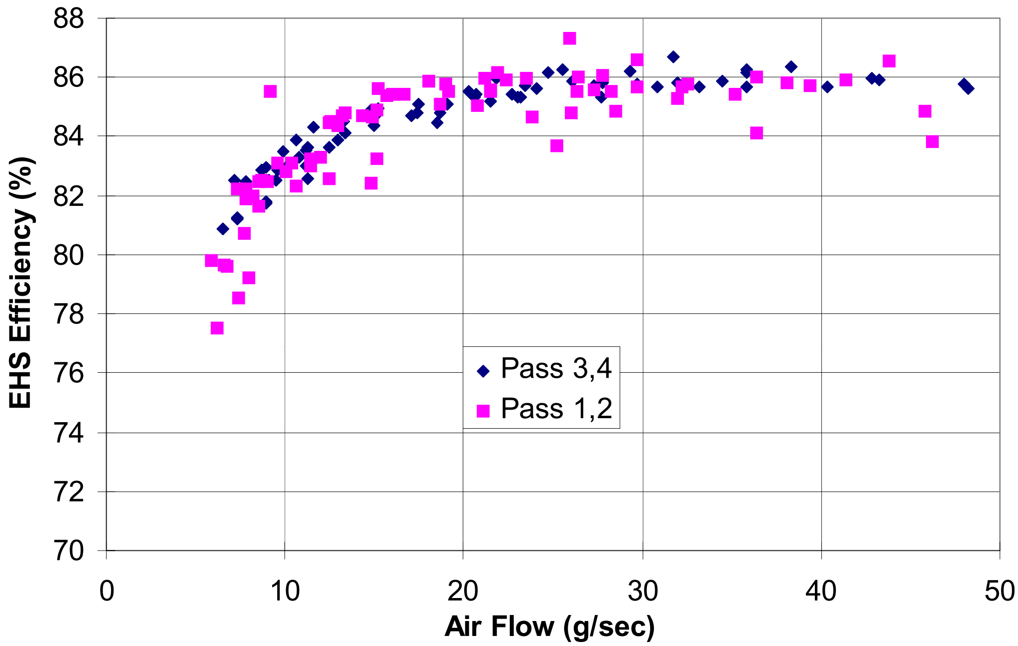


Figure 16. External Heating System Efficiency (Test runs 1, 2, 3, and 4)

Between 20 g/sec and 50 g/sec air flow, the EHS efficiency is very flat, varying between 85 percent and 86 percent. Below 20 g/sec of air flow the EHS efficiency drops and, at about 7 g/sec, is only about 80 percent. This is counter to the expected behavior whereby the EHS efficiency would increase uniformly as the air flow goes down due to the increasing NTU. The reduced EHS efficiency at low air flow has been previously observed in rig tests of the preheater and is being analyzed. It appears to be due to heat leaks from the combustion side to the exhaust and air streams bypassing the preheater. Implementing design changes in the EHS flow scheme can solve this problem.

Thermal To Shaft Efficiency

An EHS efficiency of 85 percent and gross shaft-fuel efficiency of 35 percent correspond to a gross shaft-thermal efficiency value of 41 percent.

2.6.4. Application System Testing

The PCS's have been designed with a modular concept that will allow the same basic package to be used for various applications by changing the heating system. Through the interchange of heating systems the PCS becomes capable of power generation using fuels such as natural gas, biomass, solar or liquid fuel. The objective of this task is to test these applied configurations in the field and to accumulate durability hours. STM 4-120 Generation III engines produced a total of 4,199 operating hours.

2.6.5. Engine Development Testing

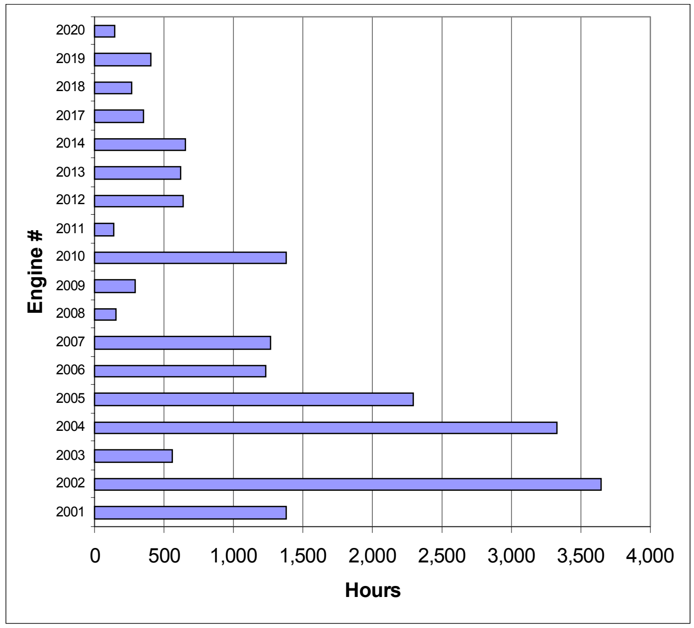


Figure 17. Engine Hours and Test Duration

The continuation of the STM funded engine development test program produced a total of 21,850 operating hours. During USJVP Phase II, all testing was conducted on the current Generation III engine configuration. The intent of engine development was to continue to induce failures while accumulating engine hours. When incidents were resolved the basic reliability of the engine and its affected components were improved. The intent was to operate the engines at full load as frequently as possible using natural gas fueled Direct Flame Heating Systems (DFHS) in order to characterize the durability of the entire system. The data summary in Figure 17 shows individual engine hours and test duration. (Also see Table 1.) This summary indicates that engine serial numbers 2002 and 2004 account for a total of 6,981 operating hours or 39.3 percent of the total laboratory engine development time while generating only one relevant incident. It must be noted that components produced for engine number 2015 were used to maintain other engines and therefore engine 2015 did not contribute any operational time toward the MTBF calculation.

2.6.6. Drive Rig Testing

All Generation III engines began their lives as drive rigs for a period of at least 100 hours. Drive rigs are designed to be motored at 1800 RPM through excitation of the 3ϕ alternator windings. The rigs are designed for full load endurance testing by maintaining maximum pressure in the cycles at variable swashplate angles. The rig configuration closely duplicates the operating full load forces produced in the STM 4-120 engine with a fully operating heating system. The cumulative laboratory test time on these rigs has been applied to the Reliability Growth Model.

2.6.7. Exhaust Emissions

Exhaust gas emissions of STM engines have been measured using the Horiba gas analysis bench. Measurements have been made in 4-120 engines with gasoline and natural gas fuels. Ultra Low Emissions of NOx, CO, and UHC have been demonstrated by controlling flame temperature either with excess air or by the use of exhaust gas recirculation (EGR). The use of EGR was found efficient in the reduction of NOx than the use of fresh air on a flow basis and is therefore preferred from a pumping power consumption point of view. The results are relatively independent of the two engine configurations because of their similar powers, operating conditions and combustor sizes. Laboratory tests results with No. 2 diesel oil have demonstrated similar results.

Table 1. Gen II STM 4-12 Engine Number, Time, Configuration, and Fuel Type

Engine	Hours	Location	Configuration	Fuel Type
2001	1,380	STM Laboratories	Drive Rig, Development	None
2002	3,643	STM Laboratories	Drive Rig, full load	None
2003	559	STM Laboratories	Engine/Generator	Nat, Gas, Biomass (wood products)
2004	3,338	STM Laboratories	Nat Gas PCS	Natural Gas
2005	2,959	STM Laboratories	Dyno/Solar hybrid	Nat. Gas, H2, Landfill gas, Solar
2006	1,235	STM Laboratories	Engine/.Generator	Natural Gas
2007	1,261	STM Laboratories	Engine/Generator & Dyno	Natural Gas, Gasoline
2008	230	STM Laboratories	Controls Development	Natural gas
2009	291	Bosal	Engine/Generator	Natural Gas
2010	1,375	Pentagon	Solar/Hybrid	Solar, Natural gas
		APS	Solar/Hybrid	Solar, Natural gas, Hydrogen
2011	135	Sandia, NM Alb.	Engine/Generator	Solar, special heat pipe version
2012	634	Golden, Co, SRP	Solar/Hybrid	Solar, Natural gas, Propane
2013	1,430	APS	Solar/Hybrid	Solar, Natural gas
2014	847	PCS 003	Solar/Hybrid	Solar, Natural gas
2017	457	STM Laboratories	Engine/Generator	Natural Gas
2018	594	STM Laboratories	Engine/Dyno	Natural gas
2019	644	STM Laboratories	Engine/Generator	Natural gas
2020	500	STM Laboratories	Engine/Generator	Natural gas
2021				
2022	245	STM Laboratories	Engine/Generator	Natural gas
Total:	20,933			

Although engines in this size class are not currently regulated for emissions, the STM engine emissions are far lower than the emissions standards set forth in the Code of Federal Regulations (CFR40-Part89) for compression-ignition (diesel) engines near their size. Operating on natural gas fuel, STM engines can meet the most stringent requirements of the South Coast Air Quality Management District (SCAQMD) for power producing gas turbines (CFR40-Part50).

Fuel flexibility is inherently better with the STM engine than internal combustion engines due to the high combustor inlet temperature, continuous combustion, and independence from engine operating conditions.

Carbon monoxide and Unburned hydrocarbons levels were characteristically much lower than the ULEV requirements. The highest points occur at high EGR and high power conditions where the residence time for completing the reactions is the lowest. Although this combustor was initially designed to be lean-direct injected, it proved to tolerate high levels of EGR quite well. Subsequent lab testing with more stable combustor designs showed that CO and UHC's can be reduced even further.

2.7. Reliability Growth Demonstration

STM established a well-disciplined method to collect and generate reliability growth data on the main engine components.

2.7.1. Objective

The objective of Phase II of the US/JVP Program was to demonstrate continuous autonomous operation of five systems (later reduced to three) with continuous operation on one system for 750 continuous hours. All Dish Stirling systems must operate within 20 percent of the system specification (22 kW net power at an insolation of 1000 W/m^2) in a solar or hybrid power production mode during solar hours. Solar hours of operation are defined as the point in time at which the sun is more than 5° above the horizon. During this period the only allowable operator intervention is to initiate and disable hybrid operation, conduct scheduled and periodic maintenance and testing or to shut down the system due to holidays, site inaccessibility, and utility grid problems. Hybrid mode of operation is counted only during solar hours when the cloud cover does not allow for solar operation, and may comprise only up to 15 percent of the total operating hours.

2.7.2. Definition & Calculation

Proof Of Concept testing is an engineering activity that involves the implementation of engineering ideas and concepts into engine hardware for purposes of improving durability and performance. This approach is sometimes referred to as Test- Analyze-Fix -Test (TAFT).

- Test the Baseline design until it breaks
- Analyze the incident using good engineering practices
- Propose and implement a comprehensive corrective action
- Test the new design to verify the fix.

Through the application of this Test- Analyze-Fix -Test philosophy, the time and cost of product research and development is being reduced. All design deficiencies identified during the reliability growth test phase are being addressed in this manner.

Before an engineering concept can be considered to be an improvement to the baseline engine design, it must be scientifically qualified as such.

Performance Concepts being tested are:

- Dynamic Seal
- H2 Permeation
- Epicyclic Actuator Module
- Gas Fired PCS
- Piston Ring
- New Crosshead Geometry
- Composite Engine Components and Dynamometer Testing.

Durability Issues currently being verified during the proof of concept test phase include a more Rigid Drive Case and Regenerator Housing, Improved Lubrication System, Radial PL Seal,

The total time on Generation III engines/drive rigs (excluding component test rigs) for purposes of reliability reporting was 20,933 Hours.

Figure 18 provides the STM 4-120 Generation III Incident Timeline.

The Incident time line in this report is for the period from May 15,1995 to October 2, 1997. The timeline chart reveals the application, cumulative time per engine and the incidents experienced on each engine. The incident distribution is as follows:

- **Relevant Incidents** – Chargeable toward the overall reliability of the engine design.
- **Non-Relevant Incidents –** These incidents are not applied toward the reliability of the engine design. These include operator induced incidents, test equipment incidents and those incidents induced by material or quality deficiencies.
- **Reoccurring Incidents** – Reoccurring incidents are incidents that are identical to those which have been determined to be relevant and may be censored out of the reliability analysis.

The timelines for units being used for engineering Proof Of Concept (POC) reveal a number of sequential non-relevant incidents. These non-relevant incidents indicate the tear down and rebuild cycles involving issues that have been revealed during POC testing. Prior to being used for specific POC testing these units were dedicated to the RGDT effort. POC components will be considered a part of the RDGT only after the design reached a point where the configuration can be frozen.

Reliability

At monthly intervals the reliability of the STM 4-120, Generation III Stirling Engine will be assessed and reported using the Duane Reliability Model to show reliability growth. The data is reviewed and scored for relevancy with respect to reliability growth per the incident definition in this document.

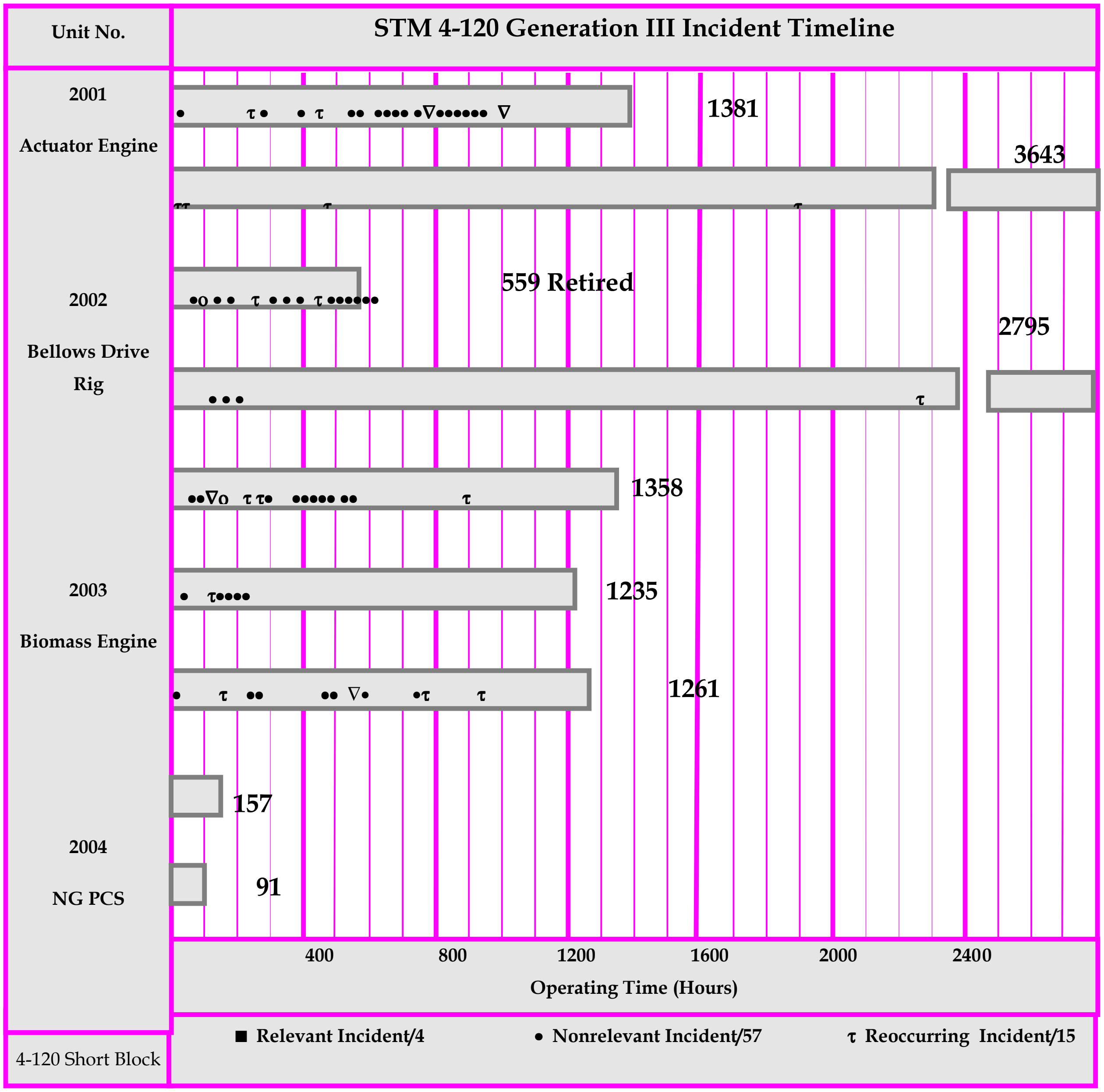


Figure 18. STM 4-120 Generation III Incident Timeline

Starting Reliability

The starting point for Reliability Growth for the STM 4-120 Short Block was determined through the use of an ideal growth plot. This ideal growth plot was based on a compilation of actual and projected data. In order to simplify this exercise, the total test time data for the Generation II and II a was used regardless of incident frequency.

Therefore it can be stated that, the STM 4-120, Generation IIa engine should exhibit an MTBF of approximately 2685 Hours. Assuming that design changes were incorporated to correct deficiencies identified during testing, the Final MTBF for Generation IIa should be approximately 5382 Hours. This is the starting MTBF for the Generation III design.

Mathematical modeling, engineering judgment and the use of Reliability Analysis Center (RAC), Nonelectronic Parts Reliability Data, NPRD-95 determined the starting point for Reliability Growth for the DFHS. The starting MTBF for the DFHS is assumed to be 1512 Hours.

Mean Time Between Failures (MTBF)

The MTBF values depicted show the individual subsystem MTBF's and the total system MTBF. The MTBF is the quotient that occurs from the total time accumulated during the test period divided by the total number of relevant failures. The Total Time is calculated as the sum of the projected Start Time (50 percent of the Predicted MTBF) and the actual test time.

Total Time = (Start Time + Test Time) Hours

The MTBF for the period from 5/95 - 11/95 is calculated using four (4) relevant incidents for the 4-120 Short Block and (1) one relevant incident is assumed for the Direct Flame Heating System (for calculation purposes only). Refer to Figure 18, Incident Summary, which gives an example of incidents vs. engine timeline, 5/15/95 – 10/2/97.

MTBF = (Total Time/Total Failures) Hours

Growth

Through the use of the Duane Reliability Model, reliability growth can be expressed as the change in the logarithmic slope of the mean.

A positive slope indicates that an Incident Reporting And Corrective Action System (IRACAS) is in place and operating properly. This results in the tracking and implementation of engineering changes and sub sequential reliability improvement.

A negative slope indicates that an IRACAS system is not in place or that the system in place is not functioning properly. This situation results in a product exhibiting little or no improvement.

$$\text{Reliability Growth} = \frac{\text{Log}(\text{MTBF2}_{(\text{Stirling System})}) - \text{Log}(\text{MTBF1}_{(\text{Stirling System})})}{\text{Log}(\text{Time2}_{(\text{Stirling System})}) - \text{Log}(\text{Time 1}_{(\text{Stirling System})})}$$

Incident Definition

Only the first occurrence for each unique incident mode will be scored as relevant with reference to the reliability of each of the systems on test. Incidents induced through the malfunction of test equipment or human error with respect to manufacturing, assembly and quality assurance will not be scored as relevant with reference to cumulative MTBF. When an incident mode is identified, a common method of corrective action will be implemented on each of the systems under test, thereby, negating the reoccurring incidents and their inclusion in the MTBF calculation. After implementation of corrective action, effectiveness will be verified through additional operation if necessary.

The STM 4-120 Gen. III reliability using actual test data and the consensus of the Incident Review Board (IRB) with respect to relevancy is calculated to be 4,725 Hours MTBF, for the STM 4-120 Gen III engine only. (See Table 2 for engine hour timeline, configuration, and lessons learned.)

2.8. Conclusions

STM is committed to the commercialization of this technology. The alliances that are noted earlier in this section will help generate unique and powerful capabilities in the burgeoning field of electrical co-generation and distributed power. The testing and reliability activity supported by government funding and discussed in this section, coupled with proprietary development activity self-funded by STM, will help commercialize this activity by delivering a unit that is competitive from both an economic and performance viewpoint.

STM will work to coordinate its proprietary efforts with all ongoing DOE initiatives to help accelerate the availability of these units to utilities and other users like the partners participating in the DOE program. In fact, STM believes that cross-fertilization of its proprietary efforts (with appropriate protection of its intellectual property) into any government program is probably essential to the eventual commercialization of SunDish technology.

Table 2. STM Generation III Engine Test Data

	Engine#	Fuel	Location	1995 Jul-Dec	1996 Jan-Jun	1996 Jul-Dec	1997 Jan-Jun	1997 Jul-Dec	1998 Jan-Jun	1998 Jul-Dec	1999 Jan-Jun	1999 Jul-Dec	2000 Jan-Jun	2000 Jul-Dec	Total Hours	Testing Ended	Lessons Learned
Development	2001	none	STM	635	339	406									1,380	Nov-96	
Full Load	2002	none	STM	1222	1474	843	104								3,643	Feb-97	Strengthen Drive case, found cracks
Engine Dynomometer																	
Dyno and Solar Hybrid	2005	Nat. Gas & Gasoline		249	459	591	762	58		436	264	61	79		2,959	Testing continues	
Dyno and Engine/Generator	2007	Nat. Gas	STM	371	528	224	120	18							1,261	Jul-97	Controls development
	2018	Nat. Gas	STM									158	191	295	644	Testing continues	
Engine Generators																	
Biomass/First Gen III Rig and Engine	2003	Nat. Gas & Woodchips	STM	221	189	149									559	Aug-97	Replace mechanical oil pump w/electric, PI-seal improvements, Strengthen HH castings
	2006	Nat. Gas	STM	178	337	607	113								1,235	Apr-97	Actuaotor housing not strong enough, strengthen
Controls Development	2008	Nat. Gas	STM			58	126	46							230	Sep-97	Controls development
Bosal	2009	Nat. Gas	STM					91	125	75					291	Delivered to Customer	Testing underway
	2017	Nat. Gas	STM								246	85	107	19	457		Exhaust gas recirculation tuning
	2019	Nat. Gas	STM									66	543	78	687	Testing continues	
	2020	Nat. Gas	STM										275	225	500	Testing continues	
	2022	Nat. Gas	STM											245	245	Testing continues	
Solar Power Conversion System																	
PCS Run on Gas	2004	Nat. Gas		822	1219	543	178	105	63	271	121	16			3,338	Jul-99	
PCS Using Heat Pipe (World Record)	2011	Solar	Sandia				22	113							135	Jul-97	
Spare Solar/Hybrid PCS for USJVP	2014	Solar & Nat. Gas	PCS#003 APS								113	284	248	202	847	Testing continues	
Solar/Hybrid PCS for USJVP	2010	Solar & Nat. Gas	Pentagon & APS					4	67		89	82	422	711	1,375	Testing continues	
Solar/Hybrid PCS for USJVP	2012	Solar & Nat. Gas	Golden & SRP						96	538					634	Testing continues	
Solar/Hybrid PCS for USJVP	2013	Solar & Nat. Gas	APS						6	90	99	462	593	180	1,430	Testing continues	
														Total	**21,850**		

3.0 Solar Power Conversion System (PCS) Development

The Solar Power Conversion System, or PCS, implements the STM 4-120 engine into an assembly with a solar/hybrid receiver, a generator, a cooling system, and a shutter/plug for hybrid operation and safety device. The solar-specific development activities carried out under this contract are described in the following subsections.

3.1. Solar/Hybrid Receiver Development

Hybrid operation of the PCS on a gaseous fuel was determined to be an important requirement for utilities in order to provide a dispatchable power system in spite of weather conditions. The Phase 1 PCS had a solar-only receiver. To incorporate a burner into the solar receiver cavity required significant changes to the receiver geometry and the PCS system.

3.1.1. Solar/Hybrid Receiver

The receiver in Phase 2 was increased in size and capacity to match the increased size of the dish concentrator. A significant change to the solar receiver was the layout to accommodate the hybrid option. Another major change from the Phase 1 system was that the tubes were connected to a header instead of bending the tubes back on themselves at the outer radius. This simplified the assembly of the heater heads and made them less costly and more robust. Also, the lengths of the heater tubes were increased to absorb the increased power from the Phase 2 dish. The longer tubes increased flow losses, which resulted in both a performance and a cost penalty. The hybrid option reduces the system power production by about 1.0 kW.

3.1.1.1. Hybrid Burner

The hybrid low-NOx burner developed by STM is based on a small conical burner element in which gaseous fuel and preheated air are mixed and burn together with very low emissions. Multiple burners are placed behind the receiver tubes to heat the tubes uniformly and completely. These burners allow high temperature combustion air to be mixed without auto-ignition. To operate the burners, a throttling solenoid valve and a mass flow meter is used to control the fuel gas flow, and a variable-speed blower is used to provide combustion air. The variable mass flow meter and blower was a requirement for variable power, should the need arise. A less costly system would have a preset fuel and air flow system for a constant power output. The exhaust gases in a recuperator preheat the incoming air. This recuperation is very important to the efficiency of the system when operating on fuel, and requires that the combustion chamber be sealed when the system is operated on fuel. Therefore, when operating on gas the shutter/plug is closed. However, the system can operate in a so-called augmented mode with the aperture open. In this case the fuel economy will be reduced, an issue of the value of the power and economics

Some leakage of the shutter/plug-to-PCS seal was been experienced in the Phase 2 systems, and plans have been made to improve that seal in the upcoming phase of operation.

The combustion air blower motor experienced difficulty in dealing with the high temperatures present in the receiver cavity during solar operation in Phoenix. During solar operation, the shutter/plug is opened and the combustion blower runs at a very low flow rate to prevent hot air from entering the blower motor area and overheating the blower and recuperator. However, at least one blower was overheated and some plastic parts were melted during solar operation. Therefore, the blower was relocated to a position in the PCS package where it is better protected from the heat generated when operating on sun. This change has not yet been tested on a dish. Testing showed that the modifications have improved the reliability of the system. It also improved access to the air filter on the blower for easier service.

3.2. Generator Selection

In Phase 1, a three-wire induction motor was used as a generator. Because no ground connection was provided on the motor, separate grounding transformers were required to meet utility requirements for ground-fault protection. In Phase 2, a four-wire, three-phase induction motor was used as the generator. This eliminated the cost and complexity of the grounding transformers.

3.3. Stirling Engine/Generator Connection

The generator in the Phase 1 system was directly coupled to the Stirling engine, which restricted engine operation to approximately 1800 RPM, the synchronous speed of the motor/generator. In order to match the hybrid receiver requirement and to be able to capture the heat from the larger Phase 2 dish the engine speed was increased from 1800 to 2200 RPM.

Throughout the Phase 2 contract, the team (Sandia, NREL, SAIC, STM and APS) debated the alternatives of increasing the engine speed via electrical power electronics or mechanical devices, such as a gear or chain drive. At the start of Phase 2, it was decided to use a gear drive to increase the engine speed from 1800 to 2200 RPM. After a meeting in Denver the team started thinking about the use of power electronics to increase the frequency of the generator from 60 Hz, 1800 RPM, to 73 Hz, 2200 RPM. One of the determining factors for this was the idea of targeting off grid customers where the $/kW value is higher. Until a final selection had been made for the generator a decision was made to use a 30 kW induction generator with a bi-directional inverter so that the system could be tested and not await a generator selection. Two systems, the NREL dish and the Washington, D.C. dish, were outfitted with the power electronics.

Several drawbacks were found with power electronics, including: 1) Cost; 2) Ability to withstand high ambient conditions (reliability); 3) Electrical losses of about 6 percent; and 4) electrical noise generation. After reviewing the data the variable speed generator option was aborted, in favor of a cheaper, more reliable and more efficient (2 percent loss) gear drive to increase the engine speed to 2200 RPM. The final product was therefore a mechanical gearbox inserted between the STM 4-120 engine and the motor/generator to increase the engine speed from 1800 to 2200 RPM. These gearboxes were retrofit first on the APS West, and later on all the remaining PCS's.

3.4. Shutter/Plug Development

Because of the sealing requirements of the hybrid burner, SAIC and STM agreed that STM would implement a shutter/plug on the PCS receiver cavity. The shutter/plug is under control of the PCS controller and consists of a large block of insulation with an actuator that rotates the shutter/plug against the front of the PCS to seal off the aperture of the receiver cavity. The actuator is powered electrically, with a fail-safe solenoid that causes the spring-loaded shutter to close automatically upon loss of power to the PCS.

3.5. PCS Test-Cell Testing

3.5.1. Performance data

The following tables give examples of the data taken at STM on the Phase 2 PCS's.

Data taken on the Washington, D.C. PCS at STM's test cell with the Baldor bi-directional inverter showed that the bi-directional inverter causes about a 6 percent loss in electrical power (Table 3).

Table 3. Washington, DC PLS Data Taken at STM's Test Cell

Date	Time	Water Inlet Temp [C]	Water Outlet Temp [C]	Air Flow [g/s]	Engine Speed [RPM]	Avg. Cycle Pressure [MPa]	Avg. Receiver Temp [C]	Power [kWe, net]	Fuel Flow [g/s]	Net efficiency [%]	Lambda
2/6/98	18:48	55	62	52.1	2206	12.7	723.5	19.6	1.6	24.9	2.0
2/6/98	21:14	55	61	52.2	2206	13.2	722.9	21.0	1.7	25.3	1.9
2/6/98	22:09	55	67	56	2209	14.7	722.2	23.3	1.9	25.4	1.8
2/6/98	22:59	54	62	53.6	2208	14.0	721.0	22.3	1.8	25.3	1.8

Data taken on the APS West PCS before delivery, at STM's test cell with a gear drive instead of the bi-directional inverter (Table 4).

Table 4. APS West PCS Data Taken at STM's Test Cell

Date	Time	Water Inlet Temp [C]	Water Outlet Temp [C]	Air Flow [g/s]	Engine Speed [RPM]	Avg. Cycle Pressure [MPa]	Avg. Receiver Temp [C]	Power [kWe, net]	Fuel Flow [g/s]	Net efficiency [%]	Lambda
1/30/99	9:39:20	46	57	53.7	2215	14.1	700.7	24.1	1.66	29.3	1.90
1/30/99	13:08:10	50	60	47.9	2215	13.0	697.3	21.6	1.55	28.9	1.82
1/30/99	20:58:00	48	57	45.8	2212	12.4	694.1	20.7	1.47	29.2	1.83
11/15/99	10:05:40	45	55	56.2	2216	15.1	703.2	25.2	1.74	29.4	1.90

A total of three PCS's were completely built for this program. The first two used the direct connect coupling with a Baldor bi-directional inverter. The third PCS was made with the gear drive. The first two PCS's were subsequently converted to gear drives before delivery to Phoenix.

3.5.2. Emissions Data

Figures 19, 20, and 21 show the results of emission measurements made on the PCS using natural gas fuel.

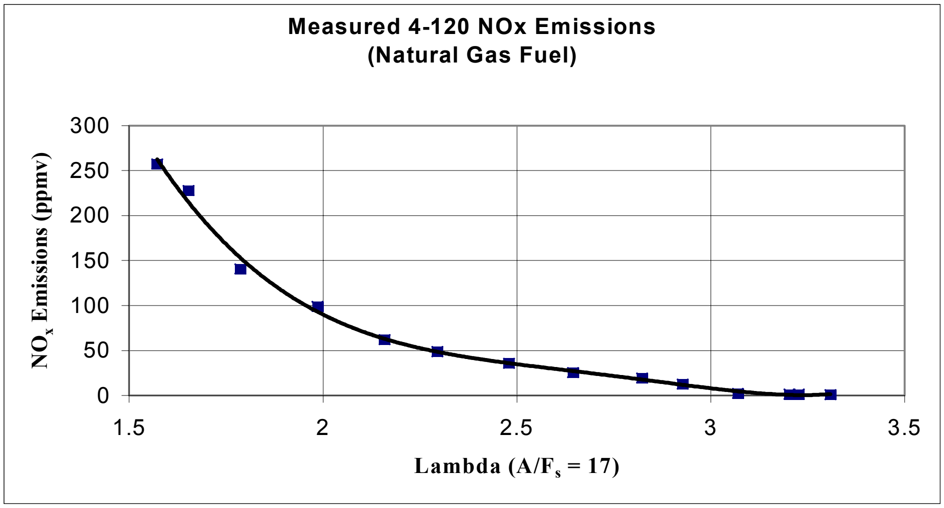


Figure 19. Measured 4-120 NOx Emissions (Natural Gas Fuel)

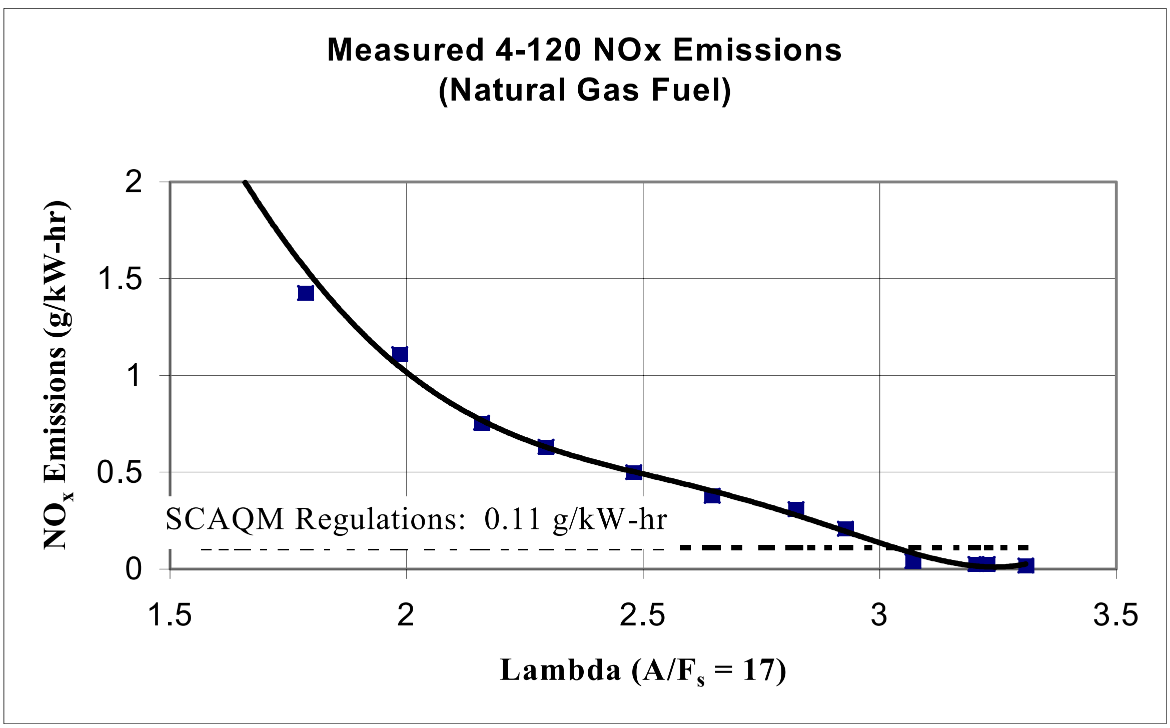


Figure 20. Measured 4-120 NOx Emissions (Natural Gas Fuel)

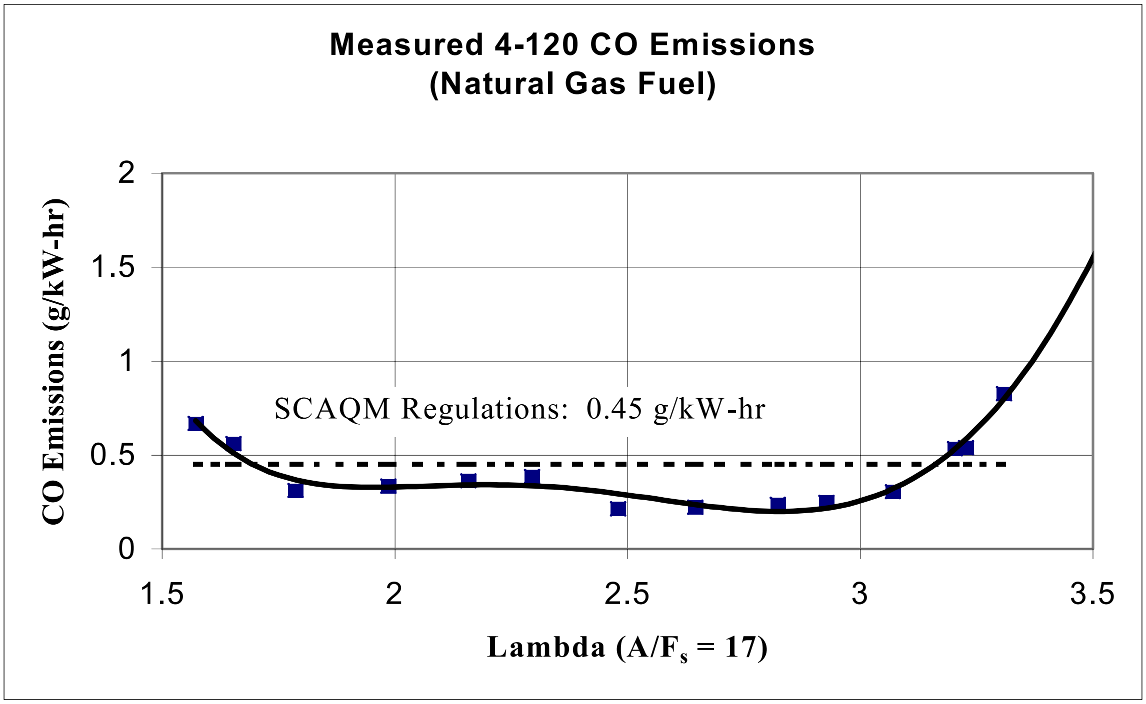


Figure 21. Measured 4-120 CO Emissions (Natural Gas Fuel)

3.5.3. PCS Testing at STM Laboratories

After each system was built, and before delivery, a series of tests was done at STM laboratories, including the following:

- Hydrogen leak test
- Coolant leak test
- Fuel system leak test
- Electrical checkout
- Oil leak check
- Part load test
- Full load testing
- 100 hour endurance tests for new systems
- Tilt test, -35 to 85 degrees, at 10 degree increments during full load tests, to simulate solar operation
- Performance testing.

A total of 969 hours were accumulated on the three Phase 2 PCS's at STM before delivery. Figure 22 shows a typical full day of test-cell operation.

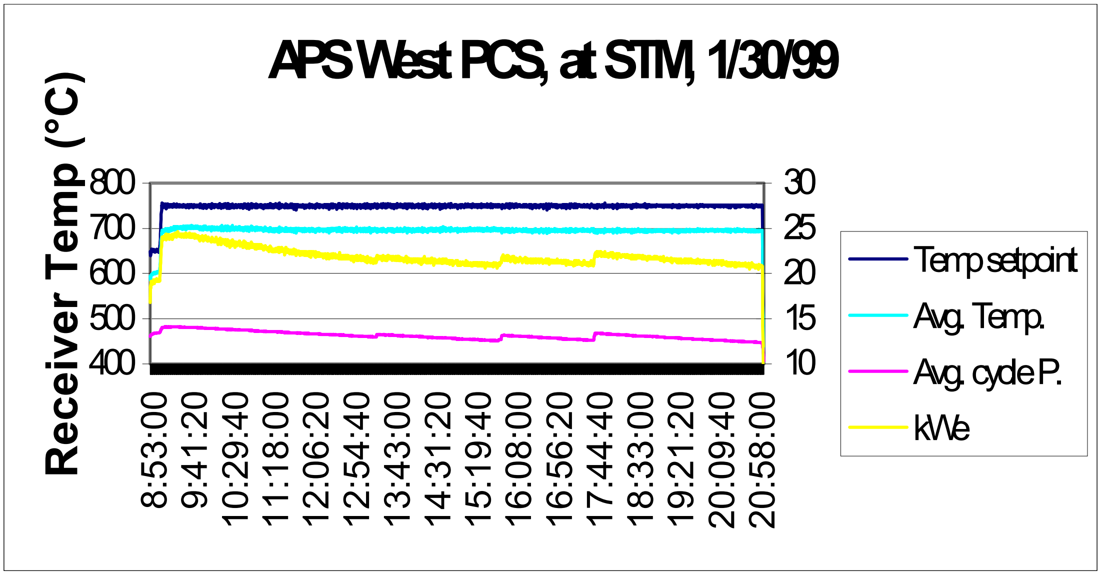


Figure 22. Typical Full Day of Test-Cell Operation

4.0 Solar Dish Concentrator Development

The dish concentrator in Phase 1 had several limitations that were addressed in the second Phase of this program. The area of the dish was insufficient to produce 25 kW, which had been determined to be an attractive power level for utilities. The radial truss structure displayed poor torsional resistance to rotation about the dish axis, and the mounting bolts for the facets were found to be difficult to adjust accurately because they were mounted through the walls of tubes. Although the structure did allow for ground-level maintenance of the PCS, it did not allow for face-down stow. This resulted in rapid soiling of the mirrors. The facets were expensive to produce. Finally, the control system for the Phase 1 dish was complex and expensive, and it did not have all the features needed for autonomous operation.

In view of the Phase 1 dishes' limitations and problems, it was decided to perform an upgrade to the dish structure and to redesign the controls in the second phase of the program. A design-for-manufacturability Analysis (DFMA) was done to aid in the redesign process. The following subsections describe the evaluations that were performed and changes that were made.

4.1. Size and Function Evaluation

4.1.1. Concentrator Size Evaluation

One of the first trade-offs to be conducted concerned the size of the concentrator. The Phase 1 dish had 9.5-ft diameter facets. To reduce assembly costs, it was desired to increase the facet size to the maximum size that could be shipped without special permits. Also, it was desired to increase the power output of the system to the maximum extent possible, so as to reduce balance-of-system costs. Counteracting the desires to increase the size of the dish were shipping size restrictions, the limited torque capabilities of existing drive systems, the hybrid operation requirement, and reductions in engine lifetime associated with increasing operating speeds. Taking all these factors into consideration, it was decided to increase the size of the dish facets to 10.5-ft diameter, an increase of about 22 percent in area. The engine speed was increased from 1800 RPM to 2200 RPM to accommodate the increased input power from the dish, as described in Section 3.

4.1.2. Face-Down Stow Evaluation

Face-down stow has been recognized for many years as an effective way of reducing soiling of the mirrors of concentrating collectors. At the Solar II plant, face-down stow was found to decrease the soiling rate by a factor of 2 compared to face-up stow. Also, face-down stow reduces the hazard of damage from hail and better protects the mirrors during high winds. An innovative system design was developed that uses an articulating PCS support arm to allow face-down stow while keeping the dish profile relatively low and drive moments within allowable ranges. When the dish descends to downward stow, a wheel on the inner part of the PCS arm contacts and rolls down the pedestal while the PCS arm hinges outward. The reaction force from this wheel counterbalances the PCS weight in such a way that the loads on the drive system remain almost balanced through the entire process. In order to protect against high winds blowing the support arm over when at upward stow, a mechanical arm latch was implemented to hold the arm whenever the system tracks above the horizon. Duplication of the latches on both lower ends of the PCS arm provided further security, and limit switches alert the control system if either of the latches fails to open when going to face-down stow.

4.1.3. Stow-Lock Evaluation

Various stow lock configurations were examined in order to remove loads from the drive system when in high-wind stow. All configurations were plagued by the fact that in order to remove loads, they needed to be very stiff, having less backlash than the drive itself. This led to either excessively massive and complex latches or high stiffness requirements on the structure, both of which were cost-prohibitive. The final decision was to eliminate the stow-lock concept. In practice, the articulation of the PCS arm when in face-down stow was found to act as a stabilizing element in high winds because of the contact of the wheel on the pedestal. In face-up stow, the mirrors are close to the ground at lower wind levels, reducing the forces. Finally, the staggering of facets on the front and back of the structure makes the structure more porous to winds and therefore tends to reduce wind loading.

4.1.4. Terminal Concentrator Evaluation

A terminal concentrator was briefly considered for the Phase 2 system. It was decided that the cost and complexity of such a concentrator would exceed its usefulness. At the same time, we recognized that a window on the aperture was needed to allow true hybrid operation along with solar input. Therefore, it was proposed to develop and test a “flux scrambler” window for the receiver cavity instead of a secondary concentrator. The intent was that, in addition to closing off the aperture, the window could help to make the solar flux within the cavity more uniform, thereby increasing engine performance. Two approaches were examined: 1) A quartz window with a shape pressed or machined into it that is optically designed to smooth the internal flux distribution; and, 2) A simple window consisting of a close-packed bank of Vycor tubes that would refract and scatter the incident solar flux on a small scale to make the flux more uniform inside the cavity. Using the SAIC optical optimization code NICOS, we developed the first concept to a preliminary design stage. Initial tests of the second concept performed at the NREL solar furnace were encouraging, but equipment failures on the Phase 1 prototype dish (which had been planned as the test bed for the system) precluded testing a prototype flux scrambler on a dish system.

4.2. Structure Design Revision

4.2.1. Dish Trusses

A trade-off between different truss arrangements was carried out at the end of Phase 1. Truss arrangements were compared on the basis of the number of parts, number of joints, estimated total length of trusses, and estimated mass of the truss system. The criteria for improvement were decreasing total truss length and mass, and reducing the number and complexity of the parts and connections. Figure 23 shows some of the truss arrangements that were examined. A decision was made to proceed with the star truss design based on these criteria.

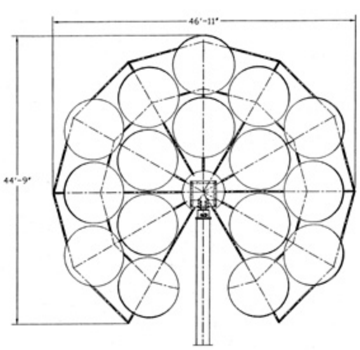
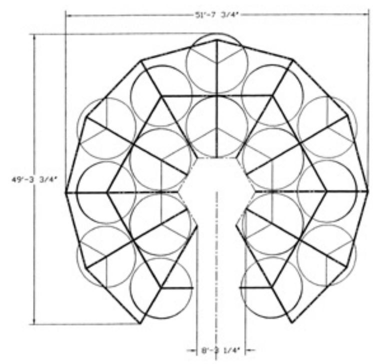
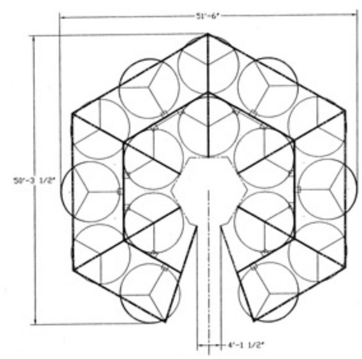
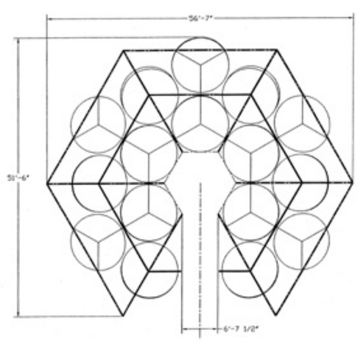
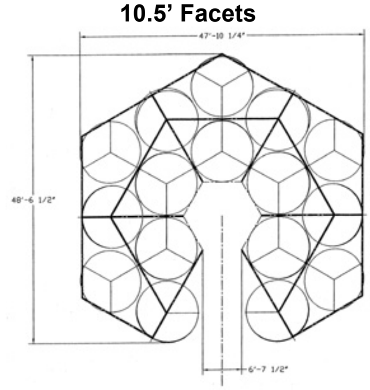
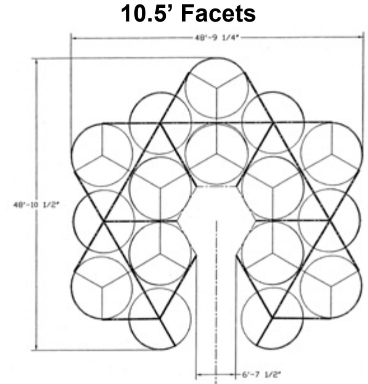
JVP Phase 1 **11 Main Truss Design** **9.5' Facets**  This design required 434′ of truss and 4 different truss details with a moment of inertia of 280 in4	**11 Main Truss Design** **10.5' Facets**  This design required 450′ of truss and 4 different truss details 24″ deep at 12 lb/ft = 5400 lb with a moment of inertia of 280 in4	**7 Main Truss Design** **10.5' Facets**  This design required 381′ of truss and 6 different truss details 28″ deep at 16 lb/ft = 6096 lb with a moment of inertia of 440 in4
1st 6 Main Design **10.5' Facets**  This design required 378′ of truss and 4 different truss details 28″ deep at 17 lb/ft = 6426 lb with a moment of inertia of 513 in4	**2nd 6 Main Truss Design** **10.5' Facets**  This design required 315′ of truss and 4 different truss details 28″ deep at 17 lb/ft = 5355 lb with a moment of inertia of 513 in4	**Star Truss Design** **10.5' Facets**  This design required 275′ of truss and 5 different truss details 28″ deep at 17 lb/ft = 4692 with a moment of inertia of 513 in4

Figure 23. Truss Arrangements

4.2.2. Dish Hub

The Phase 1 dish hub had several problems. It was not large enough to provide unrestricted motion around the fixed portions of the drive system, causing interferences. Also, the forces from the trusses were brought to a small area, which resulted in large members required to carry those forces to the drive. The Phase 2 hub structure was developed to be much larger and more open with a beam-frame rather than a webbed structure. The result was a stiffer yet lighter structure.

4.2.3. Wind-Avoidance Designs

Several concepts were proposed for reducing wind loading on the structure by avoidance of wind loads. Many of them required facet mounts that would allow motion or rotation of individual facets relative to the structure. It was determined that development of such mounts would be a significant endeavor, since they would have to hold the facets rigidly in alignment, allow them to swing free during high winds, and then re-latch reliably and securely after the wind passed. Therefore, those designs were not pursued in this contract. One concept that was implemented in the Phase 2 system was to stagger the mounting of facets on the structure. By placing some facets on the front of the main trusses, and other facets on the back of those trusses, we created large openings in the dish structure through which the wind could blow without inducing large forces.

4.2.4. Structural Analysis

The dish structure was analyzed using the ALGOR Supersap finite element program under wind and gravity loads to determine the stresses and deflections that would occur during operating conditions. We also checked the stow position to verify the strength of the dish under survival conditions. Figure 24 shows the finite element model of the structure used for the analysis. The effect of wind and gravity loads varied with dish orientation. Critical load cases for optical performance included maximum drag force, maximum lift force, maximum elevation moment and maximum azimuth moment.

The structural deflections resulting from this analysis met the requirements of the optical specification for the dish structure, which derived from the CIRCE model results for solar flux at the receiver. However, actual beam profile measurements led to the conclusion that the optical specification was too loose. Hence, umbrella struts were added to the structural model and the analysis was repeated. The resulting peak structural deflections are shown in Figure 25. The analysis indicated that the struts would reduce structural deflections by 44 percent. To ensure that the final beam profile met the target optical accuracy, a one-square-inch cross-section steel plate was added to the top and bottom flanges of the radial trusses. To simplify comparison with field observations, the structural deflections were used to calculate estimated spot motions at the receiver. Details of the results are given in the following subsections. The structural improvements were successful in stiffening the structure of the dish. Based on the most recent calorimeter data, the APS East dish has been shown to have an average optical efficiency of 87 percent, compared to the planned optical accuracy of 90 percent.

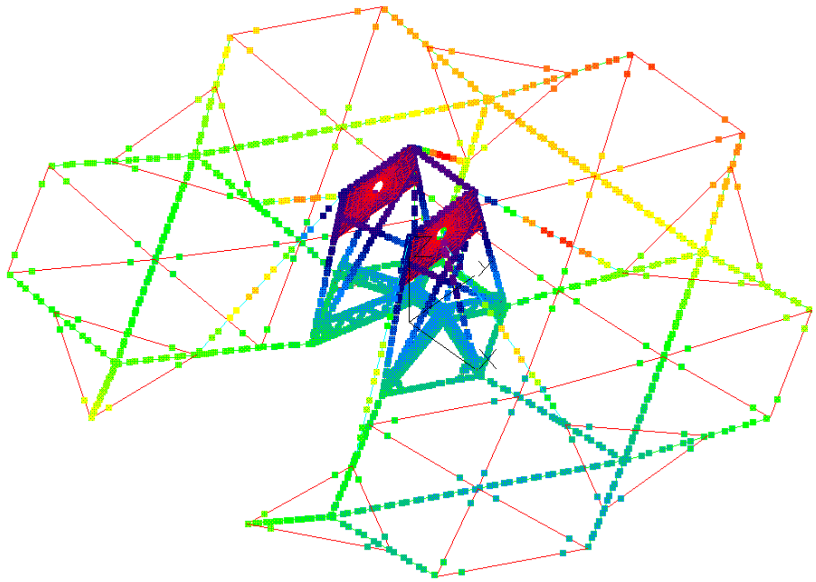


Figure 24. Two Dimensional Model of Dish and Hub

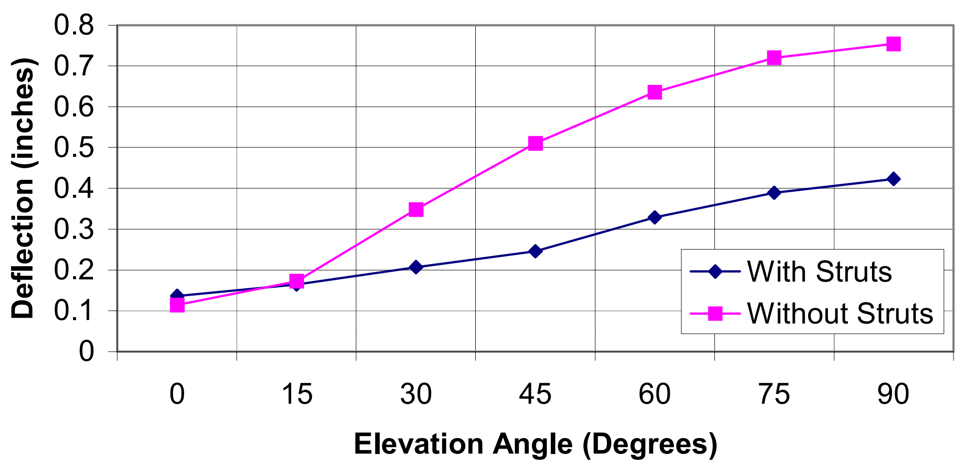


Figure 25. Deflections (inches) vs. Elevation Angle

4.2.4.1. Finite-Element Analysis Assumptions

The following simplifying assumptions were made in the finite-element analysis of the dish structure:

- To derive the wind loads used in the analysis, the faceted dish was assumed equivalent to a single parabolic dish of the same dimensions, less a 24 percent reduction for porosity (based on projected area). The resulting forces and moments were distributed over the structure using the power law formula for wind speed as a function of structure height. For load cases with asymmetric pressure distributions resulting in azimuth moments, the forces were distributed using a linear pressure distribution across the width of the dish.

- The trusses were modeled with individual line elements. Figure 24 shows this two dimensional model. This provided a simple, useful model for overall structural performance but oversimplified connection details and facet mounting conditions. In the model, all connections were assumed to be perfectly rigid, welded connections. The actual structure consists of bolted connections with oversized holes for ease of assembly.
- To account for the stiffness of the facets, it was assumed that they contributed in-plane stiffness to the dish structure. The facets were modeled as triangular braces with section properties less than the ring beam used to manufacture the facets. Although the triangular brace is stiffer geometrically than the circular beam actually used in the facets, this assumption is conservative because it does not take into account the stiffness created by the facet membrane. To restrict the facets to resist only in-plane forces, the facet connections to the truss were modeled as not capable of transferring moments.

The structural deflections due to gravity and operational wind loads were determined using two versions of the two-dimensional model, one with struts and one without struts. Figure 25 shows the results are shown in 15-degree increments from the horizon facing position (elevation angle = 0) to the face up position (elevation angle = 90). The struts were expected to reduce the peak structural deflections from 1.9 cm (0.75 inches) to 1.1 cm (0.42 inches), a 44 percent improvement.

4.2.4.2. Predicted and Observed Spot Movements at the Receiver

The structural deflections due to gravity and operational wind loads were converted to predicted spot motions of representative inner, middle and outer facets, resulting in a predicted range. As shown in Table 5, measured spot motions were consistent with the predicted range. The addition of the struts and the steel plate reduced observed spot movement by 50 percent, from 7.6 cm (3 inches) down to 3.8 cm (1.5 inches).

Table 5. Predicted and Observed Spot Movements

	Predicted	Measured
Without Struts	2.61 – 3.38	3
With Struts	1.37 – 2.46	1.5

4.3. Concentrator Drive System

It has been long recognized that improved drive systems for large solar concentrators, such as dish/Stirling systems, are needed. In this program, SAIC used existing and available gear drives (manufactured by Flenders), while recognizing the need to develop or obtain new drives in the future. A specification for the new drives, based on requirements from both the dish and heliostat systems developed by SAIC, was developed and appears in Appendix A.

In order to use the available gear drives, some improvements were made to them. Multiple failures of the same model of drive had been encountered on the Phase 1 system due to stress concentration on the elevation bearings. To reduce this, all of the Phase 2 drives were modified by adding a tapered conical element that better distributed the load to the bearing. Also, all of the Phase 2 drives were refurbished and inspected by the Flenders Company before their implementation in the field. Along with these improvements and inspections, the balance of the dish was carefully controlled during design so that the loads on the drive would be minimized. As a result, no drive failures were encountered during the Phase 2 testing.

4.4. Facet Design Revision

In addition to increasing the size of the facets to improve system performance and cost effectiveness, changes were introduced to the design of the facets themselves to reduce materials and fabrication costs and to improve the lifetime of the facets. These changes are described in the following subsections.

4.4.1. Facet Ring Design

The facet rings of the Phase 1 system were rolled and welded I-beam sections. Because of the rolling process, the top and bottom surfaces were tilted and the surface finish of those surfaces was unacceptably rough. Significant grinding was needed to prepare the surfaces for welding of the membranes. Also, being mild steel, the facet rings did not match the material of the membranes (Type 201 stainless steel) for welding, and the facet rings needed to be painted for corrosion protection.

In Phase 2, after discussions with suppliers of stainless steel membrane materials, a low-grade stainless steel (Type 410) was selected for the ring material. This made the rings more compatible with the membrane material for welding and eliminated the grinding and painting of the ring. Also, a fabricator was found for forming flat stock into a C-channel shape for the rings. Initial tests with 1″ flanges led to a ring that was too weak, so the flange width was increased to 1-1/2″ in width. The thickness of the ring material was chosen to match a sheet-metal gauge thickness that is readily available.

4.4.2. Facet Mounts

The facet mounts on the Phase 1 system consisted of a doubler plate welded to the ring with a shoulder bolt stud extending outward. A rod-end was attached to the stud to give a ball-joint connection to the facet. Although this eliminated torque into the facet, the rod-end assembly was expensive. In a parallel heliostat manufacturing development effort (the SolMaT program), a mount with a captured nut was developed and used on heliostat facets. The captured nut made facet adjustment simple and easy. At the time of the Phase 2 facet manufacturing run, the captured nuts had begun to show corrosion and there were other difficulties with that design, so a simplified mount was designed for the dish facets consisting of a threaded rod passing through an oversized hole in a piece of channel welded to the facet ring. The threaded rod was secured with oversized washers and nuts above and below the hole.

Once the systems were in place, testing showed that forces induced into the facet from these mounts were causing variations in the focus of the mirror facets. Therefore, the washers were supplemented with spherical washer sets above and below the hole to allow the threaded rod to be secured at small angles from vertical without inducing stresses in the facet ring. Some threaded rods were also reduced from 5/8-inch diameter to ½-inch diameter at selected locations to reduce the forces exerted on the facets.

4.4.3. Facet Mirrors

The mirrors on the Phase 1 system were 0.7 mm thick float glass. These mirrors had significant visual aberrations (ripples), although they tested well optically. They were also quite difficult to work with due to their thinness. For the Phase 2 systems, mirror suppliers were again contacted and alternatives were investigated. A 1.0 mm low-iron glass mirror was found that had comparable reflectance and lower cost than the 0.7 mm float glass. Therefore, 1.0 mm low-iron glass was used on all the mirror facets. Some experimentation was done with alternative mirror adhesive systems, but none with acceptable features and performance were identified. NREL researchers alerted SAIC to potential problems with the MacTac adhesives over long periods of exposure, so the Phase 2 mirrors were bonded to the stainless steel membranes with 3-M Type 966 transfer adhesive.

4.4.4. Focus Valve Improvements

The focus valves on the Phase 1 system operated well after some initial thermal expansion mismatch problems were identified and resolved. The Phase 2 focus valves were designed to accommodate the thermal effects that had been encountered in the Phase 1 valves, but the Phase 2 dishes still seemed to exhibit over focusing. An effort was directed at finding the cause of the over focusing of the Phase 2 facets, and although the primary problem was determined to be rolling of the facet rings due to forces on the facet mounts, several areas of improvement to the focus valves were identified. The initial Phase 2 valves had Delrin™ valve bodies and poppets, brass bushings, and steel adjusting screws. The clearances between the poppets, bushings, and valve bodies were variable due to temperature effects and deflection of the Delrin™. Analysis showed that the steel adjusting screws in the original design could lead to focus movement with temperature changes. Therefore, after several iterations, new valves were produced with all-aluminum valve bodies, bushings, poppets, and adjusting screws. The all-aluminum design eliminates any questions of thermal changes or materials incompatibility. The new were installed in the SRP and the APS-East dishes and will be installed on the other two systems as circumstances permit. Since their installation, no focus-valve-related problems have been encountered.

4.5. Concentrator Control and Electrical Systems

The controller of the Phase 1 system was not suitable for commercial, autonomous operation. Some needed sensors were not implemented and the system was cumbersome and expensive. Therefore, an effort was directed at simplifying and reducing the cost of the dish control system and making it capable of autonomous operation. The electrical system of the Phase 1 system also required significant changes and improvements. Again, simplification of installation and cost reductions were important considerations, but meeting electrical code requirements became the impetus for many improvements.

4.5.1. Dish Controller Development

The development of the Phase 2 dish controller went through several stages. Initially, it was thought that the dish and PCS controls might be combined into one controller, but that proved infeasible. A separate dish control system was then designed and implemented using a commercial microprocessor controller as its core. This system was retrofit onto the Phase 1 dish and then implemented on two Phase 2 systems (NREL and Washington, D.C./APS-West) with hand-wired control boards. Finally, a printed circuit board design was developed, and the upgraded control boards were implemented on all the installed systems. Appendix B contains the controller requirements specification document that was generated for the printed circuit board. The following paragraphs describe the control system implemented on the Phase 2 systems.

4.5.1.1. Dish Control System Inputs and Outputs

The dish control system is based on a commercial microcontroller (Z-World Little PLC, model BL-1200). The controller has eight digital inputs, and eight outputs capable of directly driving relays. An expansion board (Z-World ADC-4) provides an additional four conditioned and seven unconditioned analog inputs with a 12-bit A-to-D converter. The Little PLC also includes a real-time clock and two RS-485 simplex (two-wire) serial communications ports. One of these communication ports is used to "talk to" the central supervisory control and data acquisition (SCADA) system, and the other port is used to communicate with the Stirling Power Conversion System (PCS).

The dish controller has the following inputs:

- Azimuth and elevation motor encoders (for calculation of the dish orientation)
- Azimuth and elevation limit switches (for detection of limit switch operation)
- Arm latches (for verification of arm latch opening while going to face-down stow)
- Auto/manual indication (for detection of manual operation)
- PCS OK (parallel indication of PCS fault)
- Above horizon limit (for avoiding azimuth motion when too low in elevation)
- Focus on (feedback verification)
- Sun reference sensor (analog value, for deciding when focus should be enabled and for data acquisition))
- Azimuth and elevation sun sensors (analog values, for off-track detection)
- Power meter (analog value, for peak-power tracking and data acquisition).

The outputs of the controller are as follows:

- Azimuth motor run and reverse
- Elevation motor run and reverse
- Drive motor high/low speed (not used with the present motors)
- Focus blower on/off
- Scram contractor output (used with watchdog circuit)

- Fuel gas solenoid valve open/close.

The focus blower is powered by a conventional mechanical relay and the fuel gas solenoid is a conventional 24 VDC solenoid. The azimuth and elevation motors are started and stopped using solid-state relays, and a conventional mechanical relay is used to reverse the motors and switch the limit switches. Solid-state relays were chosen due to the large number of on/off cycles that are encountered in tracking the system. The dish uses magnetically-actuated, environmentally-sealed limit switches. These switches act to cut power to the solid-state relays that run the motors, so they cause the motors to stop upon hitting a limit switch. The limits are set up so that if the system is driven onto a limit in one direction, it may be reversed and driven off the limit without jumpering. To protect the system, over-travel limits are implemented with quick-disconnects that are pulled apart, physically cutting power to the motors if the system drives past the electrical limit switches (e.g., due to failure of a solid-state relay).

The SCRAM circuit was added to the system to provide a redundant, fail-safe method of stopping dish motion and focusing. The control board contains a circuit that energizes the SCRAM contractor (which provides power to the drive motors, focus blower, and gas solenoid) only if the SCRAM output is continuously set and reset with a period of a few tenths of a second. If the SCRAM output stays in either the on or off condition, the SCRAM contractor drops out, and the power to the motors, focus blower, and gas solenoid are disconnected. Two mechanical SCRAM switches are wired in series with the SCRAM control circuit, so that if either switch is actuated, the SCRAM contractor drops out. One switch is mounted on the outside of the dish control box, and the other is in the control room.

4.5.1.2. Control System Components

The microprocessor controller is attached to a printed-circuit control board that contains interfaces to the other components of the control system. On the control board, optical isolators and surge protectors protect the inputs and outputs of the controller. Indicator LED's show the status of important inputs and outputs to help with troubleshooting of problems. The major external components to which the controller is connected are as follows:

- **Sun Sensor** – Contains the sun reference sensor, sun tracking sensors, the horizon reference switch, and a circuit board with signal conditioning circuitry mounted on the dish hub.
- **Drive Motors** – Single-phase 120 VAC capacitor-start motors are used for the azimuth and elevation drives (a ½-HP motor is used on the azimuth, and a 1-HP motor on the elevation).
- **Encoders** – The system uses SAIC-developed optical encoders that give a quadrature output with one pulse per revolution. These are installed on the motor shafts between the motors and the gear drive.
- **Limit Switches** – The drive limit switches are magnetically-actuated, hermetically-sealed mechanical vane-type, normally-closed switches. Separate switches for each direction of the azimuth and elevation travel are actuated by magnets mounted on the drive.

- **Arm Latch Switches** – Each arm latch is fitted with a magnetic actuator that triggers a hermetically-sealed mechanical vane-type, normally-open switch when the arm latch is disengaged. The two arm latches are wired in series so that both switches must be disengaged before the circuit is completed to the control input.
- **Fuel Gas Solenoid** – A standard, 24 VDC, normally-closed solenoid valve is employed to turn on the fuel gas supply to the PCS when gas operation is enabled.
- **Focus Blower** – A 1/8 HP, 120 VAC regenerative blower valve is used to provide vacuum for focusing the facets of the dish. The blower is fitted with a backflow preventer and a normally-open defocus solenoid valve. The defocus valve is wired in parallel with the blower and actuates to close when the blower is in operation.

4.5.1.3. Dish Control Program

The system control software is written in the real-time Dynamic C programming environment on the Z-World Little PLC microcontroller. This controller uses a Z180 processor, and has 128K of battery-backed static RAM in which the program and data reside. The control program is designed to operate a dish/Stirling system in a stand-alone manner, including solar operation, operation on fuel, and data acquisition. The system communicates with an external SCADA system that operates over a daisy-chain network to provide user input and display of system parameters, data downloads, and overall system control to as many as 255 dishes per network. The SCADA system also incorporates a wind sensor and is programmed to inform the dishes on the network when the wind exceeds allowable limits.

Solar operation is controlled with both calculated and sensor inputs. A sun position algorithm calculates the expected position of the sun. A sun sensor gives the relative position of the dish to the sun, as well as measuring the total insolation. The insolation sensor allows decisions to be made regarding whether to give credence to the sun sensor directions and whether net power can be generated. Finally, a tracking optimization algorithm is implemented that allows the system to find and track the aimpoint at which peak power is generated by the system.

Operation on gas is allowed independent of solar operation. When operating on gas, the shutter/plug is closed in front of the receiver to maximize efficiency for fuel operation. The system is designed to automatically switch back and forth between solar and gas operation if both are enabled, depending upon whether the solar insolation is sufficient for producing power. True hybrid (i.e., with fuel and solar power at the same time) operation was not implemented in the Phase 2 system.

The controlling element in the system is a truth-table function. This function takes as its inputs the values of a set of system flags that uniquely determine the status and operating mode of the system. The flags consist of overrides, system control flags, and system status flags. The outputs from the function are flags that enable motion, focus, and running on gas, and goal values for the azimuth and elevation of the dish. The outputs are processed by other functions within the control program to direct movement and operation of the system.

4.5.1.4. Operator Interface

Operator control of the dish/Stirling system is via a SCADA computer in the control room. A Windows-based program on this computer provides an interface to the dish network controller and the dish systems on the network. The program displays the status of multiple dishes on the network and allows the operator to send commands and make parameter changes to any of the dishes. The two main system operational controls are:

1. **Enable/disable solar operation** – When enabled, the system automatically wakes itself, tracks the sun, generates power when the insolation is high enough, and stows itself at night or if high winds occur. If solar is disabled, the system will defocus and stow itself. Presently, the dish stows face-up during the day, and face-down at night, automatically.
2. **Enable/disable operation on fuel gas** – When enabled for gas operation, the system will operate automatically on gas between an operator-specified start hour and stop hour. If solar operation is also enabled, and the time of day is within the gas operation window, the PCS will operate on gas anytime that solar insolation is insufficient for solar power production.

4.5.2. Electrical Wiring Design

The Phase 1 dish employed a very simple electrical system. The power for the control systems of the dish and the PCS was supplied by a separate 120 VAC supply and the PCS generator was supplied with 480 VAC, three-phase power. Economic analyses showed that the provision of both 480 VAC and 120 VAC to multiple dishes in the field would be expensive. Therefore, the Phase 2 systems were designed to have a 480VAC-to-120VAC transformer on each dish to provide control power. Since the PCS on the Phase 2 systems have an electric oil pump, an uninterruptible power supply was added to the system to provide power to the pump in the event of a grid failure.

The first two Phase 2 systems were installed with a variable-speed AC motor driver to control the motor/generator at 2200 RPM. This required a separate 480 VAC circuit to the generator. When the variable-speed motor drive was replaced by a gearbox, the extra 480 VAC circuit was no longer needed, which simplified the wiring of the later systems.

Also implemented on the Phase 2 systems was a distribution panel for the 120 VAC loads of the dish and PCS. This, combined with an overall 120 VAC disconnect, allows individual loads (such as individual motors and the focus control blower) to be turned on and off at will by the operator. A "SCRAM" system was also included to disconnect power to the drive motors, focus blower, and gas solenoid valve, if a manual SCRAM switch was actuated either at the base of the pedestal or in the control room.

A review of the electrical design was conducted, and many wiring changes were made in order to meet National Electric Code requirements. For example, the power cable to the drive was replaced with a conduit and individual wire sizes were increased for the motors. The wire size to the motor/generator was also increased to accommodate thermal requirements.

4.6. PCS Protection System

The PCS protection system is intended to protect the PCS against concentrated solar flux. Two different protection scenarios were identified during testing of the Phase 1 system: engine problems requiring immediate removal of solar flux from the receiver; and protection of the PCS from off-track incidents in which the dish tracks off sun while still focused. The first scenario is addressed by the shutter/plug described in an earlier section. The shutter is closed if an emergency in the PCS requires that solar flux be removed from the receiver. A PCS fault also signals the dish to begin defocusing, so that the shutter only needs to withstand full flux for a minute or two.

The other protection scenario, in which the dish tracks off-sun in a focused condition, was not provided for in the Phase 1 control system. In that system, the operator was required to initiate focus and defocus manually and was responsible for ensuring that the system was actually on sun before beginning focus. In the Phase 2 dish, we decided that a sun sensor was needed to automate the focus process, to detect off-track conditions, and to serve as a check on the calculated sun-position algorithm used for tracking. The focus is controlled using a photovoltaic sensor in a collimating tube as a sun reference sensor. When the reference sensor detects sufficient solar insolation for system operation, the dish control system is enabled for focus. When the solar flux decreases or if the system tracks off from the sun, the sensor output drops and the dish controller turns off the focus blower. For the off-track sensor, a tracking sensor developed for a trough collector was adapted. The sun sensor consists of a pair of photoresistors mounted on opposite sides of a cylindrical "nose". When the nose is pointed at the sun, both sensors are equally illuminated and the control signal is zero. If the dish tracks off sun, one or the other of the sensors is shaded while the other is fully illuminated, causing a voltage signal to the controller that varies in polarity and magnitude according to the direction and amount of off-track motion. The sun sensor signal is monitored by the dish control program, which forces the system to defocus if the error becomes too large (e.g., 25 milliradians between either the calculated or sun-sensor sun position).

4.7. Fabrication Process and Tooling

The Phase 1 dish facets were fabricated using manual operations on prototype tooling. The Phase 2 program took advantage of tooling and process development for facet production developed under the parallel SolMaT heliostat program but some development was also conducted in the course of the Phase 2 contract. The following subsections describe the activities under this contract.

4.7.1. Tooling Development

A semi-automated facet tensioning system employing mechanical grippers and pneumatic cylinders was developed in the SolMaT program. In the USJVP, a parallel-gap welder was developed for automated welding of the facet membranes to the facet rings. This parallel-gap welder allowed a double roll-resistance weld to be performed between the ring and membranes (top and bottom) in an automated manner. The principle behind the parallel-gap welder is that two roll-resistance weld wheels are used in a tandem arrangement. The wheels are wired to the welder so that the current goes through one wheel to the facet ring, then back out through the other wheel. As the current passes between the wheels and the membrane/ring interface, a double weld seam is produced. Because the distance between the wheels is fixed, the resistance is constant, and welds of very good uniformity are produced.

Another area of development was an automated mirror application device. A preliminary design was generated but time constraints prevented it from being used in production. Thus, it was never tested and the mirrors of the Phase 2 systems were laminated with adhesive and applied manually to the mirror facets.

4.7.2. Quality Control Procedures

An area of major effort was the development of quality control procedures for the manufacture and design of the dish components. A quality control engineer was hired who had experience with ISO 9000 and 9001 requirements. He generated a quality assurance program, including procedures for implementing quality control in all aspects of the project. In the design phase, procedures were implemented for configuration control and drawing numbering and approval. These procedures specified a design process and documentation requirements, and provided for design reviews and approvals.

During facet production, procedures for quality control were also implemented. Each ring was measured for flatness and uniformity and the results were recorded. Then, when the membranes were applied the facet was again measured for flatness. Finally, notes were taken of any mirror breakage, including the point in the production cycle where the breakage occurred. These data allowed us to see where improvements to handling and production processes would be most helpful.

5.0 System Integration

Although the prototype dish/Stirling system in Phase 1 was successfully operated on sun, it was not built to function as an autonomous system but was operated under direct operator control. Also, with the addition of the hybrid capability and the shutter/plug on the PCS in the Phase 2 systems, the interface between the engine and the dish controller became more complex and important. The changes made in the Phase 2 system required better control and definition of the interfaces between components of the system.

5.1. PCS/Dish Interface

5.1.1. PCS/Dish Physical Interface

The physical interface of the Phase 2 PCS package to the dish included several improvements generated from experience with the Phase 1 system. The Phase 2 PCS base is constructed of steel channel, with the flanges pointing out so that the mounting bolts are accessible. Due to difficulties installing the PCS on the Phase 1 dish, the initial Phase 2 design included alignment blocks for the PCS that would allow it to be set on the support plate without requiring bolts to be in place. These alignment blocks were later found to interfere with components under the PCS and were removed. Another change is that the control cables to the PCS terminate in plugs on the bottom of the PCS. This simplifies assembly of the system and ensures correct connections.

5.1.2. PCS/Dish Controller Interface

The controller interface between the PCS and the dish consists of a switch closure that indicates that the PCS has no faults, and a RS-485 serial communication line between the PCS controller and the dish controller. The switch closure is a redundant indication from the PCS that it is able to operate. It was retained from the Phase 1 system for redundancy with the serial communication signal. The RS-485 communication line is the primary control interface between the PCS and the dish controller. Using that interface, the dish controller sends commands to the PCS to initiate and stop gas operation, and to open and close the shutter/plug. It also prompts the PCS for status, to which the PCS responds with a status message to the dish controller that gives the state of the shutter/plug, whether or not the PCS is running on gas, and if the PCS is ready for solar or gas operation. Loss of communications between the controllers causes both controllers to fault after a short time (several seconds). Any fault causes the dish to defocus, turn off the gas solenoid valve, and drive to a stow position, and causes the PCS to close the shutter/plug and shut down.

5.1.3. PCS Solar Flux Interface

The receiver of the PCS is the thermal interface between the solar dish concentrator and the engine. The desired flux profile at the PCS receiver is specified in the dish system specification (see Appendix C). Initial plans called for development and evaluation of alternative alignment and focusing approaches for the dish to achieve the proper flux profile at the PCS receiver. However, despite testing of several approaches such as distant-light alignment and VSHOT measurement of the dish, no procedure better than on-sun alignment with a beam characterization system (BCS) was found. The main advantage of the BCS alignment is that it gives a direct measure of the actual solar flux profile, although on a flat surface, not the conical surface of the receiver. With indirect methods such as the distant-light source, there is still uncertainty after the alignment is complete as to the actual flux pattern.

5.2. Quality Control

The production quality assurance program was described in an earlier subsection, related to the production of the facets. The program also included procedures and a database for reporting and tracking incidents that occur during the installation and operation of the systems. Finally, a program was implemented for evaluating and tracking engineering change requests and proposals for system improvement.

5.2.1. Incident Tracking

Once systems were installed in the field, an Incident Reporting system was implemented to monitor and record incidents and problems that arose. This system has been invaluable for tracking the MTBF of the systems and for providing a process for addressing system improvements and changes needed to avoid or repair deficiencies. Appendix D has incident summaries for each of the systems through the end of October 1999.

5.2.2. Engineering Change Process

As part of the engineering design process, a system of engineering change requests was implemented. As opposed to incident reports, which are a reactive system to events that have occurred, the engineering change process is a proactive system for proposing improvements to the system. Several significant improvements have resulted from engineering change requests entered into the system by various individuals engaged in installation, operation, and testing of the systems. Appendix E contains a summary of the engineering change requests processed during this program.

6.0 System Installation and Testing

The Phase 1 test program consisted of component tests, system integration tests, and on-sun testing of the completed prototype system. The Phase 2 test program scope included evaluating improvements made to the Phase 1 system, and gathering operational and incident data from the Phase 2 systems. Primary emphasis in Phase 2 was to have been on accumulating hours on the systems; efforts to address problems with the structure and engine precluded and re-directed some of that effort. A significant amount of testing early in the program was involved in the development of the improved control system for the Phase 2 system. The bulk of time in the latter portion of the project was spent understanding the structural and focus control issues that arose during testing of the Phase 2 systems.

6.1. Phase 1 Testing

The component and system-integration testing performed in Phase 1 of this program was documented in the report "SAIC Utility Joint Venture Program Phase I System Test Plan and Results" (Revision #4, 22 May 1995). That report contained a summary of all tests performed, detailed test plans, and test results. The report was maintained in a loose-leaf format, and new test plans and test results were attached as appendices in the form of memos distributed as the tests were completed. Updates were delivered to all project participants over the course of Phase 1 of the project, so the following is simply a summary of tests performed during the Phase 1 program.

Component and Subsystem Tests

- Dish Facets
  - Facet Shape Measurement
  - Facet Focus Control Tests (vacuum level, membrane stress, focus control knob calibration)
  - Dynamic Focusing Tests (single-facet focus rate, focus stability, single-facet defocus rate, multiple facet focus tests, focus cycling test)
  - Facet Optical Tests (laser ray-trace measurements, NREL SHOT and Sandia 2-f tests, NREL adhesive/sealant/reflector sample evaluation)
- Control System
  - Drive unit (function, no-load tests, analysis of bearing loads, failure analysis of bearings, drive flex and backlash measurements)
  - Utility Interface (relay checks)
  - Shutter Subsystem (operational tests, thermal tests)
  - Focus Control System (multiple-facet tests)
- PCS Tests (pre-delivery tests at STM, including component and subsystem checkout, fault tests, mass and CG determination, full-power tests, system characterization tests, quartz lamp tests)
- Data Acquisition calibration and sensor tests

System Integration Tests

- Sun tracking and alignment
- Drive System Baseline Measurements
- Structure Deflections
- Concentrator Wind Loads
- Focus Control Verification (time to focus/defocus, flux during focus/defocus, individual facets)
- Facet Alignment and Focusing
- Flux Mapping (facets and full-dish)
- Calorimetry
- Shutter Operation Test
- Concentrator Endurance Test (50 hours)
- Utility Interface Trip Checks
- PCS Checkout Tests

Whole-System Tests

- Demonstration of Manual Operation (manual movement)
- Demonstration of Automated Operation (sun tracking, solar operation, fault responses)
- System Operational Characterization (performance curve, wind effects, all-day power generation and efficiency, parasitic power requirements, effects of soiling)

6.2. Phase 2 Tests with Phase 1 Dish/Stirling System

The Phase 1 system was used for limited component and system testing during the Phase 2 program. Through the middle of October 1997, the system was operated using the Phase 1 controls to gather performance data and perform testing of concepts such as 3-phase drive motors, encoders, and VYCOR tubes across the aperture. Then, a prototype Phase 2 controller was installed, and the system was operated until March 1998 using that system. Unfortunately, the drive system on the Phase 1 dish, which was never rebuilt with the improvements made to the Phase 2 drives, failed twice in this period. The last failure was not repaired and the dish remained out of service from that time until it was taken down in 1999.

6.3. NREL Dish

The first of the Phase 2 systems to be installed was the one at the NREL Solar Industrial Mesa Top Area (SIMTA) site, where NREL made available a fenced test site with a control building and access to 480 VAC power. The NREL dish was the first to be assembled using the new truss system. There were significant delays and problems encountered in the fabrication and assembly of the system. It was also the first system to be built from the ground up with the Phase 2 control system, and the first system with the variable-speed bi-directional inverter drive for the motor/generator (an approach which was subsequently abandoned).

Table 6 presents a summary of the history of this system.

Table 6. Summary History of NREL Dish

Date	Events
1/9/98	System first installed on pedestal
2/2/98	System successfully tracked on sun using the Phase 2 controls
2/6/98 to 4/3/98	BCS alignment; It was found that the structure was deflecting excessively when facets were aligned, and braces were added to reduce the effect
4/7/98	PCS installed for the first time
4/24/98	PCS ran on propane gas for the first time
6/1/98 to 9/27/98	Excessive spillage on receiver and changing of the image prompted more evaluation of the structure and eventual design and implementation of umbrella struts to stiffen the structure
9/28/98 to 12/14/98	System was operated on sun and on propane gas. A peak power of 20 kW at 1000 W/sq.m was achieved
12/14/98	Receiver failure (secondary failure) due to system fault (primary failure was insulation added to the shutter mechanism to protect its wiring caused the shutter to hang up); the PCS was removed and returned to STM, and the system was idled
Sept 1999	System was removed from its pedestal for rework of the truss structure and retrofit of controls and wiring improvements.

Because of the problems encountered with deflection of the structure, and because efforts were directed elsewhere during mid-1998 (the Washington, D.C. dish installation took priority), the operation of this dish was limited. Over the course of the Phase 2 program, the system operated 393 hours on solar, and 17 hours on propane gas. During that time, the system delivered a total of 1,747 kWh of electricity to the NREL facility.

6.4. Washington, D.C. Dish

The installation of a Phase 2 system in Washington, D.C., at the Pentagon Utility Plant was funded from a source outside the USJVP. The system was installed in April 1998 operated for eight months, through November 1998. Then, it was removed and shipped to Arizona where it was re-assembled and installed as the APS-West dish.

Because this system's installation took priority away from the NREL dish, it actually became the first of the Phase 2 systems to come on-line. The process of debugging and troubleshooting the startup problems of the first Phase 2 system 2,000 miles from SAIC's office was painful and slow. Because the structural deflection problems noted in the NREL dish had not yet been resolved, this dish was never operated at full power. Instead, several facets were left defocused during solar operation to eliminate any possibility that excessive flux would be put onto the receiver at any time due to flexing of the structure. As a result, this system never delivered more than about 10kW on solar at this site.

Despite the difficulties and problems encountered in debugging the Washington, D.C. system, it achieved several significant milestones. During the month of September, the system was operated in a hands-off manner for nearly 200 hours of solar power production (over 500 hours of automated operation) over a period of 23 days without any system disruptions. Also, intermittent, on-demand, and 24-hour-per-day power production using natural gas was demonstrated. An important measure of the system's success is that by the middle of the operational period system operation was routine in both solar and gas-fired operation modes, and the operators were complaining of boredom. Another significant milestone was the disassembly and removal of the system, which was accomplished in 3 days.

Table 7 summarizes the operation of the system.

Table 7. Summary Operation of the Washington, DC Dish

Month	Hours of Automated Operation	Hours of On-Sun Tracking	Hours of Solar Power Production	Hours of Natural Gas Operation
April 1998	80.9	45.2	0.0	0.0
May 1998	118.0	61.4	19.5	0.7
June 1998	144.6	132.9	9.6	5.7
July 1998	248.8	234.8	39.0	0.0
August 1998	456.0	209.0	59.4	0.0
September 1998	714.5	307.0	241.6	7.3
October 1998	603.1	281.7	148.8	113.7
November 1998	400.8	167.8	57.5	218.5
Total:	2766.5	1439.7	575.3	345.8

A complete record of the installation and operation of the Washington, D.C. system is contained in the final report for the project (Final Report, Contract BC-1296, for Sandia National Labs, entitled "Solar Dish/Stirling Demonstration Project: Washington, D.C.", 15 December 1998).

6.5. APS-West Dish

The APS-West dish was installed in Tempe, Arizona at the Arizona Public Service (APS) Solar Test and Research (STAR) facility. Installation began on 22 January 1999. By 29 January 1999, the system was tracking on sun. It should be noted that the APS-West dish was installed with the wiring and other control components as they were on the Washington, D.C. dish, except for elimination of the variable speed controller for the PCS. It wasn't until September 1999 that the dish was upgraded to a printed-circuit control board and other wiring improvements were made. The structure was upgraded when the system was moved from Washington, D.C. to incorporate the umbrella struts and stiffened trusses that were found to be necessary.

On 3 February 1999, the system ran on sun for the first time. The Stirling engine installed on this system was the first PCS to incorporate a 2200 RPM-to-1800 RPM gear drive between the engine and the motor/generator. Initial solar operation was relatively trouble-free and continued through most of February, March, and April without serious incidents and with increasing operational time. Appendix F summarizes the cumulative operation of the system on a month-by-month basis, and Appendix G gives details on a day-by-day basis. Table 8 summarizes the month-by-month operation of the system:

Table 8. Summary of Month-by-Month Operation of APS-West Dish

Month	Solar Hours	Gas Hours	Solar kWh	Gas kWh	Solar Availability	Solar Utilization	Gas Availability	Gas Utilization
Feb '99	61.8	0.0	539	0	100%	53%	2%	0%
Mar '99	86.5	7.7	1116	159	100%	32%	54%	3%
Apr '99	139.4	7.1	1656	122	93%	39%	69%	2%
May '99	22.0	0.0	221	0	32%	16%	35%	0%
Jun '99	23.0	7.1	230	94	35%	15%	37%	3%
Jul '99	63.1	3.0	664	50	50%	29%	56%	1%
Aug '99	42.9	0.2	543	2	21%	50%	21%	0%
Sep '99	14.5	0.2	129	1	52%	8%	53%	0%
Oct '99	100.2	0.9	844	10	52%	56%	52%	0%
Total:	553.4	26.3	5,942	439	54%	32%	45%	1%

In the preceding table, availability of the solar and gas systems is defined as the time the systems were available to operate divided by the total time they could have operated (sunrise to sunset for solar, 24-hours per day for gas). The utilization is defined as the number of hours the systems were actually operated divided by the number of hours they were available to operate. As shown in the table, the solar availability in February to April was excellent, but dropped after that point to about 50 percent. This was due to maintenance activities related to the focus control system and structure. The gas system was down a significant amount of time because the combustion blower was overheating.

Appendix H gives detailed data for a single day of operation in April 1999 in which the system operated on sun for 12.26 hours, delivering 173.8 kWh with a peak power of 20 kW. On 16 April 1999, the system reached its record peak power output to date, a value of 21.6 kW. On 10 May 1999 the engine was inadvertently run backwards after some wiring changes were made to install a power meter. This damaged the engine and brought the system down until 24 May 1999 when a new engine was installed. The new engine had a special burner assembly to allow combustion of hydrogen. Problems with focus control valves caused the system to be down much of June. In early July, more testing was performed to understand the flux pattern changes that were being observed. It was determined that the focus changes were due to forces transmitted from the structure to the facets that caused the facet rings to deflect.

In August 1999, BCS testing was performed early in the month to verify that the focus was not changing over time. Then, the system operated until an engine fault in mid-August led to the engine being removed and returned to STM for evaluation. The engine was re-installed on 10 September and the system operated 129 hours through the end of the month. Operation continued through October, and in mid-October, permission was received to operate the PCS on hydrogen, which was done successfully. Unfortunately, the engine faulted again on 28 October, and exhibited pressure differences between the cycles that led to the PCS being removed and returned to STM for repair

6.6. APS-East Dish

Installation of this dish began on 7 June 1999. Alignment and BCS characterization were completed on 18 June 1999, and the PCS was installed on 15 July 1999. In early August, the PCS was removed and BCS testing was conducted through the end of the month to measure changes in the alignment over a long period. The PCS on this dish exhibited occasional faults of the actuator system (due to parameter changes made by mistake) which limited otherwise routine operation in September. The engine was finally removed and sent back to STM for investigation on 1 October 1999. With the engine off, the dish was once again outfitted with the BCS system, and the facet mounts on some facets were modified to address the facet focus and alignment shifts that continued to be noted. Appendix I summarizes the cumulative performance of the APS-East system on a month-by-month basis. Appendix J contains the monthly summaries of its operation from July 1999 through October 1999, with day-by-day details. Table 9 summarizes the operation of the system:

Table 9. Summary Operation of APS-East Dish

Month	Solar Hours	Gas Hours	Solar kWh	Gas kWh	Solar Availability	Solar Utilization	Gas Availability	Gas Utilization
Jul '99	23.6	5.8	228	90	76%	1%	77%	1%
Aug '99	7.3	0.9	90	0	2%	7%	5%	2%
Sep '99	23.4	2.2	771	122	70%	90%	70%	1%
Oct '99	0.0	0.0	0	0	0%	9%	0%	0%
Total:	54.3	8.9	1090	212	37%	27%	38%	1%

6.7. SRP Dish

The SRP dish was installed at the Pima-Maricopa Indian Reservation Landfill northeast of Phoenix, Arizona. Installation of the SRP system began on 16 August 1999, and the engine was installed on 24 September 1999. Problems with the grid interface, UPS system, and the PCS precluded all but a small amount of solar operation through the end of October, when the engine was finally removed and returned to STM for evaluation. The system was not operated on gas because the landfill gas supply system had not been installed. The completion of that system is expected by the end of November 1999. Although the system did not operate on solar, it was tracked in automatic mode during much of the month with the focus disabled. Appendix

K is the monthly summary for October; no cumulative summary is needed since the system only operated in October. The Appendix also includes the weather data recorded for September and October by the network interface at the SRP site. This data includes average wind speed and wind peaks, and the direct normal insolation measured by an Eppley NIP mounted on top of the control building.

6.8. APS Weather Data

Appendix L shows the weather data from the APS site for June 1999 through October 1999. The dish network interface records the average and peak wind speed.

6.9. PCS Service and Overhaul Chronology

Because the PCS's for the Phase 2 systems were shuffled around a significant amount during this program, Table 10 summarizes their chronologies:

Table 10. PCS Service and Overhaul Chronology

PCS Serial Number	Date	Event/Location
1	4/7/98	Installed on NREL dish with direct-coupled engine and generator
	12/14/98	Receiver tubes melted; returned to STM, where new heater heads and a gear drive were installed
	9/27/99	Installed on SRP Dish
	10/28/99	Removed and sent to STM, where it was determined that the oil had leaked out of the gearbox
2	2/98	Installed on Washington, D.C. dish, with direct-coupled engine and generator
	12/98-5/20/99	Removed from Washington, D.C. dish and returned to STM, where a gear box was installed and the hydrogen burner taken from PCS #3 was installed
	5/24/99	Installed on APS-West dish
	8/20/99	Max. Cycle Pressure Difference Fault; engine returned to STM
	8/28/99	Engine installed on APS-West dish
	10/28/99	Cycle Pressure Imbalance Fault; engine removed and returned to STM
3	2/2/99	Installed on APS-West dish, with hydrogen burner installed
	5/10/99	Accidentally run backwards; returned to STM, where the core engine was exchanged and the hydrogen burner was removed (to be installed on PCS #2, see above)
	6/99	Installed on APS-East dish
	10/1/99	Because of recurring Actuator Stall Faults, removed engine and returned to STM.

6.10. Summary of System Performance

Table 11 summarizes the performance of all the systems through the end of the USJVP Phase 2 program:

Table 11. Summary of System Performance

System	Total Solar Hours	Solar kWh	Peak kW	Total Gas Hours	Gas kWh
Rocky Flats, Phase 1	304	3,008	21.6	n/a	n/a
Rocky Flats, Phase 2	111	810	14.8	n/a	n/a
NREL	393	1,650	20.7	17	97
Washington, D.C.	575	Not Recorded	Not Recorded	346	Not Recorded
APS West	553	5,942	21.6	26	439
APS East	54	1,090	20.5	9	212
SRP	17	203	17.0	0	0
Total:	2,007	12,703	21.6	398	748

As of the end of Phase 2 of the USJVP program, the dish/Stirling systems have demonstrated many important features necessary for future production units, but some problems remain in both the dish and the engine subsystems. A summary of achievements and challenges follows:

Achievements of the USJVP dish/Stirling Systems:

- Over 2000 hours of on-sun operation with six system installations and two generations of design
- Almost 400 hours of hybrid operation, with over 300 hours of natural gas operation on a single system (Washington, D.C.)
- Demonstrated 21.6 kW(net) power on sun (Note: this is 13.6 percent below the initial rating of 25 kW, but consistent with measured system optical performance, thermal losses, and electrical characteristics and parasitics of the Phase 2 dish and PCS)
- Demonstrated simplified, low-cost dish control system with autonomous operation capability
- Demonstrated hybrid operation with propane, natural gas, and hydrogen fuels
- Demonstrated face-down stow with articulating PCS support arm

Challenges to the USJVP dish/Stirling System:

- Hybrid operation, thought to be an important component in future systems, has not yet demonstrated its full promise. Development of augmented hybrid operation (i.e., supplementing solar energy with gas fuel) would make hybrid option more practical.
- Dish structure requires more stiffening to achieve highest performance
- "Nuisance" problems continue to interfere with peak performance and limit system operation (e.g., hydrogen leakage from engines, sensor failures, etc.)

7.0 Business Development

7.1. Overview

The business development task included dish/Stirling system sales to utilities, development of the SAIC business plan to market systems, and the SAIC/STM license agreement to allow STM to sell systems. The foregoing activities were all dependent on system cost studies, which are included for completeness. The details of the market projections and proprietary offering data from the business plans and license agreement are not included. The general market trends are included, the most notable being the death of regulated utilities (utility deregulation) starting in 1997 and historically low energy prices due to a worldwide economic slowdown, causing energy prices to drop.

Financing of a dish/Stirling company has yet to be achieved. However, in October 1998, STM engaged Price Waterhouse Coopers Securities, LLC (PWC), a major investment banking firm, to seek strategic alliances to manufacture and market the STM engine for solar, distributed power generation and transportation applications.

At present, STM is entering into agreements with US companies regarding the distributed power generation application using conventional fuels versus solar. Further STM acquired a license to manufacture and market the SAIC solar concentrator world-wide.

Last year, STM engaged Black & Veach and MITI to make an assessment of the manufacturing costs of the SAIC/STM solar system called "SunDish". The task includes identification of cost driver and proposals to reduce costs as well as projections of one respectively 1000 SunDish systems. This effort is done independent of the SAIC effort described below. This information will be used to direct the remaining R&D effort to reduce cost, and improve reliability.

In parallel, STM and PWC continue to form strategic alliances to commercialize the SunDish systems. Their efforts are expected to pay off in developing a robust dish/Stirling supply business.

7.2. Cost Estimates With Performance and Reliability Goals

7.2.1. Cost Estimates

Cost estimates were prepared based on revision of the Phase 1 design and process improvements made in Phase 2. Generally reductions in truss weight and a decreased cost of 20 percent was offset by the increased cost of articulating the PCS support arm for face down stow. Facet production cost estimates remained the same.

The cost estimates by component are summarized in Table 12. Several key trends were observed. Today, the price is $10.00 per Watt. All costs must be dramatically reduced to reach $2.00 per watt. Operation and maintenance costs are also very high today and must be reduced by increasing reliability and mean time between failures.

Table 12. Cost Estimates Including Performance and Reliability Goals

	$10/W Baseline Total	$4/W 5 Years	$3/W 10 Years	$2/W 20 Years
COST				
Power Conversion System (PCS)	54%	35%	25%	20%
O&M	15%	20%	20%	15%
Installation	8%	8%	16%	15%
Structure	8%	8%	8%	10%
Drives	7%	10%	8%	10%
System Integration	4%	10%	10%	10%
Reflector Materials	2%	5%	8%	10%
Mirror Modules	2%	4%	5%	10%
PERFORMANCE				
Flux Smoothing	20%	24%	26%	26%
Higher Average Reflectance (soiling/avoidance)	85%	90%	92%	92%
Higher-Temperature Heater Heads	20%	20%	28%	28%
RELIABILITY				
System Availability	80%	95%	99%	99.99%
MTBF	40	2,000	10,000	20,000
Service Costs O&M, $/kWh	$0.10	$0.02	$0.01	$0.02
SYSTEM OUTPUT				
Annual Output (kWh)	52,000	56,000	58,000	58,000
Solar only Electricity including O&M $/kWh	**$0.85**	**$0.30**	**0.20**	**$0.13**
Solar plus 25% natural gas usage incl. O&M $/kWh	**$0.64**	**$0.23**	**0.16**	**$0.10**

7.2.2. Performance and Reliability Improvements

The system performance is limited by the amount of heat available in the aperture and the maximum flux (75 W/m^2) on the heater head tubes. The initial design specification of the concentrator was 104 kW of heat in the aperture based on 122 m^2 of reflective mirror area. The actual projected mirror area of the as-built concentrator is 113.5 m^2, since glass is not placed over the membrane seams. . The actual power at the aperture expected with 113.5 m^2 reflective area is 97 kW, and the measured value is between 95-96 kW. The 8 kW shortage of heat in the aperture is the reason for the measured 21.6 kW of electricity versus the design value of 25 kW at 1000 W/m^2 insulation.

The maximum operating temperature for the super alloy of the receiver is 800C. Limiting the heater head temperature to 800C prevents metal creep, which would eventually lead to rupture of the heater head tubes.

The temperature distribution on the receiver, especially the difference between the highest and lowest temperature, is the next contributing factor to performance. For optimal performance the temperature difference should be 25K-30K or less for a STM 4-120 engine using natural gas heated tubes. The STM solar PCS operating on natural gas produces 25 kWe net with a temperature difference of 70K-80K. The reason for this higher temperature spread is the substantially longer heater tubes. The actual temperature difference operating on solar is typically 150K-200K. The maximum temperature is limited by the maximum heat flux, which drives the average operating temperature down, and reduces performance.

We believe image refinements from facet orientation and a receiver aperture window will result in more uniform temperatures in the receiver and raise the average receiver temperature. Another alternative is high-temperature materials, like ceramics, for the heater heads thus allowing 100 W/cm^2 flux. This would allow for a smaller aperture and shorter heater head tubes, thereby reducing gas pumping losses in the engine.

NASA projected that the fuel-to-shaft efficiency will increase to 52 to 56 percent if the Stirling engine could operate at a temperature of 1050C. Assuming a combustion efficiency of 90 percent, this corresponds to a thermal engine efficiency between 58 to 62 percent, say 60 percent (heat absorbed in tubes to shaft power out). The heat absorption in the receiver is presently about 71.5 percent of the incident solar energy on the system. Assuming an overall generator efficiency of 94 percent (current), the potential solar-to-net electricity efficiency has the potential to reach approximately 40 percent. Thus, the STM engine demonstrated a major development potential in increased solar-to-electric efficiency.

Mirror soiling and cleaning remains an issue. Fast, low-water-use cleaning methods are needed. Preferably self-cleaning would be ideal. Mirror cleanliness has a large effect on the kWh delivered annually so it must be addressed. The nighttime facedown-stow position increases the time from cleaning to cleaning by a factor of two compared to face up stow. Weekly cleaning works best but is costly and labor-intensive. Automation is necessary.

Phase 2 of the USJVP did not demonstrate high reliability. The real world has grid trips at full power and power line phases being rolled inadvertently by maintenance personnel. The PCS was not capable of protecting itself against these real-life events. In one event, the phases were rolled, meaning two of the three wires were reversed, at APS by accident and the engine was run backwards. This resulted in damage that required a tear-down and rebuild of the engine. The controller was subsequently reprogrammed to detect and prevent the engine from running backwards. Grid trips under partial load cause the engine to over-speed. No damage occurred but over speed protection needs to be added.

The hybrid combustion blower had plastic and rubber drive components and was mounted an area where those components were exposed to excessive temperatures, causing them to melt. The blower was subsequently been moved out of the hot area.

These major design and systems engineering issues preclude any real assessment of the operation and maintenance costs of the current Phase 2 dish/Stirling system. We remain optimistic that the long-term cost of keeping the system available will be low once these prototype problems are eliminated.

The NREL system performance curve projected to 22 kW at 1,000 W/m^2. This would produce about 45,000 kWh per year, using Barstow direct normal insolation. The shortfall was because there is only 95-96 kW of heat available in aperture versus 104 kW anticipated by STM. The optical efficiency was also low due to a too-flexible structure that allowed the facet alignment to change after it was set. The optical bench was stiffened with umbrella struts and set properly, but some flex still remains in the structure. Tests conducted on the properly set optical bench dish at Salt River Project showed a projected power of 23 kW at 1000 W/m^2. Solar hybrid operation was demonstrated at 20 kW. Upgrades to cavity sealing should bring this up to 25 kW.

The solar thermal/gas hybrid electric power system demonstrated performance and potential for low cost. If the reliability of the system can be proven this will be a viable power generation option for utilities in the near future.

7.3. System Production Cost Estimates

The estimates described in this subsection were made by SAIC early in the program and do not reflect cost savings that Price Waterhouse Coopers Securities, LLC, Black & Veach, and MITI may have analyzed. Their installed costs and financing assumptions would be lower than those reported here. In 1995, an analysis was made of the actual costs of fabrication for the Phase 1 dish. This was combined with estimates for the Phase 2 dish design to produce two updated cost estimates for volume production in 1996. In 1997, the actual materials costs for the first Phase 2 dishes were used to update the cost estimates once again, leading to a final estimate in December 1997. Finally, cost estimates were updated for marketing opportunities that arose in 1998. Appendix M contains the December 1997 cost estimate and an estimate for the 40 and 68 units generated in May 1998.

The December 1997 cost estimate resulted in the system production costs, including fabrication, materials, installation, engineering, site costs, overhead, and capital equipment for facet production (Table 13).

Table 13. December 1997 Cost Estimate

Production Scenario	Installed System Cost	Selling Price with Overhead, Engineering, Marketing, Profit, Capital Equipment, etc.
Single System	$293,292	$847,878
First Batch of 5 Systems	$279,628	$599,808
Following Batches of 5 Systems	$275,074	$547,785
50-System build	$203,431	$300,088
150 Systems per year	$94,362	$157,377
500 Systems per year	$74,599	$107,860

A cost estimate made in May 1998 was based on 40-unit and 68-unit one-time builds, and had updated costs for the PCS and other components. Table 14 provides the results of this study for installed systems.

Table 14. Study Results

Production Scenario	Installed System Cost
40 Systems	$351,493 ea
68 Systems	$314,555 ea

7.4. Systems Sales to Utilities

As part of the Phase 2 effort, SAIC had negotiated the sale or placement of five dish/Stirling systems. Arizona Public Service Company became a team member and equity investor in the SAIC dish technology. APS agreed to test dish/Stirling systems for up to two years at their STAR facility. Salt River Project agreed to be the first utility customer for an as-yet unproven product. SAIC agreed to sell two systems to Enova/Houston Industries for $350,000 each. However, the desire to limit liability if they failed to operate caused SAIC to reconsider this sale to a utility that wanted to see generated power. Therefore, SAIC opted not to sign the final contract.

7.5. Business Plans for 2MW Fields

Portfolio standard in the southwestern United States threatened to mandate utilities to buy solar power. The state of New Mexico Public Utilities Commission ordered PNM to procure 5MW of solar power in order to be allowed to construct a 125MW natural gas fired power plant close to the city of Albuquerque. SAIC wrote a proposal to provide all 5MW at an avoided cost of $0.29/kWh. This was based on a 20-year power purchase agreement by PNM. At a system cost of $8.00/W and a DOE subsidy of $4.00/W and a 7.5 percent loan for 80 percent of the installed cost, the plant would service the debt, returning 18 percent to the equity investors before O&M costs. O&M costs were expected to be less than $0.05/kWh, the point at which all profit would be reinvested to keep the systems running.

In April 1998, SAIC and Applied Power Corporation (APC) were announced by PNM as the successful bidders. They decided to split the award so that SAIC would supply 2MW of Dish/Stirling systems (approximately 80, 25-kW systems) and APC would supply 3MW of photovoltaic systems. After the award, several large power consumers in the state of New Mexico formed the New Mexico Energy Industry Action Committee and succeeded in having the PUC ruling set aside. Efforts to revive the project persisted until mid-1999, but deregulation made the mandate very unpopular with electricity consumers, so it will not happen. The SAIC team put a lot of management effort into proposal writing and negotiations but ended up empty-handed.

7.6. Joint Venture Company Development and SAIC/STM License Agreement

At the beginning of Phase 2, SAIC was allied with a company that was prepared to incorporate and form a joint venture corporation. This arrangement did not work out, so that corporation was never formed as planned. Towards the end of the Phase 2 program, a licensing agreement was signed with STM Corp. giving them rights to produce dish systems and to market dish/Stirling systems. SAIC retained the right to develop the technology with both government and private funds. SAIC intends to continue as an optical concentrator developer.

7.7. Reliability Growth Market Path

DOE restructured their participation in the Dish/Stirling program to help industry improve the reliability of systems by a design-test-redesign process. Dish/Stirling systems are machines, just like automobiles. They must be tested and improved through several cycles in order to become ready for people to rely on them for critical power needs with minimum interruptions and outages. They will eventually be reliable at the levels of modern day automobiles, but need significant development to fulfill this promise.

SAIC's approach is to continue development of the dish system for dish/Stirling and other potential markets. Near-term demonstration projects will be pursued as they become available in order to field-test and further develop the system. Development of the dish will concentrate on improving reliability, reducing installation and maintenance costs, and improving performance for Stirling receivers. The potential for use of the dish with other receiver systems will be pursued in order to widen the potential markets for the dish system.

STM is committed to continued development of the Stirling engine for solar and other applications. As mentioned in a previous section, STM acquired a license for the SAIC dish technology, and plans to pursue marketing of dish/Stirling systems itself in parallel with continued joint marketing with SAIC. Development of Stirling engines for other applications provides a means of stimulating production and development of the engines and will be pursued as well.

8.0 Appendices

Appendix A:	Drive Specification for Dish/Stirling and Heliostat Systems
Appendix B:	Dish Control System Requirements Definition Document
Appendix C:	Dish System Specification Document
Appendix D:	Incident Summaries for the Phase 2 Dish/Stirling Systems
Appendix E:	Engineering Change Summaries for the Dish/Stirling Systems
Appendix F:	Cumulative Performance of the APS West Dish/Stirling System
Appendix G:	Month-by-Month Performance Summaries for the APS West Dish/Stirling System
Appendix H:	Single-Day Performance Summary for the APS West Dish/Stirling System
Appendix I:	Cumulative Performance of the APS East Dish/Stirling System
Appendix J:	Month-by-Month Performance Summaries for the APS East Dish/Stirling System
Appendix K:	October 1999 Monthly Performance Summary for the SRP Dish/Stirling System
Appendix L:	Weather Data from APS Dish/Stirling Network Interface
Appendix M:	Dish/Stirling System Production Cost Estimates

Appendix A:
Drive Specification for Dish/Stirling and Heliostat Systems

Large Heliostat/Large Dish Concentrator Drive Specification

October 23, 1996

Science Applications International Corporation
An Employee Owned Company

Science Applications International Corporation
Energy Projects Division
15000 West 6th Avenue
Suite 202
Golden, Colorado 80401

REVISIONS

File	Date	Description
Drive Specification 3	March 7, 1996	Increase wind loads to reflect concentrator size increase to 10.5 foot diameter facets. Increase estimated weight of the heliostat.

TABLE OF CONTENTS

1.0 SCOPE

1.1 General

This specification establishes the design criteria, performance, construction, and testing requirements for a unified azimuth and elevation drive unit for a Solar Tracker. Hereinafter, the Drive Unit, is referred to as the drive and Science Applications International Corporation is referred to as SAIC.

The drive specified herein is to be used with either a heliostat or a dish concentrator. For reference, Figure 1 illustrates the SAIC heliostat conceptual design, and Figure 2 illustrates the SAIC conceptual dish concentrator design.

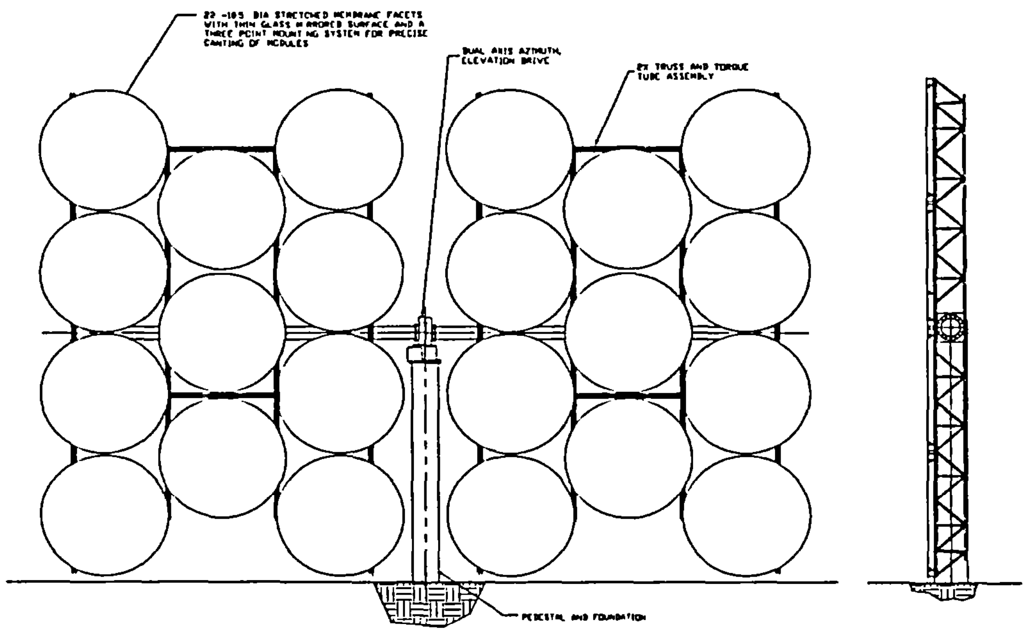


Figure 1 SAIC Heliostat Conceptual Design

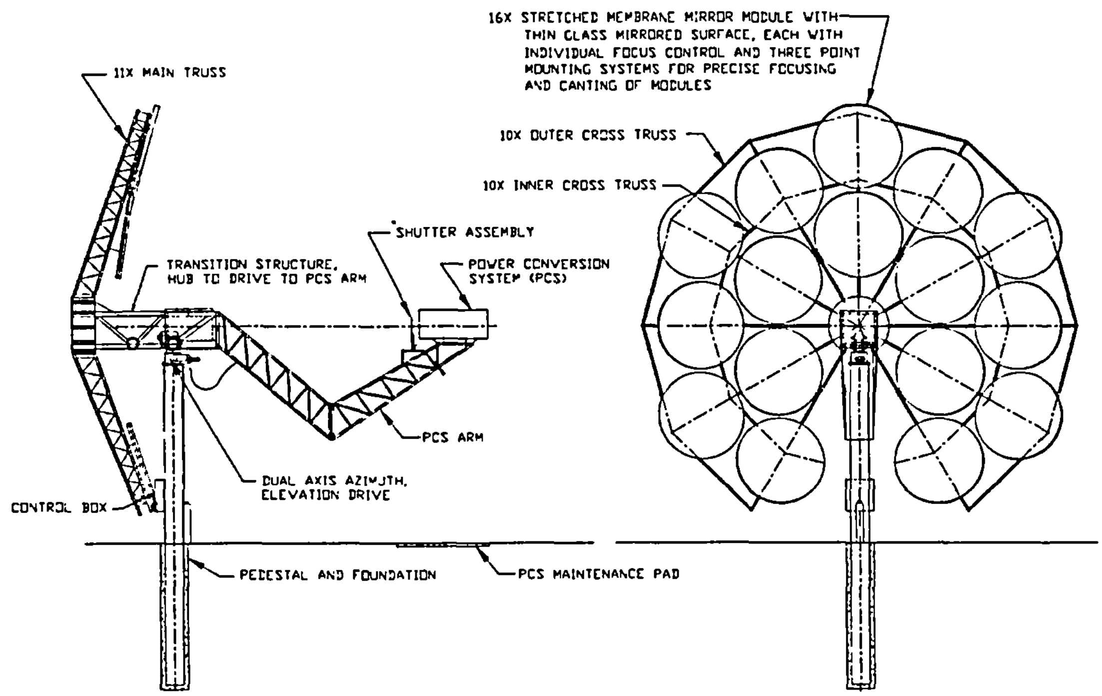


Figure 2 SAIC Dish Concentrator Conceptual Design

1.2 Classification

The drive unit shall be classified by SAIC, part number as follows:

Part Number	Nomenclature
DU0001	Drive Unit, Solar Tracker

1.3 Usage

The unit specified herein, shall be used to provide the motive power for azimuth and elevation maneuvers of a large Solar Tracker for the purpose of sun following, and to perform auxiliary maneuvers related to cleaning, maintenance and stow operations.

2.0 APPLICABLE DOCUMENTS

2.1 General

The following documents form a part of this specification. In the case of a conflict between the requirements of this specification and any reference document cited below, the requirements of this specification shall govern.

2.2 Government

MIL - STD - 1472	Human Engineering Design Criteria

2.3 Standards

ANSI CI - 1975	American National Standards Institute
AGMA 440.04	AGMA Standard Practice for Single and Double Reduction Cylindrical-Worm and Helical-Worm Speed Reducers
AGMA 110.03	Gear Tooth and Failure
AGMA 112.04	Terms, Definitions, Symbols, and Abbreviations
AGMA 250.03	Lubrication of Industrial Enclosed Gearing
AGMA 260.01	Shafting - Allowable Torsional and Bending Stresses
AGMA 240.01	Gear Materials Manual
AGMA 514.02	Load Classification and Service Factors for Flexible Couplings

2.4 Specifications

DU0002	Solar Tracker Painting Specifications

3.0 REQUIREMENTS

3.1 General

3.1.1. Maintainability

The units shall be designed so they require a minimum of routine field maintenance. The units shall be sealed to preclude moisture penetration and oil leakage, and shall be designed to operate for 5 years minimum without additional lubrication. It shall be a design goal that the re-lubrication period be 10 years or greater.

3.1.2 Environmental

The units shall perform as specified herein at ambient temperatures from 10°F (-12°C) to 130° F (55°C) inclusive, and at ambient pressure levels from 10 to 16 psia (70- 110 kPa). The units shall be capable of operating at temperatures down to 10°F. Expansion provisions shall be included to accommodate lubricant (and/or lubricant chamber) expansion or contraction to prevent oil leakage or air ingestion.

3.1.3 Materials, Processes and Parts

To the maximum extent possible, standard material and processes, and off-the-shelf components shall be used. Wherever possible, commercial specifications shall be employed.

3.1.4 Nameplate and Product Marking

Each drive unit shall be labeled with a permanent nameplate listing, as a minimum: SAIC's part no. , manufacturer, sequential serial number (starting with 000001), and date of manufacture.

3.1.5 Workmanship

The level of workmanship shall conform to the practices defined in the section 2.0, Documents and Standards. All work shall be finished in a manner that presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a uniform appearance.

3.1.6 Interchangeability

Items with a common function shall have a common part number and be interchangeable. Components with similar appearance, but different functions shall incorporate protection against inadvertent erroneous installation.

3.1.7 Safety

Any moving elements shall have smooth contours and be shielded to avoid entanglements.

3.1.8 Human Engineering

The unit shall be designed to facilitate installation and subsequent maintenance. MIL-STD-1472, Human Engineering Design Criteria, shall be used as a guide in designing the unit.

3.2 Documentation

3.2.1 Characteristics and Performance

Normal operating characteristics, any limiting conditions, physical envelope dimensions, and unit weight shall be provided for the unit.

3.2.2 Instructions

Written instructions shall be provided which cover any special installation or operating precautions, and normal preventative maintenance operations.

3.2.3 Construction

Engineering piece part and assembly drawings shall be provided which show equipment dimensions, tolerances, materials, parts list, and assembly procedure.

3.3 Performance

3.3.1 Range of Motion

A range of motion of 360° in azimuth is desirable. (This range would permit sun tracking at any northern latitude.) If this range of motion is impractical for some reason, reductions in this range shall be considered. At a minimum, 260° range of motion will be required in azimuth.

A range of motion of 190° in elevation is required. (This range permits sun tracking at any latitude as well as face-down stowage of the tracker, without hitting the stops at either end of the range.) A larger range of motion is desirable in tropical locations where "over the shoulder" tracking would be desirable.

3.3.2 Drive Motors

Input torque to the drive unit will be provided by fractional horsepower DC motors. The motors will be supplied by the vendor with the unit, and will meet the following specifications:

3.3.2.1. Motor Interface

The unit shall be designed to interface with a 56C-Face motor flange. The drive unit shall contain a suitable mounting adapter for attaching the motors, and a Flender BWN53 or Lovejoy L-095 flexible coupling for connecting each motor shaft to the drive unit. The drive-side half of the coupling shall contain a thru-pin or a steel key and set screw to provide a positive attachment to the drive pinion shaft. The drive manufacturer shall provide the coupling halves and spiders and shall install these prior to shipment.

3.3.3 Drive Speed

Both the azimuth and elevation drive subassemblies shall be designed with speed reduction ratios which enable the following speed requirements to be met when being driven by the DC motors defined in paragraph 3.3.1.

3.3.3.1 Elevation Speed

The unit shall rotate about the elevation axis from a vertical position to a horizontal position (90 degrees of motion) in 8 minutes maximum under gravity-only conditions.

3.3.3.2 Azimuth Speed

The unit shall rotate about the azimuth axis from the west-facing position to the east-facing position (220 degrees of motion) in 20 minutes maximum under no-load conditions.

3.3.4 Output Torque

The solar tracker is comprised of a support structure rack, solar reflector modules, torque tubes, support arm with engine, and the drive unit. The drive unit is elevated on a pedestal to provide clearance between the solar reflector modules and the ground as the unit moves to track the sun. All loads are transmitted through the torque tube-to-drive unit interfaces.

Each axis of the unit shall be capable of providing an output torque sufficient to overcome the maximum specified gravity loads combined with the maximum operating wind loads. The drive unit shall be self-locking to prevent back-driving when subjected to the maximum specified gravity loads combined with the maximum survival wind loads.

3.3.5 Design Loads and Deflections

The unit shall be designed with the required strength and stiffness to perform as specified herein when subjected to the following gravity, wind, and seismicly-induced loads.

3.3.5.1 Gravity Loads

Gravity imposes three loads on the drive unit:

1) a **vertical load** caused by the dead weight of the solar tracker,

2) an overall **overturning moment** about the elevation axis, caused by the offset of the tracker center of gravity relative to the elevation axis and,

3) **cantilever gravity moments** produced by cantilevered loads hanging from each torque tube. Overhanging loads cause no net moment on the drive due to the left-right symmetry of the tracker. However, the individual moments must be resisted by the torque tube interfaces of the drive.

These three loads are defined in Table I for both the case of the 140 m^2 heliostat and the 100 m^2 dish concentrator.

Table I Gravity Loads

	Heliostat	Dish	Maximum
Weight (lb)	16,000	20,000	20,000
Overturning Moment (ft-lb)	-	60,000	60,000
Cantilever Moment (ft-lb)	60,000	-	60,000

In this case the dish has the greater weight and overturning moment, due to the engine and its support structure. The structure of the dish is such that there is little moment cantilevered off either side of the drive. The heliostat, on the other hand, hangs considerable load off each side of the drive in both the face-up and the face-down positions.

3.3.5.2 Wind Loads

There are three wind conditions at which performance requirements are imposed. These are:

1) **operating mean wind:** The drive unit shall meet the deflection requirements specified below at the operating mean wind of 15 mph.

2) **operating peak gust:** The drive unit shall be capable of moving the tracker in either axis of motion against the loads imposed by an operating peak gust of 50 mph, but need not meet the deflection requirements at this wind speed.

3) **survival peak gust:** The drive unit shall be capable of surviving the loads imposed by a survival peak wind gust. The peak gust for the heliostat is assumed to be 90 mph and the peak gust for the dish concentrator is assumed to be 120 mph. The tracker is assumed to be in a stow (park) position and not in motion.

Wind imposes a force and a moment about each of three axes. The sense of this force is shown in the following Figure.

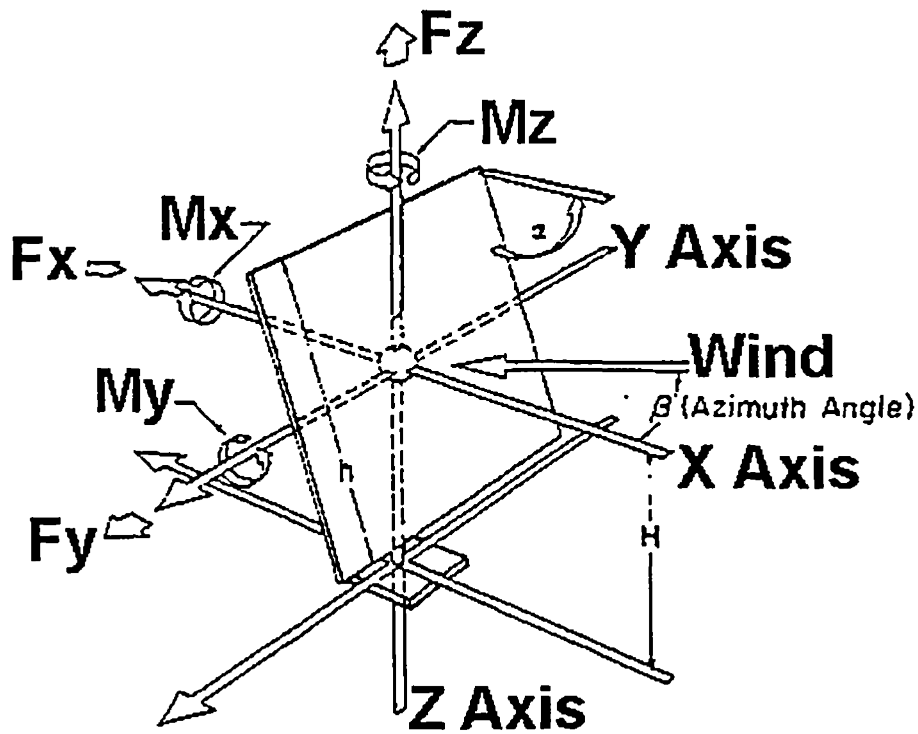


Figure 3 Wind Load Axes

The wind loads predicted for the 140 m² heliostat and the 100 m² dish concentrator are given in the following tables.

Table II Heliostat Wind Loads

	Stiffness 15 mph average	Moving 50 mph peak	Stow 90 mph peak
Fx (lb)	3,000	20,000	9,600
Fz (lb)	1,500	14,000	15,000
My (ft-lb)	12,000	120,000	130,000
Mx (ft-lb)	18,000	180,000	190,000
Mz (ft-lb)	0	125,000	12,000

Table III Dish Concentrator Wind Loads

	Stiffness 15 mph average	Moving 50 mph peak	Stow 120 mph peak
Fx (lb)	1,300	11,000	6,000
Fz (lb)	1,200	10,000	18,000
My (ft-lb)	6,000	52,000	185,000
Mx (ft-lb)	6,000	52,000	185,000
Mz (ft-lb)	5,000	52,000	17,000

It is anticipated that the drive will be used with either a heliostat or a dish concentrator. Therefore it would need to accommodate the highest load of each type. These are presented below.

Table IV Maximum Loads for Heliostat or Dish Concentrator

	Stiffness 15 mph average	Moving 50 mph peak	Stow 90/120 mph peak
Fx (lb)	3,000	20,000	10,000
Fz (lb)	1,500	14,000	18,000
MHy (ft-lb)	12,000	120,000	185,000
Mx (ft-lb)	18,000	180,000	190,000
Mz (ft-lb)	5,000	126,000	17,000

Most of the time, the system will operate with wind load much less than the design loads. The following table presents wind frequency for a typical solar site. (Barstow, from NREL TMY2 data. This frequency plot may be assumed for calculation of duty or fatigue type criteria. The wind load may be assumed to be proportional to the wind velocity squared.

Table V Wind Frequency

up to 5 mph	14.0%
10	32.3%
15	28.6%
20	13.5%
25	8.4%
30	2.1%
35	0.6%
35 and up	0.3%

3.3.5.3 Seismic Loads

The unit shall be capable of surviving seismic loads corresponding to seismic zone 4.

3.3.5.4 Combined Loads

The unit shall accommodate the combined loads of wind and gravity. Seismic loads need not be combined with wind loads.

3.3.5.5 Deflections and Backlash

The unit shall be designed with structural stiffness and output gear backlash limitation to meet the overall aiming accuracy requirement of the tracker. These limits shall be maintained under the combined loading of gravity and operating mean wind. The combined deflection and backlash limits are given in Table IV.

Table IV Combined Deflection and Backlash Limit

Combined Deflection and Backlash	
Azimuth	1.0 milliradian
Elevation	1.0 milliradian

3.3.6 Life

The unit shall be designed for a life expectancy of 30 years during which time the unit will undergo approximately 11,000 cycles. During this cycle life, the unit will be exposed to the gravity loads of paragraph 3.3.2.1 on each cycle, and the wind loads of paragraph 3.3.2.1 and 3.3.2.2. on 200 of these cycles.

3.3.7 Wear

Gear and bearing materials, heat treatment and lubricants shall be selected in accordance with the life requirements of paragraph 3.3.5 and the AGMA standards of paragraph 2.3 herein to minimize wear.

3.3.8 Exterior Finish

The unit shall be cleaned and painted per SAIC Paint Specification (to be determined). The bottom of the unit shall be coated with a suitable undercoating such as Cortec VCI-369 (Cortec Corp., St. Paul, MN) to prevent corrosion.

3.3.9 Weight

The total unit weight less motors shall be TBD pounds maximum.

3.3.10 Physical Interface

The unit shall be designed to interface with solar tracker support pedestal and torque tubes in accordance with the dimensional requirements and physical form defined in Figure 4.

Motor interface details are defined on Figure 5.

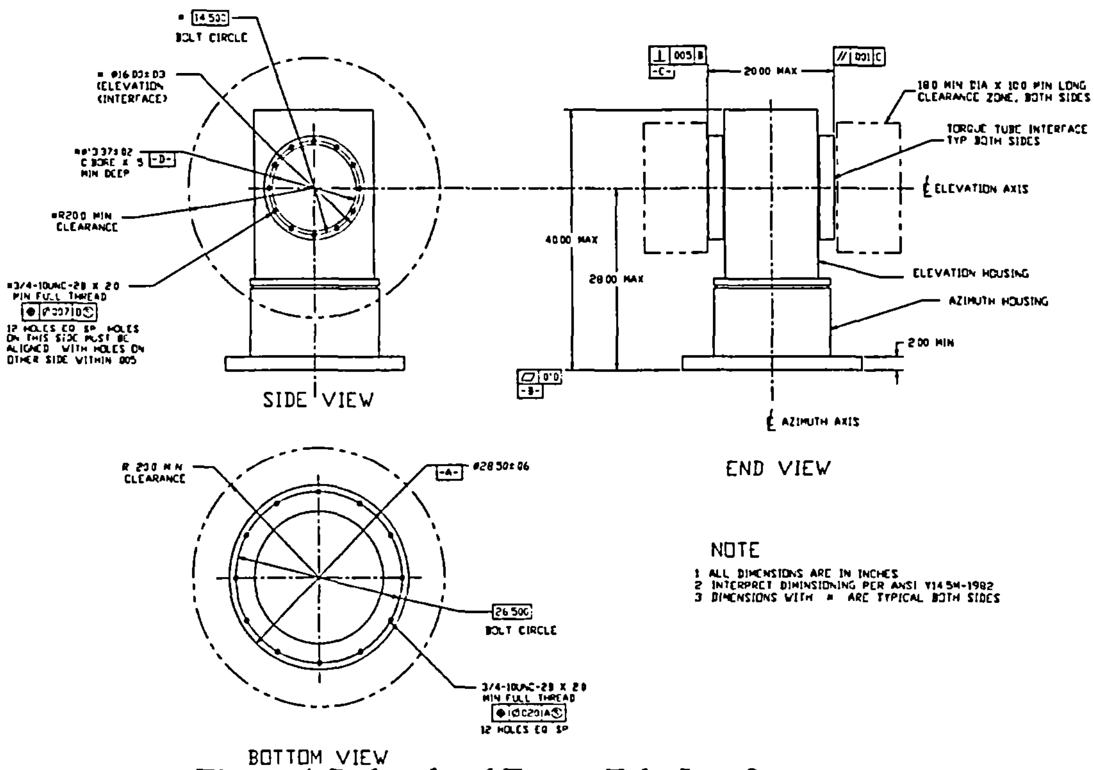
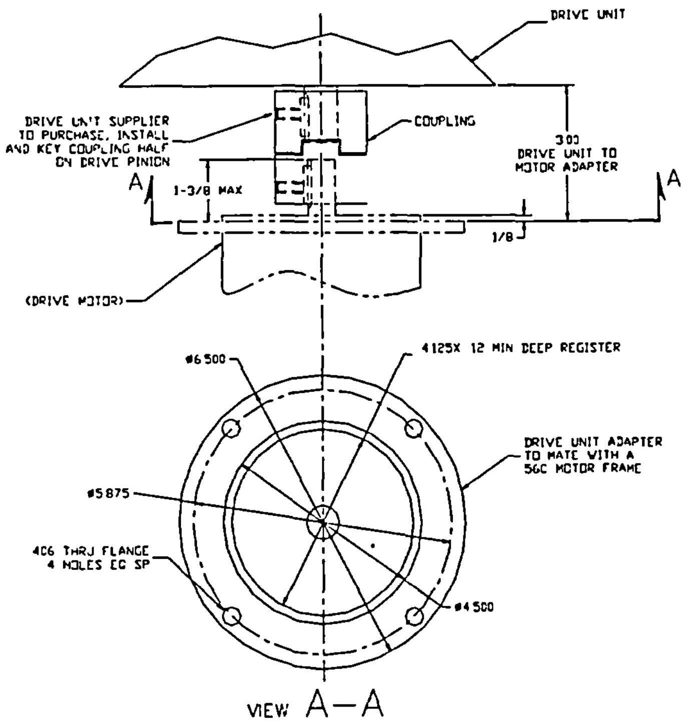


Figure 4 Pedestal and Torque Tube Interface



INTERFACE DEFINITION - MOTOR

Figure 5 Motor Flange Interface

The interface details represent a conventional approach. SAIC would welcome innovations to reduce cost in the system.

3.3.11 Lubrication

The supplier shall determine the type and brand of lubricant required to meet the working conditions of the unit described herein and shall fill each azimuth and elevation housing to the proper level prior to delivering units to the job site.

3.3.12 Leakage

The unit shall be sealed to preclude lubricant leakage. No visible leakage is permitted.

3.4 Miscellaneous Considerations

3.4.1 Compactness

In some orientations, the tracker structure may envelope the drive unit and the pedestal upon which it sits. It is therefore an advantage to minimize the diameter of the drive unit and avoid protrusions that might interfere with the range of motion of the tracker.

3.4.2 Provision for Electrical Cables and Control Sensors

3.4.2.1 Provision for Cable Pass-Through

The drive unit will be employed as a mount for equipment that will require control and power cables. It is therefore an advantage to make provisions for a cable pass-through internal to the drive from the inside of the pedestal to a location on the drive that moves in either or both azimuth or elevation. Such provisions would minimize the necessity for cable loops to accommodate the motion of the tracker.

3.4.2.2 Provision for Limit Switches

Control of the motion of the solar tracker depends upon position indexes and limits to the motion of the tracker within a certain range of azimuth and elevation. These indexes or limits are typically indicated by limit switches of contact or proximity type. It is therefore an advantage to make provisions for limit switches in azimuth and elevation that are accessible and adjustable.

3.4.2.3 Provision for Position Indication

Control of the motion of the solar tracker depends upon accurate indication of the position of the drive in both azimuth and elevation. Historically, the position of the drive has been measured using position encoders or resolvers capable of measuring the angular position with a resolution of approximately 0.2 milliradians, mounted either on the input motor shafts or on the drive output interfaces. It is an advantage to measure the output position directly, rather than calculating it by counting motor revolutions. The vendor shall make provisions for this indication of position, and may propose any arrangement capable of the accuracy given above.

3.4.3 Structural Interface

3.4.3.1 Pedestal Interface

The drive unit will sit upon a pedestal consisting of a large diameter pipe. The vendor shall propose a simple structural interface to the pedestal. Historically, this interface has consisted of mating flanges, one on the pedestal, the other on the drive.

The vendor should not be constrained to this type of interface, however, if a simpler arrangement can be proposed.

3.4.3.2 Torque Tube Interface

The solar tracker is supported by the drive unit. The vendor shall propose a simple interface between the drive and the tracker. Historically, the solar tracker interface has consisted of two torque tubes. The torque tubes have each been attached to a flange that bolted to mating flanges on either side if the drive unit. The vendor should not be constrained to this type of interface, however, if a simpler arrangement can be proposed.

4.0 VERIFICATION REQUIREMENTS

4.1 General

This section describes the requirements for the verification process during the design, fabrication, and acceptance test programs.

4.1.1 Quality Assurance Requirements

A quality assurance program shall be instituted to assure compliance with the requirements and intent of this specification and the controlling engineering drawings.

4.1.2 Responsibility

The supplier shall perform any or all of the analysis and test requirements of this specification when so required by SAIC in the procurement contract.

4.1.3 Notification of Tests

The SAIC office shall be notified at least five days prior to the time tests are to be conducted. SAIC reserves the right to witness all tests.

4.1.4 Drawing Approval

All engineering drawings shall be submitted to SAIC for review and approval prior to the initiation of fabrication. All subsequent drawing changes shall be coordinated with SAIC prior to instituting the change on the applicable hardware.4.1.5

4.1.5 Discrepancies

All hardware discrepancies which deviate from the engineering drawings and the necessary rework shall be coordinated with SAIC if such discrepancies affect the form, fit, or function.

5.0 SUPPLIER

To be determined.

Appendix B:
Dish Control System Requirements Definition Document

System Requirements Document for the SAIC Dish/Stirling Solar Power System Controls and Electrical Power System

Revision 6
13 October 1998

SAIC Energy Products Division
15000 W. 6th Ave, Suite 202
Golden, CO 80401

Revision History

Revision	Date	Description
1	5 Oct 1998	Initial version edited from Duane Gibson's format by Roger Davenport
2	7 Oct 1998	Began adding specific requirements for operator controls, indicators, etc.
3	8 Oct 1998	Completed first draft
4	8 Oct 1998	Added cabling details after meeting with Bud and Scott
5	9 Oct 1998	Including comments from Barry, Kelly, and Lem on Version 4
6	13 Oct 1998	After review with Duane Gibson on 12 October

Table of Contents

1.0 INTRODUCTION

1.1 Purpose of this Document

This specification establishes the product level functional requirements for the design and development of the overall control system and electrical power system for the SAIC dish/Stirling solar power system. Any testing of functional performance of the control system will be based on these requirements.

1.2 Scope of the Document

This document completely specifies the operational and physical characteristics of the SAIC dish/Stirling control and electrical systems. It does not specify any of the accessories or equipment used with the system.

1.3 Definition of Terms

AWG American Wire Gauge
EMI Electro-Magnetic Interference
Hz Hertz
RFI Radio Frequency Interference
VAC Volts, Alternating Current
VDC Volts, Direct Current

1.4 Related Documents

Dish/Stirling Control System Acceptance Test Plan
Dish/Stirling Electrical System Acceptance Test Plan
Dish/Stirling System Installation, Operation, and Maintenance Manual

1.5 Requirements Vs. Goals

Most of the specifications listed in this document are requirements. A requirement is a specification which must be met by the design and implementation process. Conformance to requirements will be tested according to the Acceptance Test Plan. Some of the specifications in this document are explicitly defined as goals. Goals are for information only. There is no requirement that the finished product must conform to the goal specifications. Conformance to goals will not be tested.

1.6 Requirement Tags

There are symbolic tags attached to specifications throughout this document. These are unique tags associated with particular requirements to be used during the system architecture process to ensure that all requirements are addressed by the design and that all design features address actual requirements.

2.0 MARKETING CONSIDERATIONS

NOTE: The information in this section is for reference only and is not a list of product requirements.

2.1 General Description of the Project

The objective of the project is to complete the design, development, and approval of the next-generation control and electrical systems for the dish/Stirling system.

2.2 General Description of the Product

The dish/Stirling system is a solar power generator that converts sunlight into electricity using a Stirling engine. The control system directs the dish/Stirling system in autonomous operation, including automatic wakeup, tracking of the sun, and stowing upon high winds or when the sun goes down. The system includes hybrid operation on fuel when the sun is not strong enough to allow solar operation. Operator commands are conveyed to the system using a serial RS-485 network.

2.3 Common Name

The common/usual name for the system is the SAIC dish/Stirling solar power system.

2.4 Trade / Proprietary Name

A trade/proprietary name for the system is the Thermal Hybrid Electric SunDish (THE SunDish).

2.5 Standard Configuration

The standard configuration for the dish control and electrical systems includes the following components:

- Grid Protection Panel
- Power Quality Adjustment System
- Power Box
- Dish Controller Assembly
- Cables and Conduits
- Focus Blower Assembly
- Sun Sensor Assembly, Including Horizon Reference Switch
- Arm Latch Sensor Switches
- Azimuth and Elevation Drive Motors
- Azimuth and Elevation Encoders and Limit Switches
- Network Interface for Multiple Dish/Stirling Systems

2.6 External Components

The following items are considered external components and are not part of the product as defined in this document (although interfaces to these components are defined as needed):

- Stirling Engine Power Conversion System
- Grid Connection (460 VAC, 3 phase)
- Dish Control Computer with User Interface Program
- Stirling Engine Interface Computer (this will be eliminated in production systems)

2.7 Options

Options for this system are not available at this time. Options for the future may include:

- DC motors and motor drivers instead of AC motors
- Self-deploying drive system with advanced drive components

2.8 Cost Goals

The target cost for the control system components in quantities of 2000 is $5000 each. The target cost goal for the electrical system is $5000 per system.

2.9 Intended Use

The controls and electrical systems defined in this document are intended for application on the SAIC dish/Stirling solar power system (THE SunDish).

2.10 Intended Market Locations

The primary market locations for the dish/Stirling power system are remote power in the U.S. and foreign (developing) countries and bulk power supplied to utilities in the Southwest U.S.. The system is designed to meet NEC and NESC standards for electrical safety.

2.11 Estimated Product Lifetime

The estimated product lifetime for the dish/Stirling system is 30 years.

2.12 Estimated Volume of Manufacturing

The expected annual manufacturing volumes for dish/Stirling systems are as follows:

1999	4
2000	4
2001	4 or more
2002	4 or more
2003	4 or more

2.13 Service Philosophy

The service philosophy for the dish/Stirling control and electrical systems are to provide field diagnostics and replacement to the board or module level with depot repair of boards and modules. Diagnostic procedures are outlined in the Dish/Stirling System Operation and Maintenance Manual. Remote diagnosis will be possible using the SAIC User Interface program to identify faults and test operations of the controller and outputs. On-site diagnosis tools will include visible indicator lights and manually-actuated functions.

2.14 Human Engineering

Color codes will be used with wiring harnesses to minimize wiring errors and simplify assembly and troubleshooting. Wire markers will be used as supplemental identification. All voltages above 24 VDC will be contained in enclosures, cables, or conduits to reduce the chance of personnel contact. Warning signs will be affixed to enclosures containing dangerous voltages.

3.0 SAFETY REQUIREMENTS

3.1 Systematic Defects

The control and electrical systems shall be free of known systematic defects. A systematic defect is a design flaw or process flaw which is common to all devices being manufactured.

3.2 Electrical Hardware Safety

The control and electrical systems shall meet all safety requirements contained in the regulatory standards listed in Section 10. The system shall be designed to minimize shock, thermal, and radiation hazards.

The system shall have line protection for lightning-induced transients. Lightning protection shall be included in the site grounding design. The system shall be grounded to meet current NESC requirements at the time of installation.

4.0 EXTERNAL INTERFACE REQUIREMENTS

4.1 Operator Inputs & Outputs

Multiple dish/Stirling systems shall be connected to a serial network over which commands are received from the operator and status information is transmitted to the operator. General requirements on the serial network are as follows:

- Serial data transmission
- Each network bus capable of supporting multiple (e.g., 30+) systems without degradation
- Maximum distance to furthest unit up to 2500 meters
- Provide electrical isolation between each system and the network
- Minimum baud rate 19,200 baud

4.2 Stirling Engine Communications

A dedicated RS-485 serial connection connects the dish controller and the Stirling engine controller. A RS-232 serial connection comes from the Stirling engine controller and is connected to the Stirling engine interface computer at the user station. Requirements on these interfaces are as follows:

- Provide electrical isolation between the Stirling engine controller and the dish system controller
- Minimum baud rate 2,400 in RS-485 connection
- Conversion of RS-232 to an appropriate type of serial communication link for transmission to the user station, where it shall be converted back to RS-232 to the Stirling engine interface computer.
- Provide electrical isolation between the dish controller and the serial link to the Stirling engine interface computer

4.3 Electrical Power Input

The dish/Stirling system shall accept/supply AC power as follows:

Nominal	Low Limit	High Limit	Frequency	Phase Rotation	Current
460VAC	368VAC	529VAC	57-63 Hz	A-B-C	30A nominal

The grid protection box shall be supplied that is equipped with relays that will disconnect the system from the grid if the voltage, frequency, or phase rotation deviate from proper values. The grid protection box shall also disconnect if the current to or from the dish/Stirling unit exceeds 45A per system (150% of 30A nominal current).

4.4 Electrical Power Outputs

The dish/Stirling system generates and delivers power to the grid. Characteristics are as follows:

Maximum net power:	25 kW
Nominal Voltage:	460VAC, 3 phase
Frequency:	set by grid; 57-63 Hz range
Power Factor:	determined by utility requirements; e.g., 90+% at full power
Harmonics:	determined by utility requirements

4.5 Stirling Engine Power Interface

The Stirling engine shall be provided with two power interfaces: 1) 460VAC, 3-phase for the generator system; and 2) 115VAC, single-phase for the controller and auxiliaries. Requirements on these interfaces are as follows:

4.5.1 Stirling Engine 460VAC Interface

- Nominal 460VAC, 60 Hz
- 3-Phase
- Suitable supply available for a 40-HP three-phase motor

4.5.2 Stirling Engine 115VAC Interface

- Nominal 115VAC, 60 Hz
- Single-phase

- Supplied from uninterruptable power supply with 3kVA capacity for 10 minutes

5.0 OPERATOR CONTROLS AND INDICATORS

5.1 Input Controls

The input controls available to the user are described in the Operations and Maintenance Manual for the dish/Stirling system. All operational commands are transferred over the RS-485 serial network to the dish/Stirling system as ASCII commands. The basic commands from the user are as follows:

- Enable/disable solar operation
- Set solar operation mode (calculated sun tracking, sun tracking using sun sensor, tracking to peak power output)
- Enable/disable operation on fuel
- Change system parameters (including clock updates)

5.2 Outputs and Indicators

The user outputs and indicators from the system are defined in the Operation and Maintenance Manual for the dish/Stirling system. All operational outputs from the controller are carried by the serial network. The dish controller stores data about system operation on a five-minute basis that can be downloaded by the user. Similarly, the network controller stores weather data, including wind speed and direction and allow that data to be downloaded by the user. The dish and network controller also provide their current status in real time upon request by the user or user interface program.

5.3 Manual Controls and Indicators

For debugging and other purposes, manual controls shall be provided as follows:

- Manual "Scram" button on the outside of the control box and near the operator's console, which disconnects power to the drive motors, focus blower, and gas solenoid valve
- Manual 115VAC circuit breakers accessable from outside the power box, to individually control the following components:
    - Azimuth drive motor power
    - Elevation drive motor power
    - Focus Blower power
    - Gas solenoid
    - Scram contactor
    - General-purpose outlet
    - Power to uninterruptable power supply
    - Uninterruptable power supply output to Stirling engine system
    - Uninterruptable power supply output to dish control system
- Manual dish movement system that bypasses and disconnects the dish controller outputs and allows the dish to be moved manually using a control pendant with hand switches for the azimuth and elevation motors. The manual control pendant will also include switches for the scram contactor, the focus blower, a speed control relay (for future use), and the gas solenoid switch for test purposes.
- Manual 460VAC disconnect switch accessable from the outside of the power box to turn off the power supply from the utility grid to the box. The switch shall have visible blade disconnects.

The following indicators shall be provided:

- 115 VAC power-on indication
- 24 VDC power-on indication
- Status LED's for each digital input and output of the dish controller

- Status lights to indicate that output power is being supplied by each switched component (relay or solid-state relay

6.0 OPERATIONAL REQUIREMENTS

6.1 Modes Of Operation

The dish/Stirling system shall be capable of being operated in solar or gas operating modes, or if both are disabled, the system shall proceed to face-down stow and remain there. In solar mode, the system shall wake automatically when the sun elevation exceeds a set value, track the sun using either a sun-sensor or calculated sun position, and will focus and produce power in response to the level of insolation. The system shall stow automatically if high winds occur or at the end of the day when the sun goes down. If gas operation is enabled, the system will operate using fuel within a defined period of the day (from a start time to an end time, specified by the user). If solar and gas are both enabled, then during the allowed gas operation period the system will operate on gas whenever the solar insolation is insufficient for focusing and solar operation. The transition from solar to gas or gas to solar takes about 15 minutes.

6.2 Alarms/Faults

When the system detects an fault condition, it shall perform one or more of the following actions, depending on the type of fault:

6.2.1 Status and Warning Messages

Status and warning messages shall be displayed on the screen of the user interface computer. An audio signal will sound, if not disabled by the operator, and a visual indication will appear when any fault occurs.

6.2.2 System Response to Faults

The system shall cease all solar and gas operation and stow itself upon detecting a fault condition, and shall remain idle in a stowed position until operation is re-enabled by the operator. If the system is operating on-sun at the time of the fault, it will continue to track during the defocus delay period, then proceed to downward stow. If the fault is in one of the drive motors, the system will not try to operate the faulted motor, but will move to a safe position if it can (face-up/face-down or feathered to the wind). In case of a high-wind condition, the system will stow face-up and feathered 90 degrees to the wind, or will return to face-down stow if that position is closer. **Table 6-1** summarizes the fault responses of the system.

Table 6-1. Dish/Stirling System Fault Responses

Fault:	Response:
Any, except high wind	Stop running on gas; disable solar operation; defocus, then stow
High Wind	Stow face-up, feathered 90 degrees to wind (unless below horizon to start with); continue to run on gas if enabled
Azimuth Motor	Stow face-up at present azimuth (unless at azimuth stow position)
Elevation Motor	Move to azimuth stow position at present elevation

7.0 DESIGN REQUIREMENTS

7.1 Software Requirements

The system control software shall be written in C or C++ wherever possible. Assembly language programming shall be avoided if all possible.

Programs written for system control shall be maintained under configuration control. New versions shall be documented as to new features and changes, and software changes shall be reviewed and tested before implementation.

7.2 System Components

Components for the system controls and electrical wiring systems shall be selected consistent with environmental requirements (Section 9), regulatory requirements (Section 10), and reliability goals (Section 11) for the system. Single source components shall be avoided whenever possible. The design shall be documented in mechanical assembly drawings and electrical schematics, with configuration control being exercised over the drawings and Bill of Materials.

7.3 Sub-System Design Requirements

The system is divided into the following sub-systems:

- Grid Protection Panel
- Power Quality Adjustment System
- Power Box
- Dish Controller
- Cables and Conduits
- Focus Blower Assembly
- Sun Sensor Assembly
- Arm Latches
- Azimuth and Elevation Drive Motors
- Azimuth and Elevation Encoders and Limit Switches
- Network Interface for Dish/Stirling Systems
- Stirling Engine Package

Figure 7-1 shows a block diagram of the entire system. The following sections detail design requirements on the individual sub-systems and components.

7.3.1 Grid Protection Panel

The grid protection panel shall include utility-type relays to protect the external grid against failure of the dish/Stirling system. The grid protection panel shall protect the utility grid against the following out-of-specification events:

- Over/under-voltage
- Over/under-frequency
- Loss-of-phase or change of phase order
- Over-current

Specific relay specifications and settings at which actuation must occur will be determined for each utility interconnection based on that utility's requirements. Nominal values are as follows:

- Over/under voltage: 27/59 relay type
  368VAC undervoltage
  529VAC overvoltage
  (i.e., 80% and 115% of 460VAC)

- Voltage balance/Phase loss: 1530X relay type
  383VAC low phase (83% of 460VAC)
  17.8% voltage imbalance
- Over-current: 51N relay type
  Trip after 5 seconds @ 45A per system (e.g., 150% of 30A load @ 25 kW)
- Over/under-frequency: 81/O-U relay type
  trip within 0.5 seconds if frequency goes outside the range of 57 to 63 Hz (i.e., +/- 5% of 60 Hz)

General design requirements for the grid protection box are as follows:
- NEMA 4 enclosure level
- 460 VAC, 3-phase contactor, sized for as many dish systems as are attached to the panel. Each Stirling engine generator is regarded as a 40 HP, three-phase motor.
- Manual momentary "reset" and "connect" pushbutton switches on the outside of the box, with indicator lights to show "ON-LINE" (green) and "DISCONNECTED" (red).
- Latching system for "connect" pushbutton that latches on until the system trips, then remains off until reset manually.
- 115VAC control power for relays derived from the 460VAC

7.3.2 Power Quality Adjustment System

This system acts to adjust the quality of the power produced by the induction generator in the Stirling engine system to achieve an acceptable value for the utility. Specific power quality requirements will be negotiated with each utility. For example, 90+% power factor at full power (25 kW) may be required. The factors that are controlled by this system are:
- Power factor
- Harmonics

Design requirements for this system are as follows:
- NEMA 4 enclosure level
- 460 VAC, 3-phase, 25kVA maximum power from Stirling engine/generator
- Automatic disconnect of power factor capacitors from the Stirling engine/generator system upon loss of grid to prevent self-excitation
- Discharge resistors to reduce capacitor voltage below 50V within one minute
- Automatic disconnect of power factor capacitors if installed on the utility grid side of the motor control to protect against high voltages in islanded system

7.3.3 Power Box

A block diagram of the power box is shown in **Figure 7-2.** The power box includes a manual 460VAC disconnect from the utility grid, a 460VAC-to-115VAC transformer, a 115VAC uninterruptable power supply for the Stirling engine controls and for the dish controller, a 24VDC control power supply, a device for monitoring the power output of the system as an input to the controller, relays and other components for the dish control outputs, and the dish controller components. The power box also contains a power meter for the Stirling engine, including 460VAC current transformers and voltage taps. **Figure 7-3** shows a block diagram of the dish controller and the output interface panel. Specific design requirements are as follows:
- Power Box, general
  - NEMA 4 enclosure level
  - All wiring to meet NEC requirements with 70 degree C enclosure temperature
  - All control wiring shall use 22 AWG minimum wire size for 24VDC or below, and 16AWG minimum wire size for 115VAC and above.

  - All control wiring shall use stranded copper wire; power wiring may use solid copper wire
- 460VAC Disconnect Switch
  - 60A, non-fused
  - accessable from outside of power box; NEMA 3R or better enclosure level
  - visible disconnect blades
- 115VAC transformer
  - 5kVA capacity at 115VAC, single-phase
  - Both primary legs fused at 15A (i.e., 138% of 10.9A at 5kW)
  - 115VAC neutral output grounded to 460 VAC neutral line
  - 115VAC hot output connected to 50A main disconnect circuit breaker of circuit breaker panel
- 115 VAC uninterruptable power supply
  - Surge protected
  - EMI protected
  - Capable of 3kVA output for 10 minutes
  - Input power circuit breaker at 30A
  - Battery fused (positive leg) at 350A
  - Individual circuit breakers accessable from outside of power box to disable power outputs to Stirling engine and dish control power (20A and 5A, respectively)
- 24VDC Control Power Supply
  - 115VAC input from uninterruptable power supply
  - 24VDC isolated output
  - Negative output lead grounded to 460VAC neutral
  - 1A output capacity
  - Overload protected
  - Indicator light to show 24VDC power OK
- Dish Controller Power Monitor
  - 115VAC input from uninterruptable power supply
  - 4-20mA isolated output to dish controller for 0-50A AC current (i.e., 0-5A with 50:5 current transformer)
  - Donut-type current transformer (50:5) on one leg of 460VAC
- Dish Control Outputs (Azimuth motor run/reverse, Elevation motor run/reverse, gas solenoid, focus solenoid, scram contactor, high/low speed)
  - Polarized connector to output cable from controller board to allow disconnect of all outputs from controller and connection of manual control pendant
  - Polarized connector to controller board to supply 24VDC to that board
  - Source power for outputs protected by circuit breakers accessable from outside the power box (azimuth motor, elevation motor, gas solenoid and scram contactor, focus blower, uninterruptable power supply)
  - Indicator lights (e.g., neon) to show 115VAC power available to each component
  - Indicator light (e.g., neon) on the powered side of each actuated component to verify it has actuated
  - All control outputs from dish controller are 24VDC, opto-isolated from 115VAC
  - Snubber diodes on all mechanical relay coils
  - Clearly labeled input and output power terminals on motor controls, with straight-through wiring as a goal
  - Scram contactor to control input power to azimuth motor, elevation motor, focus blower, and gas solenoid
  - Goal: motor control sub-modules that can be replaced easily
  - Motor outputs are to individual wires in conduit to the drive junction box
- Stirling Engine Power Monitor
  - 115VAC input from uninterruptable power supply

- 4-20mA output to Stirling engine system
- Donut-type current transducers on 460VAC
- Voltage taps individually fused at 1A

7.3.4 Dish Controller

The dish controller is a board that contains signal-level voltages (24VDC or less) and performs input and output signal processing and computed control functions. It may be mounted in a box within the power box, or in a separate enclosure connected to the power box. The following design requirements apply:

- EMI shielded enclosure
- Plug-removable controller "brain"
- Easily-removable circuit board for input/output signal processing
- Two weatherproof connectors to outside of power box for signal inputs
- Two cable connections between controller and power components, for output signals and 24VDC power input to controller
- All digital inputs opto-isolated on input/output board
- All inputs buffered on input/output board
- All inputs (digital, analog, and serial communications) lightning-protected with Varistors on input/output board
- Labeled indicator lights (e.g., LED) to show the state of each digital input and output and the 24VDC power supply
- Scram "watchdog" circuit that requires an output from the controller to be toggled on and off periodically, else it turns off the "Scram" contactor. Labeled indicator light to show scram status
- Limit switch switching relays to connect correct direction of limit
- Backup battery for Little PLC with 10-year life
- Converter from RS-232 to suitable long-distance serial transmission for PCS monitor computer communications line
- Isolated driver for PCS monitor computer comm line
- Shields on PCS monitor computer comm lines (both RS-232 in and output line) not terminated at controller end
- Isolated driver for dish network comm line
- Shield on dish network comm line not terminated at controller end

7.3.5 Cables and Conduits

Cables and conduits shall be pre-assembled into two harnesses before system installation. **Figure 7-4** shows the Stirling engine harness, which consists of conduits containing 460VAC and 115VAC power lines, and signal cables to the Stirling engine, arm latches, and sun sensor. The power wires will be pre-installed in the flex conduit, then pulled through the rigid conduits attached on the outer arm and secured in the junction box. The arm latch cables will also be connected to the arm latches prior to installation. During system installation, the entire harness will be lifted along with the arm and attached to the dish hub. Then the flex lines will be routed down the pedestal and connected to the power box. Finally, the sun sensor cable will be attached to the sun sensor, in which will also be mounted the horizon reference sensor. **Figure 7-5** shows the drive assembly external cabling harness. This will be pre-assembled with the drive unit along with the motors and drive sensors. When the drive is installed into the dish hub, the focus blower will be connected. Then, when the dish structure is installed on the pedestal, the flex conduit and sensor cable will be routed down the pedestal and connected to the power box. Other design requirements for the cabling and conduit system are as follows:

- Separate signal cables to sun sensor, arm latches, drive system junction box (encoders and limits), Stirling engine RS-485, and Stirling engine RS-232 monitor.
- Multiple cables may share connectors, but conductors and shields shall be connected individually for each cable

- All signal cables shall be outdoor-rated
- All signal cables will use shielded, twisted pairs, with 22 AWG minimum conductor size
- Signal cables terminate at two weatherproof connectors at the side of the power box
- Conduits from the power box onto the system are Flex-tite up to the elbow of the dish arm.
- Conductors and cables shall be contained in conduits or wire trays in the outer part of the dish arm, to protect them from concentrated sunlight. The conduits or wire trays shall be painted white
- 115VAC and 460VAC shall be run in separate conduits
- Buried conduits shall be galvanized IMC (i.e., not non-metallic) or direct-burial cable
- Minimize number of joints/connectors on conduit runs (goal is single-piece conduit runs where possible)

7.3.6 Focus Blower Assembly

- 115VAC, single-phase blower
- Automatic overload protection on blower motor
- 115VAC solenoid valve, normally-open, direct-lift (0 psi actuation pressure)

7.3.7 Sun Sensor Assembly

- Cable terminates at weatherproof connector at bottom of sun sensor box
- Horizon reference switch (tilt-switch) inside box, powered by 24VDC
- Power for sun sensor derived from 24VDC
- Output signal isolated from input power
- Output signal shield not connected at sun sensor
- 0VDC output when on-sun; +/- 5VDC full-scale for E/W and Up/Down sensors
- Reference sensor output 0-5VDC

7.3.8 Arm Latches

- Pre-wired, environmentally-sealed cable assembly with weatherproof connectors at control box and at sensors
- Magnetically-actuated, environmentally-sealed proximity switches for arm latches
- 24VDC operational power
- Switches NO, with switch closure to ground upon actuation

7.3.9 Azimuth and Elevation Drive Motors

- 115VAC single-phase motors, 1750 RPM nominal
- Capacitor-start, induction run
- 1 HP elevation, ½ HP azimuth
- Automatic thermal overload in motor or drive junction box

7.3.10 Azimuth and Elevation Encoders and Limit Switches

- Magnetically actuated, environmentally-sealed proximity limit switches
- 24VDC operational power for limit switches
- 1 pulse-per-revolution, proximity-switch encoders with quadrature output
- 24VDC operational power for encoders

7.3.11 Network Interface for Dish/Stirling Systems

- 12VDC, 500 ma plug-in power supply
- Varistor protection on RS-485 lines and all digital and analog inputs
- Termination for network and PCS communications lines
- RS-232 comm lines to host computer and PCS monitor computer
- Network configuration: minimum 19,200 baud, 1 start bit, 8 data bits, 1 stop bit, no parity

- Opto-22 protocol for messages on network
- Opto-isolated pulse input from wind sensor
- Buffered voltage input from wind sensor for wind direction
- Comm lines and shields referenced to ground at network interface

7.3.12 Stirling Engine Package

- Isolated 2-wire RS-485 communication line to dish controller
- Shield on RS-485 line not connected at Stirling engine controller
- RS-485 comm line characteristics: 2400 baud, 1 start bit, 8 data bits, 1 stop bit, no parity
- RS-232 communication line from Stirling engine controller to power box is converted to RS-485 for transmission to the user interface. At the network interface, the signal is converted back to RS-232 and connected to the Stirling engine monitoring computer
- RS-232 line to Stirling engine montoring computer, and its shield, are referenced to ground at the Stirling engine controller
- Isolated switch closure for "PCS Fault" input to dish controller

8.0 PHYSICAL REQUIREMENTS

8.1 Size

The power box containing the control system components shall fit in the available space at the base of the pedestal in such a manner that the movement of the dish system is not impeded. The motors and sensors shall likewise not interfere with motion of any part of the dish system.

8.2 Weight

There is no restriction on the weight of the control system. All components mounted in the movable parts of the system shall be carried in the system weight and balance calculation, and that calculation shall be updated upon any changes to those components.

8.3 Appearance

The system shall be fabricated and installed in a manner so as to present a neat and professional appearance. Wiring shall be bundled and cables shall be wrapped together to reduce clutter.

8.4 Stability

No requirements for stability are established for the system.

8.5 Transportability

Components and fabricated assemblies of the system shall be transportable using normal freight carriers. No hazardous materials or special permit items shall be included.

8.6 Threshold Impact Resistance

Each box within the system shall withstand, without damage, a drop of 4" on each corner and side onto a flat hard surface.

9.0 ENVIRONMENTAL REQUIREMENTS

9.1 Temperature

Operating: -30 deg. C to +70 deg. C
Storage and Shipping: -40 deg. C to +70 deg.

9.2 Humidity

Operating: 10% to 95% humidity (including condensation)
Storage and Shipping: 10% to 95% humidity (including condensation)

9.3 Pressure

Operating: 70 kPa to 110 kPa (10.2 psia to 16.0 psia)
Storage and Shipping: 110 kPa to 106 kPa (10.2 psia to 16.0 psia)

9.4 Shock and Vibration

9.4.1 Shock

Each box shall survive 4" corner drops on all corners.

9.4.2 Vibration

All components shall withstand low-amplitude, low-frequency (4-50 Hz) vibration similar to a household refrigerator, without damage or effect.

9.5 EMI/RFI/EMC

The system EMI/RFI/EMC characteristics shall comply with all specified Regulatory Safety Agencies.

10.0 REGULATORY AND STANDARDS REQUIREMENTS

10.1 Regulatory Requirements

The controls and wiring system shall meet all applicable requirements in the regulatory, safety, and workmanship documents listed below:

- National Electric Code (NEC), 1996 and as revised for 1999
- National Electric Safety Code (NESC), 1997

10.2 Standards Requirements

The controls and wiring system shall meet all applicable industry standards listed below (unless they contradict any of the Regulatory requirements listed above):

- NIST-traceable calibrations for measurement equipment

10.3 Labeling Requirements

The following labeling requirements must be met by the system:

- All boxes containing life-threatening voltages shall be labeled with "High Voltage" and the voltage levels contained within the box
- Documentation for wiring shall specify wire color and labeling. Where possible, wire of the proper color shall be used, rather than just labels

- Individual point-to-point wiring shall be color-coded according to the following color schemes:

Wire Color	24VDC System	115VAC Wiring	460VAC Wiring
White		Neutral (115VAC)	
Black	Ground (negative)	Hot (115VAC)	
Red	24VDC supply (positive)		
Green	Signal inputs	Earth ground	Neutral/Earth ground
Yellow	Outputs		Phase C
Brown			Phase A
Orange			Phase B

10.3.1 User's Manual

A User's Manual will be developed by SAIC as a section of the Installation, Operation, and Maintenance Manual for the dish/Stirling system.

11.0 RELIABILITY AND MAINTENANCE REQUIREMENTS

The control system shall operate reliably under all Environmental and Transportation conditions contained in the previous section.

11.1 MTBF

The design goal for the reliability of the control and wiring system shall be a MTBF of 10,000 hours. Actual MTBF achieved by the control and electrical systems and components will be documented from field test results. System robustness will be demonstrated using accelerated life testing with thermal and mechanical stresses.

11.2 Maintenance Requirements

The system shall be designed to require periodic maintenance no more than two times per year.

Appendix C:
Dish System Specification Document

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1.0 SYSTEM SPECIFICATIONS

1.1 General Specifications

The dish/Stirling system is designed to operate normally under the following conditions:

Operating Conditions:

Temperature:	-40 C to 85 C
Humidity:	0 to 100% relative humidity
Wind:	operate within design specs in mean winds up to 27 mph (mean wind averaged over 1 hour per ANSI58.1-1982) move in any attitude while going to stow in gusts up to 50 mph

Survival Conditions:

Wind:	130 mph peak gust with dish halted in stow position
Seismic:	Zone 4, up to 1 G horizontal
Snow and Ice:	snow/ice load of 1 psf in stow position
Hail:	1" diameter hail at terminal velocity in stow position
Rain:	rainfall rate up to 1"/hour in stow position
Lightning:	no damage from nearby strike

1.2 System Geometry

The Phase system geometry is defined based on a coordinate system oriented with the x-axis horizontal to the right (East) when looking at the front of the concentrator, the y-axis upward, and the z-axis outward along the optical axis of the dish. The origin of the concentrator coordinate system is at the vertex of the parabola which the dish approximates. **Figure 1-1** shows the dish structure along with the coordinate system.

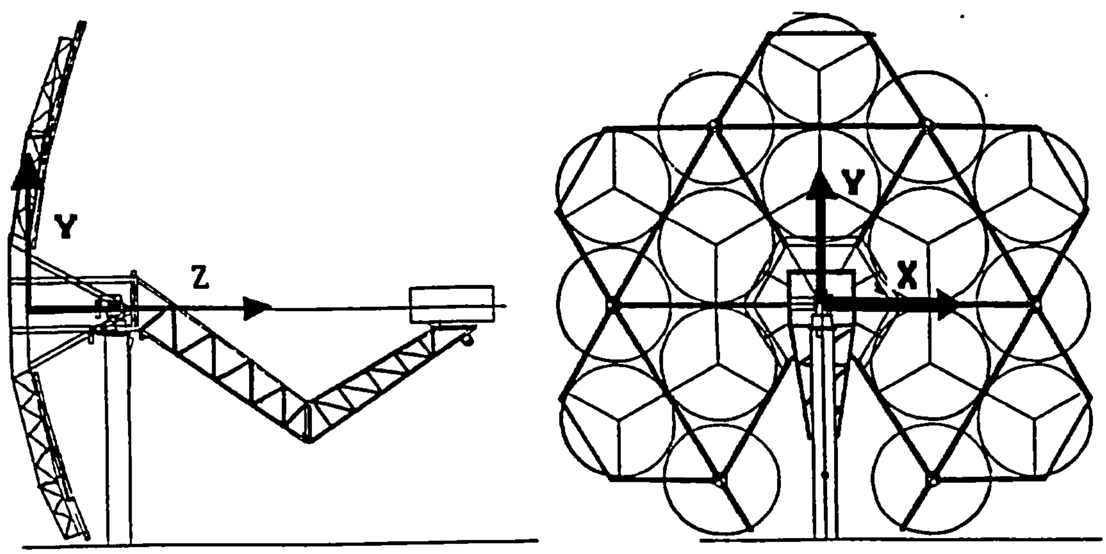

Figure 1-1. JVP Phase 2 Dish/Stirling System

The overall geometry of the system is summarized in **Table 1-1.**

Table 1-1. System Geometry

	Single Facet	Dish	
Number of Facets:		16	
Gross Facet Area (to OD of facets):	8.173 m^2	130.8 m^2	
Net Reflective Area:	7.325 m^2	117.2 m^2	
Dish Aperture Area (projected):		113.5 m^2	
Approximate Location of System CG		(0, 0.62m, 0.76m)	
Total System Weight		16,000 lb (7,260 kg)	
Location of Receiver Aperture:		(0, 0, 10.4 m)	
Facet CG Locations (meters):	X	Y	Z
Inner Facets:			
I1	0.00	3.334	-0.443
I2	-2.888	1.667	-0.443
I3	2.888	1.667	-0.443
I4	-2.888	-1.667	-0.443
I5	2.888	-1.667	-0.443
Middle Facets:			
M1	2.906	5.034	0.737
M2	-2.906	5.034	0.737
M3	5.812	0.000	0.737
M4	-5.812	0.000	0.737
M5	2.906	-5.034	0.737
M6	-2.906	-5.034	0.737
Outer Facets:			
O1	0.00	6.596	0.281
O2	-5.712	3.298	0.281
O3	5.712	3.298	0.281
O4	-5.712	-3.298	0.281
O5	5.712	-3.298	0.281

1.3 System Performance

The Phase 2 dish/Stirling system has a predicted net power output of 25.0 kW at a nominal insolation level of 1000 W/m^2. **Figure 1-2** illustrates the operation of the system at that power level as a "stairstep" diagram. As shown in the figure, the total power falling on the projected net mirror area of the dish is 113.5 kW. Of this, about 106.1 kW is reflected (assuming a nominal 2% reduction from the clean reflectance of the mirrors), and 95.8 kW enters the receiver cavity. Considering optical and thermal losses in the receiver, about 81.5 kW is absorbed by the engine and converted to 29.4 kW of mechanical power. With a 92% efficient generator and approximately 2.1 kW in parasitic power, the net output of the system is 25.0 kW.

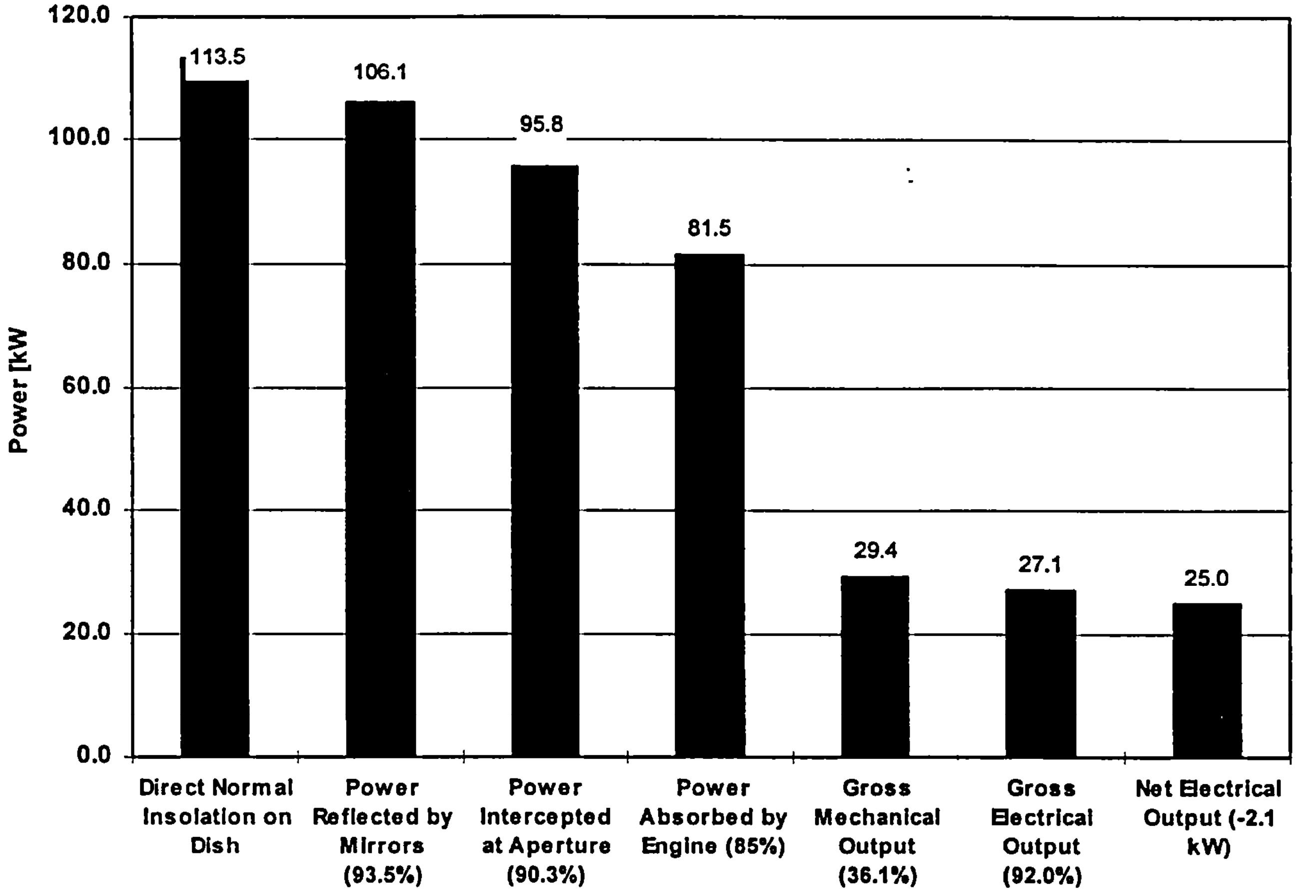

Figure 1-2. Stairstep Diagram for Phase 2 Dish/Stirling System

Because of the variable nature of solar insolation, the output of the Phase 2 dish/Stirling power system varies from the nominal operating condition as a function of the direct normal insolation. The system is expected to perform within 10% of the system performance curve shown in **Figure 1-3.**

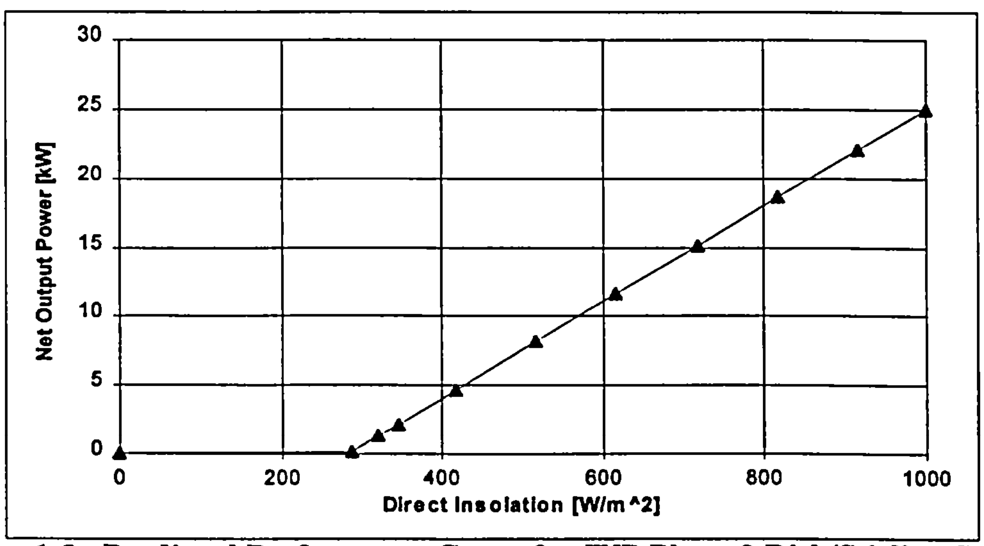

Figure 1-3. Predicted Performance Curve for JVP Phase 2 Dish/Stirling System

Using the system performance curve and Typical Meteorological Year (TMY2) data for Daggett, CA, projected annual performance of the system is estimated to be as follows:

Total Direct Normal Insolation on Dish:	318,501 kWh
Annual Energy Delivered:	56,410 kWh
System Overall Annual Efficiency:	17.7%
Total Hours of Solar Operation:	3,576

Figure 1-4 shows the predicted output of the system at Daggett, CA in terms of Southern California Edison Time-of-Day rate periods. **Figure 1-5** shows the same data by month. Finally, **Figure 1-6** shows the spectrum of power output levels at which the system operates over the course of the year. The average power output level from the system during the time it is operating is 15.8 kW over the course of the year.

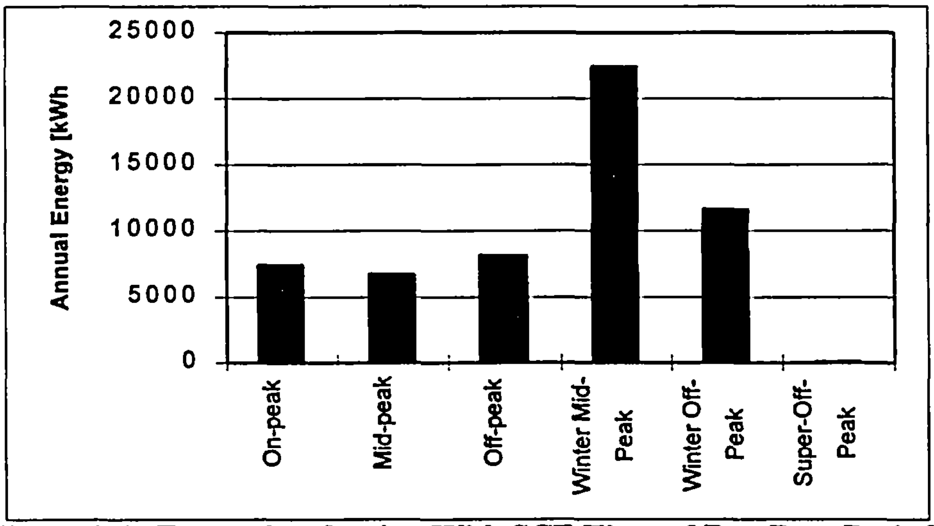

Figure 1-4. Energy Production With SCE Time-of-Day Rate Periods

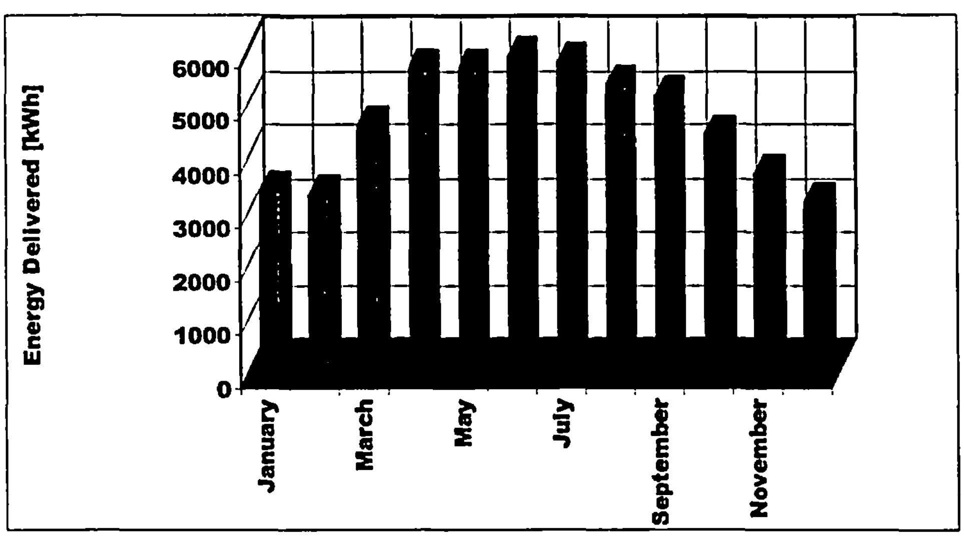

Figure 1-5. Monthly Energy Delivery

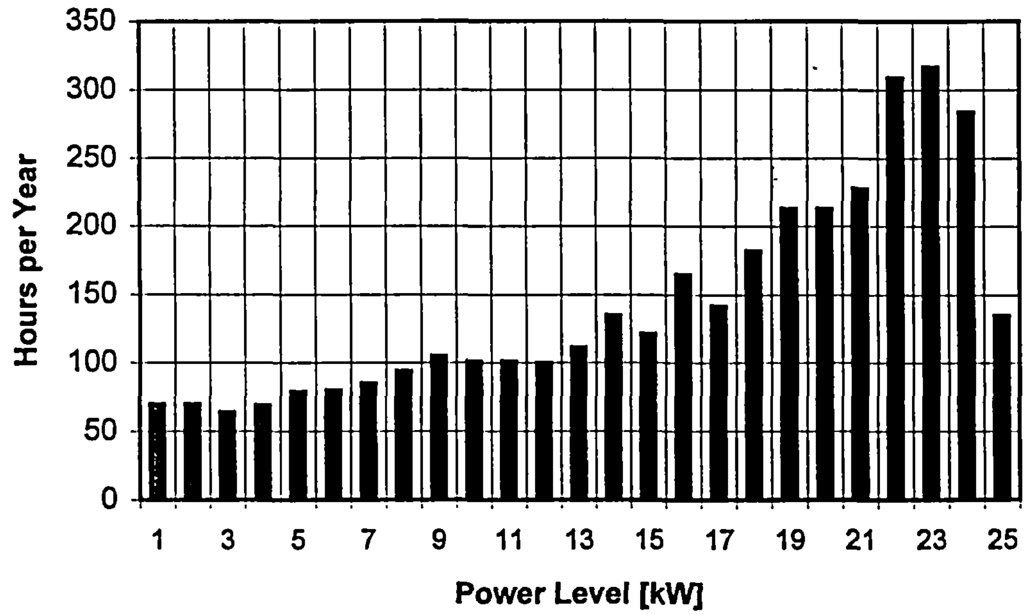

Figure 1-6. Predicted System Power Levels for Operation at Daggett, CA

1.4 Structural Requirements

Deflections of the dish structure shall result in a total equivalent RMS concentrator slope error of no more than 0.18 degrees (3.1 mrad) up to 27 mph average winds. The allowable errors are distributed among the subsystems of the dish as follows:

Facet Macroscopic Slope Error	0.14 degrees (2.5 mrad)
Reflective Surface Specularity	0.04 degrees (0.75 mrad)
Facet Support Structure Deflection	0.06 degrees (1.0 mrad)
Control System (tracking errors)	0.06 degrees (1.0 mrad)
Drive System (backlash, deflection)	0.06 degrees (1.0 mrad)

Facet and reflective surface errors are measured relative to a perfect parabola with a focal length equivalent to the best-fit parabola to the surface shape of the facet. Support structure deflections are calculated by determining the deflection of each facet and averaging their resulting pointing errors. To allow for wind increase as the system drives to stow, the concentrator structure is designed to operate without damage in 31 mph average winds (including 50 mph gusts). The structure is designed to withstand 81 mph average winds (130 mph gusts) when stopped in the stow position.

In addition to structural deflections, the drive and control system allow the system to be positioned, and that position to be measured, to within 0.06 degrees (1 mrad). This accuracy is designed to be maintained on an RMS basis, including drive backlash and deflection, in average winds up to 27 mph.

The PCS arm is designed to maintain the PCS stationary relative to the dish structure over the range of motion of the dish during tracking (i.e., elevation from 0 degrees to 90 degrees). The deflection of the PCS from its nominal position due to gravity and wind effects does not exceed 0.01 m in the X or Y directions, and does not exceed 0.03 m in the Z direction (i.e., along the axis of the dish). This deflection includes any backlash or deflection due to the linkages and hinges in the PCS arm /dish structure.

The assumptions and design approach for the structural calculations are contained in **Appendix A.**

1.5 Power Quality

The electrical power delivered by the dish/Stirling system to the utility grid is nominally 3-phase, 480VAC, 60 Hz alternating current. The power meets the following specifications:

Frequency:	58-62 Hz
Power Factor:	>90% at full load
THD:	<5%, all loads and speeds, for input line impedance of 0.5% to 5%
Harmonics:	Complies with IEEE 519 (1992) Recommended Practices for Harmonic Control in Electric Power Systems

1.6 Operation on Gas

When the system is operated in its gas-fired hybrid mode using natural gas as fuel, it will perform according to the following specifications. Note that operation on other fuels will lead to different emissions.

Output Power:	25 kW
Gas Supply Pressure:	1.5 –3.0 psig
Natural Gas Usage:	75 cu. ft./hour
Heat Rate:	2880 Btu/kWh
Emissions: NOx	XXXXX g/hr at 25 kW output
CO	XXXXX g/hr at 25 kW output
CO_2	XXXXX g/hr at 25 kW output

2.0 DISH CONCENTRATOR SPECIFICATION

2.1 Flux Interface

The alignment and focusing of the facets of the dish concentrator are adjusted to produce a flux distribution on the PCS receiver tubes that is as uniform as possible in the circumferential direction, while spreading the flux over the receiver tubes as uniformly as possible. The flux pattern is designed so a peak flux density of 80 W/cm^2 will not be exceeded at any time on the PCS receiver. The focus of each facet is also adjusted so that the flux on the receiver does not exceed the fully-focused peak value at any time during focus or defocus. **Figure 2-1** shows the predicted solar flux distribution on the receiver tubes of the STM receiver. The peak predicted flux is 60.3 W/cm^2, and the average flux on the receiver is predicted to be 37.9 W/cm^2.

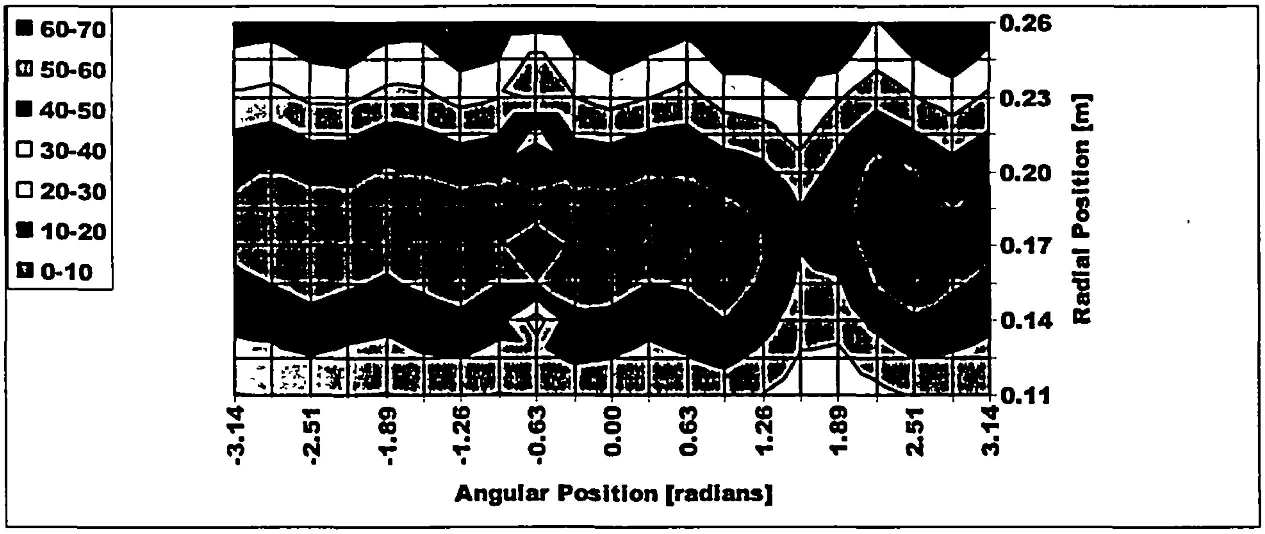

Figure 2-1. Predicted Solar Flux Distribution on STM Hybrid Receiver

2.2 Facet Alignment

Each facet is aligned to within 0.06 degrees (1 mrad) of its desired orientation. This amount of alignment error translates to approximately 2 cm of motion of the facet image at the receiver, or to approximately 3 mm axial deviation of any one of the facet mounts.

The facet aimpoints and focal lengths (defined by peak flux) are as follows:

	X	Y	Z	Focal Length
Inner Facets:				
I1	0.046	-0.111	10.585	11.554
I2	0.120	0.000	10.585	11.552
I3	-0.085	-0.085	10.585	11.555
I4	0.046	0.111	10.585	11.550
I5	-0.111	0.046	10.585	11.556

Middle Facets:				
M1	-0.057	-0.139	10.585	11.511
M2	0.106	-0.106	10.585	11.509
M3	-0.150	0.000	10.585	11.512
M4	0.139	0.057	10.585	11.506
M5	-0.106	0.106	10.585	11.509
M6	0.000	0.150	10.585	11.502
Outer Facets:				
O1	0.000	-0.150	10.585	12.316
O2	0.139	-0.057	10.585	12.315
O3	-0.139	-0.057	10.585	12.315
O4	0.106	0.106	10.585	12.313
O5	-0.057	0.139	10.585	12.299

2.3 Dish Facet Specification

Specifications of the individual dish facets are summarized in **Table 2-1.**

Table 2-1. Dish Facet Specifications

Mirror Facet Total Weight	114.3 kg (252 lb)
Facet Ring OD	3.226 m (127.0")
Facet Ring ID	3.150 m (124.0")
Mirror OD	3.124 m (123.0")
Mirrors	1 mm low-iron glass, back-silvered
Mirror Reflectance (new, clean, AM 2)	95.3%
Ring Flatness (focused)	<+- 0.060"
Facet RMS Slope Error (focused at 11.5 m)	0.14 degrees (2.5 mrad)

3.0 POWER CONVERSION SYSTEM SPECIFICATIONS

3.1 Performance Specification

The Power Conversion System (PCS) is designed to deliver the following performance:

Maximum Input Power:	90 kW thermal
Maximum Output Power:	25 kW, net
Efficiency (based on solar energy entering aperture):	XXXXX %
Efficiency (natural gas):	XXXXX %
Parasitic Power (non-operating):	XXXXX kW
Parasitic Power (operating):	XXXXX kW

3.2 Receiver Geometry

The receiver of the PCS provides the interface between the dish concentrator and the Stirling engine. The geometry of the receiver is therefore of particular importance. The receiver geometry is described in **Table 3-1**. Generally, the receiver cavity consists of circular aperture in front of a cylindrical cavity ending in the rear with a concave conical receiver section. A ceramic cone covers the center of the top of the engine.

Table 3-1. Power Conversion System Receiver Cavity Geometry

Aperture Diameter	0.380 m
Depth of Entrance Cone (Aperture to Cylinder, along dish axis)	0.065 m
Inner Cylinder Diameter	0.510 m
Depth of Cylindrical Portion	0.120 m
Depth of Absorber Section	0.131 m
Center Ceramic Stone Diameter (= ID of Absorber Section)	0.220 m
Total Cavity Depth (Aperture to Rear of Receiver)	0.316 m

3.3 Physical Interface

The physical interface between the PCS and the dish concentrator consists of the mounting provisions for the PCS and the electrical and control signal connections.

The PCS mount is shown in **Figure 3-1.** The mount consists of alignment chocks that support and align the PCS on the mounting platform, and six hold-down bolts to secure it in position.

The 480 VAC, 3-phase power and the 120 VAC power connections to the PCS are made at a junction box mounted in the structure of the PCS support arm.. Other connections are made via two cables that attach to bulkhead connectors at the bottom rear of the PCS package. The connections in these two plugs are detailed in **Table 3-2.**

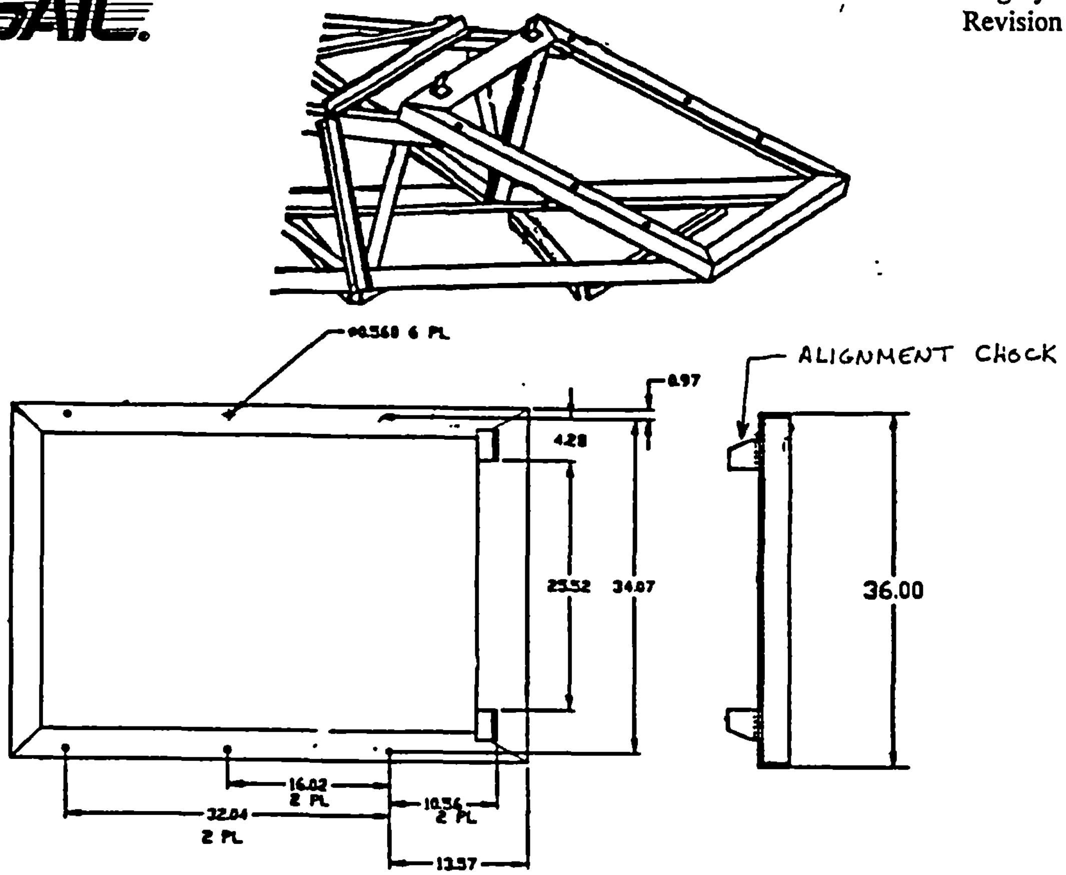

Figure 3-1. PCS Mount

Table 3-2. PCS Signal Connections

Plug #1 – 16-pin (AMP 208489-1/208488-1):

1	RS-485 +	SAIC Dish Control Box
2	~~Shield (RS-485)~~ N/C	
3	RS-485 -	SAIC Dish Control Box
4	RS-232 TX	PCS Operator Console
5	RS-232 Gnd	PCS Operator Console
6	RS-232 RX	PCS Operator Console
7	PCS Ready A	SAIC Dish Control Box
8	Shield (Ready)	
9	PCS Ready B	SAIC Dish Control Box
10	n/c	
11	n/c	
12	RS-232 TX	Diagnostic line
13	RS-232 Gnd	Diagnostic line
14	RS-232 RX	Diagnostic line
15	Shield (RS-232 Diagnostic line)	
16	n/c	

Table 3-2. PCS Signal Connections (concluded)

Plug #2 – 14-pin (AMP 208847-1/208846-1):

1	Watts +	Wattmeter
2	Watts -	Wattmeter
3	Shield (Wattmeter)	
4	Power Factor +	Wattmeter
5	Power Factor -	Wattmeter
6	n/c	
7	Baldor Gnd	Baldor Motor Controller
8	Baldor Ready	Baldor Motor Controller
9	Shield (Baldor)	
10	Baldor Grid A	Baldor Motor Controller
11	Baldor Grid B	Baldor Motor Controller
12	n/c	
13	n/c	
14	n/c	

4.0 Utility Electrical Interface

The nominal SAIC interface to the grid system is at the base of the pedestal for the dish/Stirling system, after the fused disconnect if one is installed. From that point, wiring to the control box and Stirling engine, including a 120 VAC control power transformer, is considered part of the dish/Stirling system. An electrical meter and grid protection panel may be shared among several dishes with appropriate changes to the over-current settings and contactor ratings. Overall interface specifications are as follows:

- 480V nominal voltage
- 3-phase
- Delta connection
- 60 Amp minimum service for one system, or suitable ampacity for 40 HP motor on each dish that will be connected to the interface point

4.1 One-Line Diagram

A one-line diagram for the electrical interconnection of a nominal system to the utility grid is shown in **Figure 4-1.** Multiple-dish systems would have interconnections with shared protection relays and individual disconnects at each dish, as shown in **Figure 4-2.**

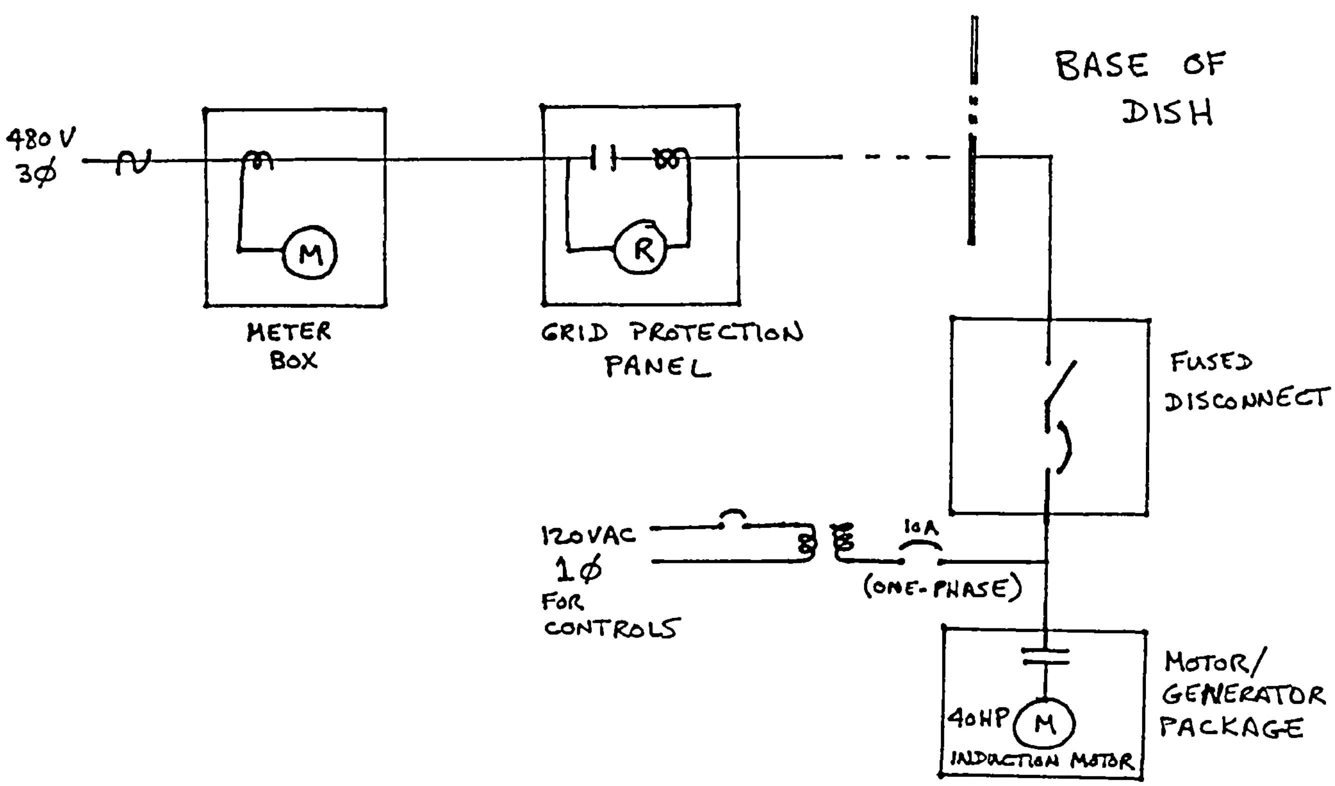

Figure 4-1. Generic Single-Dish Grid Interface One-Line Diagram

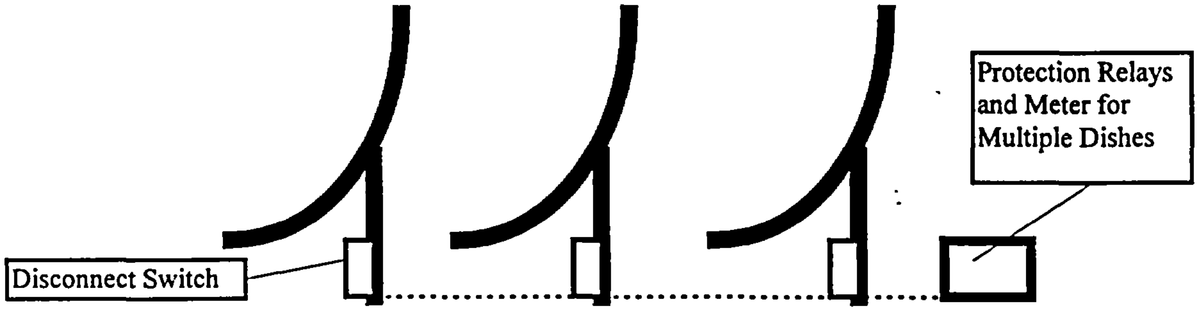

Figure 4-2. Multiple-Dish Grid Interface Approach

4.2 Protection Relay Specifications

Grid protection relays are connected in series to a three-phase contactor to protect the utility grid from over/under voltage, voltage balance and sequence, over/under frequency, and overcurrent, including lock-out logic to prevent automatic re-connection to grid after a grid fault. The relays are contained within a NEMA 4 enclosure with push-buttons switches and indicator lights on the front. **Figure 4-3** shows the connections for the grid-protection panel. Relay specifications are as follows:

Relay Type	Function	Specifications
27/59	Over/Under-Voltage	trip on <=368V (80%) in <=0.5 sec trip on >=529V (115%) in <=0.1 sec
47/60	Voltage Balance/ Sequence	17.8% imbalance <383V low voltage
81-U	Under-Frequency	trip on <=57 Hz in <= 0.5 sec
81-O	Over-Frequency	trip on >=63 Hz in <= 0.5 sec
51N	Over-Current	trip on >=45A in primary circuit in <=0.5 sec for one dish (relay setting is 4.5A with 50:5 current transformers)

4.3 Single-Dish Disconnects

A fused disconnect is required at the base of each dish if any of the following conditions are true:

- No clear line-of-sight exists between the base of the dish and the grid protection panel;
- Distance from the pedestal to the grid protection panel is greater than 200 feet (60m); or,
- More than one dish/Stirling system is attached to the grid protection panel.

Requirements for this disconnect are as follows:

- NEMA 4 enclosure
- 480V
- 3-phase disconnect
- FRS-R 60Amp Time-Delay fuses

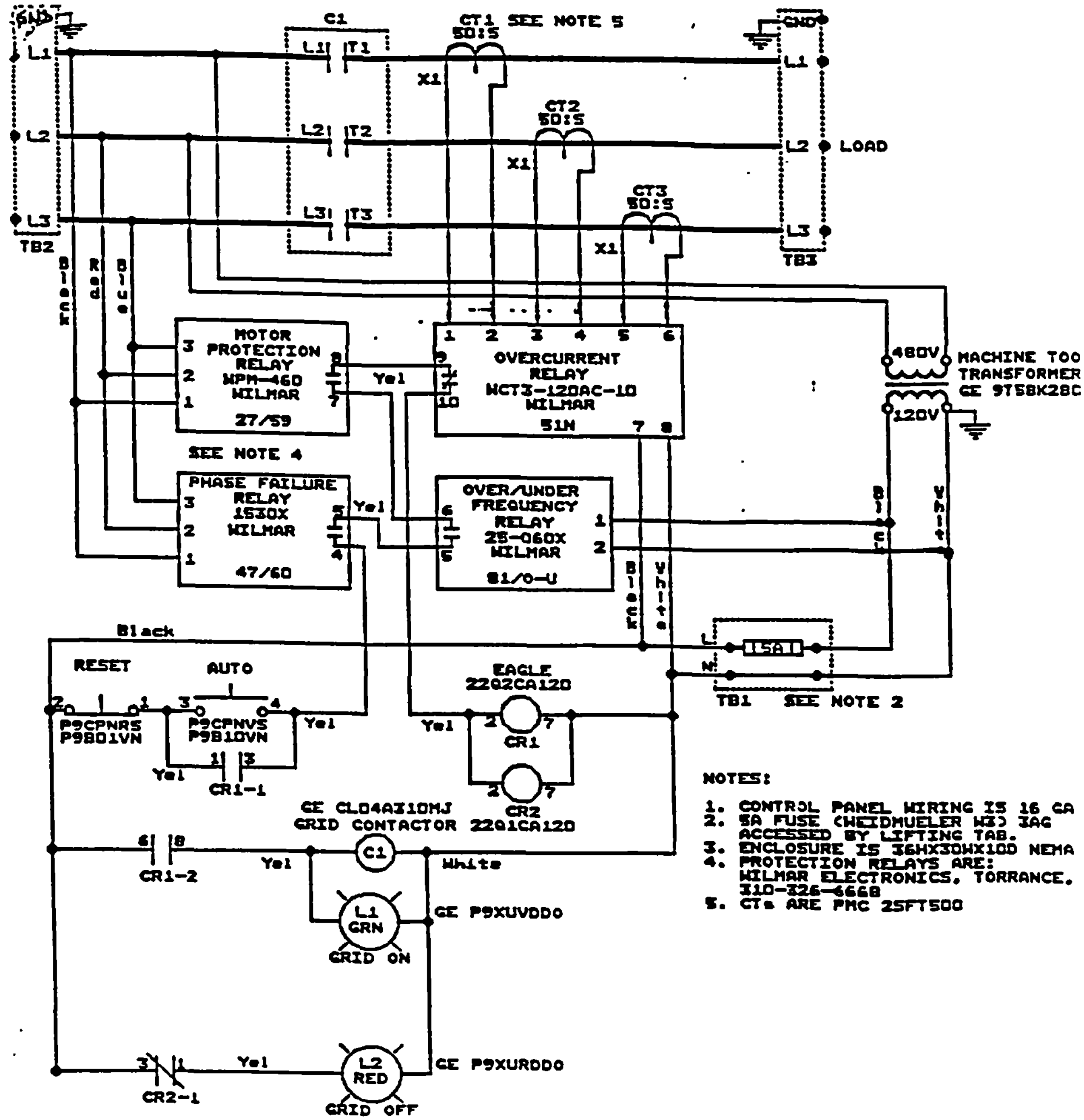

Figure 4-3. Grid Protection Panel

4.4 System Power Wiring

The wire size for all single-dish wiring is 6 AWG, in standard EMT or Seal-Tite conduit. Off-dish wire gauges should be based on run lengths and the 40 HP requirement per dish to limit voltage loss between the dish and utility interface to between 0.5% and 4.5% when operating at 25 kW.

All wiring components (conduit, junction boxes, etc.) must extend no higher than 6" above grade within 20 feet of the pedestal, except within 3 feet of the pedestal, where they may extend upward to attach to the control box. Burial of conduits leading to the pedestal is preferred.

5.0 System User Interface

The dish/Stirling system is controlled via a user interface on a computer operated by the utility to which power is being supplied. The interface allows the user to control and communicate with up to 254 individual dish/Stirling systems. The systems talk to the user's computer over a RS-485 multi-drop network via a network interface box that also serves as a weather monitoring and recording station. In normal operation, the operator chooses if solar operation and/or gas operation are enabled, and defines a starting hour and ending hour between which gas operation is allowed (e.g., 12:00pm to 8:00pm). These choices result in the following modes of system operation:

- Solar Enabled/Gas Enabled: The tracking system operates automatically to track the sun during the day, and performs night-time stows and high-wind stows when appropriate. Whenever sufficient solar energy is available, the system focuses and generates power from solar energy. Otherwise, during the allowed gas operation hours, the system runs on gas at full power.
- Solar Enabled/Gas Disabled: Same as above, except the system does not run on gas.
- Solar Disabled/Gas Enabled: The system ceases solar operation, moves to its night-time (face-down) stow position, and remains there. During the allowed hours for gas operation, the system runs on gas at full power.
- Solar Disabled/Gas Disabled: The system ceases both solar and gas operation, and moves to its night-time (face-down) stow position.

In addition, the user interface is able to communicate with individual systems during setup and on a routine basis for the following purposes:

- Set parameters for operation, including location (latitude, longitude), operating sun elevation (sun elevation at which the system wakes up), minimum insolation for operation, gas operation times (gas start hour, gas end hour), etc.
- Update the system clock
- Change tracking modes – modes available include calculated sun tracking, sun-sensor-based tracking, and optimized (peak power) tracking

Each dish control system monitors and records performance and operational data on a periodic basis (normally 5 minutes), and stores the data in the controller. The network interface controller serves as a weather data acquisition system, recording temperature, humidity, wind, and insolation data. Each night, the user interface automatically downloads the data from each dish and from the network controller and stores the data on files on the control computer. Retrieval of data may be done remotely over a phone connection to the system.

More details about the user interface are contained in the SAIC/STM Dish/Stirling System Operation and Maintenance Manual.

Appendix A

Wind Load Assumptions and Structure Design Approach

A.1 Design Wind Loads

Wind loads are developed according to the recommendations in "Wind Load Design Methods for Ground-Based Heliostats and Parabolic Dish Collectors," by J.A. Peterka and R.G. Derickson, SAND92-7009, September 1992.

Loads used for analysis of the structure to verify performance are the mean loads caused by the mean winds at the analysis point. Mean loads are calculated using the dynamic pressure of the mean wind and mean wind coefficients. Loads for survival analysis use peak coefficients and the dynamic pressure from the mean wind. The ratio of peak to mean winds is assumed to be 1.6, so that a 31-mph mean wind has a 50-mph peak wind and a 81-mph mean wind has a 130-mph peak wind.

The environmental assumptions for the dish are as follows:

- Isolated dish – no load reduction factors due to blockage
- The mean boundary layer wind is assumed to follow a power law function, $U(z) = U(zref)*(z/zref)^n$, where z is the distance from the ground, and zref and n are as defined below:
- Mean and peak winds are defined at a nominal height of 10.0 meters (32.8 ft) from the ground (zref)
- The power law exponent (n) for mean velocity variation with elevation is 0.17, which is appropriate for an open-country environment

Geometric modeling assumptions for the dish are as follows:

- The porosity of the faceted dish due to the open space between the facets is not considered to be significant. This is a very conservative assumption considering the staggered arrangement of the facets, which leads to significant open areas when winds hit the dish from oblique angles.
- The loads on the dish are assumed to be equivalent to the loads on a dish with a depth-to-diameter ratio of 0.1
- The dish is modeled as a round parabolic dish with a radius equal to the distance from the center of the dish to the outer edge of the middle facets. This is a conservative approach, since the bottom half of the dish is open (2 facets are missing at the bottom of the dish where it must clear the pedestal)

A.2 Allowable Stresses

The following guidelines are followed in the structural analysis and design to limit the maximum stresses in the structure of the dish:

Tension:

- Except for pin-connected members, F_t shall not exceed 0.5 F_y on the effective net area of the member
- For pin-connected members: F_t =0.45 F_y on the net area
- For tension on threaded parts, appropriate allowable loadings from Table 1.5.2.1 of the American Institute of Steel Construction Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings are used

Shear:

- On the cross-sectional area effective in resisting shear: F_v=0.4 F_y. The effective area in resisting shear of rolled and fabricated shapes is taken as the overall depth times the web thickness.

Compression:

- On the gross area of plate girder stiffeners: F_x=0.6 F_y
- On the web of rolled shapes at the toe of the fillet: F_x=0.75 F_y

Bending:

- The tension and compression on extreme fibers of compact, hot-rolled or built-up members symmetrical about, and loaded in, the plane of their minor axis and meeting the requirements of this section: F_b=0.66 F_y

Bearing:

- On contact areas of milled surfaces and ends of fitted bearing stiffeners, and on the projected area of pins in reamed, drilled, or bored holes: F_p=0.9 F_y
- On the projected area of bolts and rivets in shear connections: F_p=1.5 F_u

Welds:

- Tension normal to effective area: same as the base metal
- Compression normal to effective area: same as the base metal
- Tension or compression parallel to the axis of the weld: same as the base metal
- Shear on effective area: 0.3 times the nominal tensile strength of the weld metal

Other Design Considerations:

The design of the dish includes due regard for the following additional factors:

- Stability and slenderness ratios
- Fatigue
- Vibrational modes and frequencies, including possible excitation by winds

Appendix D:
Incident Summaries for the Phase 2 Dish/Stirling Systems

SAIC

Incident Summary

Rocky Flats JVP Dish "Hal"

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
2	4/4/95 5:00:00 PM	Windspeed sensor failed	Closed	'	
3	4/13/95 8:00:00 AM	Elevation motor would not run under manual or auto control to move dish from stow.	Closed	'	
5	5/18/95	Incorrect operation of focus, focus blower ran backwards	Closed	Re-design focus plumbing to incorporate check values	
4	5/18/95 9:30.00 AM	Mechanical interference between drive and structure	Closed	Re-designed hub for clearance	
6	6/11/95 9:35:00 AM	PCS continued to motor after system shutdown .	Closed	Cycled power; STM updated ROM in PCS controller	
7	6/13/95	PCS leaking oil in stow position	Closed	Added check of overflow bottle to weekly routine	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
8	6/13/95 2:00.00 PM	Not focusing; poppets sticking	Closed	Redesigned to increase clearance of poppets	
46	6/19/95	Engine case vented during operation	Closed	•	
44	6/20/95	Azimuth Proximity lost, tracked off to the West.	Closed	Change PLC logic/programming to require motion feedback within a given time interval or stop (timeout.) Modify scram button to always work. STM requests hardwire, we'll accommodate.	
45	6/20/95	Dish bumped azimuth drive going on-sun	Closed	•	
9	7/24/95	Grid protection relays tripped	Closed	Re-calibrate over/under voltage relay	
10	7/28/95 7:06:00 PM	Off-track during operation	Closed	Undeterminable at this time; control software rewritten in 2/96 to monitor dish position in real time.	
11	2/24/96 2:00:00 PM	Accidentally tracked onto PCS in focused condition	Closed	Operator error - manual control; added check in software for off-sun before focus	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
12	3/20/96	SDS system fault - intermittent	Closed	Added display and command to clear SDS faults; added fuse to wind sensor; defocus and close shutter on SDS fault	
13	3/26/96 10:10.00	H_2 solenoid failure in PCS	Closed	Replaced solenoid	
14	6/3/96 10:00.00	Mechanical interference between drive and structure	Awaiting QA Verification Lem	Re-designed hub for clearance (to be implemented in Phase 2)	
15	6/18/96	PCS stroke problem - would not go beyond 50%	Closed	Re-built engine at STM; pin had worked loose	
16	1/7/97	SDS Fault 4101 - bad elevation limit switch	Closed	Replace switch, check wiring	
17	2/21/97	Dish drove into pedestal	Awaiting QA Verification Lem	Cause unknown; changed procedure to turn off motor power at night	
18	2/21/97	Limit switch (manual) didn't operate (filled with water and shorted out.)	Closed	Elevation limit switch replaced; eliminated in Phase 2 design in favor of hermetically sealed switches	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
19	4/14/97 2:00.00 PM	Discover corrosion on the elevation proximity connector	Awaiting QA Verification Lem	Evaluating different proximity switch connectors that give better protection against environmental corrosion	
20	5/2/97 2:30.00 PM	Shutter control air compressor was not rotating, the motor was just humming and heating up.	Awaiting QA Verification Lem	'	
51	5/9/97 10.00:00	All the black tie wraps on the dish are becoming brittle. Several tie wraps have already broken or fallen off.	Closed	'	
49	5/9/97 10:30:00	Hole in vacuum hose.	Closed	'	
50	5/9/97 11:00.00	Swivel washers on facet adjustment brackets are showing signs of heavy corrosion.	Closed	'	
48	5/30/97	White paint spilled on facets from manlift.	Closed	'	
21	6/10/97 3:30:00 PM	Front thrust bearing failed in drive. (Detox testing)	Awaiting QA Verification Lem	An additional counterbalance plate will be added to the back of the dish.	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
22	6/18/97	Clearance problem between azimuth drive limit switch and hub, wire is getting pinched. (Detox testing)	Awaiting QA Verification Lem	'	
23	6/18/97	The reflective surface of the SOE (secondary optical element) is starting to show signs of bubbling and melting. Melting has occurred along the inner seam towards the quartz lens side of the reactor. Also, the tack welds along the outer surface of the SOE are starting to break loose. (Detox testing)	Awaiting QA Verification Lem	Check on status of new SOE. I will increase the cooling water flow rate and try to decrease the inlet water temperature by tapping off the cooling water tank. I also will bang back the reflective surface that is bubbling to make better thermal contact between the reflective surface and SOE. We also cleaned the cottonwood from the water cooler radiator.	
24	6/18/97 10:55.00	Tiles on facets are peeling. (Detox testing)	Awaiting QA Verification Lem	'	
55	7/9/97	Azimuth drive proximity sensor failed.	Awaiting QA Verification Lem	'	
25	7/14/97 10.00.00	Input air line to the shutter actuator melted. Reflected heat from the BCS target.	Closed	Replaced line with the same type of material, but I recommend we replace both the inlet and outlet tubing with stainless steel flex lines. Incident occurred again 7/16/97 when coming off-sun and tube was replaced with piece of SS flex line.	
52	7/16/97	Coolant leak in PCS	Awaiting QA Verification Lem	'	
53	8/5/97	Pressure transducers on cycles #1 and #2.	Awaiting QA Verification Lem	'	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
26	8/26/97 7:00.00 AM	Air compressor running continuously. Crack found in air filter bowl.	Awaiting QA Verification Lem	Replace plastic bowl with metal version.	
27	8/26/97 2.00:00 PM	Faulty Thermocouple	Awaiting QA Verification Lem	'	
54	9/6/97	Hydrogen leak in SS line from #1 on cycle block to cylinder #1 of engine.	Awaiting QA Verification Lem	'	
29	9/9/97 2:30:00 PM	Front thrust bearing failed on elevation drive	Awaiting QA Verification Lem	'	
31	9/24/97 8:00:00 AM	PCS coolant water pressure transducer failure.	Awaiting QA Verification Lem	'	
32	9/24/97 2:30.00 PM	PCS hood latch not secured, operator error	Awaiting QA Verification Lem	'	
33	10/1/97 1:00.00 PM	Cycle #3 (hydrogen) pressure transducer	Awaiting QA Verification Lem	'	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
35	10/28/97	The rate of hydrogen leakage has increased noticeably in the past week. I used the leak detector around the cycle bleed off, cycle block, and brazed lines without detecting any leaks. I sprayed a soapy solution on the cycle bleed-off, cycle block, brazed lines, and inside the receiver with no obvious leaks surfacing. I then checked inside the receiver with the leak detector and it registered on the 10^-2 scale. I was unable to localize any leaks however. Either there is a large leak or the reading is faulty. (In the past, Vern & I have seen the leak detector give faulty readings when water is present.) It is important to note that the system has not been operated in the last week due to installation of Phase 2 controls on the Phase 1 dish.	Awaiting QA Verification Lem	'	
36	11/13/97 4:00:00 PM	To simulate the face down stow on the phase 2 dish, the phase 1 dish is brought to -10 degrees elevation before being stowed in the upward position. After the dish automatically stowed at -10, I commanded the dish to its final resting position at 88 deg. The dish did not move up, but blew a fuse, causing an elevation drive fault. I replaced the fuse and it blew also. I called Roger and he came on site. We removed the drive motor and 5.5:1 gear-reduction box. The dish was driven to its balance point using a 1/2 horsepower drill. The drive motor and gear box was remounted and the dish was stowed. The next day the dish would not drive down in elevation. Brian D and I removed the motor and gearbox again. We installed a new 5.5:1 right angle gear box and filled it with synthetic gear lube. The dish still would not drive down in elevation. (Phase 2 controls checkout)	Awaiting QA Verification Lem	'	
40	12/17/97	Little PLC output control chip failed, with output #3 (EL RUN) on. Replaced chip and system behaved normally again. (Phase 2 controls checkout)	Awaiting QA Verification Lem	'	
39	12/17/97 10:00:00	Elevation encoder started giving trouble while stowing. First, a fault was triggered, but the encoder kept going. Then the encoder stopped counting altogether. (Phase 2 controls checkout)	Closed	'	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
93	3/9/98	The Data Acquisition System (DAS) is not logging data on 5 minute intervals. The data logging seems to be sporadic. We had this problem before and thought the problem was solved but the latest data download revealed that this was not the case. Roger is aware of the problem and may be able to offer additional insight. At this point I am not sure if it is a software problem or a hardware problem.	Awaiting QA Verification Lem	Fixed both problems, new version of DAS program is 3/21/98 - 1. We should be able to verify correct operation by 3/25/98.	3/21/98
92	3/9/98 7:45:00 AM	Received elevation drive motor fault (:04) after commanding the dish to 30 degrees elevation by changing elevation stow parameter [PE] from 88 to 30. Continuity test on elevation drive 20 Amp. fuse showed that the fuse was bad. I replaced the fuse and cleared the fault. The fuse blew again. I went outside with the manual control box to get a closer look. The dish would move in Azimuth, but there was no coast in the motor before coming to a stop. Usually the shaft on the azimuth drive right angle gear box will coast a few revs before stopping, but not today. I then attempted to move the dish in elevation to an avail. The motor could be heard humming, but no movement	Awaiting QA Verification Lem	'	
114	3/16/98 7:30:00 AM	The solenoid valve on the cycles is sticking. When a cold fill is initiated you can hear the valve cycling. I turned off the cold fill (FLL) and the valve stopped cycling but the engine continued to fill to the pressure on the bottle regulator.	Awaiting Investigation STM	'	3/27/98
113	3/16/98 10:00:00	After diagnosing a problem with the Solenoid Valve on the PCS I tried to stow the dish. The elevation drive fuse blew just after the PCS lifted off the 4 X 4s on the maintenance pad. The motor keeps blowing fuses and will not sow.	Awaiting QA Verification Lem	'	
133	3/20/98	I was performing a current vs. elevation test at the time of this incident. The dish was around the horizon, heading towards stow when the failure occurred. A loud creaking sound, similar to other drive failures, could be heard coming from the elevation drive. I ran the dish back down firmly on the maintenance pad. Saturday morning the dish was recovered back to stow position. - JS Recovering the dish required someone sitting on the drive picking out broken pieces (none found), and counterweighting of the system using a come-along to the bumper of a pick-up. Even so, the system needed to be nudged a few tenths of a degree at a time until it was above the horizon. Then, it broke free and ran without problems to stow.	Awaiting Implementation Don / Mike	We will replace the Flenders drive with a refurbished Flenders drive. Please schedule installation.	5/1/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
238	6/15/98	Phil and I were on-site to check on the site and the Stirling cycle pressures when we noticed that the STM control computer had stopped working. About three weeks ago there was a lightening storm that took out some of the controls on the Heliostat up on the Mesa. The control computer must be operational in order to see the cycle pressure and any faults on the Stirling motor. Once again, it is very important that the cycles and case are pressurized at all times and that the cycle pressure is greater than the case pressure.	Awaiting Investigation STM		7/10/98

SAIC

Incident Summary

NREL Dish "Charlie"

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
41	12/22/97	Three facets have failed during either fabrication or cycle testing. The weld between the membrane and the ring did not hold.	Closed	An extra set of leads was added to the weld contacts in order to reduce the heat and increase voltage on the weld. None of the facets that have been welded with the extra leads have failed during cycle test.	12/30/97
42	12/22/97	Vertex, NM missed a weld on a structural member of the hub assembly.	Closed	Scott added a weld to the member and Lem notified Vertex of the discrepancy.	1/5/98
43	12/22/97	Holes were too small on hinge. The holes ranged from .565 to .580 in diameter. Drawing calls out for .688 holes.	Closed	Scott reamed the holes to size. Lem notified vendor of discrepancy, and confirmed that they have the correct drawings.	12/23/97
56	1/7/98 3:00.00 PM	After the final installation of all mirror facets, with the hardware tightened, we noticed serious deflection in the area of the truss bracket by lifting up the end of the long cantilever truss. We could lift the truss very easily about 5 to 6 inches using around 20 to 30 pounds of pressure. The top mirror was rocking back and forth to the point where it was hitting the circumferential truss.	Closed	The truss bracket was redesigned such that all of the trusses come together at one point, eliminating the torsional spring in the bracket. The new brackets were installed on the NREL mesa dish on 3/17, and we noticed that there was less than a quarter inch deflection in the cantilever trusses.	3/17/98
69	1/19/98	Azimuth encoder connector broken at encoder body and cord/cable end.	Closed	Suspect damage occurred during manlift operation in that area. The encoder has been fixed, and we have had no other problems since.	
57	1/20/98	Mechanical interference between elevation motor and cross-piece on inner arm as system was being driven downward to stow.	Closed	We redesigned the Inner Arm to account for the elevation motor. The cross piece was replaced with two diagonals. Pat Soliday and Bill Stubstad confirmed the clearances on the NREL dish and on the solid model. Refer to ECR #44	2/12/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
59	1/20/98	The left latch did not release when driving the concentrator into the downward stow position. We hit it with a broom to release the latch.	Awaiting QA Verification Lem	Cleaned out all of the debris from widening the slot for the latch on 1/21/98. The problem has not occurred again.	1/21/98
65	1/21/98	Elevation encoder failed.	Awaiting QA Verification Lem	Design and implement magnetic encoders.	
61	1/23/98	(1) Azimuth motor will not drive east or west. (2) Hear a low humming noise from motor when trying to operate east or west. Note: Elevation motor will operate up and down.	Closed	Replaced with 1/2 HP motor.	3/23/98
64	1/27/98	Installed inner arm to hub to determine fit-up problems. Inner Arm assembly will not go flush to hub assembly near alignment pins.	Closed	Increased the slot on the hub to 2.00+/-.010 X 2.00lg. New drawing #10157.	2/3/98
66	1/27/98	In assembly of inner and outer arm we were unable to impact wrench and torque wrench on four of the bolts. (see attached) Could reach bolts with normal hand held wrench, tightening bolts by "turn-of-the-nut method."	Closed	Connecting plate was redesigned to move bolts away from the corner. See ECR #43.	2/12/98
67	1/27/98	In assembly of inner and outer arm we had difficulty in attaching arms together. The side bracket of the outer arm made it difficult for the inner arm to slide between the brackets. Note: All holes lined up o.k.	Closed	Redesigned bracket to bolt onto Inner and Outer Arms instead of welding onto Inner Arm. See ECR #43.	2/12/98
68	1/27/98	Mounted BCS support frame to PCS arm with counter weights. Counter weight mounting studs were too long. We had to cut them shorter to prevent interface with BCS support frame. Top of stud no higher than 1.5" from top plate. (see attached)	Closed	Requirements added to PCS Arm Assembly drawing 10045.	5/12/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
62	1/28/98	3/4-10 X 4" HHCS hardware callout was too long to mount Flender Drive flange to Hub flange. We used 3/4-10 X 2.5" HHCS plated Grade 5 per Bill Stubstad.	Closed	Added requirements to drawing 10031.	5/20/98
63	1/28/98	Hard to grind down/clip washer to install Flender Drive flange to hub flange. Weld bead on hub flange would not allow washer to go flat against flange surface. Used 3/4" F436 washer 1 7/16" OD, 13/16" ID. (see attached)	Closed	Created drawing 10273 to show specification for custom clipped washer from Frontier Bolt.	5/12/98
75	2/2/98	Controller not processing A/D information.	Closed	See Incident #72.	2/13/98
70	2/3/98	While moving the system from 120 deg. east to mirror down stow, the 1.5" flex conduit broke. The break occurred just under the clamp on the east side of the center hub. The break possibly happened somewhere around the stow limit.	Awaiting QA Verification Lem	Removed flex conduit. It was determined to be unnecessary.	2/28/98
82	2/3/98 9:30.00 AM	During BCS focus and alignment of mirrors, we discovered the fender washer that is used for attaching 1/2" stud to mirror bracket was yielding (concave) during adjustment of facet.	Closed	Replaced with a thicker washer.	3/17/98
83	2/9/98 10:00:00	Hydrogen flex line hits/catches where hub and arm attach to each other.	Closed	Flex line was rerouted in the other direction to avoid clearance problems. See drawing #10208.	3/5/98
90	2/9/98 10.00.00	1/2" X 6" mirror mounting studs are bending on random middle and outer mirrors during BCS. Studs bending are typically those that are extended out to its full length of adjustment.	Awaiting QA Verification Lem	5/8" washers were used on the NREL JVP dish, and added to the installation drawing 10031.	5/20/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
86	2/9/98 3.00.00 PM	While tracking the dish during BCS focus and alignment, we burned the 1 1/2" flex conduit at the end of the outer arm	Closed	Conduit has been eliminated by moving sun sensor.	2/13/98
84	2/10/98 9:30:00 AM	Struck mirror facet (M5), glass side while dish was in vertical position with manlift basket. I was performing field modification/fabrication installing temporary cross members to support the truss structure when the middle mirror mounts are loosened to focus and align mirror.	Awaiting Investigation Bud Brittingham	Please investigate methods of replacing broken tiles in the field.	5/15/98
85	2/10/98 9:30:00 AM	1 1/2" conduit clamp supporting conduit at top of pedestal broke off from pedestal where it was drilled and tapped.	Closed	Run the wires without using the conduit.	2/27/98
76	2/11/98	Control inputs from A/D converter scrambled or not reading at all. Latch input to PLC board alarming.	Closed	See Incident #72	2/13/98
72	2/11/98 8:30:00 AM	When I tried to wake up the dish from the downward stow position, three faults triggered in the fault status section on the JVP system console, (Arm Latch, PCS not ready and focus power). I tried several things to clear the faults, I cycled power to the PC and to the little PC in the wind indicator box. The faults did not clear. Don F. evaluated all the electronics in the pedestal control box and could not find the problem. Finally Don cycled the power to the pedestal control box and the faults cleared.	Closed	This is a failure of the A/D converter board. Don Farchone contacted Z-world, and they said it happens occasionally if the A/D is not reset often. They recommend adding a call to the ADC-4_init() routine just before making the calls to read the values. This has been implemented in the dish control software as of 2/13/98. This Corrective Action also applies to Incidents 75 and 76.	2/13/98
77	2/11/98 12:00.00	BCS target split apart at the braze seam. There seems to have been some residual water left in the target over night that froze and split the target's seam. The split was at the bottom of the target as the target was mounted on the PCS Arm. The split was about 6" long.	Closed	Remove BCS target every night, blow out all water and bring target inside.	
74	2/13/98 9.00.00 AM	Sun sensor appears to be inconsistent. The sensitivity is varying with time and insolation, and some of the readings appear to be drifting, (I.e. the zero point.)	Closed	The sun sensor was moved to the hub on 2/13/98. Mounting holes were added to the hub drawings, see ECR #46.	2/13/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
73	2/13/98 10:30.00	The image shape for the six middle facets appears to be shifting with time as individual facets are adjusted. During the alignment of the dish, we noticed a lot of structural movement. This movement was especially noticeable while trying to adjust the middle facets. Adjusting one middle facet caused motion of other facets, especially the outer facets. All these motions make alignment very difficult and time consuming, if possible at all. We are not even sure whether the dish will stay aligned once the alignment is complete, or whether this problem only makes the alignment procedure difficult.	Closed	The new Truss Bracket design (See ECR 56) will remove the loads being carried in the facet, and will allow for the mirrors to be aligned.	3/17/98
81	2/24/98 7:00:00 AM	PC controller lost communication with the dish. After I cycled power to the network box, communications returned.	Awaiting QA Verification Lem	Added a communication reset to the program.	
89	3/2/98 6:30.00 AM	Upon arriving to the test site Monday morning, I discovered the controls were not working because of four faults (Arm Latch, Elevation Motor, Focus Power, and PCS not ready). In order to clear three of these faults I had to cycle power to the Control PC, Network Interface Box, and the controller on the pedestal. The elevation Motor Fault would not clear and therefor I assumed this to be a separate incident (IR 88).	Awaiting Investigation Duane Gibson	Notes from 3/10/98 IRB meeting: We have been having repeated problems with faults on the system controls when trying to awaken the dish. It is still unclear as to what is causing these faults. Cycling power to the control PC can clear the faults, but this needs to be done manually. Don has sent the ADC4 board to Z-World for analysis, but they couldn't isolate the problem. Don has protected the ADC4 board on the Rocky Flats dish with buffers, and will do the same on all future dishes, but the one on the NREL dish is unprotected. Don will replace the NREL controls with the one he built for the first APS dish when they are complete. In the mean time, we will simply 'keep an eye out for more clues.' This problem may go away after buffering and filtering the inputs. - 6/17/98.	7/10/98
88	3/2/98 6:35:00 AM	Failure of the elevation drive motor.	Awaiting Implementation Roger Davenport	Roger has designed and installed a new limit switch for the elevation face-down stow limits. Drawings are being generated. The new limits are being tested on the NREL dish. They have not been installed on the DC dish. - 6/17/98.	5/22/98
87	3/2/98 6:40:00 AM	Upon downloading the Dish Performance Log with the Dish Control Interface, an error flashed on the screen stating that a file could not be found.	Closed	Problem has been fixed.	3/5/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
91	3/6/98 10.00:00	Blown 20 Amp. fuse for the azimuth drive motor.	Awaiting QA Verification Lem	Need to retrofit NREL and DC dishes with more robust fuses. - 6/17/98	
94	3/7/98 6:30:00 PM	An error message (Run-Time Error) appeared on the screen of the control computer after commanding a performance log data download. After the run-time error, "Download Successful" appeared and I reset the data log as usual. No data has been lost, the error message is the only apparent symptom or problem.	Closed	Problem has been fixed. This was the same problem as identified in IR #87.	3/12/98
138	3/11/98 9.00:00 AM	Azimuth Encoder Failed. This incident occurred while bringing the dish from downward stow to tracking mode. When the elevation angle reaches horizon the dish is allowed to move in azimuth. An azimuth motor fault was triggered just above the horizon. The fault was cleared several times, but continued to resurface after dish movements of around 1 degree. I went outside with the manual control station and was able to move the dish in azimuth with no problem. I moved the dish manually to the east around 10 degrees and back west 10 degrees so that the wheel lined up with the plate on the pedestal. The dish azimuth position was displayed as 173 degrees at this point. The actual location of the plate is closer to 179 degrees. It soon became apparent that there was a problem with the azimuth encoder. Possibly it is filled with oil.	Awaiting QA Verification Lem	This problem will be solved by DC drives and magnetic encoders.- KB	
119	3/25/98	While doing the distant light source alignment, we noticed a problem with the focus control: The more facets that we connected to the blower the harder time the blower had holding the facets in focus. Once all the facets were hooked up to the blower, we could not adjust the facets to the proper focus.	Closed	Reworked Focus Control Assembly, see IRB meeting minutes from 3/27/98. Dish focuses in around 12 min. Verified repeatability during BCS and in shop with dial indicator. Drawings have been updated.	3/27/98
135	4/4/98 6:30.00 AM	Sun sensor would not generate a large enough error signal to move system to the East. Also, the Eastern sensor appears to be shaded by the cover of the sun sensor box when far to the West of the sun. (Note: this will not be a problem in future sensors, since the sensors will be mounted differently.)	Awaiting QA Verification Lem	The sun sensor has been redesigned to solve this particular problem. See ECR #110.	7/1/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
136	4/7/98	Ran into clearance problems when installing the Stirling Thermal Motor to the PCS Arm: (1) Clearance for electrical conduits and natural gas line with PCS Frame (2) Clearance for PCS actuating shutter (3) Modification to lifting method (4) Modification to Hydrogen line (5) Insulation for PCS Actuating shutter and PCS (The modifications performed are shown in the attached drawings.)	Closed	(1) STM will modify lines to avoid clearance problems. (2) ECR 123 has been issued to modify Outer PCS Arm for clearance issues. (3) STM is developing fixture for lifting onto PCS Arm. (4) ECR 124 generated to add modification to Hydrogen installation drawing (5) ECR 116 From Russ requesting evaluation of insolation around PCS.	4/13/98
144	4/7/98 6:45:00 AM	At 6:05 I put the dish into auto wakeup mode. At 6:45 I noticed that the dish had not moved out of its stow position and that the JVP System Console was showing a "PCS Not-Ready" fault. I was able to clear this fault by cycling the solar enabled command.	Closed	Found error in PCS wiring. The documentation was OK, but the wiring was wrong. Corrected wiring of PCS to match the print. 'PCS Ready' now works.	4/23/98
137	4/10/98	Noticed that dish was stowing due to 'PCS-Not Ready' Fault. System controls were hooked up to Roger's test "Little PLC" in office. PCS was unplugged. Focus fuse was pulled.	Closed	Found error in PCS wiring. The documentation was OK, but the wiring was wrong. Corrected wiring of PCS to match the print. 'PCS Ready' now works.	4/20/98
139	4/10/98 7:00:00 PM	The unistrut and electrical box located just away from the pedestal conflicts with the truss extension by M6 on the dish when tracking in the evening. I noticed the problem before there was an interference between the electrical box and dish concentrator. I disabled the dish and manually moved the system away from the danger area. The dish was then stowed for the evening.	Closed	Re-plumbed conduit (see attached).	4/17/98
140	4/13/98 11:00.00	Keep getting a PCS Not Ready fault. The dish attempts to stow if you don't catch the fault right away. Once the fault is cleared, the system will go back on sun. This fault has shown up around 10 times today for no apparent reason. The PCS is presently not hooked up to the concentrator controls. The little PLC PCS simulator is currently connected to the dish controls, but I do not have enough experience in this area to say.	Closed	Found error in PCS wiring. The documentation was OK, but the wiring was wrong. Corrected wiring of PCS to match the print. 'PCS Ready' now works.	4/30/98
145	4/18/98 2:00.00 PM	When the 16-pin PCS connector is plugged in, the system ground is driven to around 3 V relative to the 24 V DC ground. This affects the PCS-READY signal, and possibly the focus power. It could be related to the occasional "PCS-NOT-READY" and PCS communications problems we are having.	Closed	Re-wired PCS-Ready signal to proper terminals.	7/1/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
148	4/20/98 10:15:00	Arm Latch Fault: An arm latch fault appeared as the dish approached horizon. The dish was heading towards face-down stow position at the time of the fault. I put the dish in local mode to stop dish movement to the upward stow position. The arm latch on the left side of the arm (when looking from the back of the dish) was not contacting its respective limit switch. I ascended to the arm latch in the manlift for closer inspection. Before moving the arm latch I tried to determine why it hung up. There is a weld on the inside of the box beam housing the arm latch that may be causing problems. After freeing the latch, I could not replicate the problem. I recommend taking a dremel tool to the inside surfaces of the box beam that come in contact with the arm latch.	Awaiting Implementation Roger Davenport	A couple of changes can be made to the latch assembly. We can reduce the ID and OD of the spacers, and use washers in between the latch and spacer to prevent them from twisting. The corners of the bracket may also be deburred to prevent catching on the seam weld.	5/22/98
174	4/24/98 5:00:00 PM	When PCS Comm lines were connected, the little PLC stopped running and would not respond thereafter.	Awaiting QA Verification Lem	The grounding was incorrect. We will correct the wiring of the PCS Comm line.	
177	4/25/98 10:00:00	A 'MAX OPERATING RPM' fault was triggered on the PCS after about 1.5 hrs of continuous operation in gas mode. At the time of this incident, all other operating parameters (oil pressure, heater head temps and pressure, etc.) were stable and within bounds. Immediately after the fault appeared the burner shut down, as it should when there is a fault. I attempted to clear the fault, only to get another fault after the RPM fluctuated above and below 2200 RPM. Since the heater heads were still at around 650 deg. C (even though the burner was off) I wanted to be able to spin the engine as soon as possible to get the heat off the heads. I opened the baldor box to check its status since it regulates the speed of the PCS. The baldor box was showing a 'heatsink overtemp' fault and the box was HOT to the touch. The baldor box got hot and started acting flaky and then stopped regulating frequency at 73Hz all together which caused the PCS to shut down. After realizing that the baldor box would have to cool before it could go back on-line, I tried to manually open the shutter to let the heat in the receiver cavity dissipate but I could not since there was a fault. The solution to this problem is to ventilate the control cabinet that houses the baldor box. A fan on the control cabinet may be necessary due to the amount of heat generated.	Closed	Added (2) 12" X 12" louvered vents on each corner of the Baldor box.	5/22/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
147	4/20/98 8.00.00 AM	Received an elevation motor fault when I enabled solar from a downward stow. After several unsuccessful attempts to clear this fault, I went outside with the manual control to help isolate the problem. (Control issue or motor/encoder issue.) From the manual control, when activated, the elevation motor would hum but not move. Either the motor is shot or the upward/downward stow limit switch has been tripped. (The dish has not traveled to either extreme but maybe melting snow has shorted the switch or falling snow has tripped the switch.) I ascended in the manlift for further inspection. The limit switch had not tripped. I manually tripped the switch and then reset it. The elevation motor still would only hum. I went up to the switch again and cycled it several times. This time the elevation motor was able to move.	Awaiting Implementation Roger Davenport	Notes from 4/23 IRB meeting: Roger determined the root cause of the elevation motor fault was that the range of motion of the limit switch was incorrect. Roger has determined the correct range of motion, and this will be added to the installation drawing for the limit switch. Since it is a new limit switch that Roger has been testing, drawings have not yet been generated, but they are in the process of being developed. A related problem was also discussed. Currently the limit switch will disconnect one lead to the AC motor. The AC motor has 4 leads, and in order to disconnect the motor, an actuating relay may need to be used to reverse two of the lines. Roger will investigate it further with the motor manufacturer. He also mentioned that if we were to switch to DC motors, this method would work because DC motors only have two leads. Better procedure for setting over-travel limits. 9/16/98, RD.	5/22/98
146	4/20/98 10.00:00	Azimuth Encoder Failure: The azimuth encoder continued to trigger azimuth motor faults. The dish would move a couple of degrees between azimuth motor faults. I ran the dish back west to due south using the manual control station. The dish showed a position of 137 deg. Azimuth instead of around 180 deg. This reaffirmed that the azimuth encoder was the root problem. I removed the motor and encoder. The encoder was fouled with oil. The encoder was cleaned and sent to the electronics room for repair and testing. A new 5.5:1 right angle gear box has been procured, along with a new encoder. Each of the last two encoder failures has been due to gearlube from the right angle gear box leaking into the encoder. Simply replacing the encoder does not alleviate the problem. It appears that the gearboxes are leaking due to the excessive force required to slip the motor shaft into the input shaft of the gearbox. This side loading (and other forces) takes out the input shaft seal. I installed the new gearbox and then took sandpaper and emery paper to the motor shaft. The motor shaft was polished, removing all remnants of rust. I applied grease to the mating shaft surfaces to prevent rust accumulation so the motor can be easily removed in the future if need be. In addition to using grease on the mating shaft surfaces and making sure that only clean surfaces are mated, we may want to consider a more robust gear box and thicker lubricant.	Awaiting QA Verification Lem	Notes from 4/23 IRB Meeting: James and Roger determined the root cause of the encoder failure to be excessive wear on the input shaft seal due to side loading. This caused the right angle gearbox to leak into the optical encoder, causing the encoder failure. The side loading is caused by improper installation of the motor. When the motor is installed, there is a cantilever force on the motor that causes runout in the motor shaft. This runout puts excessive side loading on the input shaft seal. A note will be added to the motor installation drawing to make sure that the motor is supported vertically when securing the bolts to the gearbox. This will ensure that the motor will be perpendicular with the gearbox, and the shaft will not rotate unevenly. A note will also be added to properly lube the motor shaft. Another idea to improve reliability was to use grease instead of oil inside the gearbox. Also, the use of magnetic encoders instead of optical encoders is still being looked into. This would ensure that contaminants such as oil would not effect operation of the encoders.	4/27/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
178	4/27/98 2:00.00 PM	Opened the shutter to inspect the receiver after the baldor box overheated on Saturday. The ceramic cone has cracked in several places. The heater head tube temperature never exceeded 700 deg. C. Digital pictures of the cone are available.	Awaiting Investigation STM	New cone arrived 4/30/98. Need to keep an eye on it for signs of thermal stresses. The new cone was tested on gas on May 13th. It failed as well. Stefan will contact the company that manufactures the cone, and schedule an IRB to discuss the required specifications. Dave Musto with Custom Technical Ceramics visited the site on 5/20/98. He mentioned that they do not have any specifications for the flux on the ceramic cone. He had some ideas as to how to improve the thermal stress distribution, and will discuss them with STM. Jim told him verbally that the requirements on the cone are 80 W/cm^2 and around 800 deg. C.	5/22/98
175	4/28/98 5:00:00 PM	PCS shows "Shutter Command Error" and refuses to clear. The dish is communicating to the PCS without problems on the RS-485, as evidenced by direct observation of the traffic on the RS-485 line. (I.e., the dish controller sends out "?<CR>" and the PCS responds "000<CR>" on about a 1-2 second period). If the PCS were ready, it should send "001<CR>".	Awaiting QA Verification Lem	PCS controls were reprogrammed so it ignores commands that it does not recognize. Baud rate was changed from 19200 to 2400 bps.	5/7/98
194	5/6/98 7:00.00 PM	One of the new features added to the dish control interface is the option to set the unit and network time equal to the system clock with the click of the mouse. In the system console this is located under configure and then operating parameters. Instead of typing in the correct unit and network time, as usual, I checked the 'set to system time' box and clicked update. The unit time displayed as 00.00.00 and didn't change. The network time changed to a time other than the system time. This is a nice feature, it probably just has a simple bug in it.	Awaiting Investigation Pat Soliday		5/22/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
180	5/7/98	After changing the communication rate from 19,200 baud to 2400 baud, the controls were communicating properly. The concentrator controls would ask for status '?<cr>', and the PCS would respond that it was ready '001<cr>'. When attempting to enable gas mode, the concentrator and PCS read as follows: Run on gas 'r<cr>', request status '?<cr>'; Running on gas, ready '101<cr>'. After a couple of seconds, the PCS would change from running on gas and ready, '101<cr>', to running on gas, not ready, '100<cr>'. When this status was received on the concentrator, it would respond with a stop command 's<cr>'. The PCS would take a couple more seconds to shut down, and then respond with a PCS not ready signal '000<cr>'. A copy of the text file written form the HyperLink terminal and the PCS data log was sent to STM.	Closed	STM discovered a bug in their controls, and a new copy of the file was e-mailed to the test site. We had trouble downloading the new file onto the PCS controller. We then disconnected the 485 port to the concentrator controls in order to download the new program without interference. The file then downloaded properly. - 5/8/98.	5/8/98
181	5/8/98 3:00:00 PM	In order to test the operation of the PCS without interference from the concentrator controls, we disconnected the 485 port to the concentrator, and attempted to run the PCS in gas mode from the STM controller PC. Shortly after igniting the burner, we noticed flames emitting through the edges of the actuating shutter. Jim immediately shut off the propane line, and the flame slowly dissipated. We then inspected the PCS and found no apparent damage. After contacting STM, we inspected the shutter mechanism and found that it was loose. Since neither James or myself have been properly trained on operating the hybrid PCS, STM agreed to send a technician to the site on Monday, May 11, to help troubleshoot this problem as well as the communications problems.	Awaiting Investigation STM	After STM's investigation, it appeared that the burner is working properly. The problem appeared to be that the actuating shutter loosened over time, and when the burner was ignited, the seal broke between the shutter and the engine and allowed flames to emit outside of the engine. We tightened the actuating shutter to create a better seal, and the system ran on gas without incident. - 5/13/98 Ran on gas and noticed heat emitting from the edges of the shutter when looking at it from the side. It appears that the shutter has loosened. -5/19/98	5/29/98
188	5/13/98	While tracking the dish, prior to going on sun, the sun sensor was giving erratic readings. The Direct Normal Insolation reading was jumping from positive to negative values. In order to trick the dish into focussing, we adjusted the minimum insolation required to a large negative value.	Awaiting QA Verification Lem		
193	5/13/98	The NREL Dish/Stirling system was operated on sun for the first time. Due to a focus time of over 10 minutes the PCS must cycle several times before there is sufficient heat for continuous operation. During the initial solar run last week an update to the engine program was deemed necessary because a PCS Not Ready fault was triggered after each engine shut down. The resulting fault would then kill focus power unless reset.	Closed	Scott Straudman with STM sent out a program update with Vern on Tuesday, May 19, and it was installed.	5/19/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
189	5/15/98 7:57.00 AM	System was tracking normally using sun sensor. Beginning about 6:58am. High wind stow alarm went off around 7:30am, and dish drove toward high wind stow position. I manually signaled low wind after winds died down and system went back on sun. About 7:57 I noticed that the dish was driving West for no apparent reason. I disabled solar, and then enabled solar and the dish tracked normally.	Awaiting Investigation Roger Davenport	Not enough info to evaluate what was happening. - RD	5/28/98
191	5/18/98 9:30.00 AM	Dish would not come out of stow due to 'PCS Not Ready' Fault. STM screen showed cycle pressures of -0.4 to -0.1. Found that Hydrogen gas is leaking from hard line - flex line junction of Hydrogen drain line.	Awaiting Investigation STM	The O-Ring was found to be missing. It has been installed. - 5/19/98. Stefan does not know why the pressures are showing zero values. They are still investigating this occurrence.	7/10/98
199	5/20/98 12:15.00	During Solar operation we keep getting 'DISH COMM ERRORS' and 'SHUTTER COMMAND ERRORS' from STM computer which is causing 'PCS_RESPONSE', and "PCS NOT_READY" faults on system console. I will try to reproduce behavior when Jim gets here. STM computer seemed to be giving error messages usually between 200 and 250 degrees which are the engine shutdown and engine startup temperatures respectively.	Awaiting QA Verification Lem	Solved with changes to 2400 baud, changes to cabling, PCS power supply.	9/1/98
198	5/20/98 2:00:00 PM	As I was stowing the dish it continued to track. The focus/defocus delay was set to 600 so it shouldn't have started to stow immediately. Since the sky was cloudy and there was no danger of damaging the exterior of the PCS I changed the focus/defocus parameter to 1 second. The system continued to track after the parameter value was updated. SOLAR OP light was off, FOCUS light was on, and SOLAR was disabled. Continued to track for 2-3 minutes.	Awaiting Investigation Roger Davenport	Defocus clock is started when defocus begins. Changing the parameter after that point doesn't affect the countdown. Turning focus on and off again would have reset the clock/counter with the new value.	5/5/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
197	5/20/98 2:30.00 PM	While troubleshooting the problems with the ceramic cone, the RS-485 communications between the dish and engine was disconnected in order to inspect the receiver cavity with the dish in the stow position. Before disconnecting the 485 line in the SAIC control panel, Phil cut power to the dish/stirling system. The RS 485 line was disconnected and the grid was then re-energized. After the dish and engine controls came back on-line, the engine control console displayed negative values for the cycle pressures (-.3, -.3, -.4, -.3). The other values including the thermocouple values appeared plausible. The low cycle pressures generated minimum cycle pressure faults and attempted to cold fill. Power to the grid was killed and reset. This time when engine console came back online, the values for cycle pressure were back to believable levels. Phil noticed this same chain of events on Monday and Vern was sent out from STM to confirm that there was no leakage. It is important to note that the Hydrogen supply was off to the engine during this entire time.	Awaiting Investigation STM		6/8/98
196	5/20/98 4:00.00 PM	This afternoon I enabled solar operation for approximately an hour. During this time period the engine cycled on the order of 10-15 times. Roughly half of the shut downs generated a PCS Not Ready fault. A text capture was taken during the latter portion of this test to show the chain of events in communication between the engine and the dish. In addition to the text capture, all applicable engine files will be sent to STM to aid in diagnosing and correcting this issue. The text capture reveals that only one 'Not Ready' response appeared each time that a fault appeared during shutdown. In the previous configuration, a string of 'PCS Not Ready' responses were observed during shut down.	Awaiting Investigation STM	STM is sending an update to the software. 5/21/98	5/21/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
195	5/20/98 5.00.00 PM	There appears to be an excessive amount of noise on the sun sensor. The sun sensor insolation value fluctuates from large negative to large positive values. The sun sensor error values for azimuth and elevation seem a bit more stable, but I noticed today that when the PCS starts up and is running the sun sensor stops displaying a value for solar insolation and the azimuth and elevation error values change drastically. In addition to the obvious problems with this condition, even in the calculated tracking mode the dish cannot be focussed. This is due to not having a value for solar insolation. To help locate the source of this problem, I propose that we cut power to the grid to shut off the Baldor Box and then run 110 VAC separately to the dish controller. If the Baldor Box is contributing to noise on the sun sensor, we should see a decrease in noise with the Baldor Box offline. Duane and Roger should probably be advised of this incident as they may have additional ideas on how to diagnose and correct this problem.	Awaiting QA Verification Lem	Appears fixed with move to sun sensor made 9/10/98.	9/10/98
200	5/21/98 7:45:00 AM	Tried to run system on solar. STM computer came up with 'MIN OPERATING RPM' faults followed by 'SHUTTER COMMAND ERROR' faults. These triggered 'PCS-RESPONSE' and 'PCS-NOT READY' errors.	Awaiting Investigation STM	Baldor Box fuses are O.K. Engine/Starter turning correct way, and developing adequate RPM, per Vern at STM I am changing RPM delay from 2000ms to 4000ms. 4000ms delay seems to have taken care of the problem. 5/22/98	6/8/98
201	5/21/98 10:56:00	A 'PCS-NOT READY' fault is triggered when the engine control temperature goes below 200 degrees and engine shuts down.	Closed	New software has fixed this problem.	5/22/98
204	5/26/98 7:26.00 AM	HOT FILL TIME LIMIT fault triggered PCS-NOT READY. Cycle pressure had gone from 12+ Mpa to 8+ Mpa. Couldn't clear subsequent shutter CMD errors and PCS-NOT READY faults. Eventually cleared faults, system began focussing again but the shutter wouldn't open. Set tolerance to 0.001 so system would de-focus. PCS-NOT READY error came on, wouldn't clear. Dish began to stow, eventually cleared PCS-NOT READY fault. System going back on sun, leaving tolerance at 0.001.	Awaiting Investigation STM		6/8/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
205	5/26/98 8:47:00 AM	Unable to restart system after clearing faults once shutter has moved to emergency stop position due to engine faults.	Awaiting Investigation STM	'	6/8/98
206	5/27/98 9:15:00 AM	Engine shut down due to MAX OPERATING RPM. Then gave SHUTTER COMMAND FAULTS and MAX CYCLE TEMP DIFF errors.	Awaiting Investigation STM	'	6/8/98
207	5/27/98 9:20:00 AM	Engine Shutter/Plug support band/strap continues to loosen up causing the insulation plug to slip out about half way towards the engine when shutter/plug is activated closed.	Awaiting Investigation STM	'	6/8/98
239	6/16/98	The STM control computer will not boot up. When powered up it makes a clicking sound. I called Stefan and he said that he will be here tomorrow and can take a look at it.	Awaiting Investigation STM	'	7/10/98
242	6/22/98 4:15:00 PM	The elevation disconnect switch triggered prematurely while the Dish was moving towards the downward stow position. At first we thought the problem was with the elevation drive motor, so we replaced the motor. After further investigation, we discovered that the disconnect switch is a double actuating switch and not a single actuating switch as previously thought.	Awaiting Investigation Roger Davenport	'	
245	7/15/98	Five facets were over-focussing during Distant Light Source alignment. The facet locations were O5, M6, I4, O3 and I3.	Closed		
257	9/11/98	'Actuator Stroke Limit' fault occurred on PCS after approximately 15 minutes of on-sun operation.	Awaiting Investigation STM	'	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
258	9/11/98 2:00:00 PM	PCS shutter was damaged by the during an Actuator Stroke Fault shutdown. The flux melted an eight inch diameter section from the center of the shutter and caused the insulation retainer band to come loose.	Awaiting Investigation STM		
261	9/14/98	9/14: Encoder E003 (Elevation) failed. Tested: 25ma was OK, 3.9/3.9 near was Bad, 0.5/0.0 far was Bad. 9/16: Encoder E002 removed from dish (Azimuth). Tested OK at office: 28ma was OK, 4.9/0 near was OK, 4.8/0 far was OK.	Awaiting Investigation Roger Davenport		
278	9/29/98	COMM (RS-485) from PCS was not reliable.	Awaiting Implementation Pat Soliday	Isolated ground from PCS COMM chip was connected to shield - ground. Disconnected ISO ground at PCS. Needs to be included in electronic drawings.	10/15/98
279	9/29/98	Wire to "K" connector broke. This led to failure of the Little PLC output chip. (5841BN).	Awaiting Implementation Pat Soliday	Single-strand wire was used. This fatigued and broke off. I recommend using stranded wire for all connections. Needs to be included in electronic drawings.	10/20/98
282	9/29/98 3:30:00 PM	We are not able to keep a stable flame in the PCS reciever while in the gas mode.	Awaiting QA Verification Lem	Gas pressure lowered from 11 psi to 5 psi.	10/7/98
281	10/2/98 7:15:00 AM	The Little PLC in the dish controller froze up. To unfreeze the Little PLC I had to push its reset button. This is the second time in the last week that I have noticed this occurrence.	Awaiting QA Verification Lem	Reloaded program. Now O.K. This is an inherent feature of the Little PLC and has never occurred in other sites or controllers. If it happens again, I would change out the Little PLC.	10/16/98
280	10/2/98 7:30.00 AM	Hydrogen fill solenoid valve on the PCS appears to have failed. I changed the hydrogen bottle and then powered up the system. The PCS cycle pressures are not adjusting to the parameter setting but rather are adjusting to the same pressure as the hydrogen bottle's regulator.	Awaiting Investigation James Sellars		10/13/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
289	10/6/98 8:00.00 AM	After the control temperature reached 250 c, the PCS controller triggered a Min Oil Pressure Fault. The oil pressure was at 5 and the minimum allowed was set at 10.	Awaiting Implementation STM	Replacement of transducer is underway. Future connectors should be RTVed.	
290	10/6/98 2:51:00 PM	A Max-Operating-RPM fault occurred after the Baldor speed controller overheated and shutdown. This fault caused the shutter to close and be damaged by a fully focused flux. Although part of the shutter's insulation crystallized, the shutter appears to still be functional and does not need to be replaced right away.	Awaiting Implementation Bub Brittingham	Add fans to increase air flow inside Baldor Box.	10/14/98
292	10/7/98 3:30.00 PM	The HT3-5 thermalcouple in the receiver failed. The thermalcouple output varied from Open to 800 c. This fluctuation caused the PCS to go into a Max Operating Temperature Fault.	Awaiting Implementation STM	Repair thermocouple before operation.	10/14/98
291	10/8/98 10.00:00	Under constant solar conditions the engine power is surging. In one second's time the stroke goes from 90% to 25%. The power drops significantly as well. When the stroke drops, the receiver head temperature rises rapidly. When the receiver head temperature rises above 300 c the PCS contoller triggers a fault shutdown.	Awaiting Investigation STM	Stephan changed the codes in the software to eliminate the Manual Stroke Dialer. It appeared that the Manual Stroke Dialer was interfering with the actuator controls. Stephan will simulate the change on the bench test, and let us know if any problems arise from the change in software. - 10/15/98.	10/14/98
297	10/19/98	-The system had been running with calculated tracking, and I wanted to run with peak-power tracking. I downloaded the system performance log, then set the # of samples to 12 to get 1 minute averages. When I tried to go to calibration mode, the following occurred: (1) General parameter screen disappeared from the PC when I was in the "Tracking Modes/Adjustments" Screen. (2) Got message "Message not sent". (3) Lost communication to dish controller. -The system appeared to be running normally, but I couldn't tell because communication was not functioning. So I went to the pedestal and reset the dish control. The system started tracking down and west, probably going to stow since it didn't know it was previously focussed. I tried to re-enable solar inside, but communication was still down. I unplugged the motor cable to stop off-track, then got the manual control and manually moved the system to the west to clear the flux. I reset the system again, this time it communicated normally. I plugged the motor cable in again, and the system moved to stow normally.	Awaiting Investigation Roger Davenport	-There appears to be damage to two wire bundles and some paint on the actuator for the shutter/plug and on the PCS Arm. The two wire bundles and paint damage locations are shown in the attached sketch. Stefan has been contacted and is seeing about a replacement for one of the wire bundles. I think we can replace the other ourselves by re-wiring the connectors.	10/20/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
300	12/1/98	When the system is coming out of stow and going to stow, the lower parts of the PCS inner arm are springing slightly, leading to creaking noises when the alignment pins engage or disengage.	Awaiting Disposition Management		11/18/99
299	12/14/98 10.35:00	The PCS stopped, and signaled a fault. This caused the shutter to close in emergency mode. Insulation that had been placed on the shutter mechanism bound up and prevented the shutter from closing fully. The receiver overheated, and tubes failed in all four quadrants.	Awaiting Implementation Roger Davenport	Eliminate Baldor motor controller.	1/19/99
310	3/29/99 8:30.00 AM	Anemometer on network interface is reading 70+ mph constantly	Awaiting Disposition Management		11/18/99

Incident Summary

Wash DC Dish

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
1	4/1/95	test	Closed	'	
149	4/16/98	Could not fit a torque wrench on the bolts holding the top flange of the pedestal to the spool piece. Wrench interfered with the O.D. of the pedestal. Used 'turn-of-the-nut method.'	Awaiting Investigation Scott Davies	Pipe OD = 30", bolt pattern diameter = 32.25", leaving 1.125" clearance. The current torque wrench needs 1.25 - 1.5" clearance. Standard crescent wrench requires 1" clearance for 3/4-10 hex head bolt. Scott will look into other torque wrenches.	7/1/98
150	4/16/98	One out of the six blades (P1 on drawing 10158) on the hub was out of alignment. If the blade is facing towards the east, it would be bending towards the south.	Closed	Vertex has adjusted there manufacturing process to eliminate any warpage caused from welding. They will tack weld the blades initially, weld the remainder of the structure, fixture the blades and complete the welding. The remaining three units were fabricated in this manner. They were inspected and checked out O.K.	5/19/98
151	4/16/98	When installing the PCS Inner Arm to the hub, there was about an 1/8" gab between the tubing where the hinges mount.	Awaiting Investigation Lem Tingley	The flatness of the tubing on the hub and the PCS arm was inspected on the remaining three units. The gap will also be measured upon installation.	7/1/98
152	4/16/98	A mounting plate on 1 of 12 cantilever truss assemblies was missing. It was replaced with thick washers in order to mount the cross brace.	Closed	SFI was informed of the discrepancy. They had fabricated just enough mounting plates for one system, and one plate had fallen on the ground and didn't get welded on the truss. The trusses were not properly inspected prior to shipment because of the accelerated schedule. All of the trusses for the next three systems have been inspected.	5/21/98
153	4/16/98	The hole pattern on the lifting lugs on the hub assembly was incorrect. The mating hole pattern on the Torque Tube Plate was correct. Should be 2.5" horizontally and 3" vertically center to center. Was 2.5" X 3.5" respectively. We lined up the bottom holes, and re-drilled the top two holes on the lifting lugs.	Closed	According to Vertex, the lifting lugs were fabricated at the last minute due to the accelerated schedule. The hole pattern was not match drilled with the hub, and the operator made a mistake in reading the dimensions. The remaining three units have been inspected.	5/19/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
179	4/16/98	Paint was insufficient on various components of the D.C. dish. (1) Rust was showing on the bottom of the hub, where it was resting on the flat bed. (2) Other rust spots were visible upon delivery on the spool pieces. (3) Paint on the cross braces came off from insufficient packaging of the tubing. The pieces were shipped touching each other, and the paint peeled off from one to the other. (4) Rust spots were visible on the pedestal, trusses and PCS Arm upon delivery. (See attached pictures)	Closed	The DC dish was made in such a rush, the paint was not allowed to cure for the required seven days. Vertex NM has sent primer and epoxy mix to DC so the dish can be touched-up. Both vendors have ensured that the 7 day cure time will be included in there production schedule. Wax paper will be used in the future to separate smaller parts. All components for the next three dishes have been inspected to MIL standards.	4/30/98
223	4/16/98	PCS Frame did not mount flush with PCS Arm.	Awaiting Investigation Lem Tingley	'	7/15/98
225	4/16/98	Paint is peeling off where roller makes contact with pad on pedestal.	Awaiting Investigation Russell Forristall	'	7/1/98
161	4/17/98 10:00:00	Azimuth motor fuse failed while we were checking out the controls.	Awaiting QA Verification Lem	'	
162	4/17/98 11:00:00	Main fuse for the dish controller failed while we were trying to get the system operational.	Awaiting QA Verification Lem	'	
163	4/17/98 12:00:00	The Little PLC for the dish controller had to be reprogrammed.	Awaiting Investigation Roger Davenport	'	6/19/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
164	4/18/98 10.00.00	Azimuth encoder was wired incorrectly.	Awaiting QA Verification Lem	The as-built NREL system was documented and used to verify the DC system.	5/5/98
159	4/18/98 10.30.00	Driver chip in the Little PLC for the dish controller blew.	Awaiting Investigation Roger Davenport		6/19/98
165	4/18/98 11:00.00	Below horizon limit switch signal was wired incorrectly.	Awaiting QA Verification Lem	The as-built NREL system was documented and used to verify the DC system.	5/5/98
166	4/18/98 11:00:00	Elevation motor was running the opposite direction from what the controls were commanding.	Awaiting QA Verification Lem	The as-built NREL system was documented and used to verify the DC system.	5/5/98
157	4/18/98 12:00:00	We could not get the controls working properly in the field. Both the encoders and limits were wired incorrectly in the terminal box on the drive.	Awaiting QA Verification Lem	The as-built NREL system was documented and used to verify the DC system.	5/5/98
158	4/18/98 3:00:00 PM	The high wind stow did not work properly during testing. In fact, pressing the high wind stow test button on the network box caused the dish controls to go down.	Closed	The cause of this problem turned out to be a bad parameter setting in the Little PLC in the network box. The "a" command was set to 0 MPH instead of 25 MPH. This problem took us more than a day of troubleshooting to finally solve. (Thorough testing of the drive and controls before shipping could have eliminated this problem and saved money and time during the installation process.)	4/20/98
154	4/20/98	A couple of holes on the spool piece needed to be reamed.	Awaiting Investigation Scott Davies	Need to inspect existing spool pieces, and then cap or grease them to ensure that debris doesn't get in the holes.	7/1/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
155	4/20/98	The latch on the east side of the dish was sticking. The slot on the hub was correct, but the welds on the alignment pin may have been holding the arm too far away from the hub, causing the latch not to function properly. The front corner of the latch was radiused so it wouldn't get hung up.	Awaiting Investigation Lem Tingley	'	7/1/98
183	4/20/98	The distance between the spool pieces was 0.25" too far. We needed to use all of the shim plates that were provided, (2 X .025" and 2 X .035").	Awaiting Investigation Lem Tingley	Vertex was informed of the discrepancy. The dimensions on the next three units is within specifications.	5/20/98
167	4/20/98 1:00:00 PM	Little PLC in the network box lost some of its program.	Closed	The Little PLC was found to have a faulty battery. It has been replaced.	4/22/98
168	4/20/98 4:00.00 PM	The dish would not stow due to an arm latch fault.	Awaiting Investigation Lem Tingley	'	7/1/98
156	4/22/98 4:15.00 PM	While testing the limit switches, we discovered that the east and west azimuth limit switches were wired up backwards. The east limit switch triggered while testing the west limit switch and the west limit switch triggered while testing the east limit switch.	Awaiting QA Verification Lem	The as-built NREL system was documented and used to verify the DC system.	5/5/98
160	4/22/98 4:30.00 PM	Driver Chip in the Little PLC for the dish failed. An elevation motor fault occurred that could not be cleared. While troubleshooting this problem, we discovered a bad driver chip on the Little PLC in the dish controls.	Awaiting QA Verification Lem	Added diodes to system.	5/26/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
186	5/1/98	After the mechanical system was installed, it appeared that the roller was sitting too low on the pedestal in face-down stow. The roller was actually sitting at the very end of the landing plate. (See attached picture).	Awaiting QA Verification Lem	The limit switch on the elevation drive was installed incorrectly, causing the dish to drive lower than 88 degrees. Scott relocated the limit switch, and the roller position was about 4" from the bottom of the plate. Larry has been working on the drawing showing the proper installation of the limits on the drive. We plan on installing the limits in the shop for the next three units. The pedestal was also installed 0.75" lower than the drawings specified.	5/5/98
187	5/1/98	After the mechanical installation, there was an interference between the PCS and the ground while going to face-down stow. Minor excavation was required in order for the dish to stow.	Awaiting QA Verification Lem	See IR 186.	5/5/98
227	5/1/98	Motor Faults are triggered while the system is in the tracking mode when initiating certain system commands. For instance, Motor Faults occur when initiating the On-Sun command, Azimuth and Elevation adjustment commands, or Tolerance command. It should be noted that when the dish controller triggers a Motor Fault, the PCS controller triggers a fault shutdown of the PCS.	Awaiting Investigation Roger Davenport		7/15/98
228	5/1/98	The communications between the dish controller software and the PCS controller software does not allow quick mode changes from Gas to Solar or Solar to Gas. If either the Gas or Solar modes are disabled, the dish controller software triggers a PCS-Not-Ready Fault. This fault remains triggered until the PCS has gone through a normal shutdown sequence (this takes approximately ten minutes).	Awaiting Investigation Roger Davenport		7/15/98
232	5/1/98	Intermittent loss in communication between the Visual Basic Dish Control Console and the unit occurs periodically. The frequency of the loss in communication starts off at about five minute intervals and gradually increases to about five second intervals. Once the frequency of the loss is at five seconds a "Runtime Error 6" occurs.	Awaiting Investigation Pat Soliday	Pat could not replicate the failure on either his simulator or on the NREL dish.	7/15/98
184	5/6/98	During Distant Light Source alignment we noticed that five facets were over-focussing due to the focus control valves allowing too much bleed through when the poppet is closed. After removing the discrepant focus controls, it was found that one did not have RTV installed in the poppet. The other four appeared to have gaps between the inside of the collett and the poppet.	Awaiting Investigation Bud Brittingham		5/20/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
224	5/6/98	Both gas and electrical conduits were rubbing against azimuth drive shaft when the dish was pointing to the West.	Awaiting Investigation Pat Soliday	An ECR has been initiated to shield the motor.	7/10/98
236	5/6/98	While trying to align the dish we noticed that facets were moving on the BCS target during the day by as much as three inches and from day to day by as much as eight inches. (a separate report will be issued after further investigation can be conducted)	Awaiting Investigation Kelly Beninga	'	
229	5/7/98	One mirror tile on facet number I1 shattered. (see attached mirror breakage form)	Awaiting Investigation Bub Brittingham	'	
230	5/9/98	While conducting a mirror survey, we noticed that hairline cracks in the mirror tiles are easily propagated by applying slight pressure to the mirrors. We also noted that most hairline cracks propagate from micro cracks along the edges of the mirror tiles. (see attached mirror breakage form)	Awaiting Investigation Bub Brittingham	'	
185	5/13/98	The blower was not functional after four days of constant rain. We removed the blower, blew out the water, and sprayed electronic contact cleaner to clean connections. After operating, the blower started to click on and off due to the tolerance on the sun sensor, and the blower got overheated. The ground to the blower was not installed correctly. Once the ground was installed and the tolerance on the sun sensor was changed so the blower wouldn't cycle, the blower ran properly.	Awaiting Investigation Pat Soliday	Is the blower designed for outdoor use, and is the airflow obstructed by the solenoid valve? We will look into making the electrical box water tight and adding a weather shroud to the system for the blower.	7/10/98
262	5/13/98	20 Amp fuse blew (F2). Fuses blowing is a reoccurring problem. We need to implement more robust fuses	Awaiting Investigation Roger Davenport	'	11/1/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
265	5/13/98	Proximity switch for arm latch did not operate, causing the dish not to go to downward stow.	Awaiting Investigation Russell Forristall		10/1/98
263	5/14/98	Intermittent loss of dish communication signal to control computer.	Awaiting Investigation Roger Davenport	Problem is sill going on. It occurs more often towards the end of the day, 8/30/98, AN.	9/30/98
266	5/15/98	Sun sensor not working properly.	Awaiting Investigation Roger Davenport		
267	5/15/98	Driver chip on Little PLC board failed.	Awaiting QA Verification Lem		
264	5/18/98	PLC Failure caused dish to run away, melting water hoses for BCS target. Blower was stuck in the on position.	Awaiting QA Verification Lem		
208	5/26/98	There is no safety disconnect of the 480 Volt service during installation and maintenance activities. From the pedestal area there is no visual means to verify that the power is disabled when working on the system.	Awaiting Investigation Duane Gibson	Recommended solutions: (1) Immediately establish a procedure with the Utility for a lock-out procedure to pull and lock-out service in the sub-station, with SAIC personnel having a lock and key. (2) Add a manual disconnect switch at the pedestal (or in single dish sites on the service entry) that can be locked and is visible to service personnel. (From DG memo, 5/26/98)	6/5/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
209	5/26/98	There are no HIGH VOLTAGE warning signs posted on the Dish System.	Awaiting Investigation Duane Gibson	Proposed solutions: (1) Prepare a standard drawing and document identifying signs and labels to be placed on each installation. (2) Where possible, place labels on hardware before it is shipped. (3) Research applicable codes for requirements of signs, I.e., NEC requires a site directory, ANSI Z535.4 identifies standards for Product Safety Signs and Labels. (from DG memo, 5/26/98) Mike Taylor has been working with Michael Stewart from NREL on labeling the Mesa dish. We will verify that it meets ANSI Z535.4 standard, and add sizes and locations to the installation drawings.	6/5/98
210	5/26/98	Instrumentation and communication signals (Sun Sensor $ RS485) need continuous shields that are not tied to ground. Splicing in power junction boxes and tying shields to ground result in noise to signals.	Awaiting Investigation Duane Gibson	Proposed solution: (1) Make continuous runs of shielded cables with connectors in place of splicing in junction boxes with the power conductors. (2) Lay out correct cabling in drawings. (from DG memo, 5/26/98)	6/5/98
211	5/26/98	The drift, repeatability and noise performance are unacceptable for reliable solar tracking.	Awaiting Investigation Duane Gibson	Proposed solution: (1) Select Photo Cell from Silonex that meets performance requirements (present cell has +/- 40% tolerance). (2) Use matched pairs of cells for Up/Down and East/west for tracking with solar intensity variations. (3) Go to printed circuit board assembly, test and burn-in and calibration prior to delivery to field. (All units should be interchangeable in the field.) (from DG memo, 5/26/98)	6/5/98
212	5/26/98	Communication with PCS is un-reliable and cause of system shutdowns. Both hardware problem and software protocol.	Awaiting Investigation Duane Gibson	Proposed solution: (1) Wire as a 3 conductor shielded (or 2 shielded pairs) from the PCS to the PLC controller. (2) Maintain shield and do not use as a signal path. (3) Establish a protocol with STM for using READY status bits. (4) Enable parity checking for identifying bad data receptions or use two data receptions that match for decisions. (from DG memo, 5/26/98.)	6/5/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
213	5/26/98	A voltage/current spike occurs each time a relay or solenoid coil is de-energized. This spike stresses solid state electronic devices. The Little PLC does have diodes across its output to suppress these spikes, but the wiring path from the coils to the diodes goes through the power supply and tie points to other circuits. This issue may be the source of a failure on the PLC on the DC dish.	Awaiting Investigation Duane Gibson	Proposed solution: (1) Place suppression diodes across the coils of relay and solenoids as close to the device as possible. (2) These diodes were placed on the DC system, and an ECO has been initiated. (3) Evaluate motor circuits for need of snubbers (solid state relays have them built in.) (from DG memo, 5/26/98)	6/5/98
214	5/26/98	The DC Dish has a 16 gauge stranded wire connected to a 14 gauge solid wire connected to a 12 gauge stranded wire and the circuit fused at 20 amps. For the rated environment of 85 deg C this combination is no better than 13 amps capacity.	Awaiting Investigation Duane Gibson	Proposed solution: (1) Perform a loads analysis of expected and worst case electrical loads on each circuit. (2) Size wire and fuses and add to system documentation. (from DG memo, 5/26/98)	6/5/98
215	5/26/98	There are two issues with lightning, surges that propagate down the power and communication lines and a near direct strike from lightning. The present system has limited protection on some of the communication lines and no protection on power lines from surges as well as no protection to mitigate a near or direct strike.	Awaiting Investigation Duane Gibson	Proposed solution: (1) Provide surge suppression on input power to control circuits and incoming phone line. (2) Install a grounding grid to mitigate the damage from a near or direct strike. I will solicit a cost estimate for designing a lightening grounding grid from photo's and other information I have collected on the DC site. (from DG memo, 5/26/98)	6/5/98
216	5/26/98	The Little PLC used at the controller has experienced a number of failures. Even though Z-World specifies the device for use to -40 deg C, they use 0 deg C components. (0 deg. C parts will work at the lower temperatures a few times, continued cycling will however result in failures.) Condensing humidity will also result in failures.	Awaiting Investigation Duane Gibson	Proposed solution: (1) Review the circuitry and add protection to the PLC and up grade non-conforming parts. (2) Review Z-World products for a more robust product that is compatible with the PLC software as a possible replacement. (3) Determine the impact of moving the software to another platform. (From DG memo, 5/26/98)	6/5/98
217	5/26/98	A single failure of the PLC controller results in the FOCUS blower stuck in the "ON" state.	Awaiting Investigation Duane Gibson	(1) Evaluate the severity of HAZARD (is this a potential threat to the public?). (2) Use redundant logic to provide power to the Focus circuit. (from DG memo, 5/26/98) It was determined that this failure could result in a severe hazard to the engine and possibly to the public. Prior to running the DC dish in solar mode we will implement a reliable solution. In addition to physical SCRAM buttons and in the controls, we will implement an "output watchdog" function that will search for the appropriate inputs in order to keep the focus blower running. (See Roger's memo dated 6/17/98 for a description of the updated software.)	6/26/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
268	6/1/98	Actuating plug on STM wasn't functioning. Needed to replace motor and plug actuator controller.	Awaiting Investigation STM	STM replaced the actuating motor for the second time on 7/1/98.	
269	6/2/98	Re-wired PCS Ready switch.	Awaiting Investigation STM	'	
218	6/3/98	The DC dish has been experiencing electronic noise related shutdowns and erratic equipment performance. This noise is both conducted and radiated, that is conducted is the result of current flow in power and ground, and radiated is coupled as RF into shields and wires. The Baldor frequency converter is the source of 90 to 95% of the conducted, and the source of 80 to 90% of the radiated. The Baldor contribution goes up as the power increases, however the Baldor "ON" noise in idle is a factor of 10 more than other sources.	Awaiting Implementation Duane Gibson	In an effort to reduce noise effects to equipment, the following improvements were made and should be reviewed for inclusion into all systems: (1) RS-232 communication line from the PCS to the monitor PC in the control hut had to be run as a separate shielded cable with the shield driven from the PCS, and isolated from all other grounds and shields. This resulted in acceptable (not perfect) communication under the worst case noise. (2) A filter capacitor was added to the wind sensor circuit which eliminated noise from the Baldor sending it to full scale resulting in a wind alarm. I will write up an ECR to incorporate this change into the wind sensor circuit. (3) Capacitors were added across the outputs of the sun sensor tracking signals at the input to the Little PLC. This eliminated spiking on the tracking signals and the need for a large tolerance setting. This is not the best way to solve this problem. A design review should be made to determine the best filtering method. (4) All shields were disconnected to the chassis in the control panel. The multi-conductor shielded cable shields are still connected together in junction boxes. Shields should be only connected at one point, preferable the source end, and not connected to each other, ground or chassis. All measurements, and communications cabling should be reviewed for optimum wiring and shielding from the source to termination. Where necessary, a signal will need to be routed in its own shielded insulated cable (I.e. PCS RS-232). It is extremely difficult to maintain shield separation in multiconductor cables. This will result in a more rugged system for tolerance to electronic noise environments. (from DG memo, 6/4/98)	6/17/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
219	6/3/98	A wiring error was found that originated in the PCS that prevented the dish from going beyond the horizon position. The wiring error effected the circuit that sensed the horizon switch, not allowing a closure to be sensed. This wiring error apparently was also on the Mesa dish. An STM error that was not communicated for corrective action.	Awaiting QA Verification Lem	Wiring error has been corrected on NREL dish and DC dish. (From DG memo, 6/4/98)	6/4/98
221	6/3/98	The entry service from the disconnect box to the Baldor box at the DC site is run through plastic conduit in parallel with the PCS and network communication lines in another plastic conduit. The conducted Baldor noise can be traced with a sensing loop along the plastic conduit. This noise couples to the communication lines and reduces the quality of the signals, with periodic drop outs. The Baldor specification requires metallic conduit to reduce noise effects. If the Baldor is to be used in the DC site, the service conduit should be changed to metallic. It should be standard practice to run metallic conduit for service entry for all installations. (from DG memo, 6/4/98)	Awaiting Investigation Duane Gibson	'	6/17/98
222	6/3/98	The wind sensor periodically shows no reading. The RJ-11 connector from the sensor to the console requires wiggling and pressure to make contact. A plastic shim was inserted to maintain contact. An RJ- telephone type connector is not a reliable connector for instrumentation purposes. Select a quality connector and replace in the design of the wind sensor instrument and console. (from DG memo, 6/4/98)	Awaiting Investigation Duane Gibson	'	6/17/98
270	6/3/98	Replaced actuator control board in PCS.	Awaiting Investigation STM	'	
231	6/8/98	The 20 AMP main motor fuse failed. (fuse F2)	Awaiting QA Verification Lem	'	
271	6/8/98	High temperatures were noticed inside the PCS. Drilled ventilation holes and changed PCS software to trigger hybrid blower even in solar mode.	Awaiting Investigation STM	'	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
233	6/9/98	The unit and system clocks on the Visual Basic controller parameter screen are not remaining in synchronization with the unit and system clocks on the Visual Basic dish control console. We have noticed as much as 30 minute differences in time between the two sets of clocks.	Awaiting Investigation Pat Soliday		
234	6/9/98	We have noticed a constant drift in the dish azimuth position versus the sun azimuth position. At times this drift has been as large eight degrees in half a day.	Awaiting Investigation Russell Forristall	We need a data plot of the azimuth position from a full day of tracking. This will tell us if the root cause of the problem is in the algorithm, the sun sensor or the encoders.	7/15/98
235	6/9/98	The High Wind Fault is tripping on the dish control console before the Network Box signals a high wind.	Awaiting Investigation Roger Davenport		
237	6/9/98	While running the dish on solar, I noticed a lot of flaring of the flux outside the PCS receiver aperture. This flaring is a good indication that some facets are still overfocusing.	Closed		
277	6/14/98	The phone jack for the wind sensor has a loose connection.	Awaiting Investigation Roger Davenport		
241	6/18/98	The East limit switch is triggering too soon on both the NREL and D.C. Dishes. The NREL Dish limit is triggering around 65 degrees and the D.C. Dish limit is triggering around 80 degrees The limits should be moved to about 45 degrees so that the Dishes can track the sun during the early morning hours.	Awaiting Investigation Duane Gibson		7/15/98
275	6/30/98	Noted CN-3 was seriously deteriorated at entry point to JB- 3. Sharp metal inner cladding could chafe wire insulation and cause a short.	Awaiting Disposition Management		11/18/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
276	6/30/98	Had unit parked in near Solar Noon upward stow position. Noticed that there was charring discoloration on the plug and ceramic face of the PCS that evening.	Awaiting Disposition Management		11/18/99
244	7/6/98 1:45:00 PM	At about 13:45 I looked up and saw a small grass fire spreading away from the base of the dish. The fire had consumed about 10 - 15 feet in a half circle, away from the trailer. I extinguished the flames as fast as I could with the trailer's door mat. I looked up and saw that a corner of the PCS had been burned. Also I noticed a white milky substance falling to the ground. I did not know where it had come from. Immediately I turned off the power. Around 14:10 the fire department arrived, and doused the charred area until the ground was thoroughly soaked. The firemen left at around 14:35. After power was restored, I stowed the dish. A hole of melted insulation, about 12" long, 5" wide, and 5" deep, leads from the PCS aperture opening to the upper-west corner. At this corner, about a 10" long, 1-2" strip of metal cowling is burnt. This charred area is slightly warped. (see attached pictures in file oops.jpg and incident description from Albert Nunez.)	Awaiting Investigation Lem Tingley	•	7/31/98
272	7/14/98	The 20 Amp main motor fuse failed. (F2)	Awaiting QA Verification Lem	•	
286	7/15/98	#1 Pressure transducer failed due to excess moisture from cleaning.	Awaiting Disposition Management		11/18/99
273	7/18/98	Inverter was not powering on when system was started.	Awaiting Investigation Russell Forristall	•	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
246	8/6/98	The sample period (ds) and samples to average (dn) parameters for the performance log are not retaining there assigned values. Both values are being reset to zero for some unknown reason. This incident causes the performance log to fill up after only a minute worth of data. The ds value should be about 5 and the dn value should be about 60, with these values the performance log can retain up to two days worth of data before being reset.	Awaiting Investigation Roger Davenport		
247	8/6/98 1:10.00 PM	Loose terminal strip screws allowed arcing to occur and an ultimate melt down of terminal strip. Resulting short tripped breakers in pump room effectively killing power to unit, freezing it in its tracks and blanking out communication with computer consoles. After terminal strip was replaced wire nuts, unit was enabled but continued to trip at grid interface box after approximately 6.33 min of focus time. Not sure if this is when engine is trying to start or what is exactly causing trips. Will continue to investigate and try to determine exactly what is the cause of tripping. System seems to track OK, so will track unfocussed while trying to trouble shoot cause. Bottom Line: Tighten terminal screws every month.	Awaiting Investigation Roger Davenport		8/21/98
249	8/8/98	Computer stopped working correctly. Dish control program would only go to icon at bottom and would not restore. Data sampling/# of samples display as 1/60 and 5/0 for the network and dish respectively. It should be 5/60 for both. Serial port stopped responding.	Awaiting QA Verification Lem	8/22 - After evaluation, sent old computer back to site in working order. 8/24 - Computer reinstalled and working properly.	8/24/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
248	8/24/98 1:35.00 PM	System was just starting to reach run temperatures (250 deg. C +) and ECU had begun start processes when a "HOT FILL TIME LIMIT" tripped out a "PCS NOT-READY" fault. This closed plug and started defocus processes. In order to keep dish tracking, with Stefan's approval, we cleared fault on PCS and regained a start system state (plug was still closed), reenabled dish which cleared "PCS NOT-READY" fault and unit went back on-sun and started to focus up mirrors (plug still not open). Tried "Disable" and "Enable" to see if plug would open, but no luck. Called Roger, reset time delay for focus/defocus to 6 seconds. Disabled and Enabled. Software as currently configured sticks on focus even when plug is not open as described above, during some situations. I think that unit needs to be allowed to go through its complete cycle of defocusing before it is re-enabled. (Full 20 min defocus and refocus time out.) Or PCS needs to be 'smarter' to know that plug needs to open on a re-enable signal before de-focus loop has "timed-out" and I think it would be a good added safety to have a thermister/thermocouple embedded in the plug and in series with the plug alarm limit switches so if the plug is closed and the heat sensor reaches say 250 or 300 deg. C then "PLUG FAILURE" JVP fault occurs from too high a temperature, indicating a plug closed/focused situation. -AN	Awaiting QA Verification Lem	Changed software 9/10/98 to check plug and focus power every 30 seconds while focussed, beginning 60 seconds after initial command to focus.	9/10/98
250	8/27/98 9:40.00 AM	After going on-sun normally, the system began running down until the PCS arm hit the ground at about 109 degrees azimuth. There were no indications of any trouble before the event , and the azimuth continued to rack normally even as the elevation was going awry. The operators noticed just as it hit the ground and stopped it by killing power. The only damage was to the rear shroud of the PCS. In trying to see what went wrong, the direction relay was damaged.	Awaiting Investigation Roger Davenport		8/31/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
252	8/27/98 10.45:00	At about 10:45 while working with Roger Davenport on trouble shooting the system parameters and trying to determine the cause of the "Swan Dive Incident" we proceeded with configuring lap link to allow Roger to control the system while I was at the pedestal control box. We deleted what appeared to be a superfluous AT&T modem that was "sharing" com 3 with the "real" CommWave 336 PCMCIA USA modem card that was actually in the lower slot and functioning on com 3 port. This report specifically deals with the now inoperable system and access to both AOL and Accuset via this modem. Ever since these modem setting modifications were initiated to allow LapLink program to function properly, that is Roger Davenport controlling the console remotely from Golden, I have not had any functional modem on that Laptop (Charlie Brown) except for lap link. The problem may be as simple as Laplink locking out all other access to the modem due to it being on standby waiting for remote access from Golden but I thought that if the program was closed that this would not be the case??	Awaiting QA Verification Lem	Problem was solved with switching out the modems. Megahertz unit is working fine in Charlie Brown.	
274	8/28/98	Elevation motor faults due to blown fuses. Replaced elevation motor on 8/29/98. Found water inside the motor casing.	Awaiting QA Verification Lem	'	
256	9/4/98 6:28:00 PM	At approximately 18:28, while the JVP Control System was running, the red "TEST" button on the Network control box was accidentally pushed and initiated a HIGH WIND SIMULATION TEST. This, of course, shut off the blower motor and started the defocusing process. I thought that the system would return to normal operation and downward stow position after the High Wind Time Out Period (30 minutes) of low wind readings. By 20:55 after sending out the daily performance logs, it was obvious that the unit was going to stay in the upward stow position all night. (See attached Incident Report from Albert Nunez).	Awaiting Investigation Roger Davenport	Operators just need to be more careful. When the button is pushed, an alarm sounds so they should notice it.	9/18/98
254	9/5/98 10:49:30	At approximately 10.49:30 ECU time, while the Gateway keyboard was being cleaned, the F9 key was accidentally pressed; and as a result, the 480vac power was disconnected from the PCS causing a "maximum rpm fault" to trip, shutting the PCS and the JVP systems down. (see attached report from Albert Nunez).	Awaiting Investigation Pat Soliday	'	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
255	9/5/98 5:10.00 PM	At approximately 17:10, wile the JVP control system was running in the background and I was typing up the incident report on Microsoft Word the Solar system was inadvertently disabled. (See attached Incident Report from Albert Nunez).	Awaiting QA Verification Lem	see IR #248.	
287	9/8/98	Dish lost communication with controller. Albert unplugged the computer from the network box and rebooted the computer to restore communication.	Awaiting Disposition Management		11/18/99
283	9/25/98 7:32:00 PM	An PCS-not-ready fault occurred when trying to enable solar after running the system on gas all day. This fault occurred eventhough the PCS control computer was showing that the PCS was in the ready mode. This fault was able to be cleared by cycling the enable/disable buttons.	Awaiting QA Verification Lem	This problem was fixed by STM.	
285	9/28/98 8:20:00 AM	When the operator arrived this morning he noticed that the controller was showing a shutter command error and a PCS-not-ready fault. He was able to clear both of these faults and the system continued operating.	Awaiting QA Verification Lem	This has been fixed.	
284	10/1/98 11:30.00	The Network Box Controller stopped communicating with the controller computer after a high wind alarm was triggered. Communications was regained after cycling power to the Network Box.	Awaiting Investigation Albert	'	10/15/98
295	10/1/98 12:08:00	At 12:08 dish time, the STM PCS gave an 'Actuator Stalled Timeout' fault. Actuator control board failed, and Stephan stated that he would fly out to replace in the AM, which he did. After the new board was installed, system went back on line without any further problems. ECR recommendation is that hardware reengineering/modification(s) be made to maintain full system operation and communications for a minimum of 50,000 hours without repairs or transients.	Awaiting QA Verification Lem	Stephan replaced the entire actuator board on 10/2/98.	10/2/98

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
294	10/7/98 1:24:00 PM	At 13:24 dish time, the PCS tripped out on a "Maximum Operating Temperature' fault. The history log was saved to disk and fault clearance was approved by Stefan. After F5 fault clearing, the PCS was re-enabled on Solar/Gas. Communications were re-established when Solar/Gas enabled. Note: A "Maximum Operating Temperature" fault also occurred on October 3, 1998.	Awaiting Investigation	Stephan changed the codes in the software to eliminate the Manual Stroke Dialer. It appeared that the Manual Stroke Dialer was interfering with the actuator controls. Stephan will simulate the change on the bench test, and let us know if any problems arise from the change in software. - 10/15/98.	
293	10/8/98 11:41:00	At 11:41 dish time when it had been raining for most of the morning, intermittently heavy at times, the dish was in downward stow position for an elevation motor rain-cap installation. All communications were lost between the PCS and the ECU controller. The JVP system console lost communication with the ECU (PCS). Communications were not able to be reestablished by power rebooting the PCS system. Had to wait for the rain to stop before PCS electronics could be analyzed. CorCom EMI Filter #3 ET 1 is defective, and a new one will be FedExed overnight. Not sure if there are any further problems downstream of the EMI filter. ECR recommendation is that a PCS hardware modification(s) be made to maintain full communications during periods of heavy rain in all possible system attitudes and full gas power output.	Awaiting QA Verification Lem	Stephan sent new EMF filter, to filter noise from actuator board.	

SAIC®

Incident Summary

APS West Dish

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
301	2/9/99	The user interface appears to send the wrong command for setting the data logging parameters. When the number of data items to average is changed, instead of a "xxxdn y" command to change the number of data points, the command "n y" appears to be sent, which changes the number of dishes on the network. Also, we get a "Run-Time Error 380" on an occasional basis. It says that a button is in an indeterminate state (not up or down) and hangs up the control program. Finally, the question of automated downloading with multiple dishes came up. This has not been addressed to date.	Closed	User interface will be updated to fix this and other minor bugs and make improvements needed. This will be installed on the network control computer when ready. This does not affect system operation.	3/23/99
303	2/9/99	Dish appears to be over-focusing. Flares of light are visible on the front of the PCS when fully-focused.	Closed	The dish has been realigned and focus has been adjusted to achieve a good flux profile on 5/22/99. Focus valves will be retrofit after other dishes are installed. See memo of 22 March 1999 documenting the results of a meeting called to discuss the problem. Existing focus valves will be left in place with the adjustable bleed valves, and the system power output and focused image will be observed over time for possible changes. For the upcoming systems, minor improvements to the valves will be made to reduce temperature sensitivity and leakage around the poppet/bushing. A long-term effort will be initiated to develop an improved focus valve based on a design with the membrane closing off an opening to close the valve. A meeting has been called on 5/17 to discuss progress on valve development.	5/22/99
302	2/12/99 2:45:00 PM	PCS indicated fault in actuator ("Actuator Time-Out"). Dish defocused, plug closed, and PCS shut down. System stowed normally and was shut off for the weekend.	Closed	This has been assigned to STM for continued evaluation. This is not a common occurrence in the operation of the engines. STM has increased the size of the fuse from 7A to 10A. Est. time to diagnose: 4 mh, repair 1mh. Cost to repair: $10 for fuse and $50 time to install	2/16/99
304	2/24/99	Stirling engine reported "Blower Failure". System stowed.	Closed	STM will implement any changes needed.	3/17/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
306	3/10/99 7:21:00 AM	Max. operating temperature fault on heater head thermocouple. Thermocouple 1-3 shows OPEN.	Closed	Disconnected thermocouple per Stefan's instructions	3/10/99
307	3/12/99 6.00.00 PM	Dish controller reported arm latch fault while going to stow.	Closed	Arm latches have been modified to have a brass bushing that limits side play and freedom of movement. This allows adjustment of the position and reduces side play to <1/8". Better installation notes have been written to tighten the spec on the actuator clearance to 0.050" or less.	4/6/99
305	3/23/99 9.00.00 AM	The 20A circuit breaker for the UPS supply power failed to a partially-connected condition. A voltage of 10VAC was measurable on the output of the circuit breaker. Because input power was not being supplied, the UPS began supplying the load from the batteries, leading to depletion of the batteries. Thankfully, the problem was noticed before the batteries were completely depleted. Otherwise, a failure of the PCS could have occurred if it lost 120VAC supply while in operation.	Closed	The circuit breaker on the output of the UPS has been bypassed. The circuit breaker on the input power to the UPS has been increased to 30A. Also, the battery charging setting on the UPS will be set to the low power setting, limiting the battery charging rate to 10A on the AC side instead of 20A. This will result in a maximum draw of 25A for full-load with battery charging. The dish control power has been moved to the same breaker as the UPS input so that in case of failure of the bus, the dish controller will lose power, causing a PCS fault when the communication stops even if the dish is not trying to move. This system will be retrofit with a SCRAM contactor later, and that contactor will be powered from the breaker for the UPS supply power.	6/2/99
309	3/24/99 7:00.00 AM	Elevation motor fault reported by dish controller.	Closed	Develop alternative to pull switches, based on pull-apart connectors. See memo of 1 April 1999 regarding evaluation and testing of alternatives. Recommendation is weatherized quick-disconnects. Adjustment of cable using a turnbuckle allows setting to required pre-tension (see memo of 4/14/99 from Russell Forristall).	4/6/99
308	3/25/99 6:45:00 PM	Arm latch on West side of dish did not indicate it was unlatched when going to stow. The dish faulted and stowed face-up.	Closed	Added jam nuts on both sides of arm latch to position the latch and reduce side play to less than 1/8". Added installation notes to drawings to specify clearance <0.050" between actuator and sensor. See IR #307. Rounded front corner of arm latch to prevent jamming.	4/6/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
311	4/6/99 12:40 00	Enabled solar and gas at 10 00. Engine began to run immediately as the dish tracked to the sun. When the dish began on-sun tracking, the engine started its normal shutdown from gas operation, and the mirrors started to focus. The plug at this point was still closed. When it came time to open the plug, it would not open and so there was a plug fault. The engine was still running at this point. I waited until the engine stopped and tried re-enabling solar ONLY, but the plug still would not open. The problem was corrected by removing power to the whole system for 1 minute.	Closed	New software has been written to eliminate this error.	4/1/99
312	4/8/99 1:40:00 PM	PCS computer faulted out on a "Hot Fill Time Limit". Dish stowed. Checked hydrogen bottle -- 12.75 MPa	Closed	Changed hot fill time period to shorter period. Disabled hot fills for normal operation	4/1/99
313	4/9/99 4:15:00 PM	PCS faulted on "Hot Fill Time Limit" Dish Stowed. Hydrogen bottle pressure OK.	Closed	See IR #312	4/1/99
314	4/12/99 2:30:00 PM	Anemometer cups fell off	Closed	Glue cups to shaft.	4/1/99
315	4/12/99 6:45:00 PM	Dish was going to stow when it got to the point of turning the azimuth angle to 180 degrees, it stopped (did not fault) and sat there. Called Roger, and we changed the stow parameters to start the dish upward and then reset it to the original setting (-87). The dish then stowed normally.	Closed	Changed dish program parameter so dish is only allowed to go to -25 degrees instead of -30 degrees in elevation while going to stow. The new software has been transferred to APS and will be installed 4/16/99 before the start of operation.	4/16/99
318	4/16/99 12:00:00	Dish was operating in solar mode when a "Max Temp" fault occurred. The maximum temperature was at HT1-1, thermal couple 11, in the PCS receiver. The hot spot occurred while the dish was operating in the solar calibration mode.	Closed	Re-align/re-focus dish. This was carried out on 5/19-24. See IR #302, 303.	5/22/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
317	4/20/99 2:48.00 PM	Dish operation stopped and dish went to stow due to a "Hall Sync Errors" fault.	Closed	Re-wired control board with correct resistor to give right amount of current.	4/1/99
319	4/22/99 1:45:00 PM	Dish faulted while attempting to startup in gas mode (Ignition Warmup Time fault).	Closed	Increased warm-up parameter value	5/1/99
321	4/27/99	Shortly after the dish reached its stow position, a "Communication Error" fault occurred. The grid protection tripped off.	Closed	None. Note that new comm chips have been received by SAIC for RS-485 communications. The new chips include over-voltage protection and are a pin-compatible replacement for the present comm chips. These will be implemented on 5/19/99, and will make the communications more robust to help prevent problems in the future.	
320	4/27/99 6:55:00 AM	Received a "Actuator Stall Timeout" fault shortly after enabling solar mode.	Closed	See IR #317.	4/1/99
322	5/10/99 10:15:00	Started dish up; it went up OK, but after about 45 minutes, it came down with an actuator stall limit fault. Sent logs to Stefan and he said to leave the dish down because the logs didn't look good.	Closed	STM has requested that the engine be sent back for evaluation. Many components have been over-stressed and possibly damaged. For the future, operator procedures have been modified to include a test spin of the engine after any 480 VAC or utility wiring changes to ensure engine remains wired correctly. STM has implemented a software change that detects negative stroke (indicative of reverse rotation) and stops the motor. It has been determined that the motor protection relay in the grid protection panel protects the system from phase reversal.	5/12/99
323	5/19/99 2:00:00 PM	The motor protection relay would not engage.	Closed	Reversed voltage leads for phases B and C. Relay engaged normally.	5/27/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
324	5/25/99 10:53:00	PCS faulted with "Actuator Stall Timeout"	Closed	STM is installing a surge protection device upstream from the UPS.	6/2/99
325	5/27/99 3:00.00 PM	PCS faulted with "Actuator Stall Timeout" fault.	Closed	See IR #324	
326	6/7/99 10:15:00	PCS faulted on "Water Over Temp" fault.	Closed	STM directed operators to increase upper limit temperature from 80C to 85C.	6/3/99
327	6/7/99 11:09:00	PCS faulted with "Max Cycle Pressure Difference" error	Closed	Replace pressure transducer	6/8/99
328	6/8/99 8:37:00 AM	PCS faulted with "Max Operating Temperature" error	Closed	None - disconnect thermocouple. The heater head now has 2 failed thermocouples, and can run with 3 failed.	
329	6/8/99 10:28:00	PCS faulted on "Max Cycle Pressure Difference"	Closed	Replace pressure transducer	
330	6/9/99 12:08:00	Min. oil pressure fault. Heard a short howling noise prior to fault.	Closed	Software has been changed in PCS.	6/18/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
331	6/9/99 4:05 00 PM	Max. operating temp fault on HT 2-3 sensor	Closed	Replaced o-ring	6/10/99
332	6/10/99 2:20 00 PM	Lost grid power from grid protection box. Lost all communication from dish. PCS not ready fault.	Closed	None; consider adding alarm for loss of comm.	
333	6/11/99 5:23:00 PM	PCS shutter did not close completely after disabling solar	Closed	6/14: Stefan adjusted the shutter and tightened the bolts.	6/15/99
334	6/14/99 7:40:00 PM	PCS Fault - "Ignition Warmup Time". This occurred about 15 minutes after starting on gas.	Closed	Keep shutter adjusted	
335	6/15/99 2:30.00 PM	Stefan noted one facet appeared underfocused -- Facet image was about the size of the front of the PCS.	Awaiting QA Verification Lem	Replace poppets with brass poppets. Re-machine bushings to have consistent clearance. Also, replace steel focus adjustment screws with aluminum screws to eliminate other temperature effects.	6/28/99
336	6/17/99 1:10:00 PM	PCS fault - "Max Ignition Retries" after running on gas for 6 hours.	Awaiting Investigation STM	7/7: Stefan on site to investigate	
339	6/24/99 10:00:00	PCS shroud is showing signs of heat damage (charred paint). The damage occurred when the dish was in upward stow position during mid-day sun.	Awaiting Disposition Management		11/18/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
338	7/2/99 7:00 00 AM	Engine would not start on gas; gave "MaxIgnitionRetries" fault	Awaiting Investigation STM	'	
341	7/2/99 12:00:00	Engine faulted with Blower fault when starting on gas	Awaiting QA Verification Lem	No changes to system.	
340	7/8/99 9:30·00 AM	Appears that facets are not aimed correctly. One facet appears defocused. Temp. difference across receiver as large as 370K.	Awaiting QA Verification Lem	Replace delrin poppets with brass. Replace adjustment screws with aluminum screws. Seal bushings to valve body, and valve body to aluminum pipe with silicone. Use adjustable breather ports. Eliminate vacuum regulator in focus plenum. Eventually, redesign valve to eliminate temperature effects, variation in focus.	6/24/99
342	7/13/99 7:00:00 AM	Lost communications to both dishes from network controller.	Awaiting QA Verification Lem	Network controller program changed to default to 2 dishes on the network. Version n990718	7/19/99
347	7/19/99 4:41:00 PM	PCS faulted -- Max Water Temp fault.	Awaiting QA Verification Lem	None. System placed back in operation.	
348	7/20/99 10:40:00	PCS Faulted on Max Water Temperature again (see Incident #347)	Awaiting QA Verification Lem	See Incident #347	7/20/99
349	7/20/99 5:15:00 PM	PCS Faulted on Max Water Temp. Also at 5:15pm	Closed	Write parameters to EEPROM.	7/20/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
351	7/21/99 10:18:00	PCS Faulted on High Water Temp.	Awaiting Investigation STM	'	
353	7/21/99 4:15:00 PM	PCS Faulted on Max Water Temperature	Awaiting Investigation STM	7/21: Checked shutter and water coolant level after fault occurred. Both looked OK.	
354	7/21/99 5:30:00 PM	PCS Faulted on Warmup Timeout	Awaiting Implementation '	Re-design shutter attachment to eliminate shifting in position.	
356	7/22/99 7:18:00 AM	PCS Faulted on Max Operating Temp	Closed	No design changes.	7/22/99
357	7/22/99 2:06:00 PM	Elevation motor fault.	Awaiting QA Verification Lem	To reduce hunting, the deadband value was increased from 20 to 22.	7/22/99
358	7/23/99 6:15:00 AM	PCS faulted with Warmup Time Exceeded.	Awaiting Investigation STM	'	
359	7/23/99 6:25:00 AM	PCS Fault - Warmup Time Limit starting up on gas	Awaiting Investigation '	'	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
360	7/24/99 7:21:00 AM	PCS Fault - Ignition Warmup Time while starting up on gas	Awaiting Investigation		
362	7/25/99 6:08:00 AM	PCS Fault - Cold Fill Time Limit	Awaiting Investigation		
365	7/27/99 11:30:00	Azimuth Motor Fault	Awaiting Investigation	Replaced solid state relay and placed system back in operation. Relay later tested OK in lab. Possible that system is coasting longer than program allows, so motion after coast time is interpreted as motor fault.	
363	7/28/99 9:58:00 AM	PCS Fault - Max Cycle Pressure.	Awaiting Investigation		
366	7/29/99 2:00:00 PM	PCS Fault - Max Ignition Retries. Actually, PCS ran from 1230 to 1400 on gas without problems, then stopped for no apparent reason. Fault occurred when it attempted to restart. Tried several more times (1424, 1530) to get PCS to start on gas, without success.	Awaiting Investigation		
368	8/4/99 3:39:00 PM	PCS Fault - Low Oil Pressure when first started on gas, then Ignition Warmup Time when restarted	Awaiting Investigation STM	Shutter/plug had been replaced with new one and adjusted just before attempting to start engine on gas.	
369	8/9/99 12:25:00	Motor protection relay in grid protection cabinet failed, causing loss of 480VAC to both systems. Both systems were on-sun at the time, the East dish with the BCS system installed.	Closed	Replaced relay.	8/10/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
370	8/10/99 12:00.00	PCS Fault - Max Cycle Pressure Difference. The system was restarted on sun and faulted again at 16:20 with the same fault.	Awaiting Disposition		
			Management		11/18/99
371	8/10/99 2:54:00 PM	Max. Cycle Pressure Difference Fault	Awaiting Disposition		
			Management		11/18/99
372	8/10/99 5:31:00 PM	Lost Grid	Awaiting Disposition		
			Management		11/18/99
373	8/10/99 5:31:00 PM	Lost comm to dish	Awaiting Disposition		
			Management		11/18/99
374	8/11/99 7:03:00 AM	Found hydrogen leak in fill line to PCS	Awaiting Disposition		
			Management		11/18/99
375	8/11/99 7:37:00 AM	Max Pressure Differential fault	Awaiting Disposition		
			Management		11/18/99
383	9/12/99 8:24:00 AM	PCS Max. Op. Temp Fault	Awaiting Investigation		

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
395	10/20/99 9.00:00 AM	While igniting on hydrogen, shutter was blown out, causing insulation around aperture to break loose.	Awaiting Investigation		
397	10/22/99 6:00:00 PM	Cables caught up on the azimuth motor.	Awaiting Investigation		
398	10/23/99 6:10:00 AM	Hydrogen pressure bleeding down from 7.5 Mpa to 5.4 Mpa in 24 hours	Awaiting Investigation		
399	10/25/99 6:25:00 AM	While the dish was stowed, the PCS faulted with a "Low Oil Pressure" fault.	Awaiting QA Verification Lem	Reset fault and enabled solar	
400	10/26/99 6:04:00 AM	PCS Fault - Max Operating Temperature on HT 2-1 occurred overnight while the PCS was idle.	Awaiting QA Verification Lem		
401	10/28/99 7:27:00 AM	PCS Fault - Wrong Engine Direction, after engine had been running on-sun for about ten minutes. There was a change in the engine sound right before the fault occurred.	Awaiting Investigation		

SAIC

Incident Summary

APS East Dish

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
337	6/30/99 7:00:00 AM	Dish tracked past sun azimuth and showed azimuth motor fault	Awaiting QA Verification Lem	Replaced solid-state relay and reversing relay. Avoid using SCRAM contactor when dish is moving.	6/30/99
343	7/13/99 12:30:00	Large amount of overfocus/spillage on calorimeter front.	Awaiting Implementation Russell Forristall	Considering changing valve body to aluminum to eliminate any deflection with temperature and match thermal expansion of pipe.	
345	7/14/99 6:45:00 AM	Arm latch fault coming out of stow	Awaiting QA Verification Lem	Remove tie-wrap causing abrasion; route cable and attachments so they don't rub.	7/15/99
344	7/14/99 7:00:00 AM	Lost comm to E. dish.	Awaiting QA Verification Lem	See Incident #345; arm latch cable repaired	7/15/99
346	7/19/99 9:00.00 AM	Could not establish RS-485 communication link to PCS controller from trailer.	Awaiting Implementation STM	Connected RS-232 lines directly to control trailer for the present. Need long-term solution in order to connect controls into STAR center.	
350	7/21/99 8:10:00 AM	PCS Faulted on Actuator Stall Timeout.	Closed	Correct value was entered and saved to EEPROM, and system was run with the new parameter.	7/21/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
352	7/21/99 12 00 00	After starting up normally on gas, and achieving steady-state with 100% stroke, 14.7 MPa, 675C, and ~16 kW, the PCS simply shut down. There was no indication of a fault or any other problem. It just shut down. We re-enabled gas operation at 13:30 and it ran without problems until 15:45.	Awaiting QA Verification Lem	8/2: Stefan cycled power to the PCS and it came up OK.	
355	7/22/99 6:00:00 AM	PCS had cold-fill fault.	Closed	None	
361	7/24/99 8:47:00 AM	PCS Fault - Max Operating Temperature; when fault was cleared, got Actuator Stall Timeout fault	Awaiting Investigation ,	'	
364	7/27/99 11:23:00	PCS Fault - Actuator Stall Timeout	Awaiting Investigation ,	'	
367	8/3/99 2:20:00 PM	PCS Fault - Hall Sync Error	Awaiting Investigation ,	'	
376	8/11/99 10:31:00	Elevation motor fault	Awaiting Disposition Management		11/18/99
377	8/13/99 5:53:00 AM	Elevation motor fault	Awaiting Disposition Management		11/18/99

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
378	8/20/99 5:43:00 AM	Az motor faulted	Awaiting Disposition Management		11/18/99
379	8/28/99 11:25:00	PCS Actuator Stall Fault when PCS was powered up after connecting power meter	Awaiting QA Verification Lem	None. Make sure connectors are secure	
380	9/2/99 12:50:00	PCS Actuator Stall Fault	Awaiting Investigation '	'	
381	9/10/99 6:17:00 AM	PCS Max Cycle Pressure Fault	Awaiting Investigation '	'	
382	9/11/99 7:50:00 AM	PCS Actuator Stall Timeout Fault	Awaiting Investigation '	'	
384	9/12/99 1:20.00 PM	PCS Fault - Max. Operating Temp (TC HT4-6)	Awaiting Investigation '	'	
385	9/12/99 3:10:00 PM	PCS Actuator Stall Fault when powering up PCS	Awaiting Investigation '	'	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
387	9/14/99 12:30.00	PCS Fault - Actuator Stall Fault	Awaiting Investigation		
389	10/9/99 10:40:00	Elevation encoder failure	Awaiting Investigation		

SAIC

Incident Summary

SRP Dish

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
402	9/29/99 12:00:00	Grid protection panel tripped when engine was cold-motored.	Awaiting Investigation	Suspected motor protection relay, but replacing relay did not fix problem.	
403	9/30/99 3:27:00 PM	Uninterruptable Power Supply (UPS) stopped working -- blew fuse to batteries, then stopped operating.	Awaiting Investigation		
404	10/16/99 8:00:00 AM	PCS Fault - Wrong Engine Direction.	Awaiting Investigation		
405	10/18/99 6:30.00 AM	Dish faulted consecutively with El and Az motor faults numerous times. Once system reached on-sun status, the tracking was off and had to be adjusted to be truly on-sun.	Awaiting Implementation	Encoders will be replaced	
406	10/18/99 8:10:00 AM	PCS did not start, nor did it sound very good when it tried.	Awaiting Investigation	Tried to cold-motor -- tripped grid protection. Could not turn by hand. On 10/21, Russ F. was able to move by hand after releasing actuator brake and manually rotating actuator shaft to low stroke. Stefan evaluated PCS and requested engine be sent back to STM.	
408	10/27/99 9:08:00 AM	PCS sounded like something was wrong when cold-motored	Awaiting Investigation	Cold motored at 10:35am with relays and contactor bypassed. Loud banging noise from motor	

IR #	Incident Date and Time	Incident Description	Status / Responsibility	Corrective Action / Investigation	Impl. Date
409	10/28/99 9:13:00 AM	Elevation motor fault	Awaiting Implementation	Encoders will be replaced	
410	10/29/99 11:55:00	Azimuth motor fault	Awaiting Implementation	Encoders will be replaced	

Appendix E:

Engineering Change Summaries for the Dish/Stirling Systems

Closed Engineering Change Request Summary

ECR #	Date Requested	Requested by	Description of Request	Implementation
1	10/30/97	Lem Tingley	Pursuant to conversations with Hale Engineering, it was noted that the above referenced drawing was not at the proper scale when it was dimensioned. The drawing has been modified to the proper dimensions, and I have approved and replaced the original in the released package.	
2	10/30/97	Roger Davenport	H2-2000: (1) Change weld spec on pedestal flange from '3 - 6' interrupted stitch weld to continuous weld. This makes it easier for them to hold the flange flatness spec. (2) Delete note 3, which refers to the interrupted weld. H2-3000: (1) The weld spec for the plate assemblies is incorrect. It now reads '2 - 2' and should be '2 - 4' both top and bottom. A '2 - 2' stitch weld actually is a continuous weld as noted on the original drawings.	H2-2000 (1 and 2) Already incorporated. H2-3000 Weld spec fixed.
3	10/31/97	Roger Davenport	The arm hinge (D2-123000, Rev A) has holes in both leaves. Since Leaf A is welded onto the hub structure, the four holes in that leaf are unnecessary. Therefore, I have changed the drawing to eliminate them. The resulting drawing is Rev B.	
4	11/6/97	Mike Taylor	Changes to H2-1100: See attached	Added 1/2" X 1" Chamfers
5	11/17/97	Lem Tingley	(1) Item 14 in view BB, sheet 5 of 6, is not shown in isometric views on sheet 2 of 6. (2) Fit-up of Hub Frame shown on sheet 4 of 6 does not allow for enough surface on hexagon plate for welding. (ref: Joint B sub-assembly D2-121006) (3) Item 14 is shown going in the wrong direction in the isometric view of drawing #D2-121000. According to drawing #D2-122038, the bevel on the bottom end is facing out of the drawing.	
6	11/17/97	Lem Tingley	.025 and .035 Shim plates are toleranced to +/- .03. We need to research what tolerances are required in order to make these plates more manufacturable. The .13 tabs, 4 places, are especially difficult to hold +/- .03" tolerance.	Increased tolerances to +/-.060 on drawings 10163 and 10164.

ECR #	Date Requested	Requested by	Description of Request	Implementation
7	11/18/97	Lem Tingley	(1) D2-121009 rev B does not specify correct material thicknesses for Details B and C. Thicknesses should be 0 25" If Detail D were also 0.25" thick, they all could be made on the same blank. (2) Updates that were made to the Radial Truss Assembly on 11/4/97 by P. Soliday were not on revision B for the same part. An obsolete CAD file was used to do the revision change. We need to revise D2-121009 rev B to show the changes on the approved drawing for D2-121009 rev A. This includes removing some dimensions and reducing the amount of decimal places on many dimensions.	New drawings 10191, Radial Truss Assembly and 10192, Truss, Specification Control Drawing.
8	11/18/97	Lem Tingley	Parallelism callouts of .060 are not necessary. What would be more appropriate would be an angular callout of 90 +0 -2 degrees. It is o.k. for the flange to be underbent, but if the flange is overbent the membrane will not sit properly on the flange for welding.	Change was already made to the drawings for the Heliostat facets.
9	11/21/97	Lem Tingley	Item 14, is shown going the wrong direction in the isometric view of drawing #D2-121000. According to drawing #D2-122038, the bevel on the bottom end is facing out of the drawing. To match the isometric, it would need to show a phantom line to represent the bevel facing the opposite direction.	Change has been added to ECR #5
10	11/21/97	Lem Tingley	Updates that were made to the Radial Truss Assembly on 11/4/97 by P. Soliday were not on revision B for the same part. An obsolete CAD file was used to do the revision change. We need to revise D2-121009 rev B to show the changes on the approved drawing for D2-121009 rev A.	Change added to ECR #7
11	12/2/97	Roger Davenport	Increase length of jamb tube to match inner PCS arm. Now the hub is 1.9" too short. This makes the ends of the tubes not match, making the implementation of the arm latch more difficult. (see attached)	
12	12/9/97	Lem Tingley	The leafs on the hinges are not welded all around, but on three sides. A weld on the top of the flange would have interfered with the movement of the hinge. This weld will still be a couple of factors stronger than both the welds on the hinge and the tubing itself. Refer to drawing D2-121000, sheet 5 of 6, note 4.	Added note 4 to drawing 10158
13	12/9/97	Lem Tingley	Vertex, NM, suggests we cap the ends of the tubing on the hub assembly to prevent moisture and corrosion on the inside of the tubing. The capping would be done on all of the tubing except the two pieces where the PCS Arm hinge mounts. I will do some research to see if creating drain holes is necessary.	

ECR #	Date Requested	Requested by	Description of Request	Implementation
14	12/9/97	Lem Tingley	The obround for the PCS arm is in one place, not in 2 places. The drawing (D2-122028) refers to one item, that has a quantity of two. Obround needs to be bigger to accommodate weld on latch pin. See Incident Report #64.	Increased slot to 2.00+/-.010 X 2.00lg slot.
15	12/9/97	Lem Tingley	The lifting lugs exceed the legal shipping height when installed onto the hub assembly. I could not find where the print calls out how to install them. Vertex suggests bolting them on so they can be removed for shipment.	New lug drawing 10162. Bolts shown on assembly drawing 10158.
16	12/9/97	Lem Tingley	A lot of deformation was caused on the hub due to excessive heat from the continuous welds. We should evaluate the structure using stitch welds in some places. I feel that the reduction in stability (if any) will be offset be the improvement in dimensional characteristics and geometry. There will also be a cost reduction in manufacturing. Vertex suggests a 2-6 stitch, although we may need a little more weld (3-6).	Added note 5 to sheet 5 of drawing 10158, 3-6 stitch weld.
17	12/9/97	Lem Tingley	Fabricate the hub in two pieces using the bolt patterns proposed by Vertex. The added cost would be offset by the savings in shipping since the hub will no longer need to be shipped as a wide load. The change may also make the installation of the hub to the drive easier.	
18	12/9/97	Lem Tingley	Update finish callouts for the flanges where the drive mounts. This would entail adding zinc chromate, and leaving the surface free of paint.	Added notes "this area to be free of paint. Finish w/ Zinc Chromate per MIL 8514."
19	12/9/97	Lem Tingley	A 2" Radius is called out on the Joint A sub-assembly, drawing D2-121005. It would be easier to add a note to deburr the corners.	Note 4: Deburr called out. New drawing 10159.
20	12/9/97	Bill Stubstad	Channel width called out in the material list is incorrect. AISI C3 X 5 (.258 WEB) should be C5 X 6.7 (.190 WEB) Channel.	Drawing #10168 released 2/19/98 is to be replaced with drawing #10168 released 3/2/98.
21	12/23/97	Lem Tingley	Blank ECR	
22	1/6/98	Kelly Beninga	Truss mounting blade is too thin. -Excessive side flex under load. -Excessive tolerance between blade and truss.	Increased 'B' plate thk from .375 to .500. New drawing 10159.

ECR #	Date Requested	Requested by	Description of Request	Implementation
23	1/6/98	Kelly Beninga	(1) Stiffener plates on radial truss do not allow truss half to spread to allow ease of installation on hub blade.	New drawing #10191.
			(2) Stiffener plate is not long enough on bottom side. Does not engage blade on hub.	
24	1/6/98	Kelly Beninga	Bolt pattern for mounting radial truss to hub is inadequate for solid mounting.	Holes also added to drawing #10191.
25	1/6/98	Kelly Beninga	(1) Beveled washers are not needed for mounting on inner 5 facets to trusses. Standard 0.5" washers work fine.	Refer to drawing 10031.
			(2) Large OD (fender) washers for attachment of facet mounting studs to facet are too thin. Suggest using 3 of the 3/64" thick or finding thicker washers.	
26	1/6/98	Kelly Beninga	Gusset on truss bracket is too small to provide adequate resistance to twisting. Suggest increasing gusset size by 6 inches in both length and width. More if possible and practical.	Refer to Incident Report #56 for truss bracket redesign
27	1/6/98	Lem Tingley	The Focus Control Assembly exhibited a few problems when installed on the replacement facet for the Rocky Flats dish.	Drawings were redlined. Focus Control Assembly will be redesigned to aid mfg and alignment.
			(1) The spring retainer on item 11 is loose, enabling the spring to be knocked off-center. The spring can also ride up on the spring retainer.	
			(2) The filtered vent, item 10, is too dense, and does not let enough air pass through.	
			(3) The 1/4-20X4-1/2 bolt, item 5, does not have enough thread to allow for a wide enough adjustment range. It should be replaced with a bolt with more thread, or a fully threaded bolt.	
			All three issues may cause failures during installation and/or operation on the NREL dish, and should be addressed prior to installation.	
			Note: The drawing package for the Focus Control Assembly was not completely approved nor was it released for fabrication.	
28	1/16/98	Dave Knapp	Decals do not adhere to acetone cleaned ring adequately. Even with oil free fingers the applicator (usually me) must hold decal for several minutes, still resulting in about 75-90% adhesion.	
30	1/21/98	Roger Davenport	Eliminate one tilt switch on the elevation disconnect. Presently there are two switches, but the range of motion is appropriate for only a single switch, (I.e. 180 deg.)	

ECR #	Date Requested	Requested by	Description of Request	Implementation
32	1/26/98	Mike Taylor	Need assembly drawing of counter weights on PCS arm. Mounted counter weights to PCS Arm using: (see attached) (6) 1/2 X 10" All Thread grade 2 (4) 1/2" Nuts grade 5 (4) 1/2" washers	Counter weight plates added to drawing 10045, along with (6) 1/2-13 X 8", (24) 1/2" nuts and (24) 1/2" washers.
33	1/27/98	Mike Taylor	Need hardware callout for pedestal flange to Flender drive spool piece. Used: 16-3/4-10 X 3" length SHCS plated 16-F436 washers 1 7/16" OD plated	Added to drawing 10001.
34	1/27/98	Mike Taylor	Hydrogen system installation is extremely labor intensive in the field, it took around 8-10 hrs. I would like to request investigation into a more cost effective and efficient method to install. i e., implement drawings to prefabricate the tubing with bends, pre-drill and tap the holes in the structure on weld mounting brackets in the fabrication shop. Possibly evaluate a uni-strut fabricated from angle iron or tubing that can be pre-drilled and tapped to hold all of the hydrogen lines, vacuum tube, electronic cables, etc.	New drawing number 10147, Item 7, unistrut #P3300.
35	1/27/98	Mike Taylor	Need to have assembly drawings of Hydrogen System starting from the bottom of the pedestal to attaching at PCS. -Show length of liner with bends. -Drill and tapped hole locations -Mount/Bracket design for Hydrogen bottle and lines.	Created Hydrogen System Drawing #10208.
36	1/27/98	Mike Taylor	(1) Need drawing of Sun Sensor mounting plate. (2) Need drawing of Sun Sensor location at the end of the outer PCS arm.	See ECR 46
37	1/27/98	Mike Taylor	(1)Need BCS camera mount design to be able to attach and detach without drilling holes on inner arm assembly. (2) Need drawing of BCS camera location. (3) Need entire system layout.	Drawings 10274, 10275, 10276, 10277 and 10282.

ECR #	Date Requested	Requested by	Description of Request	Implementation
38	1/27/98	Mike Taylor	(1) Need to install elevation limit switches in shop on Flender drive. (2) Need to design a slotted bracket to hold switch so easy adjustments can be done in the field. (3) Need to install mercury limit switch in shop on Fender drive. I.e. drill and tap. (4) Need to design a slotted bracket to hold switch so easy adjustment can be done in the field.	Limit switches require further investigation and documentation, see ECR 169.
39	1/27/98	Mike Taylor	(1) Need drawing of lifting method of assembled hub, truss and mirror assembly onto pedestal. (2) Need drawing of lifting method to attach inner and outer PCS arm assembly to hub, truss, mirror, pedestal assembly. Note: Need to drive unit to south/horizon position to release straps. (3) Need drawing of lifting and setup method for attaching inner arm and outer arm during assembly on the ground. (Drawings that show balance points where straps should be mounted will eliminate the guess work during installation, and save time in the field.)	Drawing 10292 is complete.
40	1/27/98	Mike Taylor	Request assembly drawing of BCS to PCS area on arm. Mounted BCS frame to PCS counter weights using the following hardware: (see attached) (4) 3/8 X 5" all thread (12) Fender washer 2.0 X 17/32 ID X 3/64 thick	
41	1/26/98	Mike Taylor	Current process to focus and align mirror facets using the BCS is labor intensive and not cost effective for off-site installation. Request investigation into using 2F or distant light source method. These methods should reduce field time from 3-4 days to 6-8 hours. Note: 3-4 days is sun dependent, where the 6-8 hrs is done at night., and both include install, focus and align.	DLS is currently being used and evaluated
42	1/29/98	Sandra Doty	(1) #9 BAR CHANGED TO #10 BAR (2) Note added to clarify that torsional load dictated the foundation requirements.	New drawing number 10160.

ECR #	Date Requested	Requested by	Description of Request	Implementation
43	2/5/98	Lem Tingley	(1) Plate-shear, arms design currently bolts one the outer arm, and is welded onto the inner arm. This caused fit-up problems during installation due to the tight fit, see incident #67. Request we change the design to bolt the shear arm onto both the inner and outer arms. New drawing #10177. (2) Change bolt pattern on Frame Assembly, Inner/Outer Arm. Remove Item 3 and remove 4 holes in corners. Replace with 6 holes around edges. New drawing #10167.	
44	2/4/98	Larry Burns	Had clearance problems with elevation motor and inner arm cross-bar. Refer to incident #57 Remove item 2, cross-bar, and item 4, gussets. Replaced with 2 diagonal cross bars.	
45	2/6/98	Larry Burns	Changes requested by SFI: (1) Added (2) 8X8 gussets and (4) 5X5 gussets to Inner Arm. (2) Added (4) 5X5 gussets to Outer Arm. (3) Updated dimensions on roller bracket.	
46	2/9/98	Roger Davenport	Move sun sensor to East side of Hub, on top of hexagonal plate. Advantages include: (1) Reducing wiring costs by eliminating the cable to end of the arm and reducing the size of the conduit on the arm. (2) Simplify the adjustment by not having to be at the dish focal spot. (3) Improve reliability because the sun sensor currently heats up when the dish is tracked unfocussed. (4) Improve sun sensor operation because the sensor is currently bathed in reflected solar flux when unfocused. (5) Increase safety because you won't have to be at dish focus to adjust. (6) Provide better protection for device, because it would be protected at night during face-down stow, not at kick-level.	New drawing numbers 10185, Joint C sub-assembly and 10186, Sun Sensor bracket.
47	2/12/98	Bill Stubstad	Material callout was incorrect. Structural Steel per ASTM A 500 B, should be Structural Steel per ASTM A 500 Grade B for Tubing, and ASTM A 36 for Angles and Plates.	
48	2/9/98	Mike Taylor	Add mounting holes for J-boxes, blower and manifold to hub assembly. J-box: Add (8) 0.31 dia. holes to Plate, Torque Tube, new drawing number 10185. Blower: Add (2) 0.44 dia. Holes 6.75" apart to Detail D on drawing 10181. Manifold: Add (2) 0.44 holes 26.50" apart on sheet 4 of 6 of drawing 10158. These holes are to be drilled after the assembly of the hub to ensure 26.50" dimension is held within tolerance.	

ECR #	Date Requested	Requested by	Description of Request	Implementation
49	2/9/98	Scott Davies	(1) Add a .330 hole for latch on drawing #10170. (2) Add a note to drawing #10165 to drill .330 holes in frame before welding to remaining structure.	
50	2/18/98	Roger Davenport	Wrote ECR #34 requesting brackets for Hydrogen System. Write-up did not include or was not transferred from hard written version to include bracket for holding hydrogen bottle on dual flanged pedestal.	
51	2/18/98	Roger Davenport	The PCS shear plates are probably unnecessary and make it harder to align and bolt up the two halves of the PCS Arm, according to Mike. Recommend deleting them after verifying remaining bolts are sufficient. Note: We already changed the shear plates so they would bolt onto both the inner and outer arms to ease installation, see ECR 43. However, we have not done any analysis to see if they are necessary.	
53	2/20/98	Lem Tingley	(1) Alignment spool piece Inner Diameter incorrect on drawing10011. 11.0" ID should be 10.0". (2) Material callout incorrect on drawing 10024. 4 X 4 X .120 should be 4 X 4 X .50.	Please replace drawings 10011 and 10024 released 2/18/98 with drawings 10011 and 10024 released 2/20/98.
54	2/20/98	Don Farchone	Rearranged hole pattern for J-Box mounting holes in order to make them more accessible. Also changed the holes to tapped holes.	Please replace drawing 10185 released 2/18/98 with drawing 10185 released 2/10/98.
60	2/23/98	Roger Davenport	Recommend building an encoder test apparatus (see attached) for go/no-go testing of encoders and encoder sensors. The apparatus would immediately indicate if the LEDs had enough current (but not too much) and would indicate if the sensors were able to drive loads (both conducting and not.) The apparatus would have a socket for component testing as well as a connector for encoder testing.	Assembly by Dave Knapp. (see attached sketch)
62	2/23/98	Roger Davenport	Change encoder design to incorporate the following: (1) Add drain slots to permit egress of water or oil from inside or front or back of unit. (2) Add front and rear seals on sensing wheel. (3) Elongate sensing wheel to eliminate oil/water ingress path along shaft. (4) Extend 0.5" hole for connector to accommodate possible plug-in sensor design in future. (See attached changes marked on Drawing H2-5500)	Drawings have been completed.
63	2/25/98	Mike Taylor	Need to change round slab foundation pad to square configuration per customer on APS foundation. See attached drawing per Sandi Doty.	

ECR #	Date Requested	Requested by	Description of Request	Implementation
64	2/25/98	Mike Taylor	Need mechanical construction/site plàn drawing for Hydrogen and Natural Gas layout at pedestal of dish for APS installation. See Mike Taylor for details on drawing.	Created new site layout drawing with hydrogen and gas lines, ref. Dwg. 10204.
65	2/25/98	Mike Taylor	Need assembly drawing of propane system on dish to include all valves, solenoid valves, swivels, flex lines and lengths, black pipe and lengths and brackets to attach to dish.	
67	2/25/98	Mike Taylor	Mirror mounts on inner mirrors are extremely close to adjacent mirrors, making it very difficult to adjust during alignment of mirror facets. We have discussed the option with the engineering team to adjust the facets from the truss angle iron, but it still may be difficult to adjust the facet.	Facets can be adjusted from the truss.
69	2/6/98	Larry Burns	Added latch notch to Leg-Hub interfaceframe drawing 10170. This makes drawing D2-3154, Modification Inner Arm Tube obsolete.	
70	2/26/98	Mike Taylor	(1) To reduce the cost of the pedestal with flanges on both ends, we loosened the parallelism tolerance from 1/16 to 1/8. This will reduce the cost of fabrication by $100. (2) Added Four tapped holes to mount hydrogen bottle brackets. (Also refer to ECR #35) (3) Moved unistruts (Item 7) up 0.5" to avoid clearance problems with gussetts.	Please replace drawing number 10147 released 2/19/98 with drawing number 10147 released 3/10/98.
71	2/26/98	Mike Taylor	Current design of spool piece does not allow for using washers in counter-bored hole that uses SHCS to attach spool piece to Flender Drive. Currently not using washers, are they required?	Changed C-bore to 1.56 diameter, drawing10193.
72	2/26/98	Mike Taylor	Request a more durable , robust and easy to assemble and disassemble BCS target shroud for field BCS installation.	Defer action until after alignment study.
73	2/26/98	Roger Davenport	Need drawings for blower assembly.	Blower assembly Drawing #10239. Part of vacuum system 10219.
74	2/26/98	Bud Brittingham	Need to update facet drawings to reflect JVP Phase 2 configurations.	
75	2/26/98	Scott Davies	Add (4) 3/8-16 tapped holes to one 1" thick counter weight plate. Add (4) .500 clearance holes in the .5" counterweight plate. These holes would fall in line with each other. The current drawing D2-3250 does not show these holes.	

ECR #	Date Requested	Requested by	Description of Request	Implementation
76	2/26/98	Mike Taylor	Request mounting bracket extension for APS hydrogen bottle installation. This is needed for the dual flange pedestal. See Mike Taylor or Scott Davies for recommendation.	Bracket drawing number 10211
77	2/27/98	Roger Davenport	(1) Standardize drawing frames for A, B, C, D size drawings. (See attached drawing for some suggestions at B-size) (2) Change dimensional tolerance defaults.. I e. .X +/- .05, .XX +/-.005, .XXX +/-.001. Tolerances currently have redundant decimals.	B and D size borders are ready for comments.
78	2/27/98	Mike Taylor	(1) Added note to weld call-out to allow for clearance for bolts, nuts and washers. (2) Channel width called out in the material list was incorrect. AISI C3 X 5 (.258 WEB) should be C5 X 6.7 (.190 WEB) Channel.	Drawing #10168 released 2/19/98 should be replaced with drawing #10168 released 3/3/98.
80	3/2/98	Mike Bailey	Modified 1" O.D. tubes to fit all the way through the 3 X 3 tubing on the Manifold Weldment, drawing 10187. Cut a slot in the middle of the 1" tube 2.75 X .750 to allow the vacuum to flow.	Changed to full thru tube, see drawings 10187, 10188 and 10207
81	3/2/98	Scott Davies	We need to weld a 1.5 X 2 X .25 thk plate under and in line with the plate on the top of the truss. (See redmarked drawing # 10191, sheet 2 of 3)	4.5 X4.5 X .25 thk. Plate added to drawing 10191
89	3/5/98	Mike Taylor	Request use of 5/8" X 8" mirror mounting studs do to the bending from BCS focus and alignment (see IR 90). Also concerned with the length during adjustment in BCS. The install team will install (3) 5/8 X 8" on one inner mirror facet. We need to review change on AutoCAD solid model for fit-up and length.	Implemented on dishes and on dwg 10031.
92	3/11/98	Kelly Beninga	Modify control software to allow automatic transition from solar to gas operation. I suggest transition at nightime stow with an input time for when to stop operation on gas.	Go ahead with inputting start and stop times for Unit 4.
94	3/6/98	Roger Davenport	Consider re-configuration to eliminate need for encoder quadrature. When under auto control, direction can be determined from control program. In local control, outputs from the manual control pendant can be generated to tell the controller the direction. This can be tested with the existing controller and encoders by making only software changes.	

ECR #	Date Requested	Requested by	Description of Request	Implementation
96	3/6/98	Roger Davenport	Need to change stow/unstow logic. With tilt corrections, the movement from horizon to face-down or back may result in azimuth motion, which cannot be allowed to happen once the wheel hits the pedestal. Options include adding logic to inhibit azimuth motion below the horizon, disabling tilt corrections below horizon, and changing stow/unstow to specifically avoid azimuth motions. This problem is made worse near -90 degree elevation, single small elevation movements can result in large azimuth swings when tilt angles are non-zero.	Added separate enables for azimuth and elevation.
97	3/11/98	Russell Forristall	As suggested by Richard Houser, I agree that we investigate adding a higher logic to the high wind indicator. Both Dick and I have noticed the systems stowing unnecessarily during windy conditions. On a windy day the systems may move to stow and back to tracking as much as a half a dozen times. We feel a lot of this could be eliminated by adding a second stow criterion. For example, winds > 15mph for 30 seconds and winds > 20 MPH for 15 seconds.	No funds for Solmat. Do we have this problem on the dish?
98	3/11/98	Russell Forristall	I request that we investigate a different Angled Gear Oil Seal for all of our systems. I have noticed leakage on all the oil seals. This is very apparent on the Albuquerque Heliostat.	We will implement the DC motors - KB
99	3/16/98	Lem Tingley	Added Item 1, Rectangular Washer, to Short and Long Cantilever Truss drawings 10038 and 10036 in order to mount Cross Brace. Redesigned truss webbing and lengthened Short Cantilever to account for Cross Brace.	Complete redesign of Cantilever Truss drawings 10036 and 10038. Eliminated drawings 10037 and 10039.
101	3/18/98	Mike Taylor	Need a full scale template drawing of the anchor bolt pattern on the APS foundation, (multiple sheets to tape together are OK) Drawing will be used by Caliente Construction in Arizona to build metal fixture/template to support anchor bolts when pouring concrete.	
102	3/19/98	Mike Taylor	Added Unistruts to Inner and Outer PCS Arm drawings. (Item 28 on 10165, item 21 on 10166).	Please replace drawings 10165 and 10166 released 2/19/98 with drawings 10165 and 10166 released 3/25/98.
103	3/13/98	Richard Hauser	Suggestions for additions to the Heliostat controller screen. Add the following lines to the controller screen: Cosine loss: (Cosine 1/2 angle of sun position to target position) Reflectivity: (Last measured reflectance) Calculated Total Power: (Area X NIP X Cosine loss X reflectivity) The reflectivity can be entered after the last measured reflectance of the Heliostat. The NIP can be entered whenever needed with date if possible.	No funds to implement. _KB

ECR #	Date Requested	Requested by	Description of Request	Implementation
104	3/13/98	Philip Cuka	Request change in procedure for computer printing to command logs for Heliostats. When both heliostats 1 and 2 are operating it is difficult to identify which heliostat is undergoing automatic position changes (tracking, stow, high wind stow, etc.) under various weather conditions, especially high wind. Reference heliostat command log for 2/26/98 10:31:47 to 2/26/98 10.57:58. Request that a numerical identifier be printed into the command log indicating the heliostat which is changing position. Example: (Heliostat) 1:Automatic transition from tracking to high wind stow.	Single change to output, 4/4/98 - RD.
108	3/20/98	Mike Taylor	Need to mount electrical junction box onto outer arm near PCS area. Identify size of electrical box and pre-drill holes on arm so installation can bolt on.	
110	4/1/98	Roger Davenport	Change mount of sun sensor to allow adjustment. (see attached)	
111	4/4/98	Roger Davenport	(1) Recommend disabling sun sensor tracking when more than 5 degrees from the sun. If the system is far off-sun, the sensors may give spurrious signals due to reflections off adjacent mirrors, or bright objects in the field of view. This would be easy to implement in the control program. (Change implemented 4/4/98.) (2) Change SA, SE, SX so no faults are triggered when position is changed.	Already implemented.
112	4/4/98	Roger Davenport	Changes to user interfaces; Operating Parameters, Main screen, High-wind override, data logs, parameter menus, etc. (See Attached)	See notes on attachment.
114	4/7/98	Russell Forristall	I request we design a simple alignment target on the side of the hub so that we can have a common reference when both orienting the dish on-sun and orienting the distant light source alignment. The target can simply be two parallel plates, one in front of the other with a hole in the front plate and cross hairs on the back plate.	I will ask Russ if he feels this issue is resolved. - Kelly
116	4/7/98	Russell Forristall	While doing the calorimeter testing, we noticed that the area directly below the PCS mounting platform was receiving a lot of heat. There was enough heat in this area to melt our rubber water hoses. To solve this problem I propose we add a heat shield along the first vertical cross supports from the end of the PCS Arm. I further propose that we move the conduit run and PCS controller junction box from the right side of the PCS Arm to the middle.	Shrouds have been designed and implemented.

ECR #	Date Requested	Requested by	Description of Request	Implementation
120	4/8/98	Kelly Beninga	Water is collecting on the edge trim at the bottom edge of the facets. We already have corrosion in this area on the NREL heliostat. We need to either notch the trim at the bottom for drainage, or come up with a new edge trim.	
122	4/9/98	Philip Cuka	Recommend changing date on Incident Report Forms to a year:Julian:Alphabetical (I e. 98:002·AA) Format. Sorting incidents by a chonological system will help keep Incident Reports organized. Currently Reliability Summary printouts are sorted by incident number (which are not in chronological order) keep separate column for calender date. Or change incident numbers to year:julian date:alphabetical (YY:JJJ:AA) for ease of sorting in chronological order.	All Reports are now sorted by Incident Date and Time.
123	4/10/98	Lem Tingley	Created new drawings of the modifications needed to the Outer PCS Arm to provide clearance for the PCS Actuating Shutter. Added modifications to Assembly drawing to show location of angles modified.	New drawings 10237 and 10238 show modifications to angles. Drawing 10166 shows location of modifiactions on Outer Arm.
126	4/14/98	James Sellars	Currently the Performance Data and Weather Data must be manually downloaded by the dish operator. With this arrangement data is lost if the site is unoccupied for more than 2 days or if the operator fails to download the data. My recommendation is to have the dish control interface program automatically download the weather and performance data files on a special time and interval. This change will ensure that no data is lost.	Changes have been implemented.
127	4/16/98	Roger Davenport	(1) "Latitude" is misspelled in Parameter Entry Screen (2) "Unit Not Responding"/"Network Not Responding" messages should reset automatically if system/network come back on line.	Changes have been implemented.
130	4/21/98	James Sellars	In the current configuration, 110 VAC power is cut from the PCS when the dish is in local mode. The PCS uses 110 for the controller, water pump and oil pump. If an encoder fails during solar power production, (or for any other reason we need to switch to local mode during operation), oil pressure, cooling and control is lost on the PCS. In order to avoid this situation I recommend that power is supplied to the PCS at all times, whether in local or auto mode.	The change has been implementd on both systems. Still needs to be documented. - 6/17/98
131	4/21/98	Scott Davies	The STM motor mounting frame has six (6) .875 holes. We use 1/2-13 X 2" bolts to mount the STM engine on our system. This allows the engine to possibly shift back and forth, also the flat washers are pulled in when tightened. (see attached)	Drawing 10253, Bushing, Engine Mounting
134	4/21/98	Scott Davies	Request a drawing of a lifting method for the Flender's Drive. (See attached picture)	Lifting methods drawing #10292

ECR #	Date Requested	Requested by	Description of Request	Implementation
135	4/24/98	Roger Davenport	We would like to recommend that STM install a thermostat in the PCS that would activate the oil and water pumps at a given temperature. They also could be activated in the controls for hybrid operation. This same principle could also be applied to the fans in the Baldor box, which also runs continuously. This change would reduce parasitic power in the system.	Change will be included in future systems.
136	4/22/98	Russell Forristall	I request that we increase the length or change the position of the landing pad for the PCS/Arm wheel. With the dish in the downward stow position, the wheel is right at the end of the landing pad and therefore there is little to no room for the elevation limit and disconnect. Add 10" X 4" X 0.50" thick ASTM A516 Grade 70 to bottom of plate.	Item 8 added to drawing 10147, released 5/4/98.
138	5/1/98	Lem Tingley	(1) Removed alignment lugs, items 1 and 2 on drawing 10065. (2) Increased length of cutout to 14" on drawing 10237. (3) Created cutout on horizontal angle on drawing 10166. Detail shown in drawing 10256. (4) Updated assembly drawing 10166 to show changes.	(1) Replace drawing 10065 released 2/19/98, with drawing 10065 released 5/4/98. (2) Created new drawing 10237, released 5/4/98. (3) Created new drawing 10256, released 5/4/98. Replace drawing 10166 released 3/25/98 with drawing 10166 released 5/4/98.
147	5/7/98	Lem Tingley	(1) Added removable shrouds to the front and sides of the Outer PCS Arm to protect conduits and junction box from focussed sunlight. Need to manufacture shrouds and add installation holes to the Outer PCS Arm. (2) Need to add mounting holes for Junction Box 4 at the end of the Outer PCS Arm.	PCS Shrouds are shown in drawings 10266 and 10267. Locations of mounting holes for shrouds and J-box are shown in 10279 and 10280. Assembly drawings 10045 and 10166 have also been updated. All drawings were released on 5/20/98.
151	5/5/98	Philip Cuka	Request purchase and installation of large plastic owl on top of heliostat to scare away birds perching on heliostat when it is tracking sun. The mirrors were washed on 4/27/98, two days later the upper facets were fowled with excrement.	
153	5/22/98	Duane Gibson	Remove GFI duplex receptacle, add industrial rated switch. Hardwire from switch to control panel 115 VAC power, use 16 gauge stranded wire.	This change has been implemented on both dishes. The scheme is still being revisited.
157	6/3/98	Pat Soliday	Hole layout on sun sensor mounting bracket was changed to make either side of angle interchangable. This requires a change in the hole pattern on hub drawing #10158 and #10184.	
166	5/28/98	Barry Butler	Suggest adding 'umbrella struts' to increase rigidity of structure.	

ECR #	Date Requested	Requested by	Description of Request	Implementation
176	6/15/98	Lem Tingley	Changed out breather valve on focus control to adjustable breather port.	
196	8/30/98	Albert Nunez	The fault status audible alarms are a big move in the right direction. Voice chips or audio chips that actually say which fault has occurred would be even better. Also, verbal notification of operational status changes would also be a great addition for the operators sake. One that should have a count up/down would be focus/defocus. Fully defocussed, 1,2,3,4,5, fully foccussed, 5,4,3,2,1, etc.	
203	9/29/98	Roger Davenport	Add time delay before defocusing because of low insolation. This would avoid cycling when partially cloudy.	Version d981008.c
212	1/20/99	Roger Davenport	Add "Scram" contactor to turn off 120VAC power to blower and motors.	Implemented on APS-East dish and SRP Dish. Will be retrofitted to APS-West dish and NREL dish when controls are upgraded to Mod. 3
213	2/2/99	Roger Davenport	Add disconnects for both motor windings of the drive motors. Currently, only the run windings are disconnected by the over-travel disconnect system, but as the motor slows, the start windings become engaged and continue motor rotation. This could be implemented as follows: Azimuth: add a parallel disconnect cable like the existing one, that is connected to the start windings. The start winding disconnect should be made slightly shorter than the run winding. Elevation: Add a second pull switch next to the existing one, to switch the start windings. Connect both switches with a single cable looped around the throttle cable eye.	Implemented on APS-West dish. No problems.
215	3/12/99	Roger Davenport	Updates to User Interface: 1. Alarm resets when you open the "data logs" screen 2. The auto-download doesn't start a new file at midnite 3. The status lights need to be re-arranged on the console and the Field view so they light up in order as the system comes on line 4. Blank lines are being inserted in the performance data file each time data is appended.	All these items have been addressed, as well as starting a new file just after the midnite download and making all downloads on the hour after the first day. Also, the system functions properly with two dishes on-line.
216	4/1/99	Roger Davenport	Replace pull-switches with weatherized quick-disconnects on azimuth and elevation overtravel limit circuits. Also, add disconnects to both run and start windings of each axis.	Implemented on all systems

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Open Engineering Change Request Summary

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
31	1/20/98	Roger Davenport	Add counters for hours of operation; hours on-sun; and hours focussed to dish controller program.	Awaiting Implementation	Roger Davenport	3/3/98
52	2/19/98	Roger Davenport	Replace lower cross pieces on arm with unistrut, so cables/conduit/pipes can be directly connected. Only the perpendicular cross pieces would need to be replaced. -These are items (2) on drawing 10166, Outer Arm, 9 each. -This could also be done with items (7) and (19) on drawing 10165, Inner Arm.	Awaiting Evaluation	Jeff Sandubrae	4/1/98
66	2/25/98	Mike Taylor	Had problem with threading nuts on 1/2-13 X 6" mirror mounting studs. Thread end of stud was not prepared properly to thread nut on end galvanizing was too thick on 35% of the studs. We need to have a specification on the stud.	Awaiting Evaluation	Lem Tingley	4/15/98
79	3/2/98	Russell Forristall	I request that we investigate a different controller cable plug connector. The plastic plug connectors that we are currently using strip out easily and are difficult to get connected properly.	Awaiting Evaluation	Roger Davenport	3/20/98
82	3/3/98	Barry Butler	Design an Advanced Drive capable of meeting or exceeding system specifications.	Awaiting Evaluation	Jeff Sandubrae	7/20/98
83	3/3/98	Barry Butler	Create 'Generation 2' controls that are reliable and easily manufacturable.	Awaiting Evaluation	Roger Davenport	12/31/98
84	3/3/98	Barry Butler	Design wiring harness for electrical system.	Awaiting Evaluation	Roger Davenport	12/31/98
85	3/3/98	Barry Butler	Design tubular PCS support truss that would eliminate external conduits.	Awaiting Disposition	Management	12/14/99
86	3/3/98	Barry Butler	Research possibility of putting controls, conduits and lines inside of the pedestal.	Awaiting Disposition	Management	12/14/99
87	3/3/98	Barry Butler	Research changing facet ring and membrane material to 316L Stainless Steel.	Awaiting Evaluation	Bud Brittingham	12/31/98
88	3/3/98	Barry Butler	Research alternatives and improvements to our glass to stainless steel adhesive.	Awaiting Evaluation	Bud Brittingham	12/31/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
95	3/6/98	Roger Davenport	Recommend adding a limit switch sensor to the azimuth drive to detect stow position. Presently the only indication of being at the stow azimuth position is based on the calculated position of the dish. There is a danger of getting off in azimuth and going to stow off the stow landing area on the pedestal. This would also simplify a less-computer-controlled controller (e.g. PAL). It would add some complexity and parts to the wiring system.	Awaiting Implementation	Roger Davenport	11/1/98
100	3/18/98	Roger Davenport	Add a drawing of Generic Electrical Interface for dish, per atteched. Add specific drawings for each site to document as-built installations. Note: PMC should be able to supply the drawing designated "sketch 2."	Awaiting Implementation	Pat Soliday	4/15/98
105	3/19/98	Kelly Beninga	We need formal drawings of the control system and data acquisition system in accordance with our quality manual drawing policies and numbering system.	Awaiting Implementation	Roger Davenport	4/30/98
115	4/7/98	Russell Forristall	I request that we relocate and reattach the conduit loops and hydrogen loop so that they form cleaner looking loops about the torque tube. Currently, these runs have broken loose from their brackets and look as if they were hastily installed.	Awaiting Evaluation	Pat Soliday	4/20/98
119	4/8/98	Kelly Beninga	Please provide an evaluation of the pros and cons of switching to DC drive motors, call a meeting to discuss your reccomendation, and provide a schedule as to which dish unit will have any change implemented.	Awaiting Evaluation	Roger Davenport	4/30/98
121	4/9/98	Roger Davenport	Water accumulates in the truss brackets and at the bottom joint of the PCS Arm. The PCS Arm joint drains when you come out of stow, but the truss bracket top portion will not drain until stow, and some will not drain completely.	Awaiting Evaluation	Pat Soliday	8/1/98
124	4/10/98	Lem Tingley	Add Hydrogen interface tube to PCS to Hydrogen Installation Drawing 10208, per attached.	Awaiting Implementation	Pat Soliday	4/17/98
125	4/10/98	Lem Tingley	Create new drawing of PCS lifting method per attached.	Awaiting Evaluation	Pat Soliday	7/1/98
128	4/17/98	Roger Davenport	Propose to add connectors to little PLC and ADC-4 boards to simplify changing them out. They would connect to the "WAGO connectors on the boards to provide a plug-in/plug-out system. (See attached)	Awaiting Implementation	Roger Davenport	5/4/98
129	4/17/98	Roger Davenport	Add a test/calibration section to the control boards, with DIP switches that allow each input to be forced. This would help with initial system installation and checkout, and with troubleshooting. For example, during installation, the PCS Ready input could be forced on so the dish could be tracked before the PCS was installed. Besides forcing digital inputs, switches could also put known voltages onto analog inputs for calibration.	Awaiting Implementation	Roger Davenport	5/4/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
132	4/20/98	Scott Davies	Tabs on the shim plates were too small to hold them onto the spool pieces. Request we make them larger.	Awaiting Evaluation	Pat Soliday	5/30/98
133	4/20/98	Scott Davies	The welds on the alignment pins on the PCS Inner Arm are interfering with the slot on the hub. Request we evaluate reduceing or relocating the weld.	Awaiting Evaluation	Lem Tingley	5/30/98
137	4/22/98	Russell Forristall	I request that a limit switch indicator be added to the JVP Console screen so that if a limit switch is actuated there is some type of indication on the screen to show this. The indicator would both help during the system checkout and help during troubleshooting.	Awaiting Implementation	Roger Davenport	11/15/98
139	3/13/98	Lem Tingley	Comments from Vertex regarding problems with Hub fabrication: (1) Drawing 10158, sheet 4, 2.7" dimension doesn't fit up. Will be around 3.6". (2) The location of the mounting holes for the blower shown in detail D of drawing 10181 isn't clear. Add orientation to drawing 10158, sheet 3.	Awaiting Implementation	Pat Soliday	4/15/98
140	5/11/98	Lem Tingley	Recommend moving location of hydrogen lines to the bottom of the PCS where the other gas and electrical lines are located, rather than the side. This would eliminate the need to run an extension around the side of the PCS.	Awaiting Evaluation	STM	7/1/98
141	5/11/98	Lem Tingley	Recommend changing PCS mounting holes to 9/16 instead of 7/8. This would eliminate the need for any bushings for 1/2" hardware. We are unable to increase the size of the holes on the Outer PCS Arm due to clearance problems with the 3" angles.	Awaiting Evaluation	STM	7/1/98
142	4/16/98	Mike Taylor	The Unistrut closest to the top of the pedestal interferes with the impact wrench. Would like to move this unistrut down 12" for future production.	Awaiting Implementation	Pat Soliday	7/15/98
143	4/20/98	Mike Taylor	Request a new method for leveling the hub prior to installing the truss assembly. The current method using leveling blocks is time consuming.	Awaiting Evaluation	Scott Davies	7/15/98
144	4/20/98	Mike Taylor	Add location of the Hydrogen warning sign to the installation drawings. Also add tapped holes on the system for quick mounting. Note: We can either mount the sign directly on the pedestal or onto the front of the Baldor Box.	Awaiting Evaluation	Pat Soliday	5/20/98
145	5/12/98	Roger Davenport	(1) Suggest eliminating flex conduit from JB2 junction box to bottom of PCS Arm elbow. The two cables that run in the conduit are exterior cables anyway, so they don't need additional protection. They still need to run in the rigid conduit out the outer half of the arm for protection from the sun. (2) Suggest reducing 120V power conduit running from JB3 to the PCS from 1" to 1/2". There are only three #12 wires in the conduit. Smaller conduit would be easier to route, lighter and less expensive.	Awaiting Implementation	Roger Davenport	5/29/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
148	5/8/98	Lem Tingley	Need to protect actuating shutter from focussed sunlight. We temporarily wrapped components with kao-wool and aluminum foil.	Awaiting Evaluation	Lem Tingley	5/20/98
149	5/15/98	James Sellars	The PCS is currently supplied hydrogen from a bottle which is located at the base of the pedestal. During normal operation the PCS may require a coldfill at the beginning of operation and a couple of hotfills during the course of the day. Coldfills and hotfills are controlled automatically by the PCS, but require a constant supply of hydrogen to the PCS. In order to meet the requirements of the PCS for cold and hot fills while maintaining safety I feel that there are three issues that should be addressed: (1) Leakage in the stainless line/swagelock fitting run from the hydrogen bottle to the PCS. (2) A solenoid valve located at the hydrogen bottle. (3) A hydrogen compressor or bottles with higher pressure so that hot fills are possible. (Currently we get hydrogen from general Air and the bottles start out with around 12.5 Mpa.)	Awaiting Evaluation	Roger Davenport	5/28/98
150	5/18/98	Kelly Beninga	We need to test the leak rate in the Hydrogen line from our bottle to the PCS. This line should remain pressurized during normal operation once we start the 750 hour test, so we can use the PCS automatic refill mode. We also need to test the PCS automatic refill. NREL won't allow a manual refill during the 750 hour test.	Awaiting Evaluation	Russell Forristall	5/22/98
152	5/11/98	Roger Davenport	Suggest adding a guard on the azimuth geardrive to protect cables from the rotating shaft extending out from the angle geardrive, (see attached). There are orientations in which the cables/flexhoses could be damaged.	Awaiting Implementation	Pat Soliday	7/15/98
154	5/22/98	Duane Gibson	Add (2) 220 Ohm, 1/8 Watt, 5% or less Resistors from +485 to -485 channel 0 and from +485 to -485 channel 1. Needed to correct Xy bias 485 bus.	Awaiting Implementation	Duane Gibson	7/10/98
155	5/22/98	Duane Gibson	Add diode (IN5402 or equivelent) across coils of focus, elevation and azimuth relays. Reduces inductive spike to PLC. Probably source of failure on PLC relay drivers. (See attached)	Awaiting Implementation	Duane Gibson	7/1/98
156	6/1/98	Roger Davenport	Cut out material from mounting bracket to improve access. (See attached sketch.) presently, you can't get a wrench on the inner bolt; it can only be reached with a long socket.	Awaiting Implementation	Roger Davenport	7/10/98
158	6/4/98	Roger Davenport	Eliminate frequency-to-voltage circuitry and display of wind speed in network interface. The speed is measured by the little PLC from the pulses themselves and displayed on the user interface. Also, there is a parameter in the network interface program for the high wind stow value, so the manual knob is not needed. The little PLC can turn on the light/audible alarm, it has plenty of unused outputs. This would simplify the network board significantly. The board is also more accurate than the analog system. (See attached)	Awaiting Implementation	Roger Davenport	7/20/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
159	6/5/98	Roger Davenport	(1) Run separate wires to each motor fuse and focus blower fuse. Now all current is carried by single 16AWG wires from the terminal strip. (2) Add diodes at relay coils to eliminate back surges. (3) Move fuses for motors to upstream of relays. Make them FRN-R-10 fuses. (4) Identify wire colors: (see attached list). (5) Add ground for -24 V DC. (6) Identify terminal strips and terminals (7) Change "P" designation for receptacles to "J". (see attached schematic).	Awaiting Evaluation	Duane Gibson	7/1/98
160	6/5/98	Roger Davenport	(1) Make separate wires for power to each motor. Now, all current is through a single 16 gauge wire up to the fuses. (2) Identify wire colors: (see attached list) (3) Move RS-485 network connection to P2, pins 13 and 14 to match dish. (4) Change receptacle designation from "P" to "J". (5) Identify terminal strip and receptacles (6) Eliminate terminal strip 2 (7) Add diodes across relay terminals (See attached schematics)	Awaiting Evaluation	Duane Gibson	7/1/98
161	6/12/98	Roger Davenport	Put receptacles on bottom of drive junction box (JB1) and connectors on cables. This will: -Save hours during installation. -Allow use of manual control box for drive movement before cables are attached. -Allow testing of drives in the shop using a manual control box.	Awaiting Implementation	Roger Davenport	7/10/98
162	6/15/98	Mike Taylor	Request adding a second hydrogen bracket and bottle to the system. One would be used for engine hot fills, and when the pressure gets too low, it would be moved and used for engine cold fills. This would conserve the hydrogen that would be lost due to the pressure requirements for hot fills.	Awaiting Evaluation	Lem Tingley	8/1/98
163	6/15/98	Mike Taylor	Need interface drawings of conduit runs into Baldor box, or future power box. (see attached pictures)	Awaiting Evaluation	Roger Davenport	7/31/98
164	6/15/98	Mike Taylor	Disconnect for 480 Volt on Baldor/alternate power box. Disconnect in the dish control box.	Awaiting Evaluation	Duane Gibson	7/13/98
165	6/15/98	Mike Taylor	Need method to prevent conduits from interfering with azimuth motors and hub tubing where arm attaches. Suggest covering azimuth and elevation motor with a cutout to see rotation of shaft and use springs to hold conduits on place. Need to remove stresses from JB2 and JB3. (see attached pictures)	Awaiting Evaluation	Duane Gibson	7/13/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
167	6/15/98	Mike Taylor	Need a test procedure to check full range of motion of the dish.	Awaiting Evaluation	Russell Forristall	7/31/98
168	6/15/98	Mike Taylor	Need pre-drilled and tapped holes in the hub for hydrogen lines. (See attached pictures)	Awaiting Implementation	Pat Soliday	7/15/98
169	6/15/98	Mike Taylor	Need to review primary and secondary limits for azimuth and elevation. If we had a more reliable primary limit, we may not need a secondary.	Awaiting Evaluation	Russell Forristall	7/15/98
170	6/15/98	Mike Taylor	Request written installation procedures. I will create an outline prior to the APS install and update the procedures and add photos during the installation.	Awaiting Evaluation	Scott Davies	7/31/98
171	6/15/98	Mike Taylor	Need drawing for connecting underground conduit to Baldor/alternate power box on pedestal.	Awaiting Evaluation	Duane Gibson	7/17/98
172	6/15/98	Mike Taylor	Need grouting procedure and drawing for pedestal installation. -Need styrofoam plug to prevent grout from moving in the center of the pedestal. -Drain tube -Cement required.	Awaiting Implementation	Pat Soliday	7/30/98
173	6/15/98	Mike Taylor	Need bi-directional electrical power meter to read both parasitic power and power output at grid.	Awaiting Implementation	Russell Forristall	7/10/98
174	6/15/98	Mike Taylor	Need to identify the spare parts that should be included in installations.	Awaiting Evaluation	Roger Davenport	7/30/98
175	6/15/98	Mike Taylor	Need to adjust bleeder valve in manifold prior to installation.	Awaiting Disposition	Management	12/14/99
177	6/15/98	Mike Taylor	When grid connection is severed, where does the power from the generator go? Do we need a means to dissipate the residual power from the generator?	Awaiting Evaluation	Duane Gibson	7/17/98
178	6/15/98	Mike Taylor	Is a secondary power source required for engine auxillaries when grid is shut off, so that the PCS cooling system and oil pumps continue to operate?	Awaiting Evaluation	Duane Gibson	7/17/98
179	6/15/98	Mike Taylor	Need to identify the holes in the junction boxes.	Awaiting Evaluation	Duane Gibson	7/17/98
180	6/15/98	Mike Taylor	Need to paint conduits white at the end of PCS Arm.	Awaiting Implementation	Pat Soliday	7/30/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
181	6/15/98	Mike Taylor	Need medal or plastic cover for hydrogen tank regulator.	Awaiting Evaluation	Pat Soliday	7/15/98
182	6/16/98	Russell Forristall	I request that the dish control software be modified so that there is a separate tolerance setting for the stow position. The stow tolerance and on-sun tolerance are currently the same parameter; therefore, if the on-sun tolerance is changed during tracking or debuging, it is up to the operator to change the tolerance back to a safe value before allowing the system to stow. For example, as experienced during the D.C. install, the tolerance during tracking was changed to five so that the blower would remain on -- due to tracking errors -- ,if this tolerance had not been changed back to a smaller value, the dish would have stowed within a + or - 5 degrees from the actual stow position. This potential problem, if not corrected, could someday cause structural damage.	Awaiting Evaluation	Roger Davenport	7/31/98
184	6/16/98	Russell Forristall	I request that we modify the dish controls so that all the system clocks are automatically synchronized each day.	Awaiting Evaluation	Roger Davenport	7/31/98
185	6/16/98	Russell Forristall	I request that we implement a weather station package for the D.C. dish. We will not be able to compile any performance data without atleast an accurate NIP.	Awaiting Evaluation	Russell Forristall	7/1/98
186	6/16/98	Russell Forristall	I request that a new manual control pendant be designed and shipped to the D.C. dish. The pendant that is currently on-site in D.C. was modified on location with four toggle switches, two switches for the azimuth motor and two switches for the elevation motor. There is a separate switch for the stator and rotor for each motor. Therefore if both the stator and rotor switches are not operated together, the motor would eventually burn up. Furthermore, the existing manual control pendant has no controls for manual PCS operation.	Awaiting Evaluation	Roger Davenport	7/1/98
187	6/16/98	Russell Forristall	I request that the azimuth disconnect be shortened so that it actuates before any cables or hoses can be damaged. I also request that the elevation disconnect be evaluated and installed on the D.C. dish.	Awaiting Evaluation	Duane Gibson	7/17/98
188	6/16/98	Russell Forristall	I request that a blower on indicator be added to the controls logic. Current there is no positive way of knowing if the blower is on without going out to the pedestal and listening for the blower noise. In some cases, as in D.C. where we had a lot of air traffic, the blower could not be heard.	Awaiting Evaluation	Roger Davenport	7/31/98
190	6/1/98	Stefan Johansso	Request we update the control software to stay focussed during intermittent cloudy periods. Due to the length of time to focus, we will loose performance during partly cloudy conditions.	Awaiting Evaluation	Roger Davenport	8/1/98
191	6/18/98	Roger Davenport	Re-design sun sensor circuitry: -Eliminate offset with flux level -Filter and buffer signals at sensors and at control box	Awaiting Implementation	Duane Gibson	7/15/98
192	6/18/98	Roger Davenport	Place sun ref. Sensor in collimating tube?	Awaiting Implementation	Duane Gibson	7/15/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
193	6/25/98	Mike Taylor	Need design and schematic for remaining Baldor unit out of Power box and installing on West side of pedestal on Mesa/NREL dish.	Awaiting Evaluation	Roger Davenport	9/1/98
194	6/25/98	Mike Taylor	Need tensioning procedure for umbrella struts after installation of NREL unit.	Awaiting Disposition	Management	12/14/99
195	7/21/98	Roger Davenport	Modify Visual Basic program so times get set properly in dish and network controllers upon synchronization request. Now, the ten digit appears to be always set to "0" in the minutes value sent to the dish controller. E.g. "10:42:16" would come out as "10:02:16".	Awaiting Evaluation	Pat Soliday	7/31/98
197	8/30/98	Albert Nunez	An umbrella should be fabricated and added to the open end (top) of motor to minimize rain, sonw and ice build up in motor workings. (See attached sketch.) The reason for this request is that water came out of motor that was replaced yesterday, do not know if this was a contributor to its premature failure or the elevation relay sticking but am sure water and electricity don't mix.	Awaiting Evaluation	Roger Davenport	10/31/98
198	9/4/98	Roger Davenport	Reverse default direction for elevation relay. Change so relay must be energized to go down. This way, if relay sticks and doesn't energize, the system can go up to the upward limit in any orientation without damage. This is a redundant change to the software change that watches the direction of motion and faults if the motor is going the wrong way.	Awaiting Evaluation	Roger Davenport	9/1/98
199	9/10/98	Roger Davenport	Change contactor in grip protection, specify as Min. 40 HP. At NREL dish, it is now a GE CL04A310M, rated 22 HP @ 440VAC.	Awaiting Implementation	Roger Davenport	9/11/98
200	6/30/98	Albert Nunez	When installing new inverter, noted the following errors on sketches: Cable: c 10- Power Meter Terminals: 1 Black/Red Black/White 2 Red (not White) 3 White (not Red) BB (Baldor Box) - (Power Meter) terminal 5 = H (not N) & 6 = N (not H)	Awaiting Evaluation	Roger Davenport	10/8/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
201	9/24/98	Roger Davenport	Change reference sensor to be Li-COR pyranometer sensor. The present reference sensor output is highly temperature dependent, so it will vary from winter to summer and in the course of a day as it heats and cools. The Li-COR systems are good to +/-5% compared to lab equipment (Eppley PSP), and routinely calibrate to +/-3%. They are good to 0.15% per deg. C. E.g. -40 to 60 deg. C, 15% variation, and <2% per year drift. This would solve the temperature variation and give us a data acquisition quality sensor for the dish insolation so we wouldn't need one on the data acquisition system. The change will involve physical changes to the sun sensor and collimating tube, and electrical changes to the amplifier in the sun sensor and network interface (to delete the NIP sensor). See attached redline of drawing 10321.	Awaiting Implementation	Roger Davenport	10/15/98
202	9/28/98	Roger Davenport	Add defocus valve to focus valves: (see attached sketch)	Awaiting Evaluation	Roger Davenport	10/31/98
204	9/30/98	Kelly Beninga	We need an accurate readout of the system power and solar insolation in our control room. This will require that we either correct STM's readout or find a way to display power output from our own meter. I would prefer to have an independent reading apart from STM. We need to get the accurate DNI sensor on the dish and display the output in the control room. I know Roger is working on this. However, I don't understand how we will know if we have enough insolation to go on sun with our DNI sensor mounted to the dish.	Awaiting Evaluation	Roger Davenport	10/15/98
205	10/2/98	Roger Davenport	As currently arranged, there is no easy way to kill power to the PCS. If there were an electrical problem, you would have to open the power cabinet and turn off the UPS. I recommend putting in a switch for the UPS where it is accessible. This is even more important if we put the UPS on the PCS Arm.	Awaiting Evaluation	Roger Davenport	10/30/98
206	10/7/98	Russell E. Forris	In response to Barry's suggestion, I request that we install two more ventalation vents in the front of the Baldor controller box so that they are located just in front of the Baldor cooling fans. Once the vents are in place there should be proper cooling air flow through the front of the Baldor controller box into the Baldor controller itself and out the ventalation vents on the sides of the Baldor controller box.	Awaiting Evaluation	Russ/Bud	10/15/98
207	10/7/98	Russell E. Forris	After close inspection of the pattern of the solar flux as the dish comes into focus, I have come to the conclusion that the facets are over focusing. It appears that the flux pattern goes through a minimum profile and then begins to flare. I am convinced that we could reduce the flux spillage and increase the PCS output by reducing the focus on all the facets. The proper procedure for doing this would be to remove the PCS and reinstall the BCS equipment. With the BCS equipment installed we would need to set individual focuses by visually minimizing the flux pattern for each facet.	Awaiting Evaluation	Lem Tingley	10/20/98

ECR #	Date Requested	Requested by	Description of Request	Status	Responsibility	Due Date
208	10/9/98	Kelly Beninga	Create new radial truss drawings for the two keyhole trusses. Add 1/8 in X 4 in steel plate to top and bottom of trusses as shown on attached redline drawing.	Awaiting Implementation	Pat Soliday	10/16/98
210	10/16/98	Roger Davenport	I suggest that we rearrange the status buttons in the Visual Basic user interface: (see attached)	Awaiting Disposition	Management	12/14/99
211	1/20/99	Roger Davenport	Shake-and-bake testing of control board/components to verify weather-resistance.	Awaiting Disposition	Management	12/14/99
214	2/16/99	Barry Butler	1. Reverse direction of focus control valve. This will allow over-focus to compress spring, and upon pull-off of membrane during defocus, the pull will be exerted against a hard stop, improving the strength. 2. Add a vent valve that opens under force of over-focus.	Awaiting Evaluation	Russell Forristall	9/30/99
217	2/1/99	Roger Davenport	1. Existing focus valve has unknown leakage and potential temperature sensitivity due to clearance between the poppet and bushing and use of a steel adjusting screw instead of aluminum. 2. Re-design focus valve to actuate directly by having the membrane close off an opening on the top of the valve.	Awaiting Evaluation		9/30/99
218	4/1/99	Roger Davenport	Modify arm latches to reduce side play and allow adjustment. Also, eliminate problem of sticking of latches on inside of hub tube by grinding off corner at inside of latch.	Awaiting Evaluation		4/5/99
219	6/22/99	Roger Davenport	Move OSI power meter input from PCS controller to dish controller. The dish controller already accepts a 4-20 mA signal from the current sensor, so it could accept the signal directly with only recalibration needed. This would have the following advantages: 1. The power displayed on the operator display would be correct. 2. This would increase the effectiveness of peak power tracking calibration. Currently, the "power" measurement used by the dish is not very accurate, especially at low powers. 3. Data reduction would be simplified, since we would not need to process the 10-second data from the engine into 5-minute data for comparison with other dish data, or 10-minute data for use with the STAR direct normal data. 4. Another available analog channel on the dish control board could be used for power factor measurement, too. 5. This would allow better decisions regarding focus on/off since the true power output would be known to the dish controller. So, the dish controller could turn off focus when the net power became negative, instead of at an arbitrary insolation level. 6. This would eliminate one 4-conductor cable from the pedestal to the end of the PCS arm. 7. This would satisfy the SRP requirement for data acquisition since they could see actual kW and power factor on the operator screen, and they would be logged along with other dish data.	Awaiting Evaluation	Roger Davenport	6/29/99

Appendix F:
Cumulative Performance of the APS West Dish/Stirling System

Cumulative Performance Summary - APS West Dish

through Oct 1999

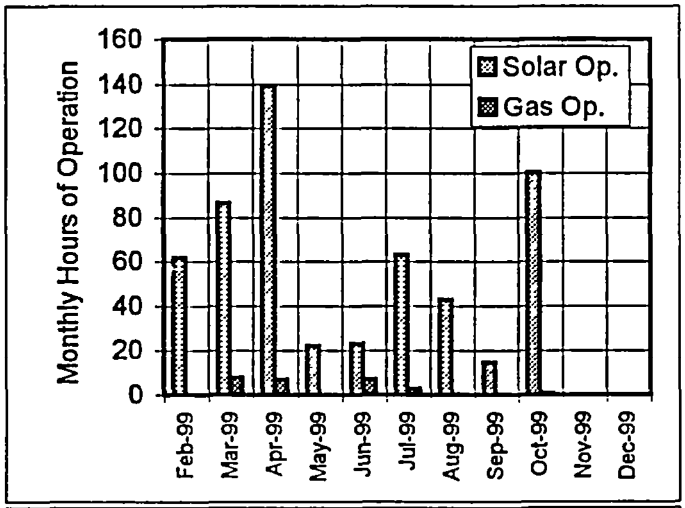
System Records:

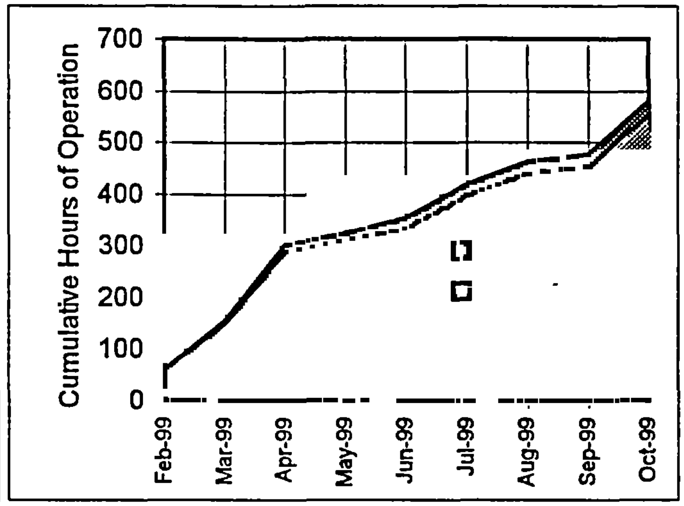
21.6 kW Peak Power Delivered
27% Peak Instantaneous Efficiency
56% Monthly Solar Utilization
1,656 kWh Monthly Solar Energy Delivery
159 kWh Monthly Gas Energy Delivery
139.4 hours Monthly Solar Operation
7.7 hours Monthly Gas Operation

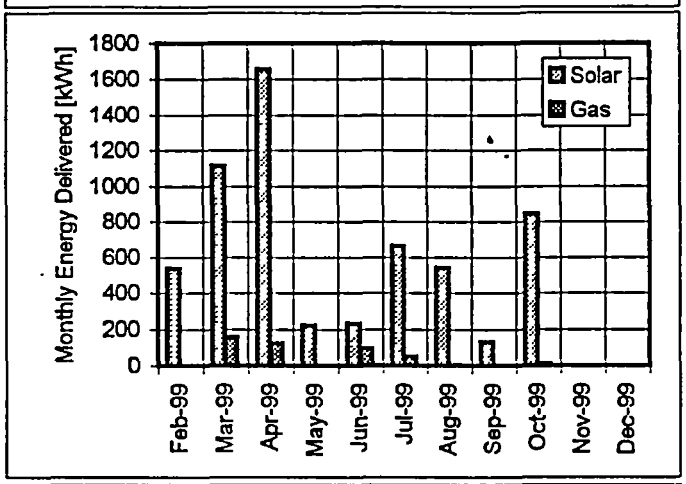
Totals:

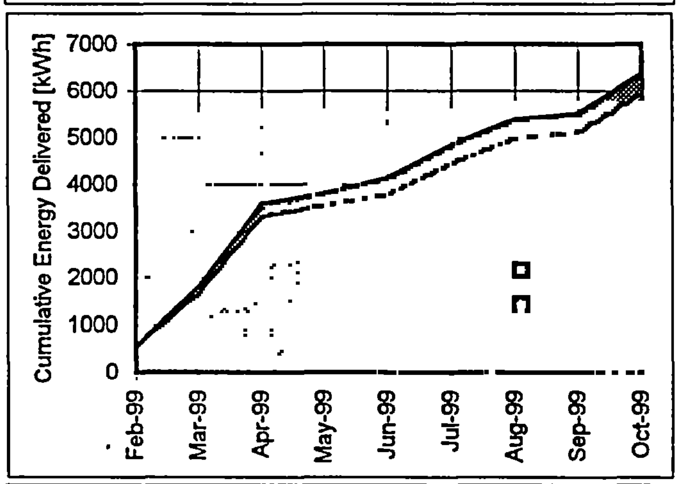
553 Hours of Solar Operation
26 Hours of Gas Operation
580 Hours of System Operation

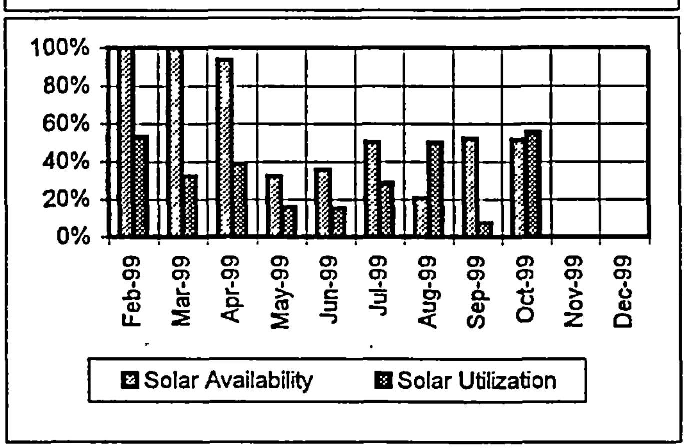
5,942 kWh Solar
439 kWh Gas
6,381 kWh Delivered by System

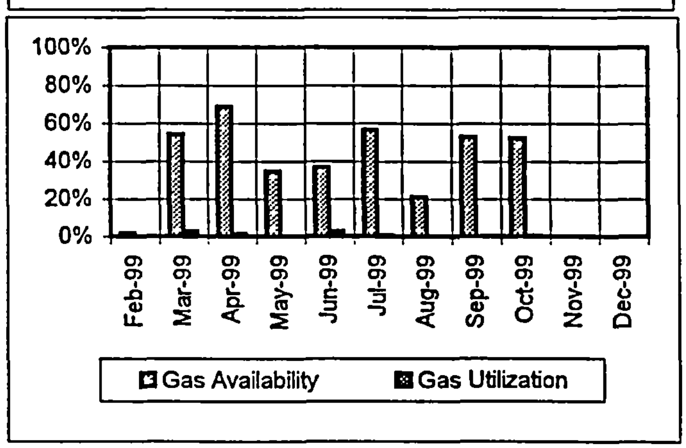












APS-West Dish Cumulative Performance Summary

Monthly Data:

	Total Hours Month	Daylight	Solar Op.	Gas Op	Solar Down	Gas Down	System Records: Power	Efficiency	Energy [kWh]: Solar	Gas	Monthly Availability/Utilization Solar Availability	Solar Utilization	Gas Availability	Gas Utilization	
Feb-99	228.8	116	61.8	0.0	0.0	225.0	20.3	0%	539	0	100%	53%	2%	0%	
Mar-99	558.4	267	86.5	7.7	0.0	255.5	20.4	21%	1116	159	100%	32%	54%	3%	
Apr-99	681.7	384	139.4	7.1	25.3	213.6	21.6	27%	1656	122	93%	39%	69%	2%	
May-99	744.0	427	22.0	0.0	288.9	485.6	18.5	18%	221	0	32%	16%	35%	0%	
Jun-99	720.0	427	23.0	7.1	275.5	453.0	19.0	16%	230	94	35%	15%	37%	3%	1.11447 Factor to correct to El Meter
Jul-99	744.0	433	63.1	3.0	215.3	324.0	16.6	17%	664	50	50%	29%	56%	1%	
Aug-99	744.0	412	42.9	0.2	326.7	588.5	17.9	17%	543	2	21%	50%	21%	0%	
Sep-99	720.0	370	14.5	0.2	177.2	339.0	15.4	14%	129	1	52%	8%	53%	0%	
Oct-99	744.0	350	100.2	0.9	169.8	354.5	18.7	18%	844	10	52%	56%	52%	0%	
Nov-99	720.0	314													
Dec-99	744.0	312													
Maximums:			139.4	7.7			21.6	27%	1656	159	100%	56%	69%	3%	

Cumulative Values:

	Total Hours Date	Daylight	Solar Op.	Gas Op.	Solar Down	Gas Down	System Records: Power	Efficiency	Energy [kWh] Solar	Gas	Cumulative Availability/Utilization Solar Avail	Solar Util	Gas Avail	Gas Util
Feb-99	228.8	115.9	61.8	0.0	0.0	225.0	20.3	0%	539	0	100%	53%	2%	0%
Mar-99	787.2	383.4	148.3	7.7	0.0	480.5	20.4	21%	1655	159	100%	39%	39%	3%
Apr-99	1468.9	767.6	287.7	14.9	25.3	694.1	21.6	27%	3310	281	97%	39%	53%	2%
May-99	2212.9	1194.6	309.8	14.9	314.2	1179.6	21.6	27%	3532	281	74%	35%	47%	1%
Jun-99	2932.9	1621.6	332.8	21.9	589.7	1632.6	21.6	27%	3762	375	64%	32%	44%	2%
Jul-99	3676.9	2054.6	395.8	25.0	805.1	1956.6	21.6	27%	4426	426	61%	32%	47%	1%
Aug-99	4420.9	2466.9	438.7	25.2	1131.7	2545.1	21.6	27%	4969	428	54%	33%	42%	1%
Sep-99	5140.9	2836.7	453.2	25.4	1309.0	2884.1	21.6	27%	5098	429	54%	30%	44%	1%
Oct-99	5884.9	3187.0	553.4	26.3	1478.8	3238.6	21.6	27%	5942	439	54%	32%	45%	1%
Nov-99														
Dec-99														
Totals:	5884.9	3187.0	553.4	26.3	1478.8	3238.6			5941.7	439.2				

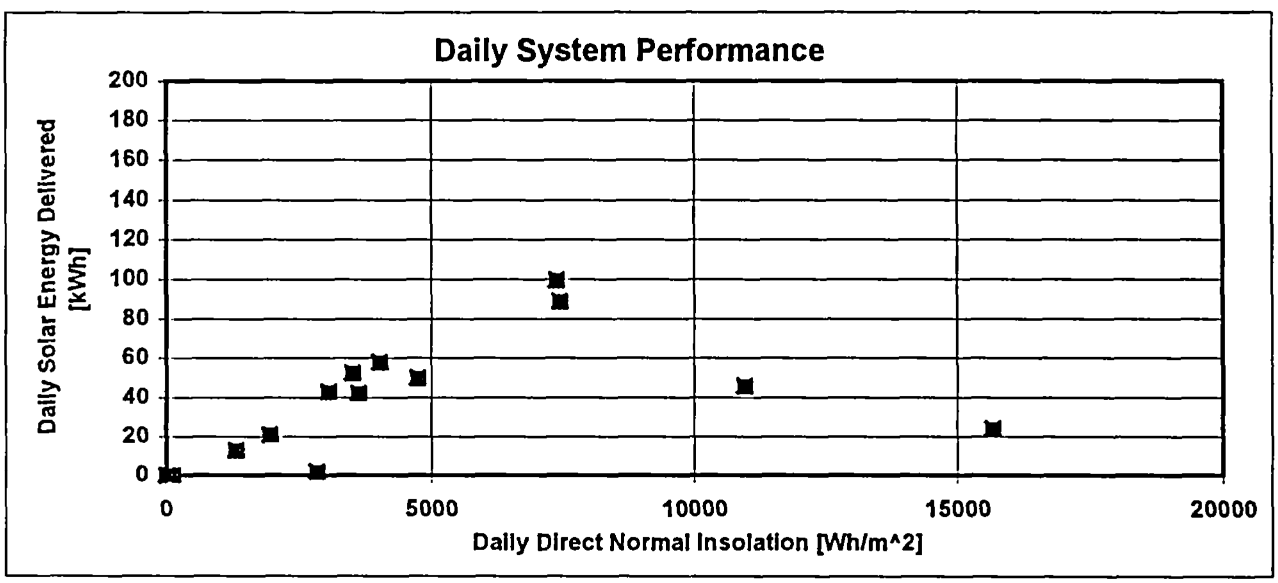
Appendix G:

Month-by-Month Performance Summaries for the APS West Dish/Stirling System

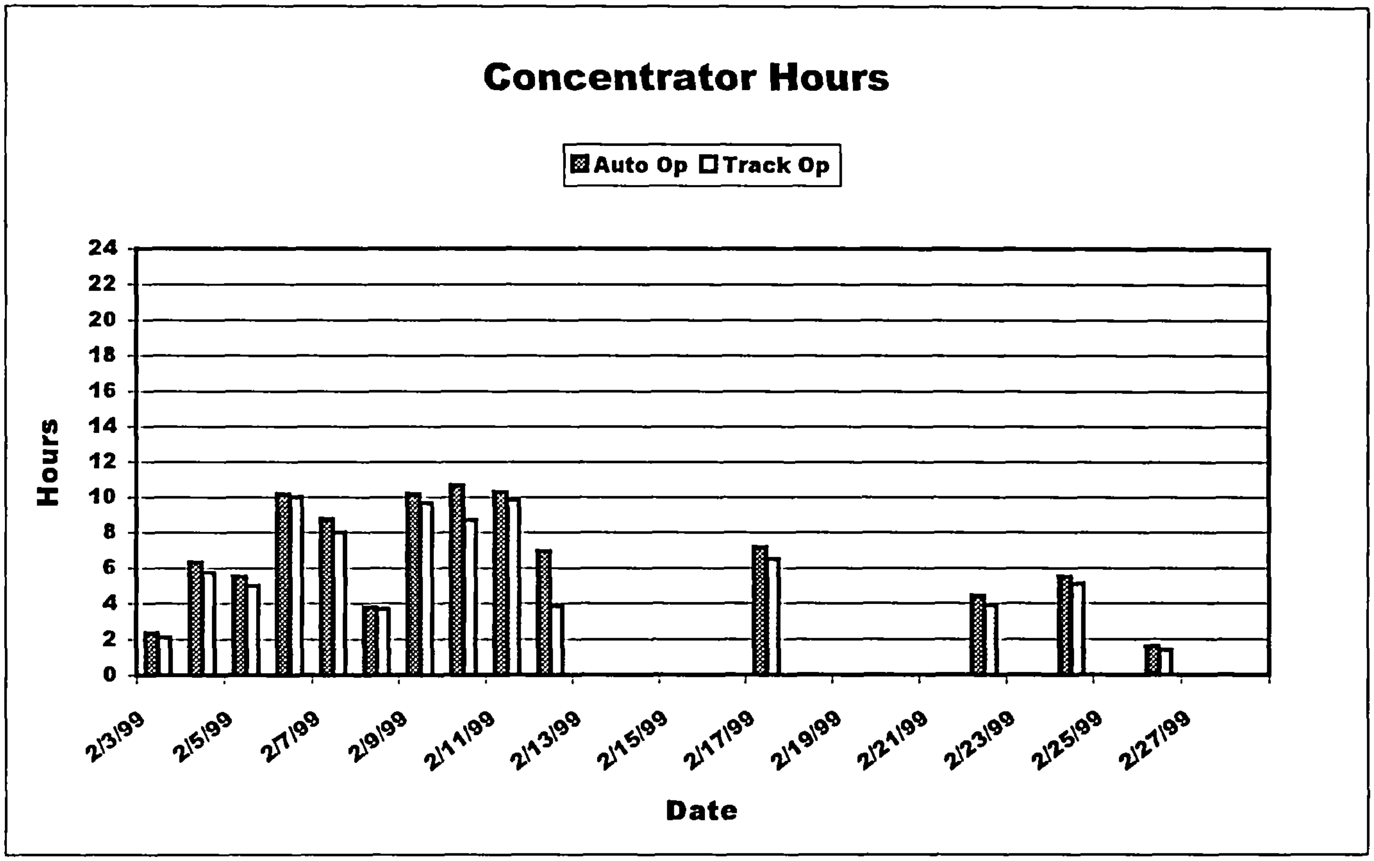
APS-West Dish Monthly Performance Summary

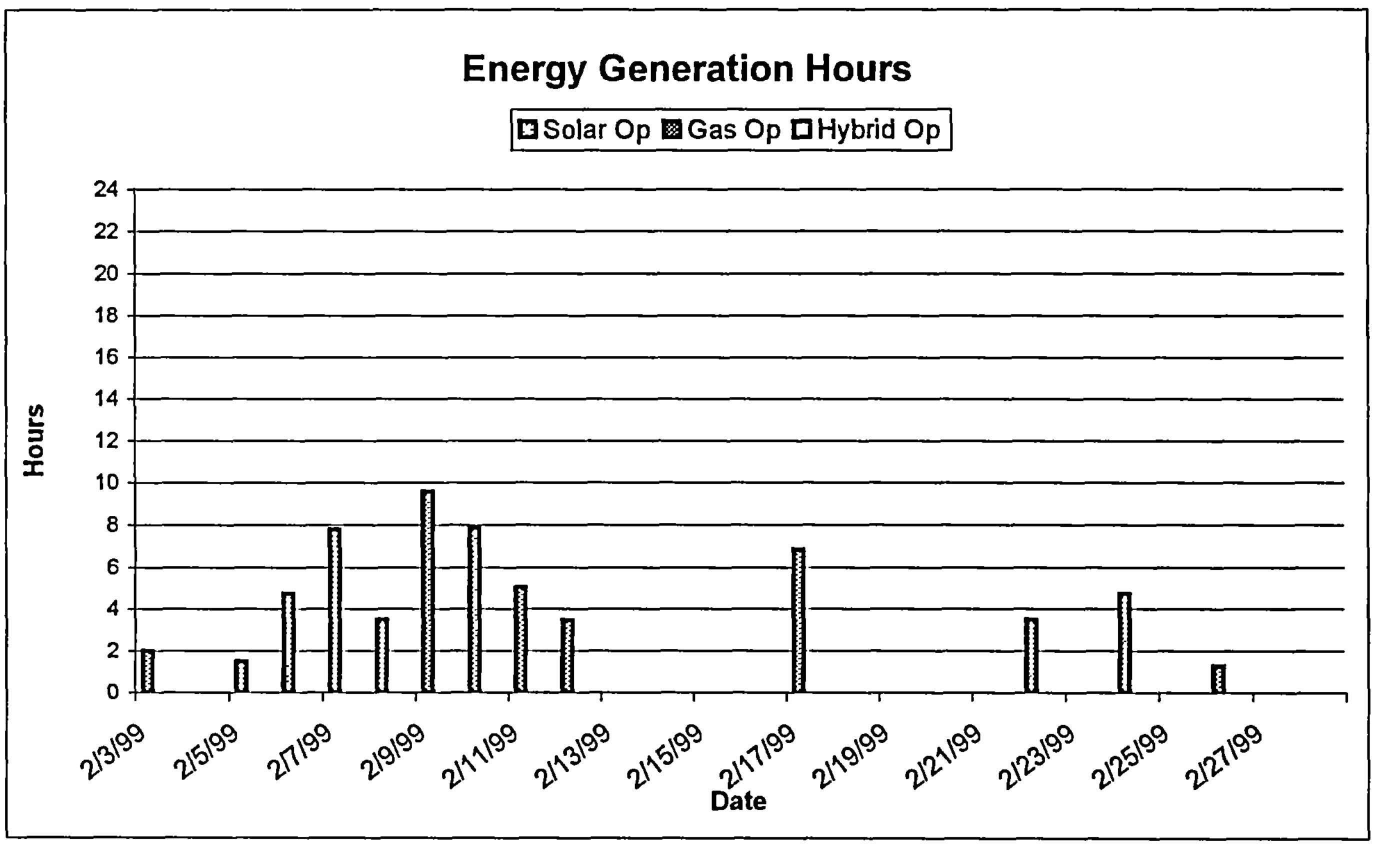
February-99

Day	Summary of Operation
1	BCS Alignment of Dish
2	Installation of Stirling Engine
3	First operation on-sun with Stirling engine in PM
4	Operated, but with clouds and rain; checked high-wind stow
5	Operated most of the day; cloudy in afternoon
6	Operated most of the day with clouds; AM data file lost
7	Operated all day
8	Operated all morning; shut down for lunch; AM data file lost
9	Operated all day, performing tracking calibration; AM data file lost
10	After morning high wind, operated all day; performed tracking calibration
11	Operated all day, but cloudy and breezy
12	Operated in AM until high-wind stow; continued after wind dropped in PM; not operated late PM
13	System not operated
14	System not operated
15	No Data
16	No Data
17	Operated all day
18	No Operational Data
19	No Operational Data
20	No Operational Data
21	No Operational Data
22	Operated
23	Operated
24	Operated; gas blower down
25	Operated; gas blower down; no operational data
26	Operated to test over-focus; gas blower removed for repair
27	Not operated
28	Not operated



APS-West Dish Monthly Performance Summary

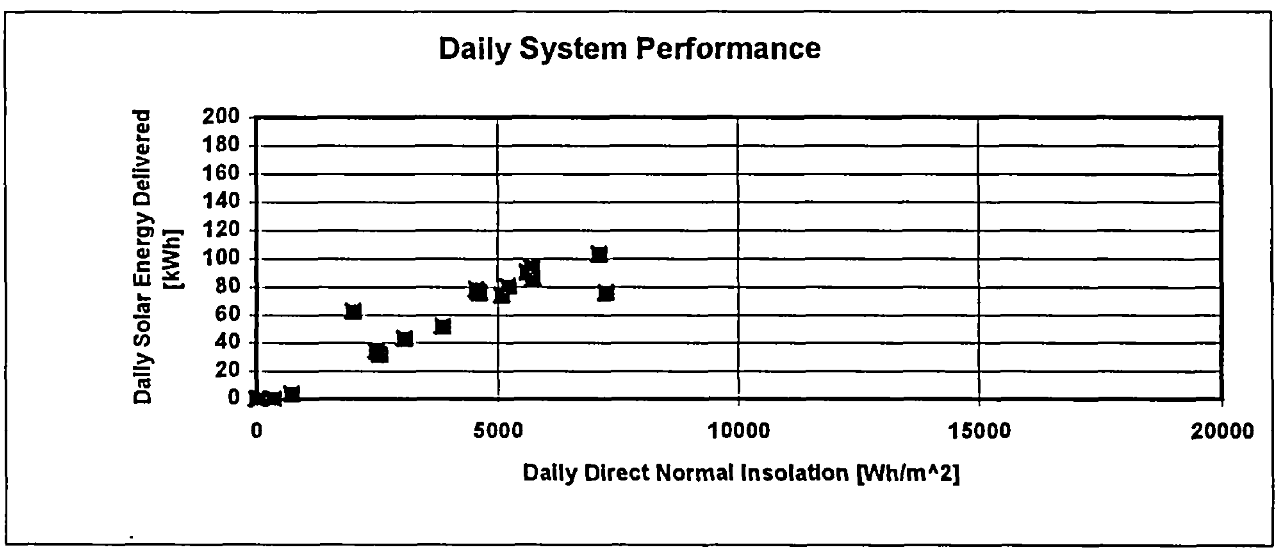




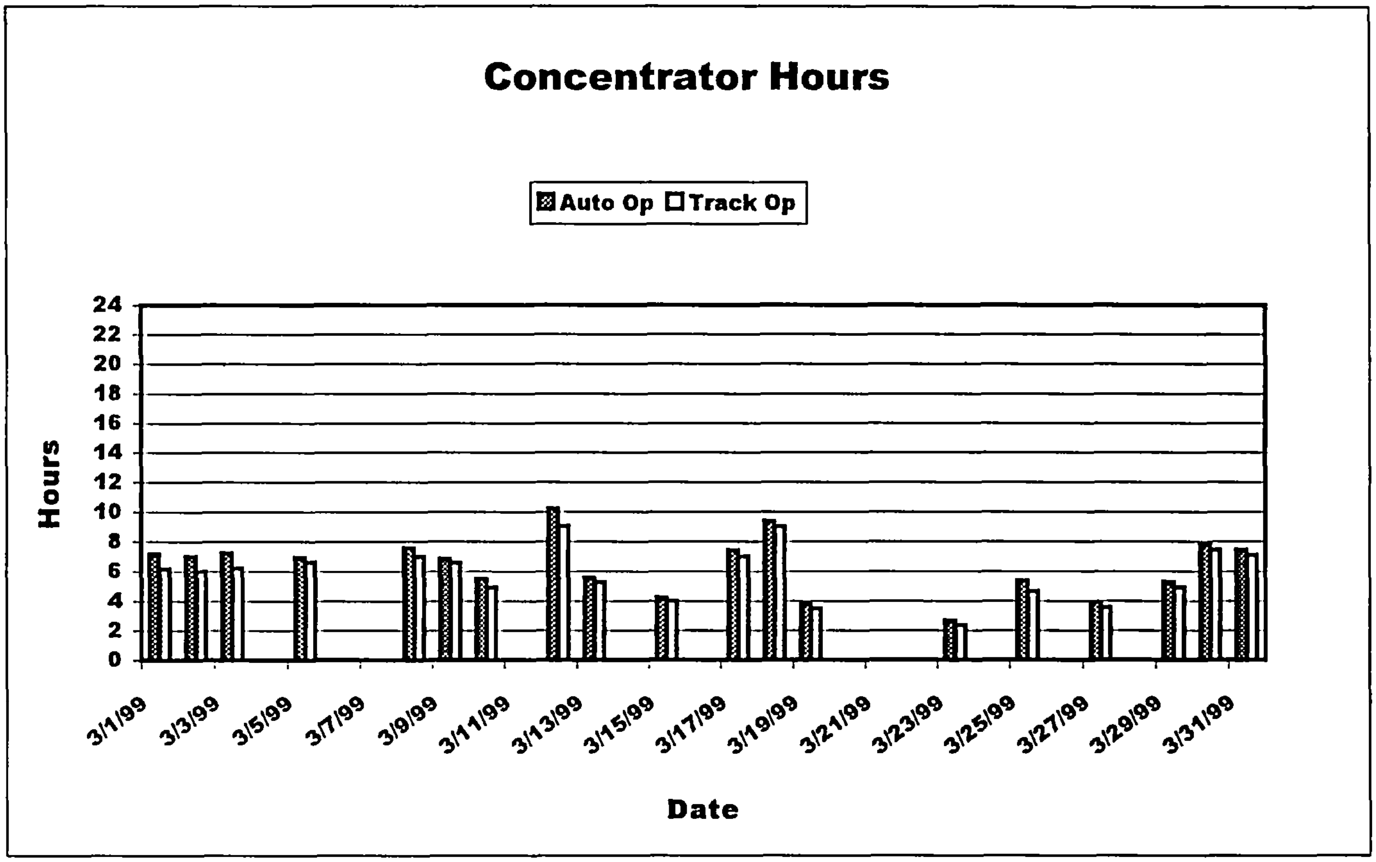
APS-West Dish Monthly Performance Summary

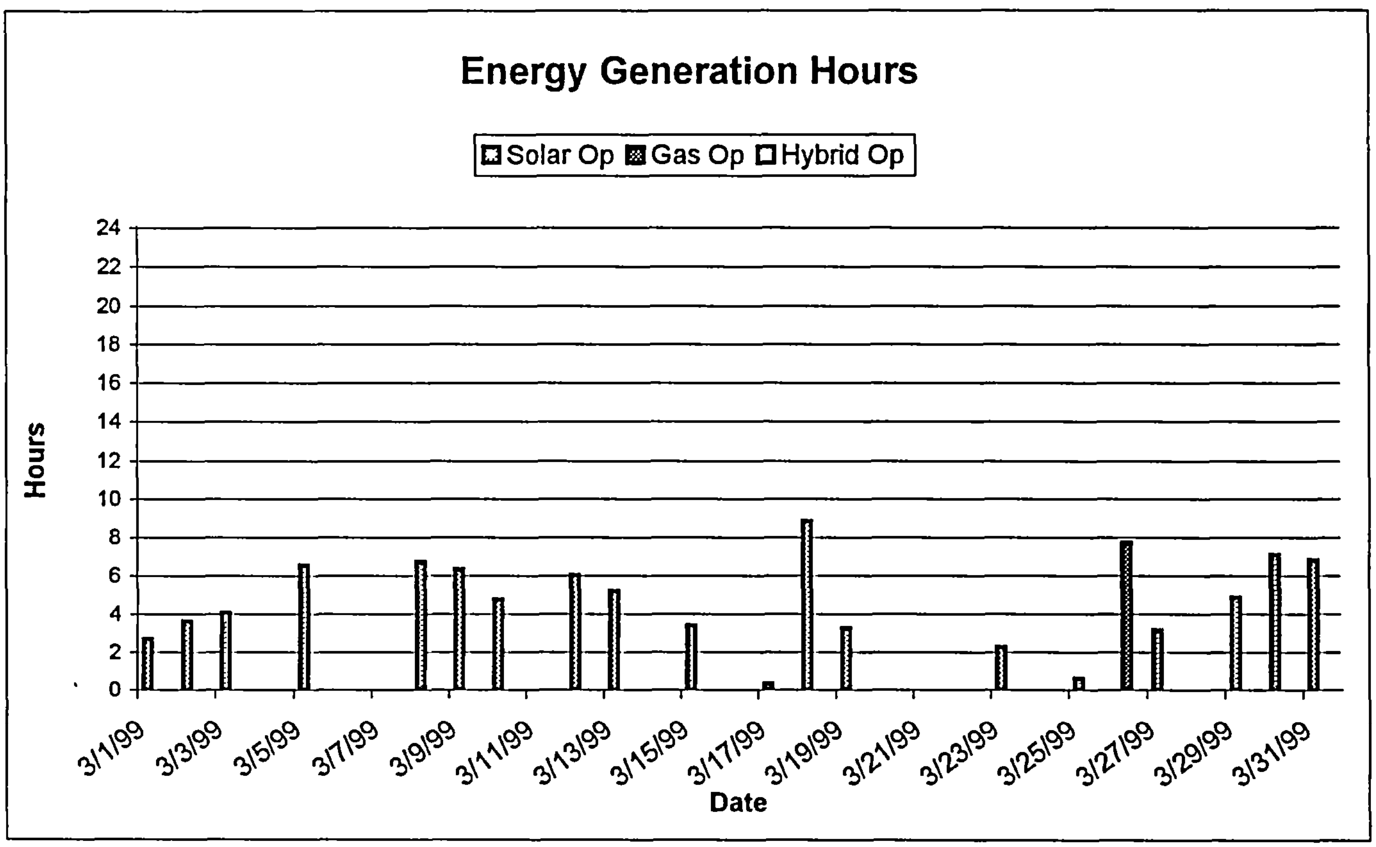
March-99

Day	Summary of Operation
1	Operated 0650 to 1400; focus off 1100 to 1230; no dish data
2	Operated 0645 to 1345; focus off 1100 to 1250; no dish data
3	Operated 0750 to 1530; focus off 1055 to 1235; no dish data
4	Not operated -- cloudy conditions
5	Operated 0650 to 1350
6	Not operated -- weekend
7	Not operated -- weekend
8	Operated 0630 to 1400
9	Operated 0650 to 1350
10	Operated 0640 to 1330; thermocouple faulted and was disconnected (IR #306)
11	Repair work to facet focus controls (RLD)
12	Installed power meter; adjusted focus; operated >1520; calibration 1520 to 1750; arm latch (IR #307)
13	Operated 0700 to 1310; calibration mode 0800 to 1240
14	Not operated - weekend
15	Operated 0915 to 1415; cloudy
16	Not operated - cloudy, power outage at site
17	Operated 0650 to 1420
18	Operated 0630 to 1550; calibration mode 1220 to 1550
19	Operated 0630 to 0710, 0730 to 1100
20	Not operated - weekend; no data
21	Not operated - weekend; no data
22	Repairs to combustion blower; no data
23	Circuit breaker failure (IR #305); tracked in PM
24	Elevation motor fault (IR #309)
25	Replaced elevation overtravel switches; tracked 1300 to 1845; arm latch fault (IR #308)
26	Operated on gas 0710 to 1450; cloudy, so didn't track
27	Operated 0620 to 1020
28	Not operated - weekend
29	Operated 0630 to 1430
30	Operated 0700 to 1400
31	Operated 0720 to 1400

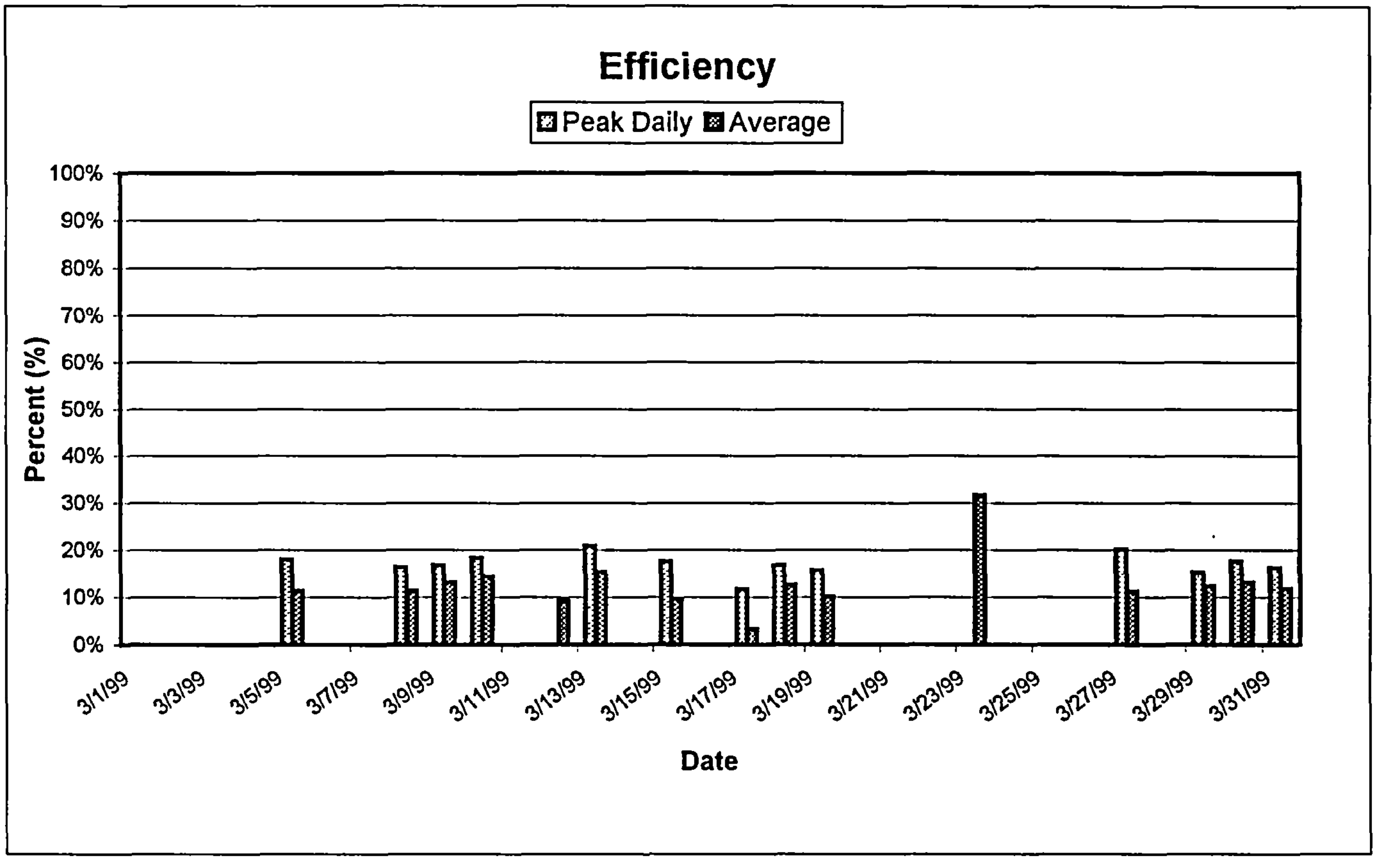


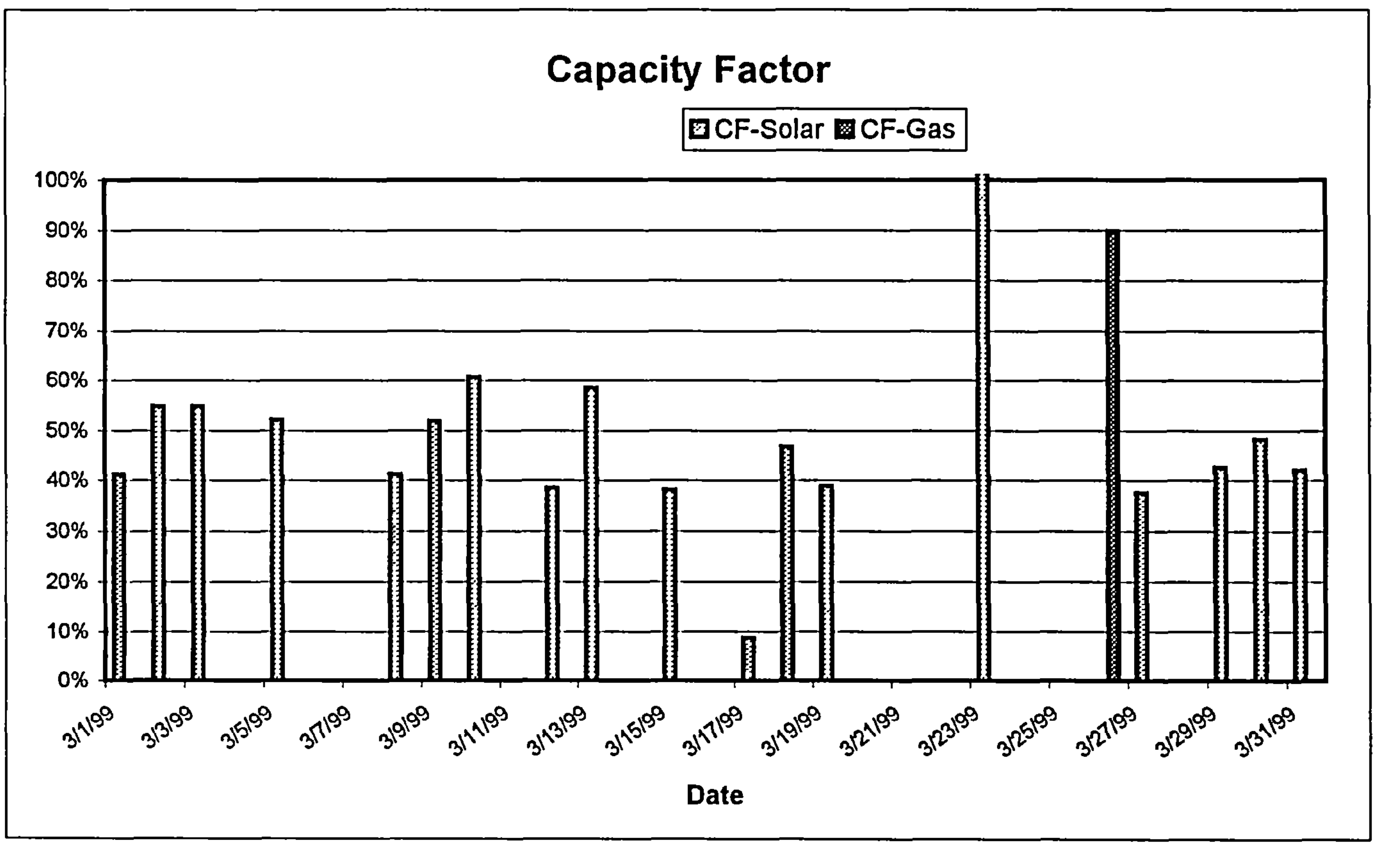
APS-West Dish Monthly Performance Summary



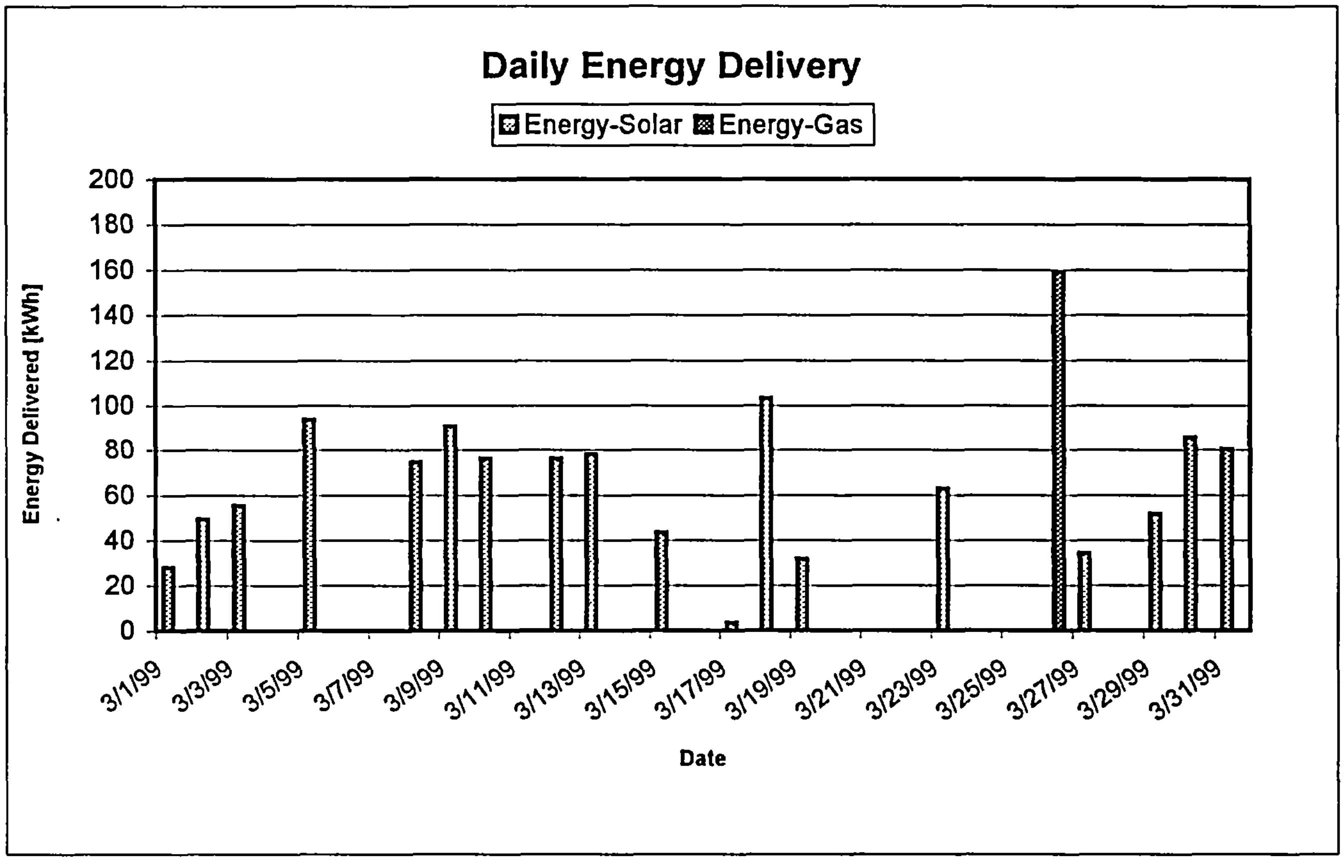


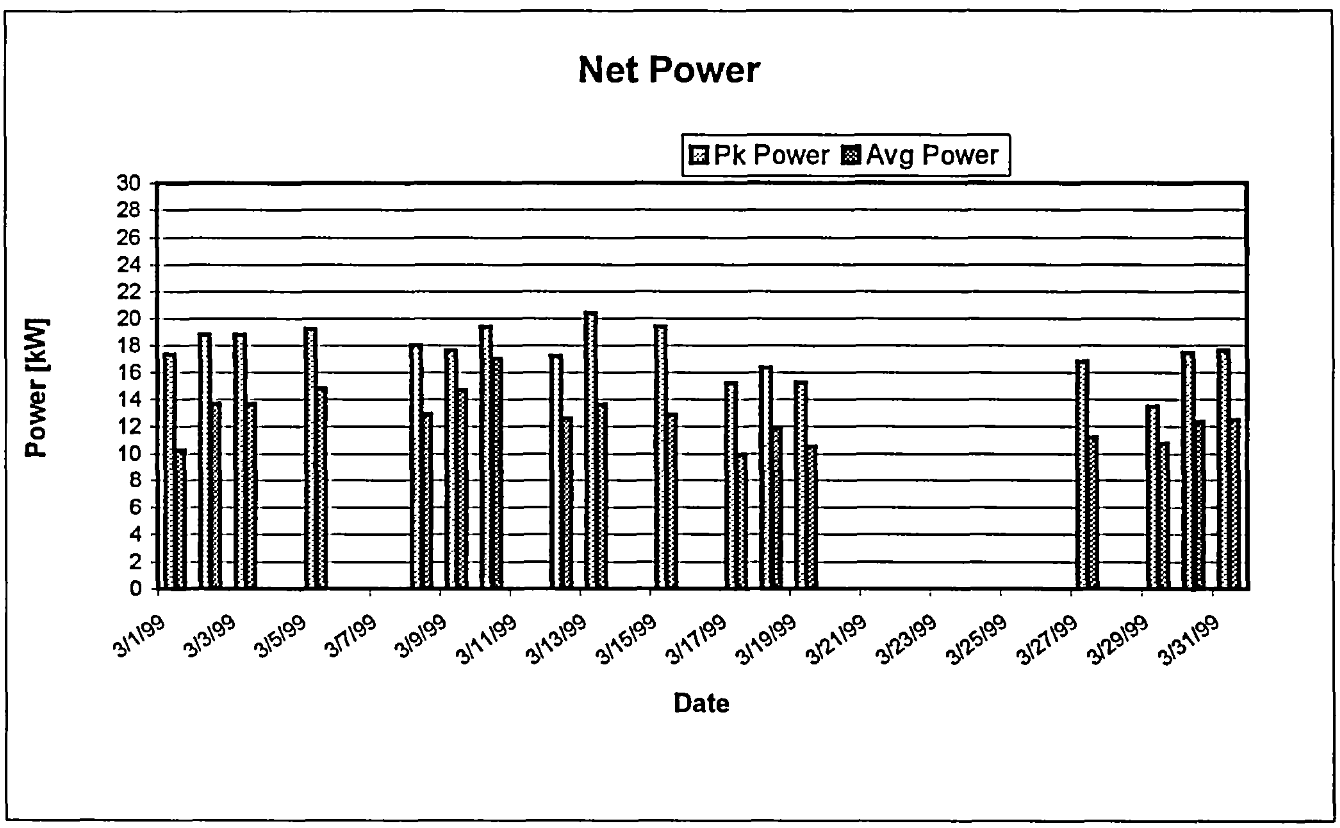
APS-West Dish Monthly Performance Summary



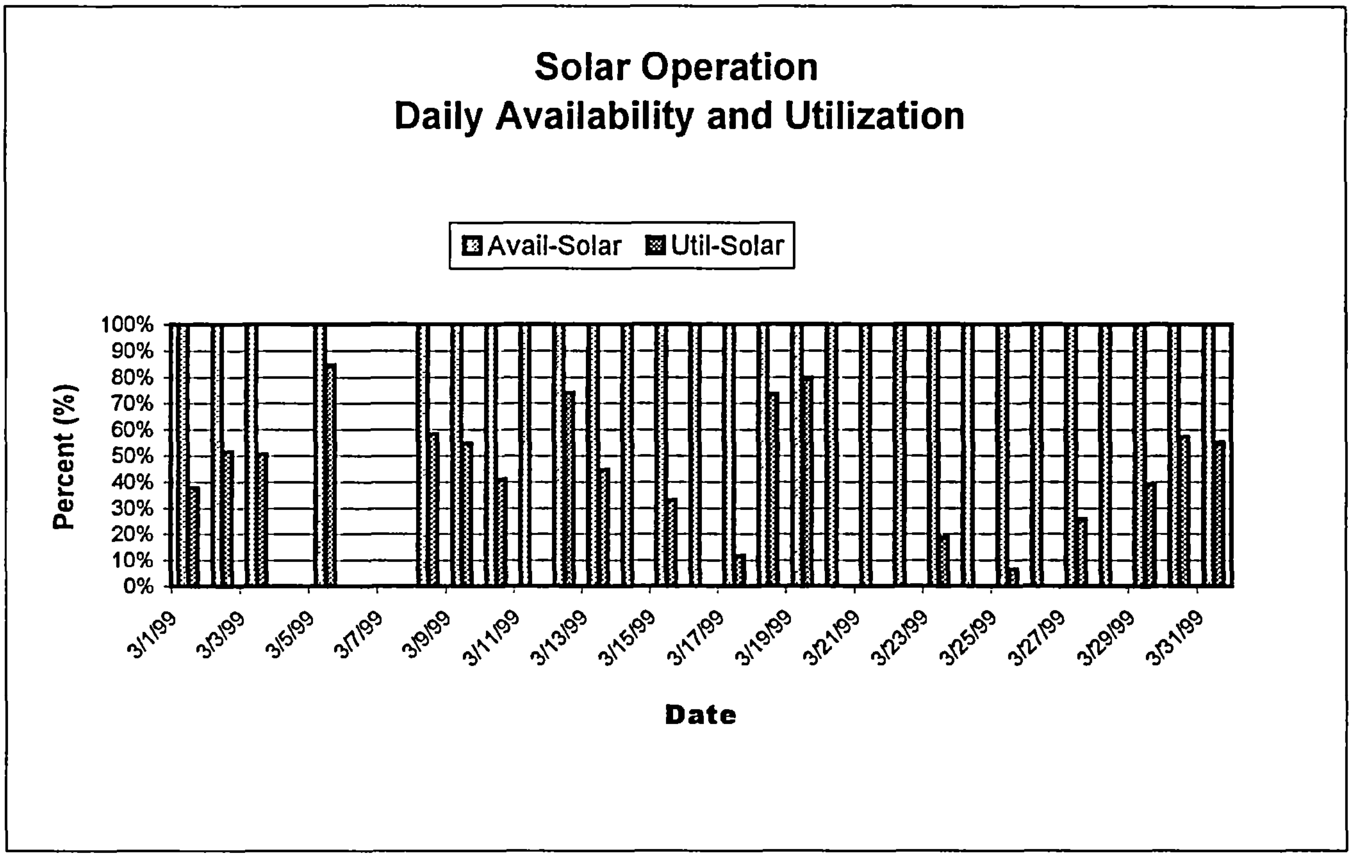


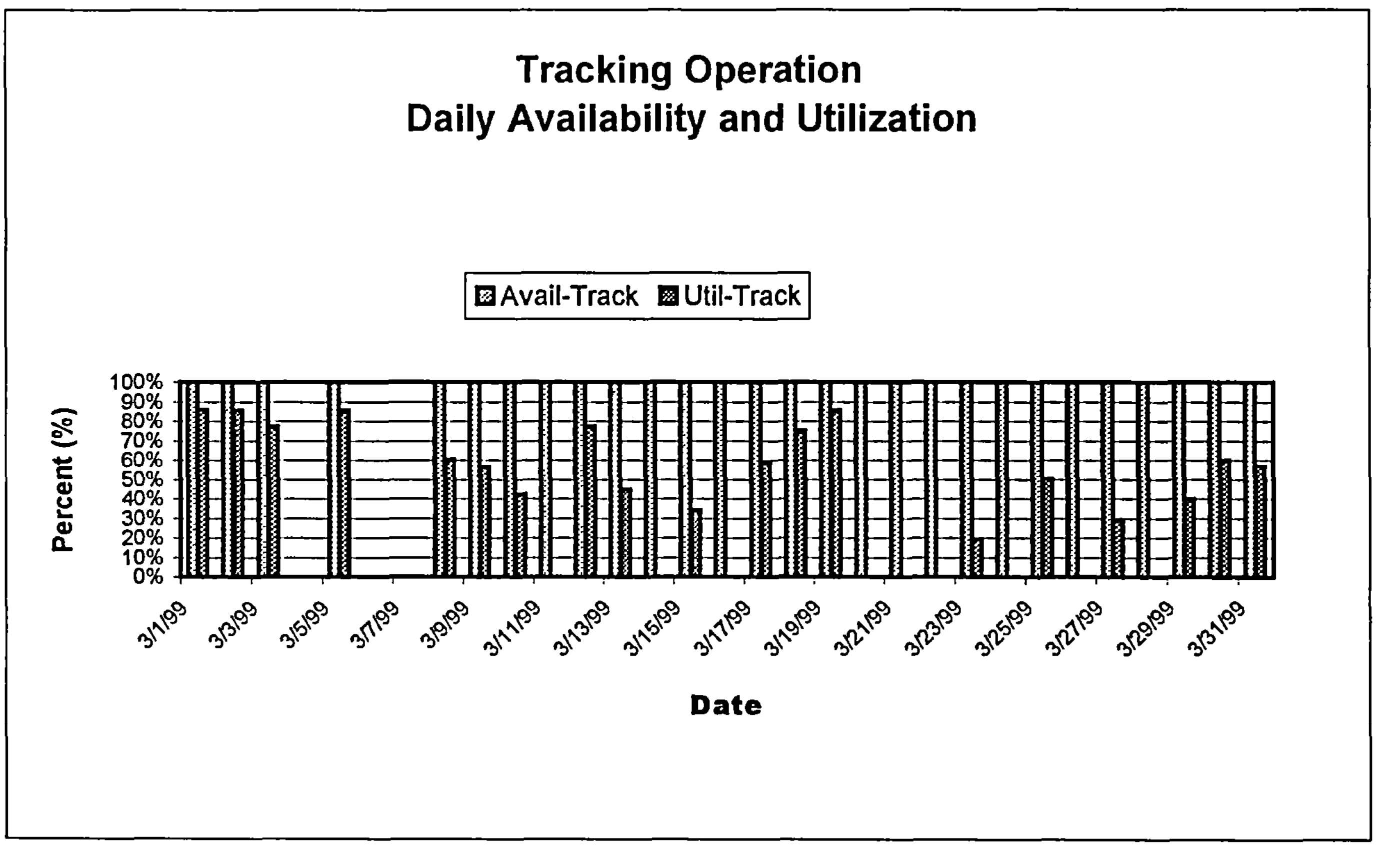
APS-West Dish Monthly Performance Summary



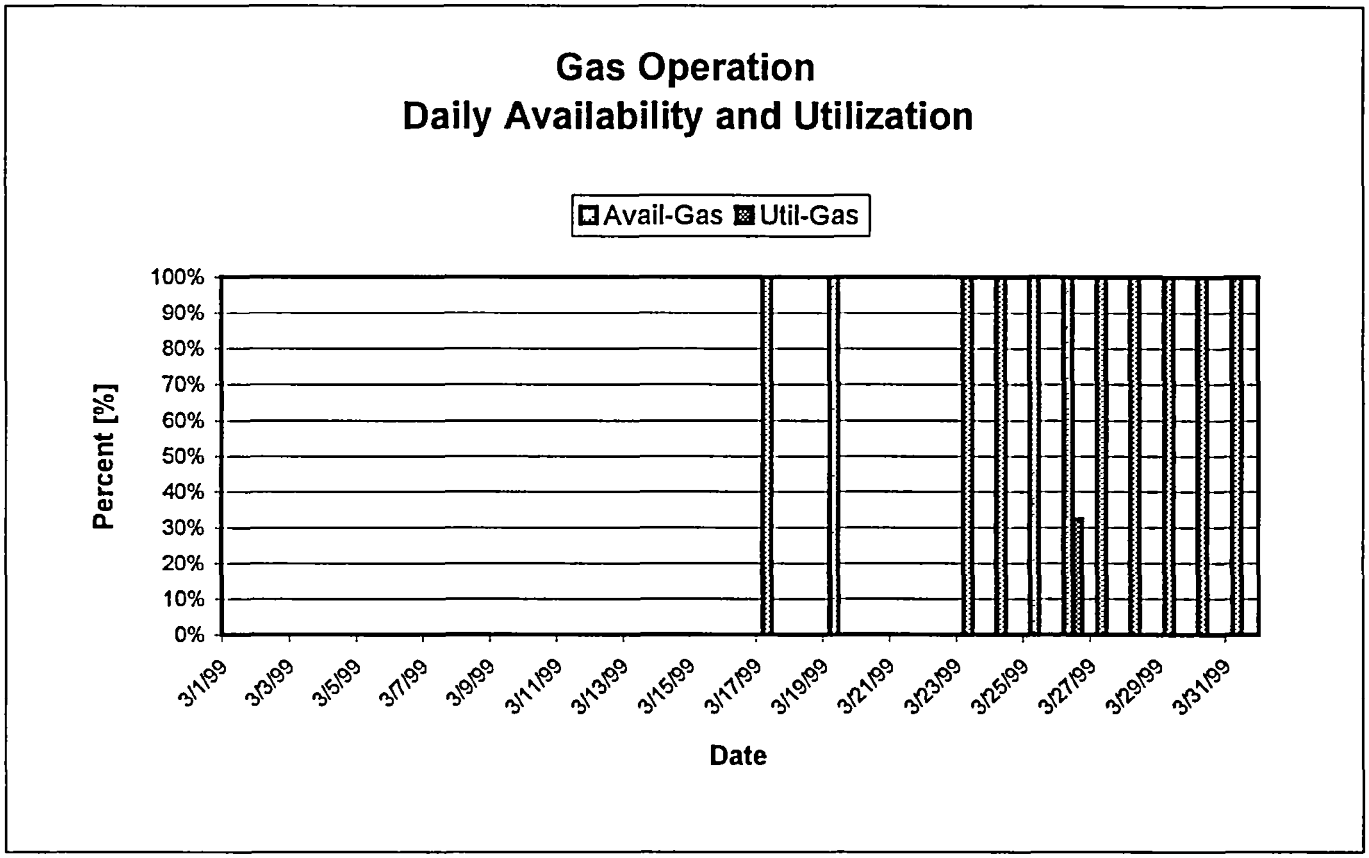


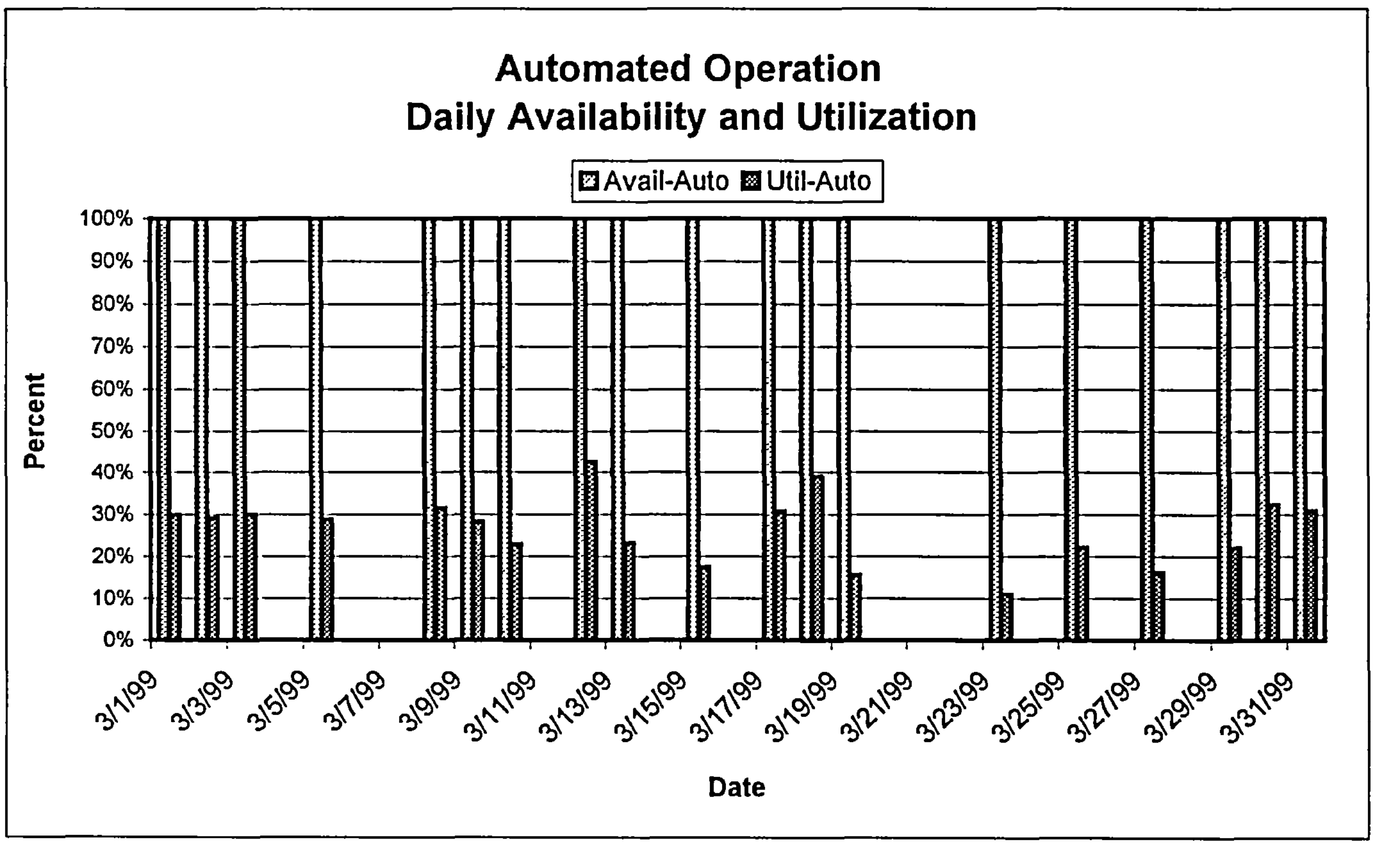
APS-West Dish Monthly Performance Summary





APS-West Dish Monthly Performance Summary





MARCH 1998 - APS WEST

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	System			Hours								Downtime Hours							Insolation		Power [kW]		Energy [kWh]				Effic
	Rating [kW]	Dish Area	Grid Avail	All Data	Daylight	Auto Op	Track Op	Solar Op	Gas Op	Hybrid Op	Energy-Delv	Day [24hr]	Daylight	Auto	Track	Solar	Gas	Hybrid	Pk [W/m^2]	Total [Wh/m^2]	Pk Power	Avg Power	Energy DLVRD	Energy Solar	Energy Gas	Energy Hybrid	Peak Eff
Mar-98	25.0	113.5	24.0	558.4	267.4	121.1	111.3	86.5	7.7	0.0	91.7	0.0	0.0	0.0	0.0	0.0	255.5	267.4	981.0	66194.9	20.4	13.9	1275.1	1116.1	159.0	0.0	21%
				744 Month																		dish/engine	1276.7	1117.5	159.2	0.0	

467.1 3/1 to 3/11
511.8 best est 3/1 to 3/11
813.7 3/12 to 3/31
763.3 Electro Industries Meter 3/12 to 3/31

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	System			Hours								Downtime Hours							Daily Insolation		Power [kW]		Energy [kWh]				Effic
Date	Rating [kW]	Dish Area	Grid Avail	All Data	Daylight	Auto Op	Track Op	Solar Op	Gas Op	Hybrid Op	Energy-Delv	Day [24hr]	Daylight	Auto	Track	Solar	Gas	Hybrid	Pk [W/m^2]	Total [Wh/m^2]	Pk Power	Avg Power	Energy DLVRD	Energy Solar	Energy Gas	Energy Hybrid	Peak Daily
1-Mar-99	25.0	113.5	24.0	24.0	7.2	7.2	6.2	2.7	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	24.0	7.2			17.3	10.3	27.8	27.8	0.0	0.0	
2-Mar-99	25.0	113.5	24.0	24.0	7.0	7.0	6.0	3.6	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	24.0	7.0			18.8	13.7	49.3	49.3	0.0	0.0	
3-Mar-99	25.0	113.5	24.0	24.0	8.0	7.2	6.2	4.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	24.0	8.0			18.8	13.7	55.4	55.4	0.0	0.0	
4-Mar-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0%
5-Mar-99	25.0	113.5	24.0	11.5	7.7	6.9	6.6	6.5	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	11.6	7.7	947.0	5724.7	19.2	14.8	93.6	93.6	0.0	0.0	18%
6-Mar-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
7-Mar-99	25.0	113.5	24.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0%
8-Mar-99	25.0	113.5	24.0	23.9	11.6	7.6	7.0	6.7	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0	23.9	11.6	920.0	5081.4	18.0	12.9	74.3	74.3	0.0	0.0	16%
9-Mar-99	25.0	113.5	24.0	23.9	11.6	6.8	6.6	6.3	0.0	0.0	6.2	0.0	0.0	0.0	0.0	0.0	23.9	11.6	927.0	5624.6	17.6	14.7	90.5	90.5	0.0	0.0	17%
10-Mar-99	25.0	113.5	24.0	23.9	11.6	5.5	4.9	4.7	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	11.6	981.0	4618.6	19.4	17.0	76.3	76.3	0.0	0.0	18%
11-Mar-99	25.0	113.5	24.0	23.8	11.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.8	11.6	6.0	32.2	0.0	0.0	0.0	0.0	0.0	0.0	0%
12-Mar-99	25.0	113.5	24.0	23.2	11.7	10.2	9.1	6.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	23.2	11.7	968.0	7257.9	17.2	12.8	78.0	78.0	0.0	0.0	
13-Mar-99	25.0	113.5	24.0	22.9	11.7	5.6	5.3	5.2	0.0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	22.9	11.7	977.0	4556.2	20.4	13.6	78.2	78.2	0.0	0.0	21%
14-Mar-99	25.0	113.5	24.0	23.9	11.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	11.8	6.0	43.2	0.0	0.0	0.0	0.0	0.0	0.0	0%
15-Mar-99	25.0	113.5	24.0	22.9	11.7	4.2	4.0	3.4	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	11.7	940.0	3067.7	19.4	12.9	43.5	43.5	0.0	0.0	18%
16-Mar-99	25.0	113.5	24.0	23.9	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.9	3.0	17.9	0.0	0.0	0.0	0.0	0.0	0.0	0%
17-Mar-99	25.0	113.5	24.0	23.7	11.9	7.4	7.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	11.9	767.0	709.1	15.2	9.9	3.4	3.4	0.0	0.0	11%
18-Mar-99	25.0	113.5	24.0	23.2	12.0	9.4	9.0	8.8	0.0	0.0	8.7	0.0	0.0	0.0	0.0	0.0	23.2	12.0	876.0	7124.4	16.3	11.9	103.4	103.0	0.0	0.0	17%
19-Mar-99	25.0	113.5	24.0	10.6	4.1	3.7	3.5	3.2	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	864.0	2546.5	15.2	10.6	31.5	31.5	0.0	0.0	16%
20-Mar-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
21-Mar-99	25.0	113.5	24.0	7.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	1.7	4.0	59.7	0.0	0.0	0.0	0.0	0.0	0.0	0%
22-Mar-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
23-Mar-99	25.0	113.5	24.0	22.9	12.1	2.7	2.3	2.2	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	12.1	808.0	1992.6			65.2	62.8	0.0	0.0	
24-Mar-99	25.0	113.5	24.0	13.9	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	5.0	31.1	0.0	0.0	0.0	0.0	0.0	0.0	0%
25-Mar-99	25.0	113.5	24.0	14.5	9.3	5.3	4.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.3	721.0	353.4	0.0	0.0	0.0	0.0	0.0	0.0	0%
26-Mar-99	25.0	113.5	24.0	24.0	12.2	0.0	0.0	0.0	7.7	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	12.2	6.0	28.7			159.2		159.2	0.0	
27-Mar-99	25.0	113.5	24.0	23.9	12.2	3.9	3.6	3.2	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	12.2	840.0	2478.4	16.8	11.2	34.2	34.2	0.0	0.0	20%
28-Mar-99	25.0	113.5	24.0	23.9	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	6.0	42.1	0.0	0.0	0.0	0.0	0.0	0.0	0%
29-Mar-99	25.0	113.5	24.0	23.9	12.4	5.3	4.9	4.8	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	12.4	793.0	3860.7	13.5	10.7	52.1	51.6	0.0	0.0	15%
30-Mar-99	25.0	113.5	24.0	23.9	12.4	7.8	7.4	7.1	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	879.0	5729.3	17.4	12.3	86.5	85.6	0.0	0.0	18%
31-Mar-99	25.0	113.5	24.0	23.9	12.4	7.4	7.1	6.9	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	12.4	865.0	5214.5	17.6	12.5	80.5	80.5	0.0	0.0	16%

Month Transition Data

	DN Insolation*Time	
	PK*E$_{DSL}$ HRS	Avg*E$_{DSL}$ HRS
1-Mar-99	0.0	0.0
2-Mar-99	0.0	0.0
3-Mar-99	0.0	0.0
4-Mar-99	0.0	0.0
5-Mar-99	6103.2	36894.4
6-Mar-99	0.0	0.0
7-Mar-99	0.0	0.0
8-Mar-99	5264.0	29184.8
9-Mar-99	5723.5	34727.2
10-Mar-99	4399.7	20714.1
11-Mar-99	0.0	0.0
12-Mar-99	5841.6	43890.3
13-Mar-99	4974.0	23196.3
14-Mar-99	0.0	0.0
15-Mar-99	3177.7	10370.5
16-Mar-99	0.0	0.0
17-Mar-99	265.3	245.2
18-Mar-99	7610.0	61891.3
19-Mar-99	2589.8	7633.1
20-Mar-99	0.0	0.0
21-Mar-99	0.0	0.0
22-Mar-99	0.0	0.0
23-Mar-99	1946.0	4811.0
24-Mar-99	0.0	0.0
25-Mar-99	0.0	0.0
26-Mar-99	34.7	221.9
27-Mar-99	2727.9	8048.7
28-Mar-99	0.0	0.0
30-Mar-99	6168.1	40203.7
31-Mar-99	5780.8	34848.5

ncy [%]	Capacity Factor			Availability and Utilization									
Average	CF_{Solar}	CF_{Gen}	CF_{Hybrid}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Truck}$	$Util_{Truck}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gen}$	$Util_{Gen}$	$Avail_{Hybrid}$	$Util_{Hybrid}$
7%	52%	82%	0%	100%	22%	100%	42%	100%	32%	54%	3%	0%	0%

ncy [%]	Capacity Factor			Availability and Utilization										Electro Industries Meter	
Average	CF_{Solar}	CF_{Gen}	CF_{Hybrid}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Truck}$	$Util_{Truck}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gen}$	$Util_{Gen}$	$Avail_{Hybrid}$	$Util_{Hybrid}$	end-day Readi	Daily
	41%	0%	0%	100%	30%	100%	86%	100%	38%	0%	0%	0%	0%		
	55%	0%	0%	100%	29%	100%	86%	100%	61%	0%	0%	0%	0%		
	55%	0%	0%	100%	30%	100%	78%	100%	51%	0%	0%	0%	0%		
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
11%	52%	0%	0%	100%	29%	100%	86%	100%	84%	0%	0%	0%	0%		
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
11%	41%	0%	0%	100%	32%	100%	60%	100%	58%	0%	0%	0%	0%		
13%	52%	0%	0%	100%	28%	100%	57%	100%	55%	0%	0%	0%	0%		
14%	61%	0%	0%	100%	23%	100%	42%	100%	41%	0%	0%	0%	0%		
0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0 0	
9%	38%	0%	0%	100%	43%	100%	77%	100%	74%	0%	0%	0%	0%	64.2	64.2
15%	58%	0%	0%	100%	23%	100%	45%	100%	45%	0%	0%	0%	0%	140 8	76 6
0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	140 8	0 0
10%	38%	0%	0%	100%	17%	100%	34%	100%	33%	0%	0%	0%	0%	183 1	42.3
0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	183 1	0 0
3%	9%	0%	0%	100%	31%	100%	59%	100%	12%	100%	0%	0%	0%	186 4	3.3
13%	47%	0%	0%	100%	39%	100%	75%	100%	74%	0%	0%	0%	0%	300 0	113 6
10%	39%	0%	0%	100%	16%	100%	86%	100%	80%	100%	0%	0%	0%	343 1	43 1
0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	343 1	0 0
0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	343 1	0 0
0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	343 1	0 0
32%	112%	0%	0%	100%	11%	100%	19%	100%	19%	100%	0%	0%	0%	?	
0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	?	
0%	0%	0%	0%	100%	22%	100%	50%	100%	6%	100%	0%	0%	0%	?	
	0%	90%	0%	0%	0%	100%	0%	100%	0%	100%	32%	0%	0%	600.2	157 1
11%	37%	0%	0%	100%	16%	100%	29%	100%	26%	100%	0%	0%	0%	?	
0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	633 4	33.2
12%	43%	0%	0%	100%	22%	100%	40%	100%	39%	100%	0%	0%	0%	692 8	59.4
13%	48%	0%	0%	100%	32%	100%	60%	100%	57%	100%	0%	0%	0%	684 7	91.9
12%	42%	0%	0%	100%	31%	100%	57%	100%	65%	100%	0%	0%	0%	763.3	78 6

EFFICIENCY
AVG"E

EFFICIENCY AVG E_{DR} HRS
0
0
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0 731860596
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0 649113539
0 803208223
0 637746749
0
0 553894242
0 77464862
0
0 321544379
0
0 01114731
1 00923946
0.303690078
0
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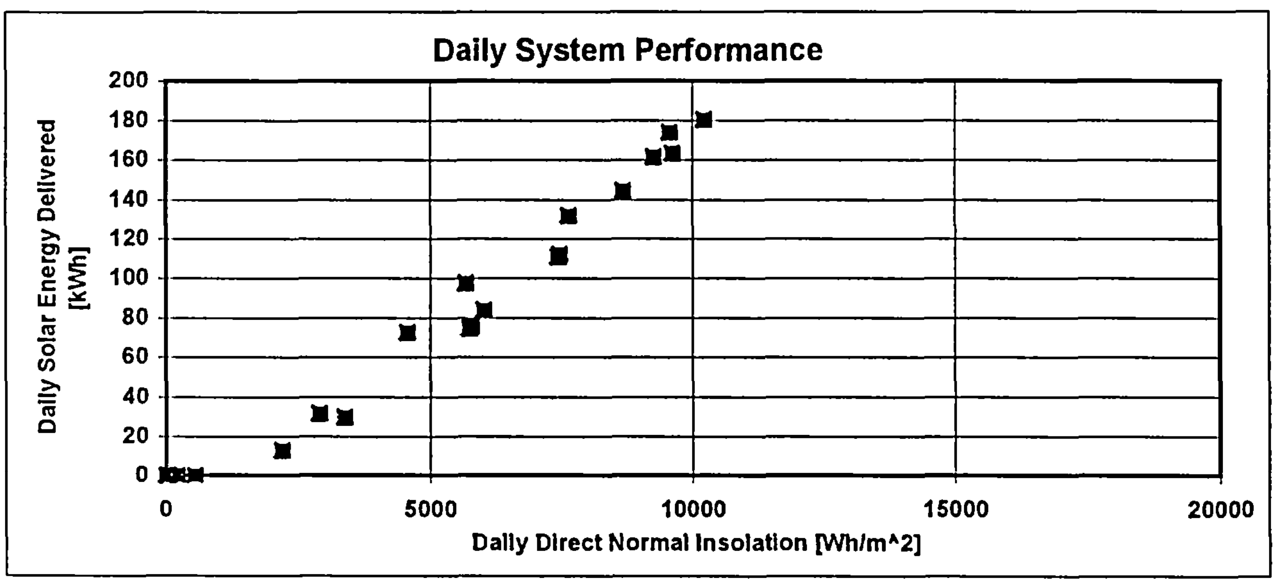
0
0 761171309
0
0
0
0.363145814
0
0.918610818
0 778597441
0

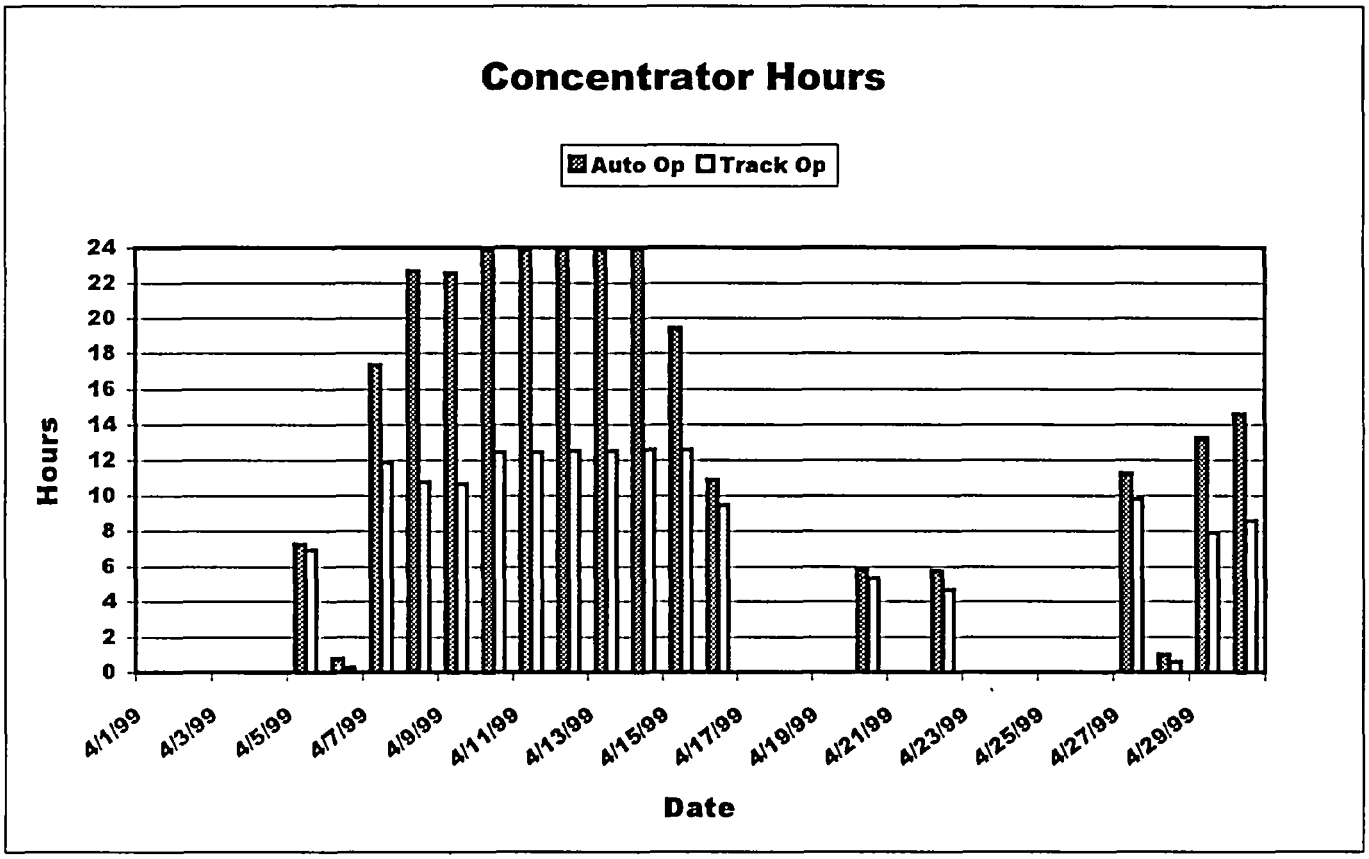
APS-West Dish Monthly Performance Summary

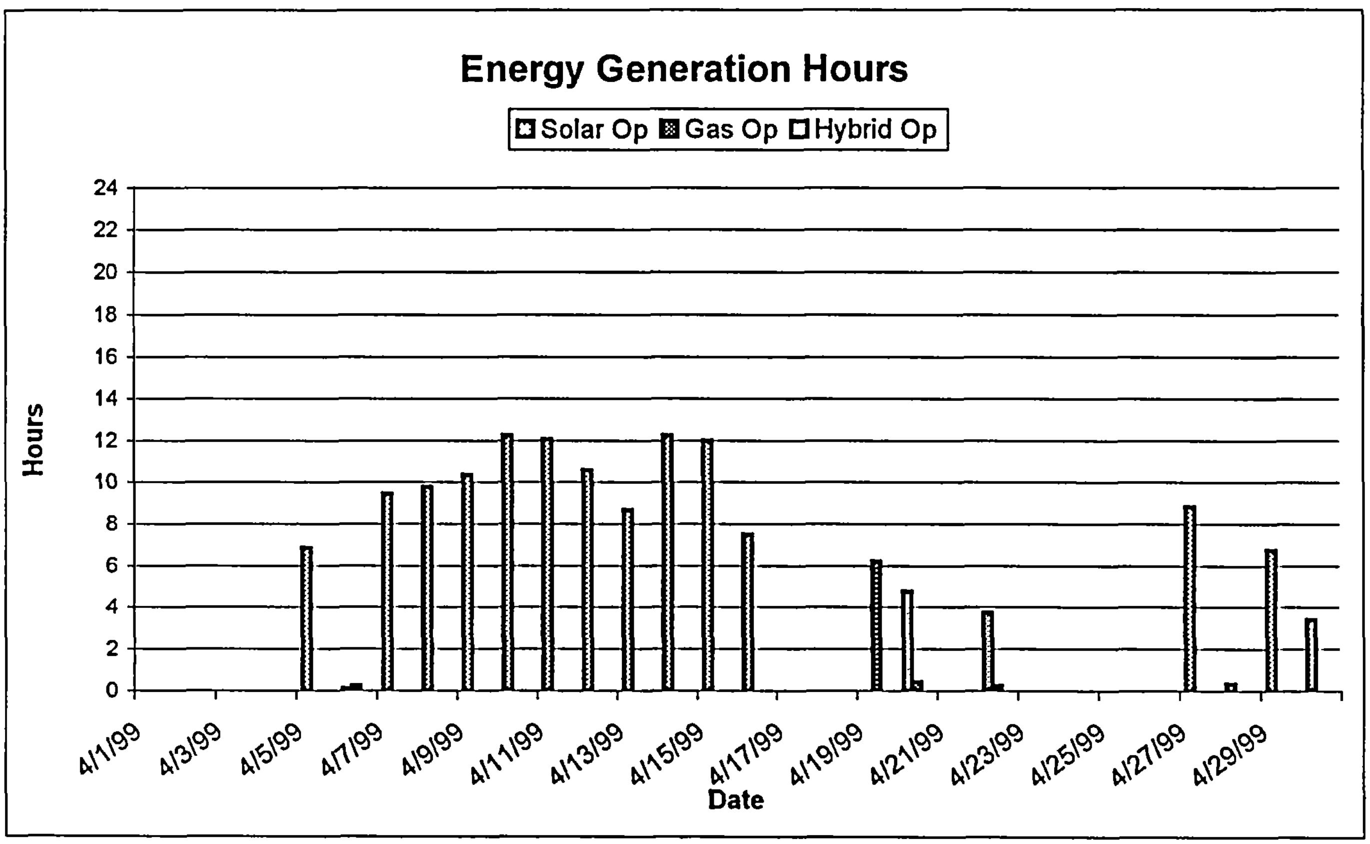
April-99

Day	Summary of Operation
1	Not operated; rainy
2	Not operated; rainy
3	Not operated; weekend
4	Not operated; weekend
5	Operated 0640 to 1400
6	Operated 1215 to 1300, 1400 to 1500 (IR #311)
7	Started 50-hour Test
8	Continued 50-hour test; hot fill fault (IR #312)
9	Continued 50-hour test; hot fill fault (IR #313)
10	Continued 50-hour test
11	Continued 50-hour test
12	Continued 50-hour test; anemometer and tilt switch faults (IR #314, 315)
13	Continued 50-hour test
14	Operated 0600 to 1900; calibration 0900 to 1830
15	Operated 0600 to 1900
16	Installed new dish software (fixes for IR #311, 315); Operated 0800 to 1200, 1300 to 1900
17	Not operated; weekend (engine hydrogen leak test)
18	Not operated; weekend (engine hydrogen leak test)
19	Operated on gas
20	Operated on solar/gas; calibration 0930 to 1400; Hall Sync fault (IR #317)
21	Not operated; down due to IR #317
22	Replaced PCS controller (fix for IR #317); PCS preheat fault (IR #319); solar op. 1400 to 1900
23	Not operated; operator vacation
24	Not operated; weekend
25	Not operated; weekend
26	Not operated; operator vacation
27	Actuator fault (IR #320); grid fault (IR #321); solar 0900 to 1900; calib. 1200 to 1900
28	Operated until 0815, then actuator stall timeout fault on engine
29	Operated from 1040 to sundown (1900)
30	Operated 0600 to 1440; overcast

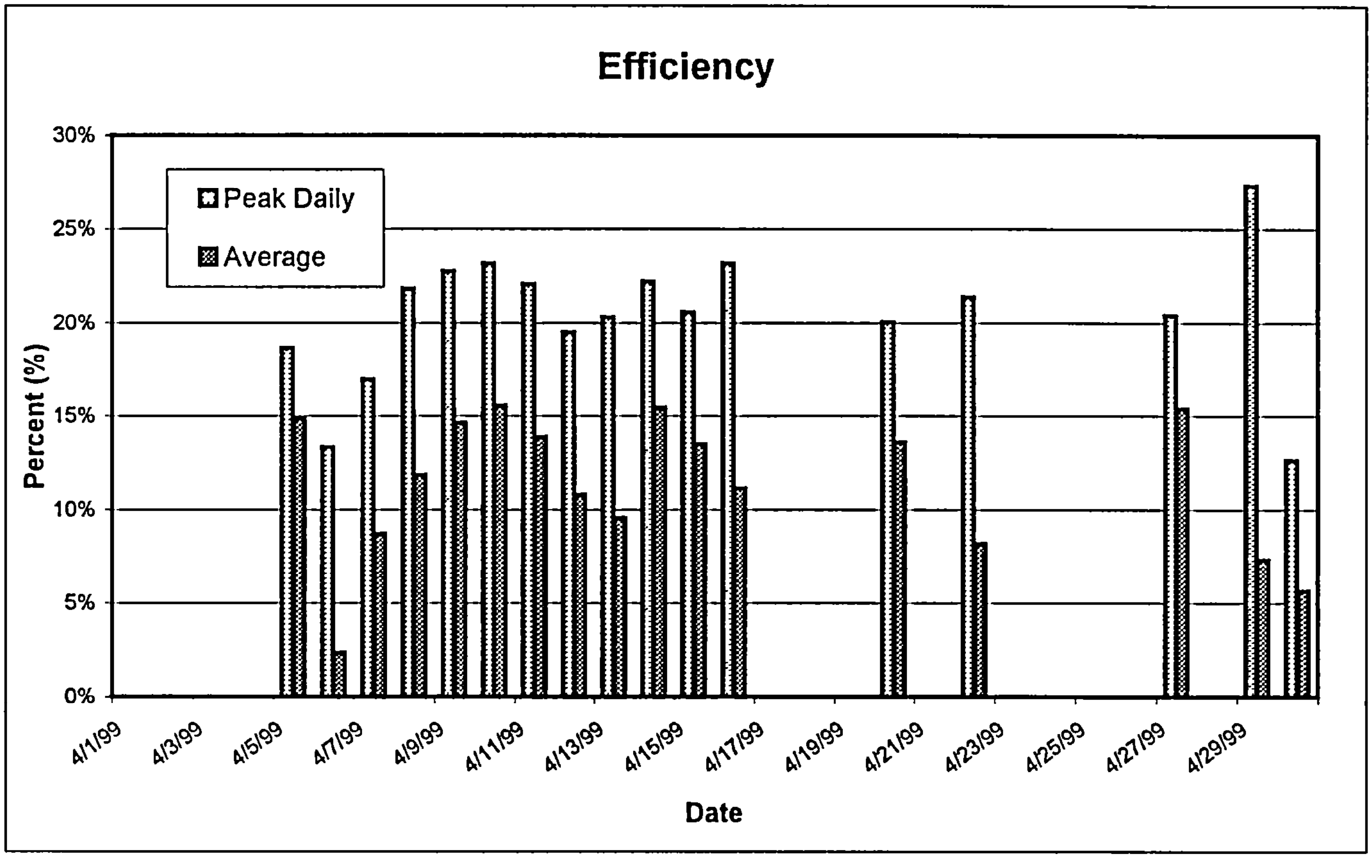


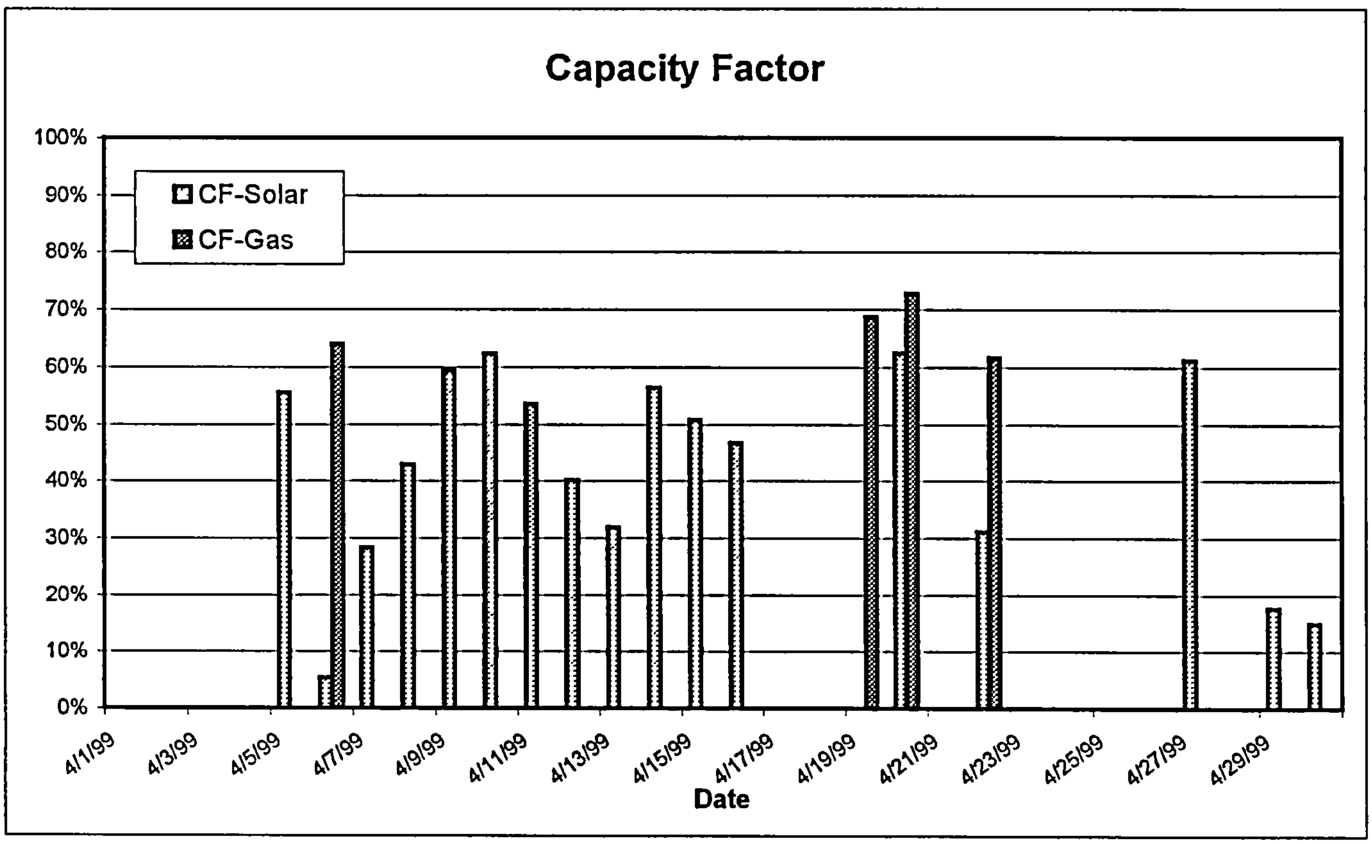
APS-West Dish Monthly Performance Summary



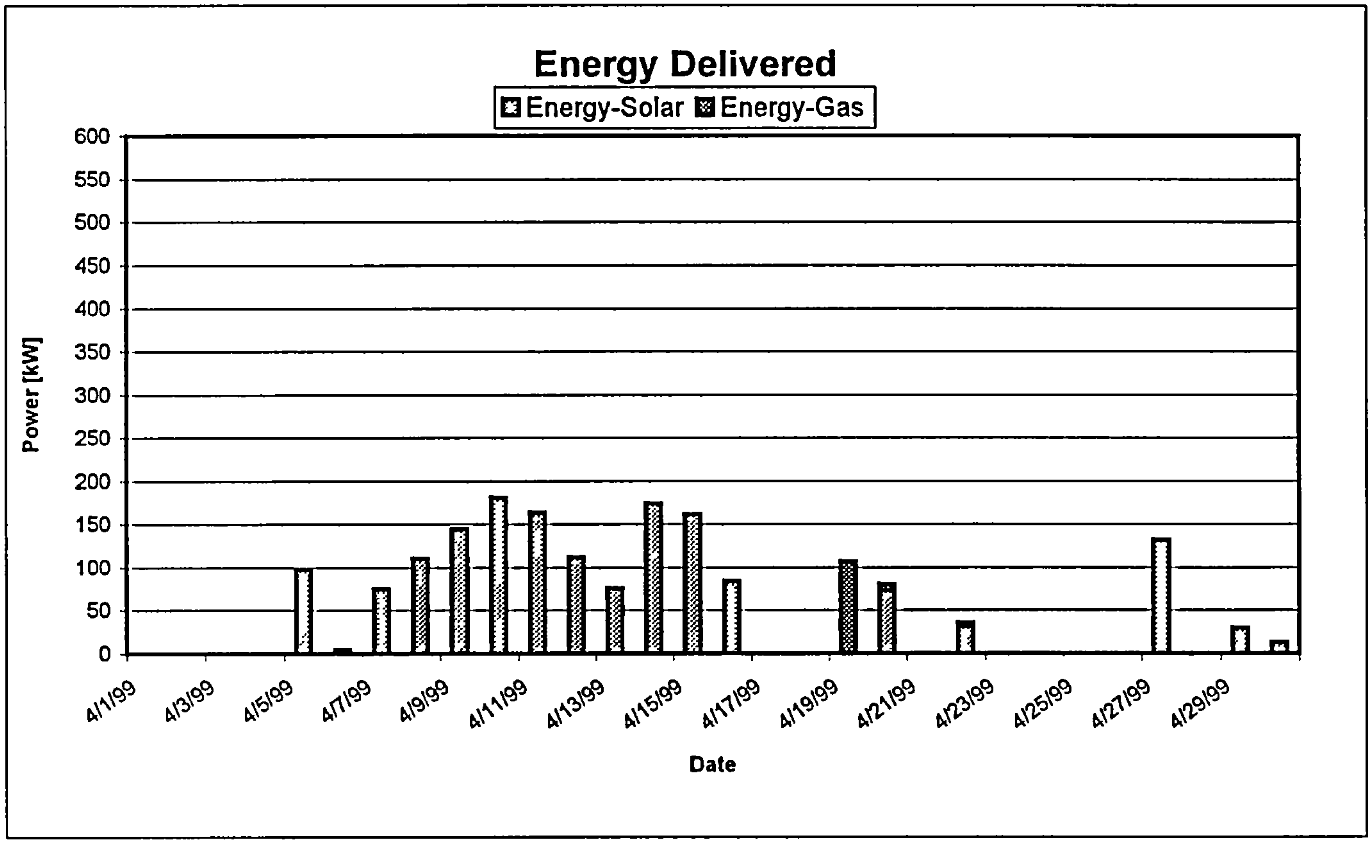


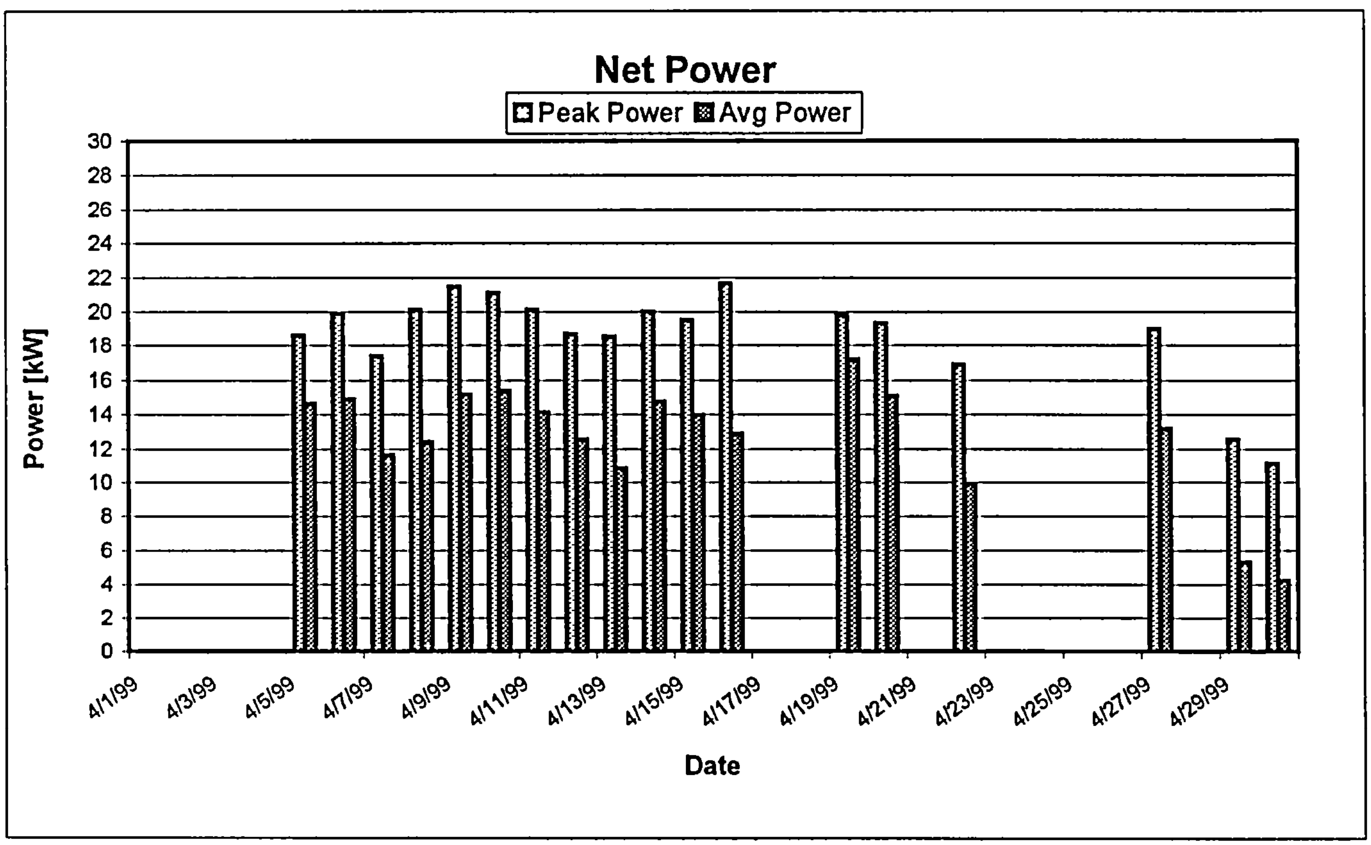
APS-West Dish Monthly Performance Summary



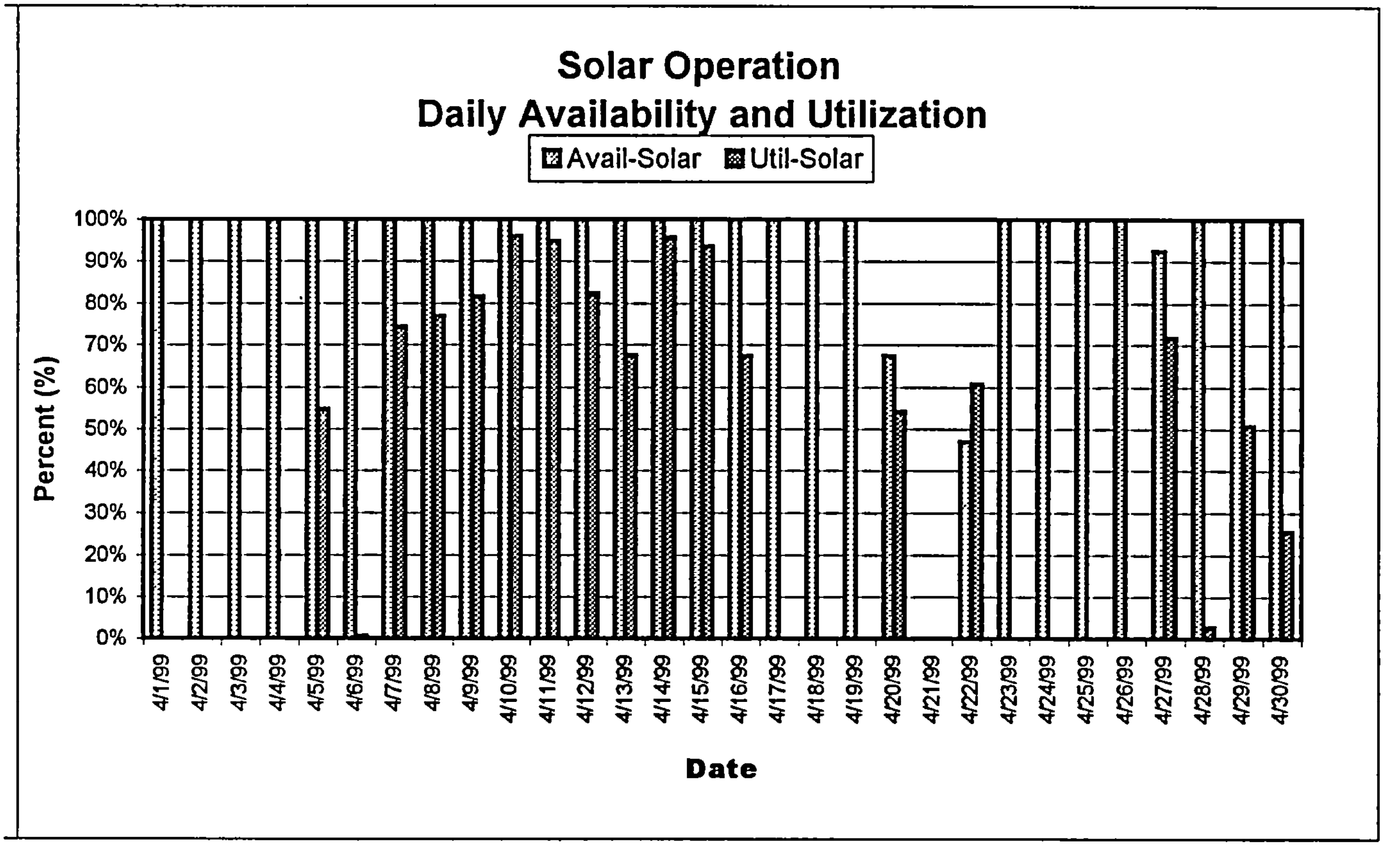


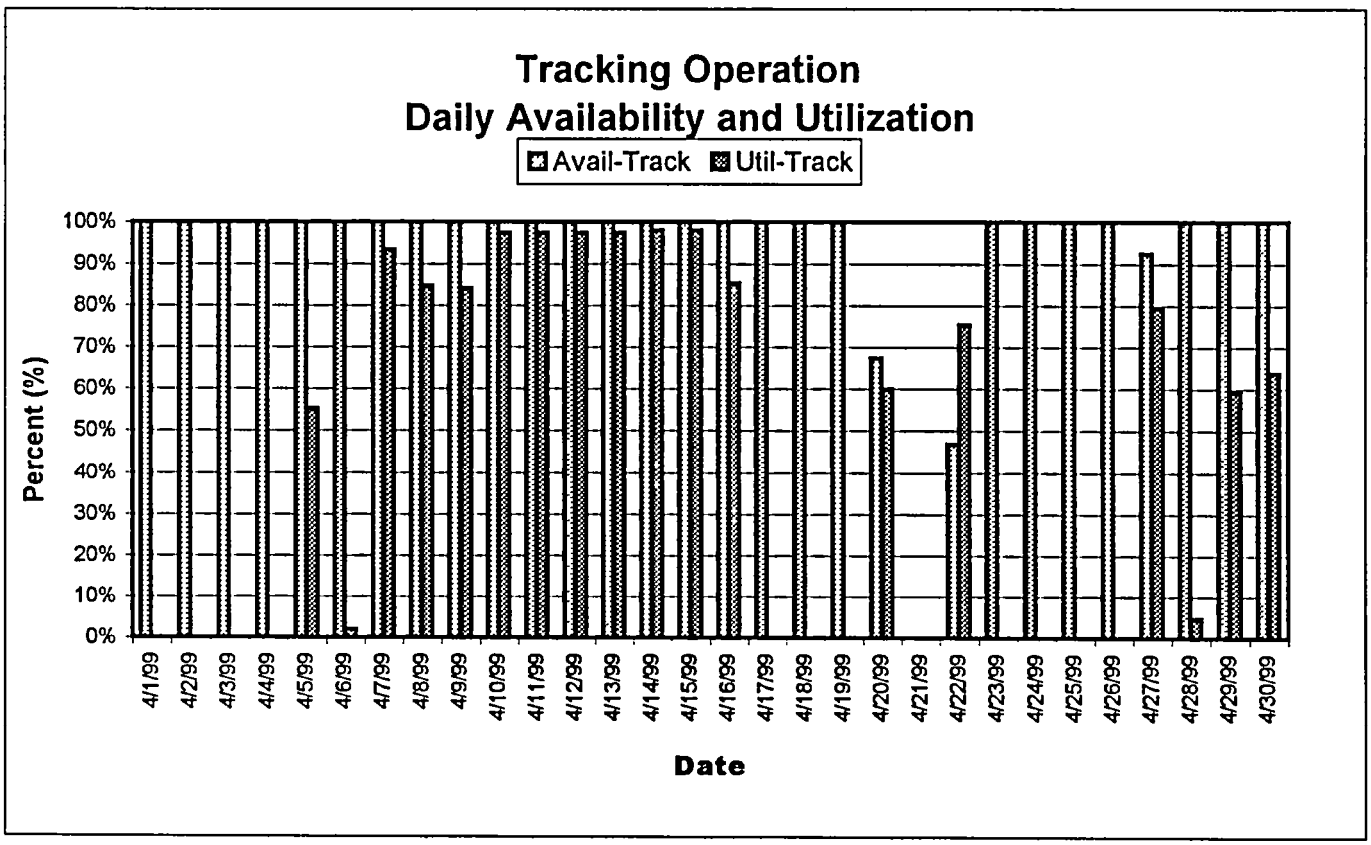
APS-West Dish Monthly Performance Summary



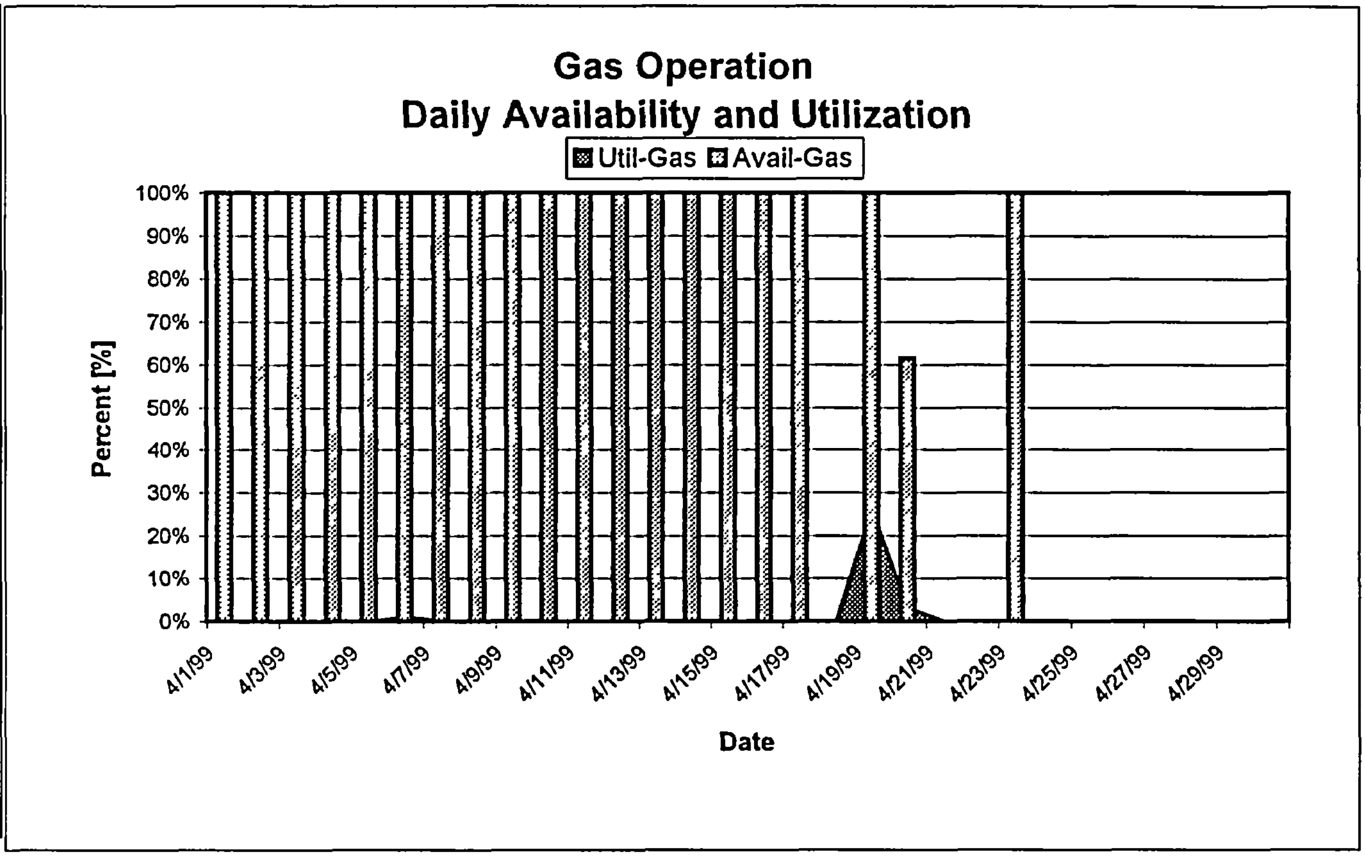


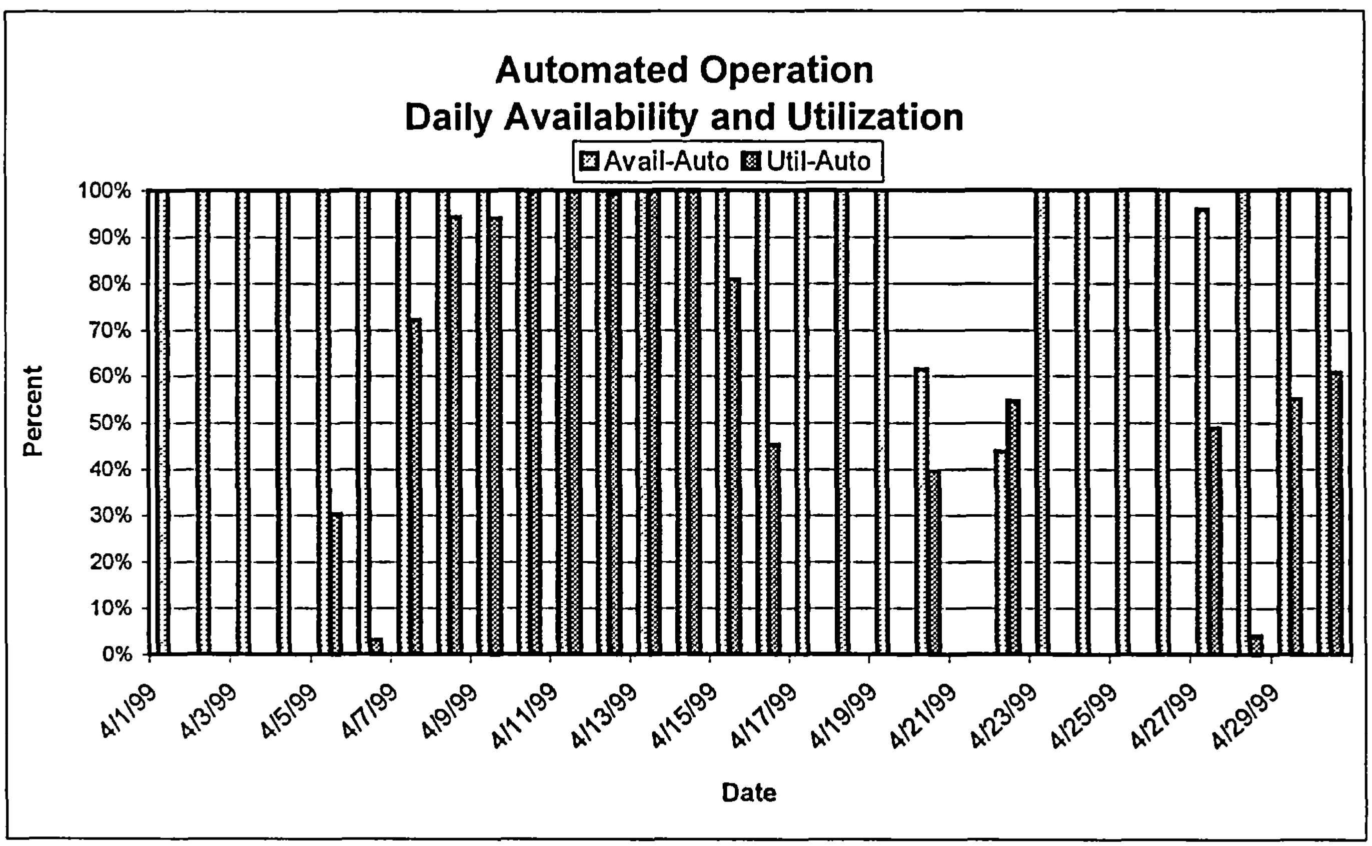
APS-West Dish Monthly Performance Summary





APS-West Dish Monthly Performance Summary





Appendix H:
Single-Day Performance Summary for the APS West Dish/Stirling System

APS-West Dish – April 1999

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	System			Hours								Downtime Hours							Insolation		Power [kW]		Energy [kWh]				Efficiency [%]		Ce
	Rating [kW]	Dish Area	Grid Avail	All Data	Daylight	Auto Op	Track Op	Solar Op	Gas Op	Hybrid Op	Energy-Deliv	Day [24hr]	Daylight	Auto	Track	Solar	Gas	Hybrid	Pk [W/m^2]	Total [Wh/m^2]	Pk Power	Avg Power	Energy DC/AC	Energy Solar	Energy Gas	Energy Hybrid	Peak Eff	Average	CF Solar
Apr-99	25.0	113.5	24.0	681.7	384.2	271.9	181.6	139.5	7.1	0.0	140.3	0.0	0.0	47.6	25.3	25.3	###	384.2	1004.0	107397.5	21.6	12.7	1778.0	1855.8	122.4	0.0	27%	18%	47%

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	System			Hours								Downtime Hours							Daily Insolation		Power [kW]		Energy [kWh]				Efficiency [%]		Ce
Date	Rating [kW]	Dish Area	Grid Avail	All Data	Daylight	Auto Op	Track Op	Solar Op	Gas Op	Hybrid Op	Energy-Deliv	Day [24hr]	Daylight	Auto	Track	Solar	Gas	Hybrid	Peak [W/m^2]	Total [Wh/m^2]	Peak Power	Avg Power	Energy DC/AC	Energy Solar	Energy Gas	Energy Hybrid	Peak Daily	Average	CF Solar
1-Apr-99	25.0	113.5	24.0	24.0	12.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	2.0	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
2-Apr-99	25.0	113.5	24.0	23.9	12.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	3.0	19.3	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
3-Apr-99	25.0	113.5	24.0	23.9	12.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	4.0	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
4-Apr-99	25.0	113.5	24.0	23.1	12.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	3.0	20.7	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
5-Apr-99	25.0	113.5	24.0	24.0	12.5	7.3	6.9	6.9	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0	12.5	877.0	5678.1	18.6	14.6	97.4	97.4	0.0	0.0	19%	15%	56%
6-Apr-99	25.0	113.5	24.0	23.9	12.5	0.7	0.2	0.1	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	12.5	907.0	546.0	19.9	14.9	4.1	0.1	4.0	0.0	13%	2%	5%
7-Apr-99	25.0	113.5	24.0	23.9	12.7	17.3	11.8	9.4	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	12.7	878.0	5753.7	17.4	11.7	74.6	74.6	0.0	0.0	17%	9%	28%
8-Apr-99	25.0	113.5	24.0	24.0	12.7	22.6	10.7	9.7	0.0	0.0	9.5	0.0	0.0	0.0	0.0	0.0	0.0	12.7	925.0	7441.5	20.1	12.4	110.6	110.6	0.0	0.0	22%	12%	43%
9-Apr-99	25.0	113.5	24.0	23.9	12.7	22.6	10.7	10.3	0.0	0.0	10.1	0.0	0.0	0.0	0.0	0.0	0.0	12.7	962.0	8685.8	21.5	15.2	144.5	144.5	0.0	0.0	23%	15%	59%
10-Apr-99	25.0	113.5	24.0	23.8	12.7	23.9	12.4	12.2	0.0	0.0	12.1	0.0	0.0	0.0	0.0	0.0	0.0	12.7	939.0	10223.5	21.1	15.4	180.3	180.3	0.0	0.0	23%	16%	62%
11-Apr-99	25.0	113.5	24.0	23.9	12.7	23.9	12.4	12.1	0.0	0.0	11.9	0.0	0.0	0.0	0.0	0.0	0.0	12.7	916.0	9620.5	20.1	14.1	163.3	163.3	0.0	0.0	22%	14%	64%
12-Apr-99	25.0	113.5	24.0	23.8	12.8	23.8	12.5	10.6	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8	911.0	7470.3	18.7	12.5	111.9	111.9	0.0	0.0	19%	11%	40%
13-Apr-99	25.0	113.5	24.0	23.9	12.8	23.9	12.5	8.7	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	12.8	879.0	5793.7	18.5	10.9	75.8	75.8	0.0	0.0	20%	10%	32%
14-Apr-99	25.0	113.5	24.0	23.9	12.8	23.9	12.6	12.3	0.0	0.0	11.9	0.0	0.0	0.0	0.0	0.0	0.0	12.8	895.0	9578.0	20.0	14.6	173.8	173.8	0.0	0.0	22%	15%	56%
15-Apr-99	25.0	113.5	24.0	23.8	12.8	19.4	12.6	12.0	0.0	0.0	11.7	0.0	0.0	0.0	0.0	0.0	0.0	12.8	886.0	9266.1	19.5	14.0	161.3	161.3	0.0	0.0	21%	14%	51%
16-Apr-99	25.0	113.5	24.0	23.9	11.1	10.9	9.5	7.5	0.0	0.0	6.6	0.0	0.0	0.0	0.0	0.0	0.0	11.1	1004.0	6029.1	21.6	12.9	83.9	83.9	0.0	0.0	23%	11%	47%
17-Apr-99	25.0	113.5	24.0	23.9	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	7.0	51.3	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
18-Apr-99	25.0	113.5	24.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	7.0	31.8	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
19-Apr-99	25.0	113.5	24.0	23.9	13.1	0.0	0.0	0.0	6.2	0.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0	13.1	7.0	52.9	19.792	17.2	106.5	0.0	106.5	0.0	0%	0%	0%
20-Apr-99	25.0	113.5	24.0	23.8	13.1	5.8	6.3	4.8	0.4	0.0	6.2	0.0	0.0	9.3	4.3	4.3	9.3	13.1	919.0	4568.0	19.3	15.1	80.2	72.5	7.7	0.0	20%	14%	62%
21-Apr-99	25.0	113.5	24.0	23.9	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	13.1	13.1	23.9	13.1	6.0	51.2	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
22-Apr-99	25.0	113.5	24.0	23.8	13.2	6.7	4.7	3.7	0.2	0.0	4.1	0.0	0.0	13.5	7.0	7.0	23.9	13.2	905.0	2893.0	16.9	9.9	35.6	31.4	4.2	0.0	21%	8%	31%
23-Apr-99	25.0	113.5	24.0	23.9	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2	6.0	39.1	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
24-Apr-99	25.0	113.5	24.0	24.0	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	13.2	6.0	38.7	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
25-Apr-99	25.0	113.5	24.0	23.8	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	13.2	6.0	41.3	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
26-Apr-99	26.0	113.5	24.0	23.9	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	13.2	7.0	47.6	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
27-Apr-99	25.0	113.5	24.0	19.7	13.3	11.2	9.8	8.8	0.0	0.0	9.1	0.0	0.0	1.0	1.0	1.0	19.7	13.3	918.0	7652.6	19.0	13.2	131.7	131.7	0.0	0.0	20%	15%	61%
28-Apr-99	25.0	113.5	24.0	17.3	12.4	1.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.3	12.4	398.0	205.1	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
29-Apr-99	25.0	113.5	24.0	23.9	13.3	13.2	7.9	6.7	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	23.9	13.3	636.0	3371.4	12.6	5.3	29.7	29.7	0.0	0.0	27%	0.1	0.2
30-Apr-99	25.0	113.5	24.0	23.9	13.4	14.6	8.6	3.4	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	23.9	13.4	784.0	2188.5	11.1	4.2	12.7	12.7	0.0	0.0	13%	0.1	0.1

Month Transition Data

	DN Insolation*Time		EFFICIENCY
	PK*E_DEL HR	Avg*E_DEL HRS	AVG*E_DEL HRS
1-Apr-99	0.0	0.0	0
2-Apr-99	0.0	0.0	0
3-Apr-99	0.0	0.0	0
4-Apr-99	0.0	0.0	0
5-Apr-99	5934.4	38408.1	1.0035461
6-Apr-99	223.7	134.7	0.0058045
7-Apr-99	7164.2	46948.8	0.709769
8-Apr-99	8780.0	70634.0	1.1253337
9-Apr-99	9692.2	87509.3	1.4737426
10-Apr-99	11336.6	123428.6	1.8796556
11-Apr-99	10906.3	114545.4	1.6547986
12-Apr-99	9102.2	74639.1	1.0765303
13-Apr-99	7319.1	48242.3	0.7961548
14-Apr-99	10629.1	113749.7	1.8368532
15-Apr-99	10444.4	108012.0	1.575492
16-Apr-99	6568.8	39565.9	0.7292547
17-Apr-99	0.0	0.0	0
18-Apr-99	0.0	0.0	0
19-Apr-99	43.4	#REF!	0
20-Apr-99	4801.5	23866.3	0.7114905
21-Apr-99	0.0	0.0	0
22-Apr-99	3692.4	11803.5	0.3343175
23-Apr-99	0.0	0.0	0
24-Apr-99	0.0	0.0	0
25-Apr-99	0.0	0.0	0
26-Apr-99	0.0	0.0	0
27-Apr-99	8355.1	69649.0	1.4016767
28-Apr-99	0.0	0.0	0
29-Apr-99	4663.6	16807.0	0.4096609
30-Apr-99	2350.3	6560.6	0.169634
			0

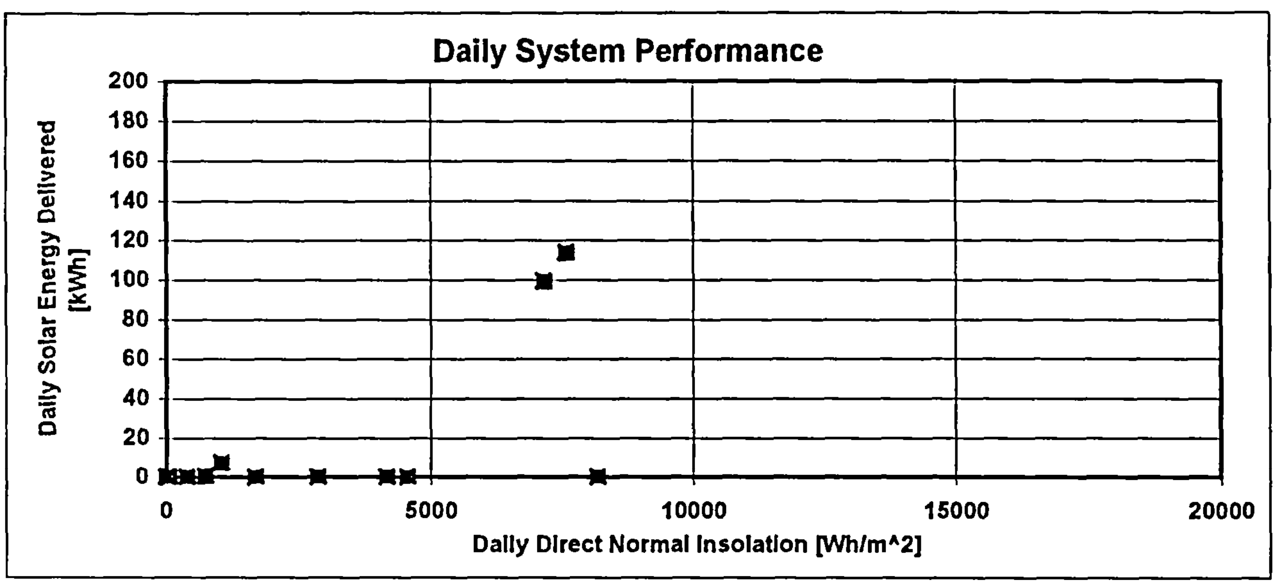
acity Factor		Availability and Utilization									
CF_{Gen}	CF_{Hybrid}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Track}$	$Util_{Track}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gen}$	$Util_{Gen}$	$Avail_{Hybrid}$	$Util_{Hybrid}$
69%	0%	93%	43%	93%	45%	93%	39%	69%	2%	0%	0%

acity Factor		Availability and Utilization									
CF_{Gen}	CF_{Hybrid}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Track}$	$Util_{Track}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gen}$	$Util_{Gen}$	$Avail_{Hybrid}$	$Util_{Hybrid}$
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	100%	30%	100%	55%	100%	55%	100%	0%	0%	0%
64%	0%	100%	3%	100%	2%	100%	1%	100%	1%	0%	0%
0%	0%	100%	72%	100%	93%	100%	74%	100%	0%	0%	0%
0%	0%	100%	94%	100%	85%	100%	77%	100%	0%	0%	0%
0%	0%	100%	84%	100%	84%	100%	82%	100%	0%	0%	0%
0%	0%	100%	100%	100%	97%	100%	96%	100%	0%	0%	0%
0%	0%	100%	100%	100%	97%	100%	95%	100%	0%	0%	0%
0%	0%	100%	99%	100%	87%	100%	82%	100%	0%	0%	0%
0%	0%	100%	100%	100%	97%	100%	68%	100%	0%	0%	0%
0%	0%	100%	100%	100%	98%	100%	96%	100%	0%	0%	0%
0%	0%	100%	81%	100%	96%	100%	94%	100%	0%	0%	0%
0%	0%	100%	45%	100%	85%	100%	67%	100%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	0%	0%
69%	0%	100%	0%	100%	0%	100%	0%	100%	26%	0%	0%
73%	0%	61%	40%	67%	60%	67%	54%	61%	3%	0%	0%
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
62%	0%	44%	55%	47%	75%	47%	61%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	0%	0%
0%	0%	96%	49%	92%	79%	92%	72%	0%	0%	0%	0%
0%	0%	100%	4%	100%	5%	100%	3%	0%	0%	0%	0%
0 0	0 0	1 0	0 6	1 0	0 6	1.0	0 5	0 0	0 0	0 0	0 0
0 0	0 0	1.0	0 6	1 0	0 6	1.0	0.3	0 0	0 0	0 0	0 0

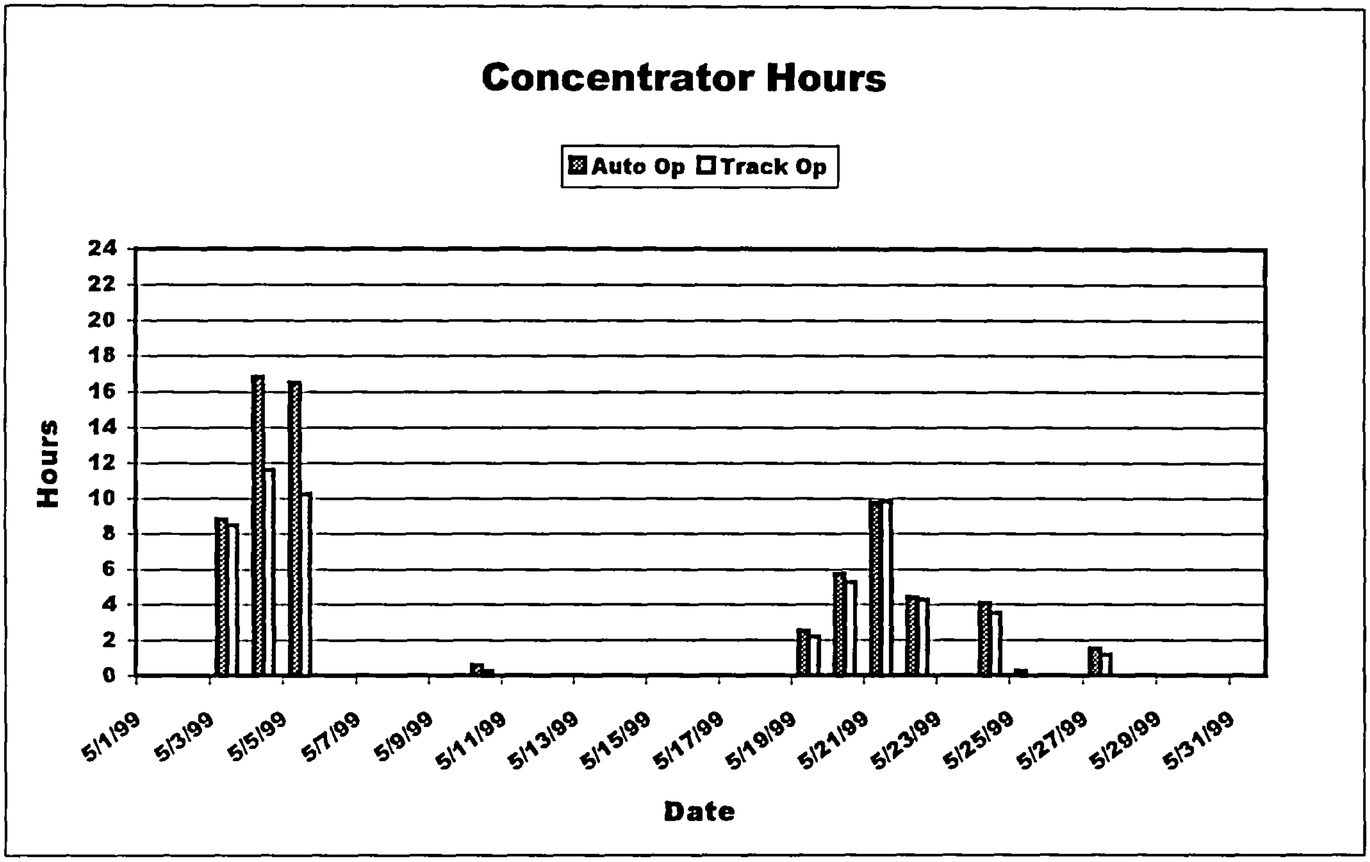
APS-West Dish Monthly Performance Summary

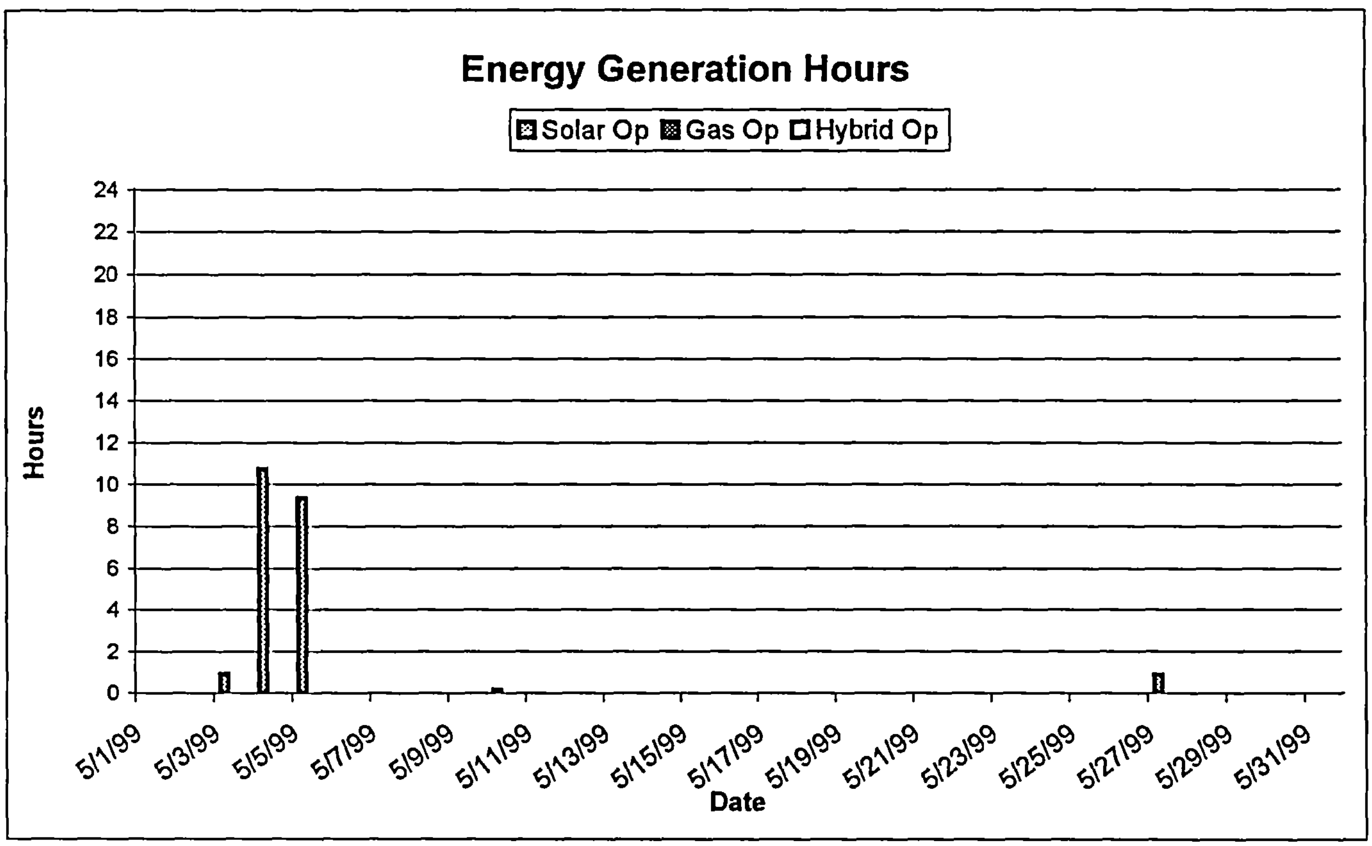
May-99

Day	Summary of Operation
1	Not operated: weekend
2	Not operated: weekend
3	Operated 0700 to 1540; cloudy
4	Operated 0700 to 1930
5	Operated 0530 to 1130 and 1400 to 1930
6	Not operated: meter installation -- grid down
7	Not operated: meter installation -- grid down
8	Not operated: weekend
9	Not operated: weekend
10	PCS was run backwards -- Incident #322; Engine damaged
11	System down
12	System down
13	System down
14	System down; Removed engine and shipped to STM
15	System down
16	System down
17	System down
18	System down
19	System down; Performed calorimetry; Incident #323 (motor protection relay)
20	System down; Performed calorimetry and BCS
21	System down; Performed BCS alignment/focus adjustment
22	System down; Performed BCS alignment/focus adjustment
23	System down; weekend
24	Perrformed calorimetry; Installed new engine (s/n 0002)
25	Operated 1030 to PCS actuator fault (Incident #324) at 1053
26	System down: Actuator fault in PCS
27	Ran on gas 1315 to 1320; Operated on solar 1450 to PCS Actuator Fault (IR #325) at 1618
28	System down: PCS actuator fault
29	System down: PCS actuator fault
30	System down: PCS actuator fault
31	System down: PCS actuator fault

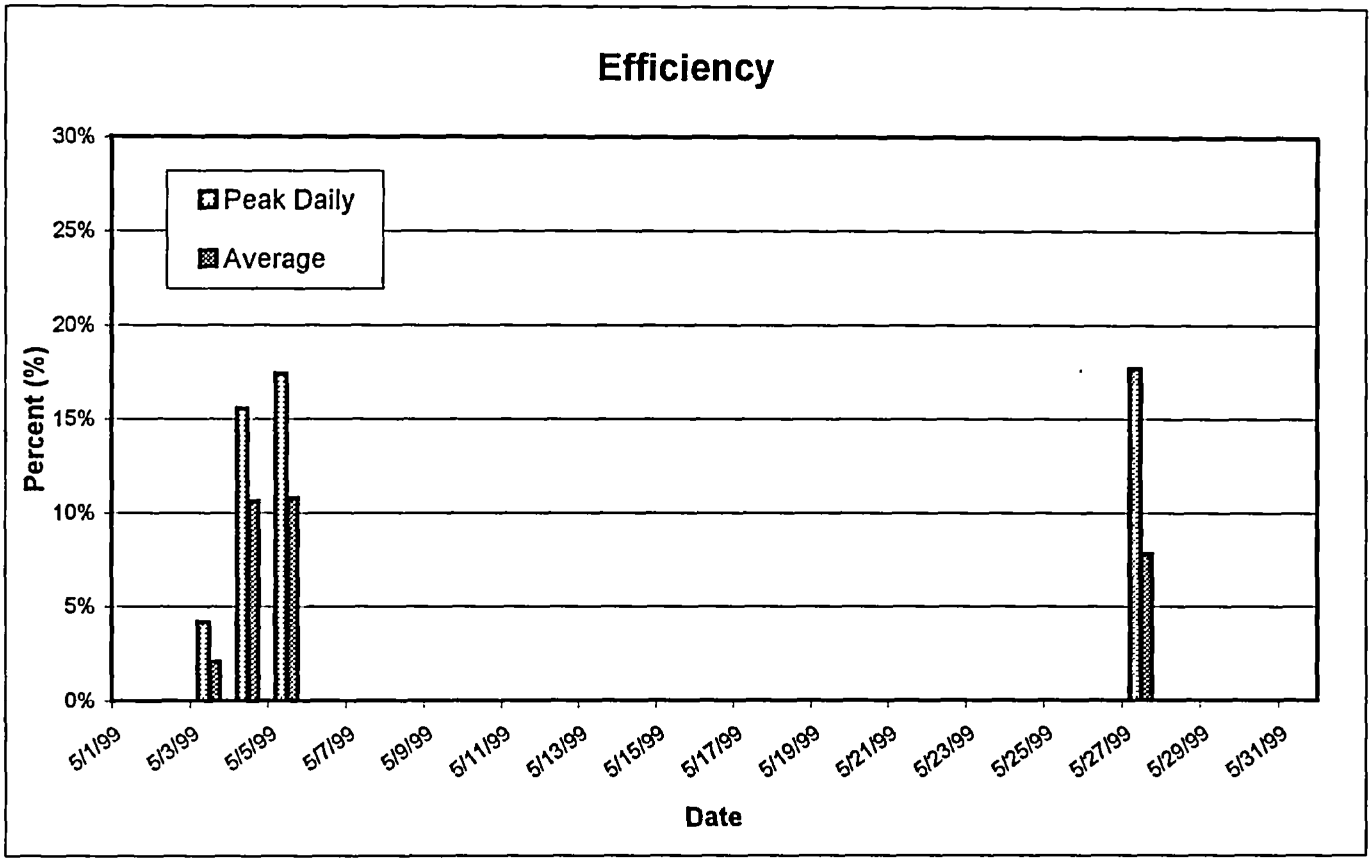


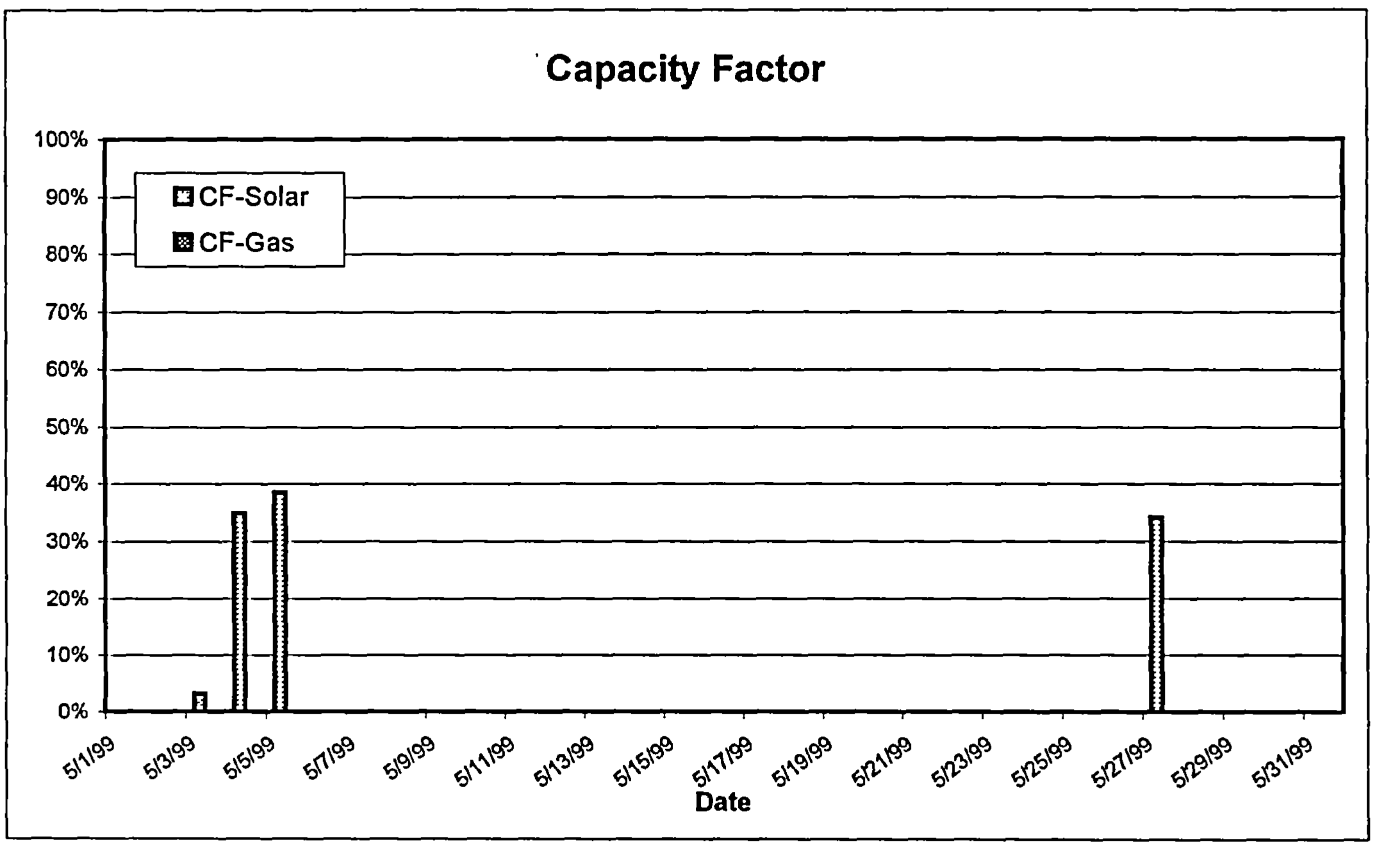
APS-West Dish Monthly Performance Summary



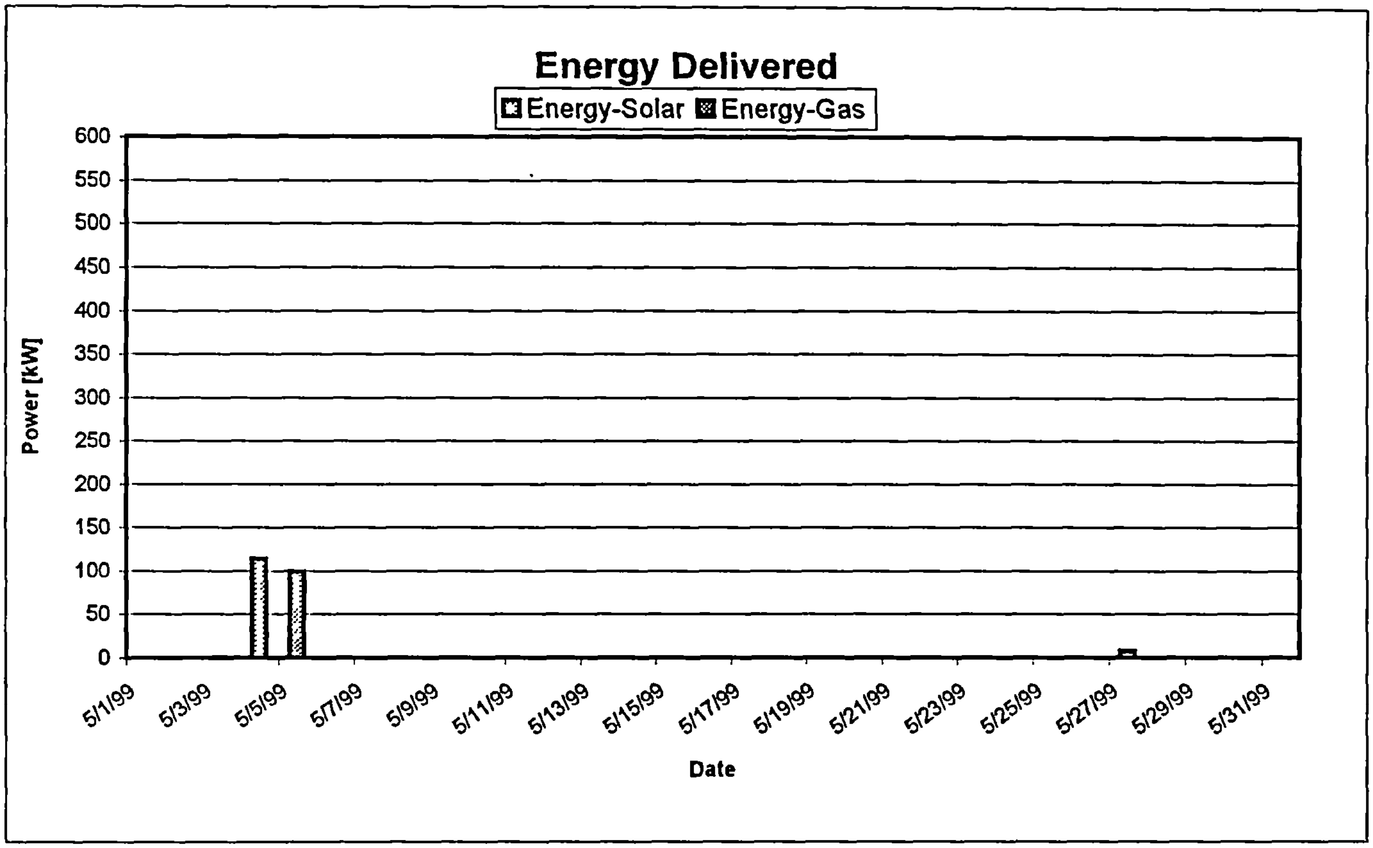


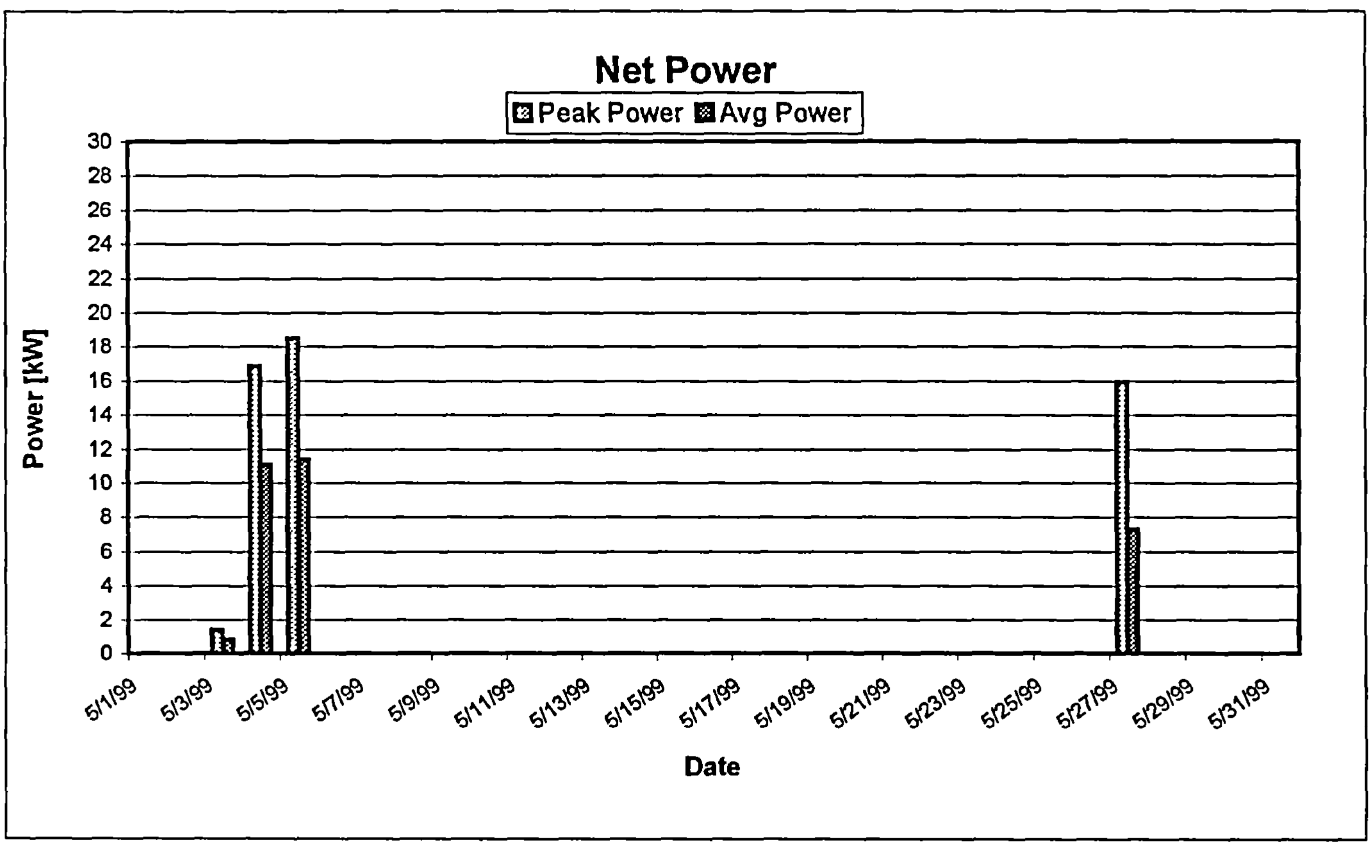
APS-West Dish Monthly Performance Summary



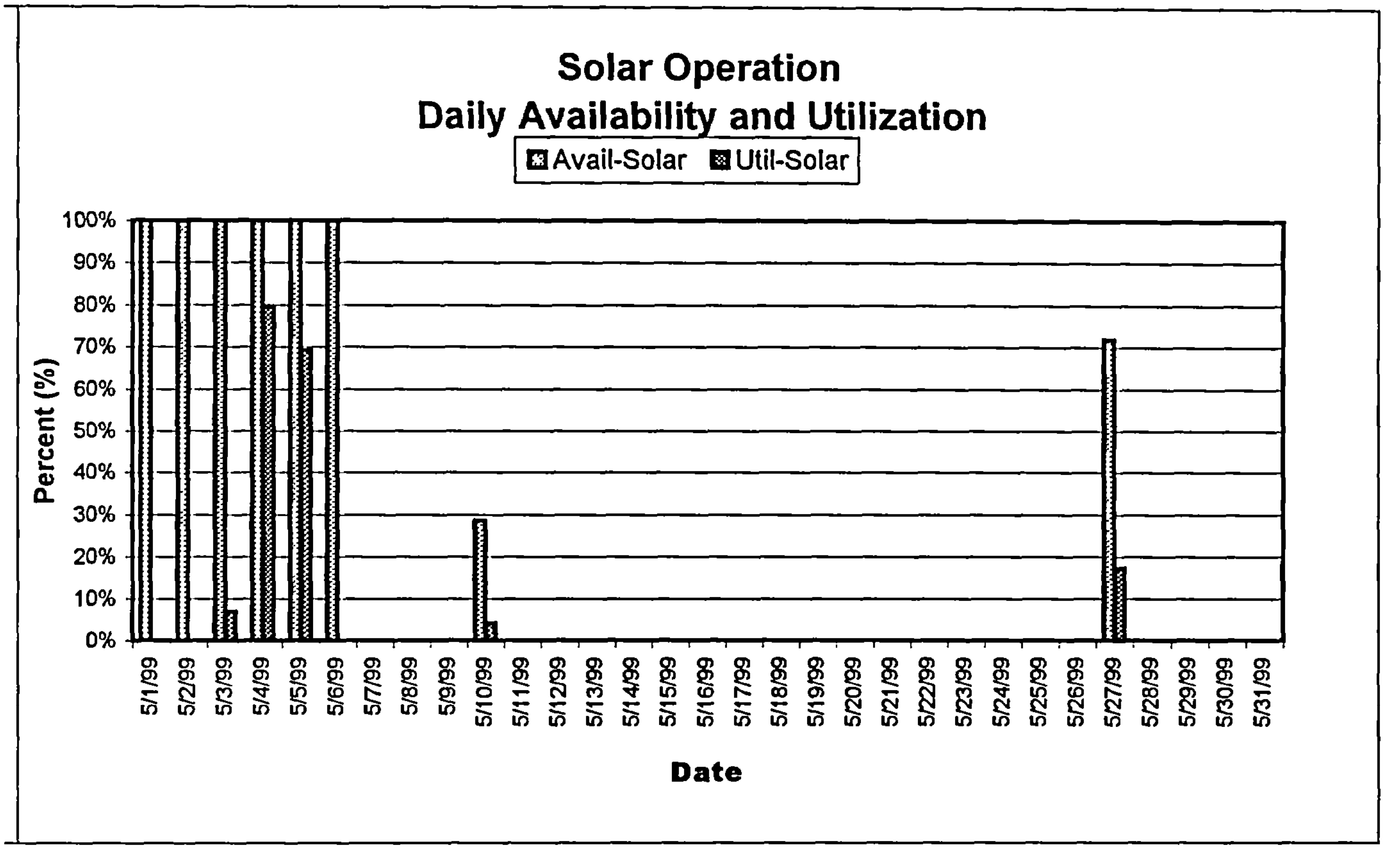


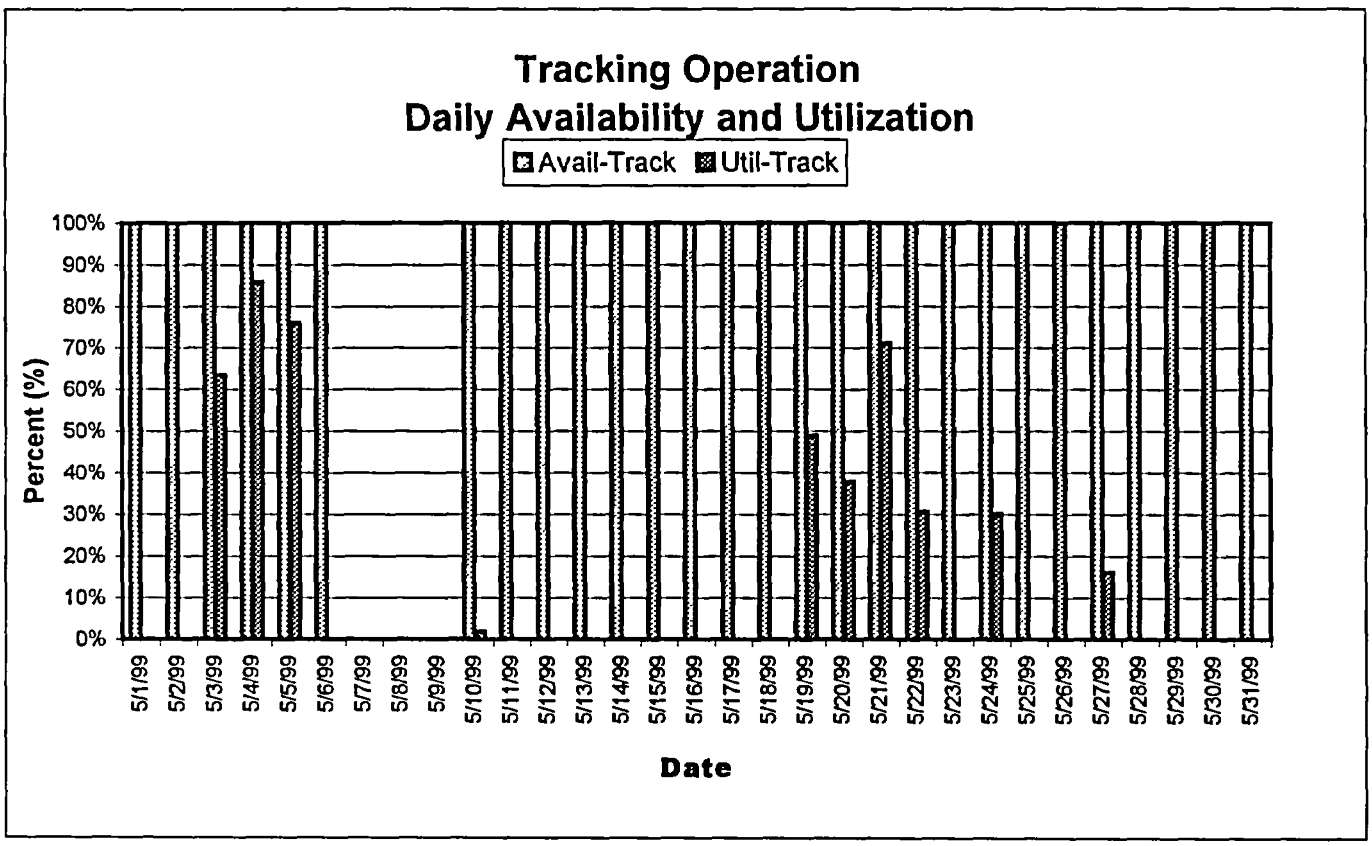
APS-West Dish Monthly Performance Summary



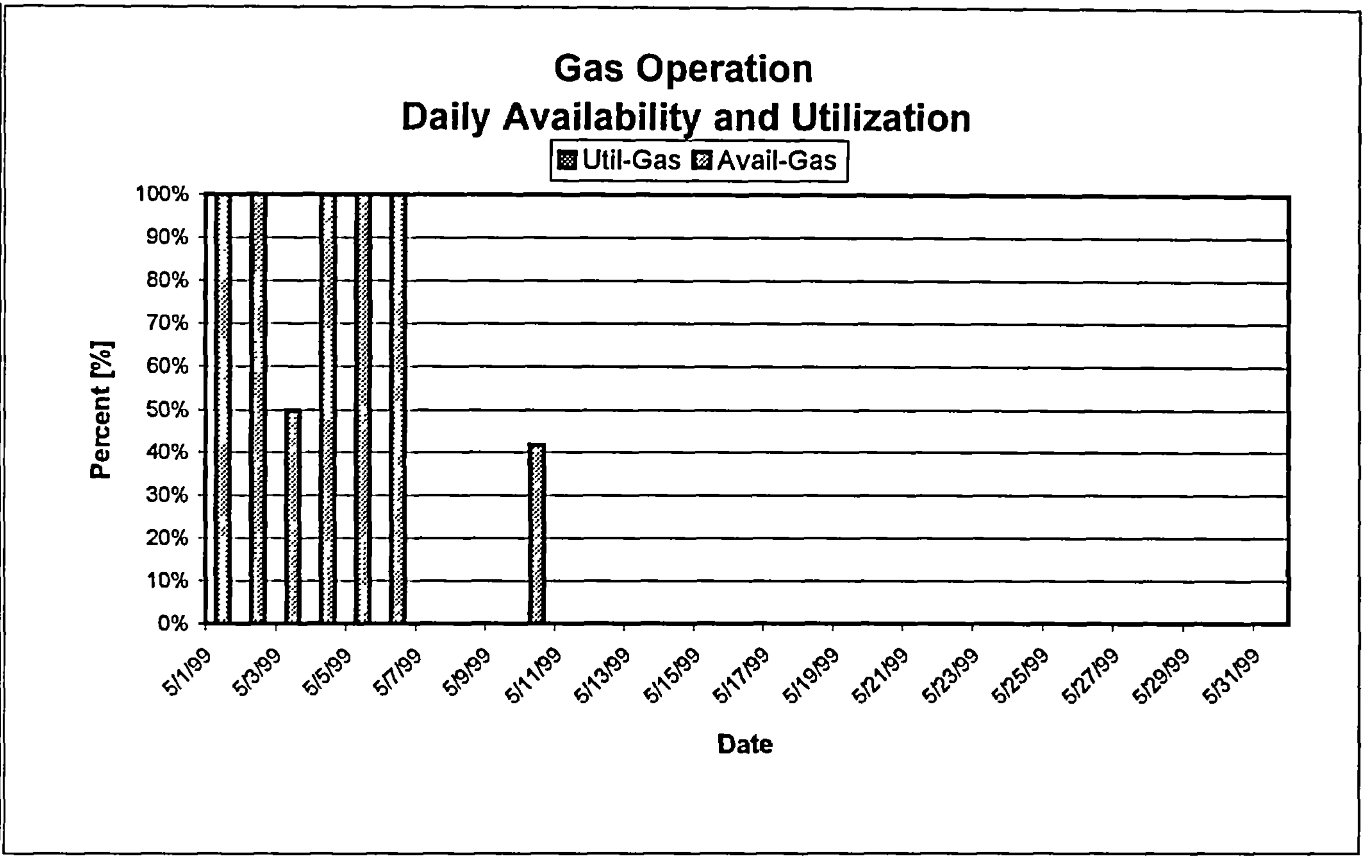


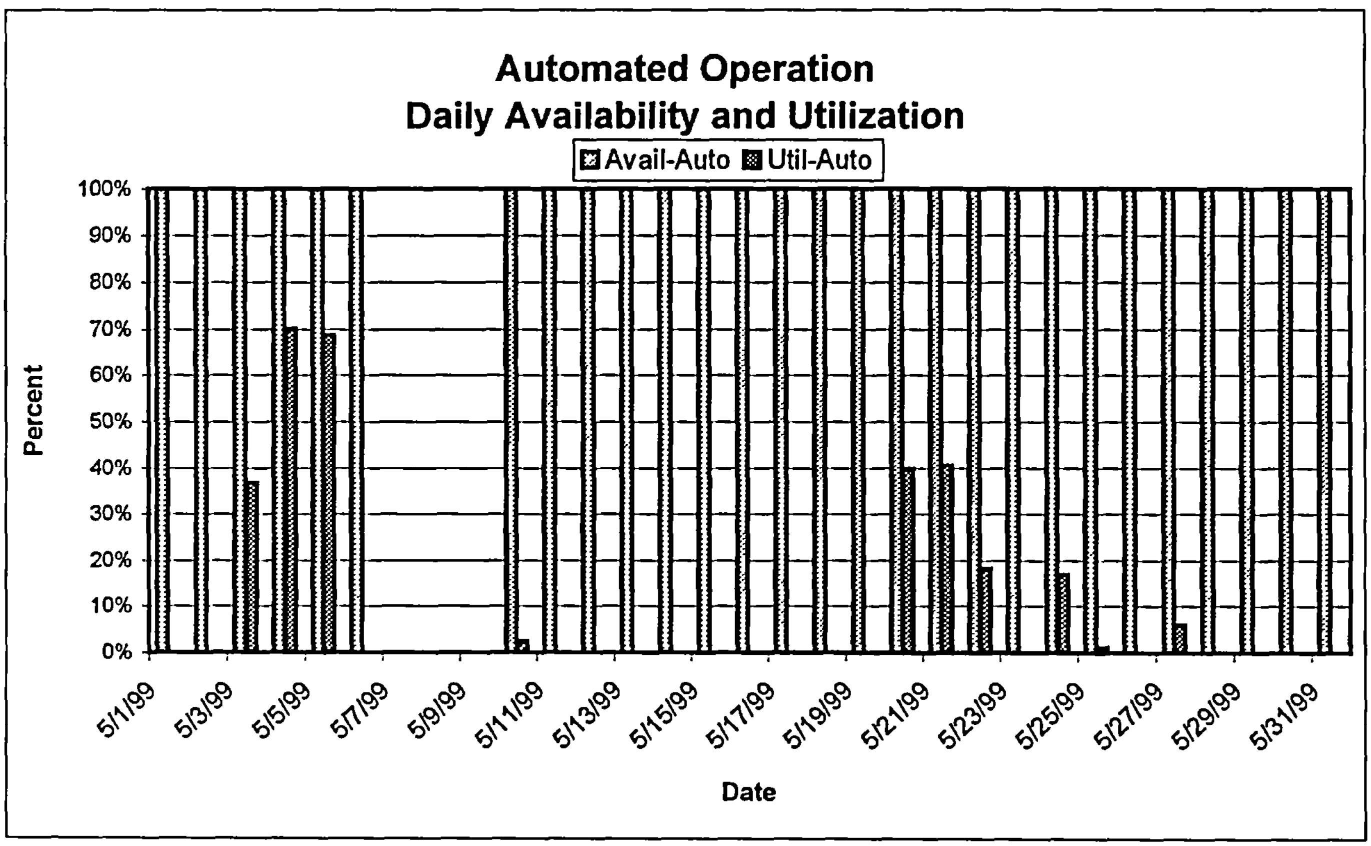
APS-West Dish Monthly Performance Summary





APS-West Dish Monthly Performance Summary





APS-West Dish – May 1999

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	System			Hours								Downtime Hours							Insolation$_{DNI}$		Power [kW]		Energy [kWh]				Efficiency [%]		Ca
	Rating [kW]	Dish Area	Grid Avail	All Data	Daylight	Auto Op	Track Op	Solar Op	Gas Op	Hybrid Op	Energy-Deliv	Day [24hr]	Daylight	Auto	Track	Solar	Gas	Hybrid	Pk [W/m^2]	Total [Wh/m^2]	Pk Power	Avg Power	Energy$_{DLVRD}$	Energy$_{Solar}$	Energy$_{Gas}$	Energy$_{Hybrid}$	Peak Eff	Average	CF$_{Solar}$
May-99	25.0	113.5	20.9	283.3	164.9	70.8	56.7	22.0	0.0	0.0	21.4	14.0	10.0	0.0	0.0	####	###	717.1	964.0	38516.2	18.5	10.3	221.3	221.3	0.0	0.0	18%	11%	40%

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	System			Hours								Downtime Hours							Daily Insolation$_{DNI}$		Power [kW]		Energy [kWh]				Efficiency [%]		Ca
Date	Rating [kW]	Dish Area	Grid Avail	All Data	Daylight	Auto Op	Track Op	Solar Op	Gas Op	Hybrid Op	Energy-Deliv	Day [24hr]	Daylight	Auto	Track	Solar	Gas	Hybrid	Peak [W/m^2]	Total [Wh/m^2]	Peak Power	Avg Power	Energy$_{DLVRD}$	Energy$_{Solar}$	Energy$_{Gas}$	Energy$_{Hybrid}$	Peak Daily	Average	CF$_{Solar}$
1-May-99	25.0	113.5	24.0	23.9	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	5.0	37.6	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
2-May-99	25.0	113.5	24.0	24.0	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	6.0	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
3-May-99	25.0	113.5	24.0	23.9	13.4	8.8	8.5	0.9	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	12.0	24.0	387.0	727.1	1.4	0.8	0.7	0.7	0.0	0.0	4%	2%	3%
4-May-99	25.0	113.5	24.0	24.0	13.5	16.8	11.6	10.7	0.0	0.0	10.6	0.0	0.0	0.0	0.0	0.0	0.0	24.0	791.0	7588.5	16.8	11.1	113.8	113.8	0.0	0.0	16%	11%	35%
5-May-99	25.0	113.5	24.0	23.9	13.5	18.5	10.2	9.3	0.0	0.0	9.2	0.0	0.0	0.0	0.0	0.0	0.0	24.0	878.0	7164.5	18.5	11.4	99.2	99.2	0.0	0.0	17%	11%	38%
6-May-99	25.0	113.5	0.0	7.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	1.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
7-May-99	25.0	113.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
8-May-99	25.0	113.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
9-May-99	25.0	113.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
10-May-99	25.0	113.5	24.0	24.0	14.0	0.6	0.3	0.2	0.0	0.0	0.0	14.0	10.0	0.0	0.0	10.0	14.0	14.0	880.0	387.8	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
11-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
12-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
13-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
14-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
15-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
16-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
17-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
18-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
19-May-99	25.0	113.5	24.0	9.1	4.4	2.5	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	787.0	1675.1	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
20-May-99	25.0	113.5	24.0	24.0	13.9	5.7	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	24.0	24.0	911.0	4565.1	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
21-May-99	25.0	113.5	24.0	23.9	13.8	9.7	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	23.9	24.0	964.0	8181.1	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
22-May-99	25.0	113.5	24.0	23.9	13.9	4.4	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	23.9	24.0	963.0	4170.8	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
23-May-99	25.0	113.5	24.0	23.8	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	23.9	24.0	6.0	51.1	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
24-May-99	25.0	113.5	24.0	17.0	11.6	4.1	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6	17.0	24.0	963.0	2863.6	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
25-May-99	25.0	113.5	24.0	3.8	3.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.8	24.0	6.0	18.3	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
26-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	24.0	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
27-May-99	25.0	113.5	24.0	7.1	7.1	1.5	1.2	0.9	0.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	7.1	7.1	821.0	1037.9	15.9	7.3	7.5	7.5	0.0	0.0	18%	8%	34%
28-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
29-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
30-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%
31-May-99	25.0	113.5	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	24.0	24.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0%	0%	0%

Month Transition Data

	DN Insolation*Time		EFFICIENCY
	PK*E$_{DEL}$ HR	Avg*E$_{DEL}$ HRS	AVG*E$_{DEL}$ HRS
1-May-99	0.0	0.0	0
2-May-99	0.0	0.0	0
3-May-99	257.8	484.3	0.0136028
4-May-99	8364.4	80244.1	1.1230478
5-May-99	8041.5	65619.2	0.9892818
6-May-99	0.0	0.0	0
7-May-99	0.0	0.0	0
8-May-99	0.0	0.0	0
9-May-99	0.0	0.0	0
10-May-99	0.0	0.0	0
11-May-99	0.0	0.0	0
12-May-99	0.0	0.0	0
13-May-99	0.0	0.0	0
14-May-99	0.0	0.0	0
15-May-99	0.0	0.0	0
16-May-99	0.0	0.0	0
17-May-99	0.0	0.0	0
18-May-99	0.0	0.0	0
19-May-99	0.0	#REF!	0
20-May-99	0.0	0.0	0
21-May-99	0.0	0.0	0
22-May-99	0.0	0.0	0
23-May-99	0.0	0.0	0
24-May-99	0.0	0.0	0
25-May-99	0.0	0.0	0
26-May-99	0.0	0.0	0
27-May-99	848.8	1072.7	0.0808356
28-May-99	0.0	0.0	0
29-May-99	0.0	0.0	0
30-May-99	0.0	0.0	0
31-May-99	0.0	0.0	0

acity Factor		Availability and Utilization									
CF_{-Gas}	$CF_{-Hybrid}$	$Avail._{Auto}$	$Util._{Auto}$	$Avail._{Track}$	$Util._{Track}$	$Avail._{Solar}$	$Util._{Solar}$	$Avail._{Gas}$	$Util._{Gas}$	$Avail._{Hybrid}$	$Util._{Hybrid}$
0%	0%	100%	25%	100%	34%	-75%	0%	-71%	0%	-335%	0%

acity Factor		Availability and Utilization									
CF_{-Gas}	$CF_{-Hybrid}$	$Avail._{Auto}$	$Util._{Auto}$	$Avail._{Track}$	$Util._{Track}$	$Avail._{Solar}$	$Util._{Solar}$	$Avail._{Gas}$	$Util._{Gas}$	$Avail._{Hybrid}$	$Util._{Hybrid}$
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	100%	37%	100%	63%	100%	7%	50%	0%	0%	0%
0%	0%	100%	70%	100%	86%	100%	80%	100%	0%	0%	0%
0%	0%	100%	69%	100%	76%	100%	69%	100%	0%	0%	0%
0%	0%	100%	0%	100%	0%	100%	0%	100%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	2%	100%	2%	29%	4%	42%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	49%	0%	0%	0%	0%	0%	0%
0%	0%	100%	40%	100%	38%	0%	0%	0%	0%	0%	0%
0%	0%	100%	41%	100%	71%	0%	0%	0%	0%	0%	0%
0%	0%	100%	18%	100%	31%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	17%	100%	30%	0%	0%	0%	0%	0%	0%
0%	0%	100%	1%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	6%	100%	16%	72%	17%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%

APS-West Dish Monthly Performance Summary

June-99

Monthly Totals:

Energy Delivered on Solar:	206.4 kWh
Energy Delivered on Gas:	84.4 kWh
Net Energy Delivered:	277.6 kWh
Automated Operation:	40.2 hours
Tracking Operation:	28.2 hours
Solar Operation:	23.0 hours
Gas Operation:	7.1 hours

Monthly Records:

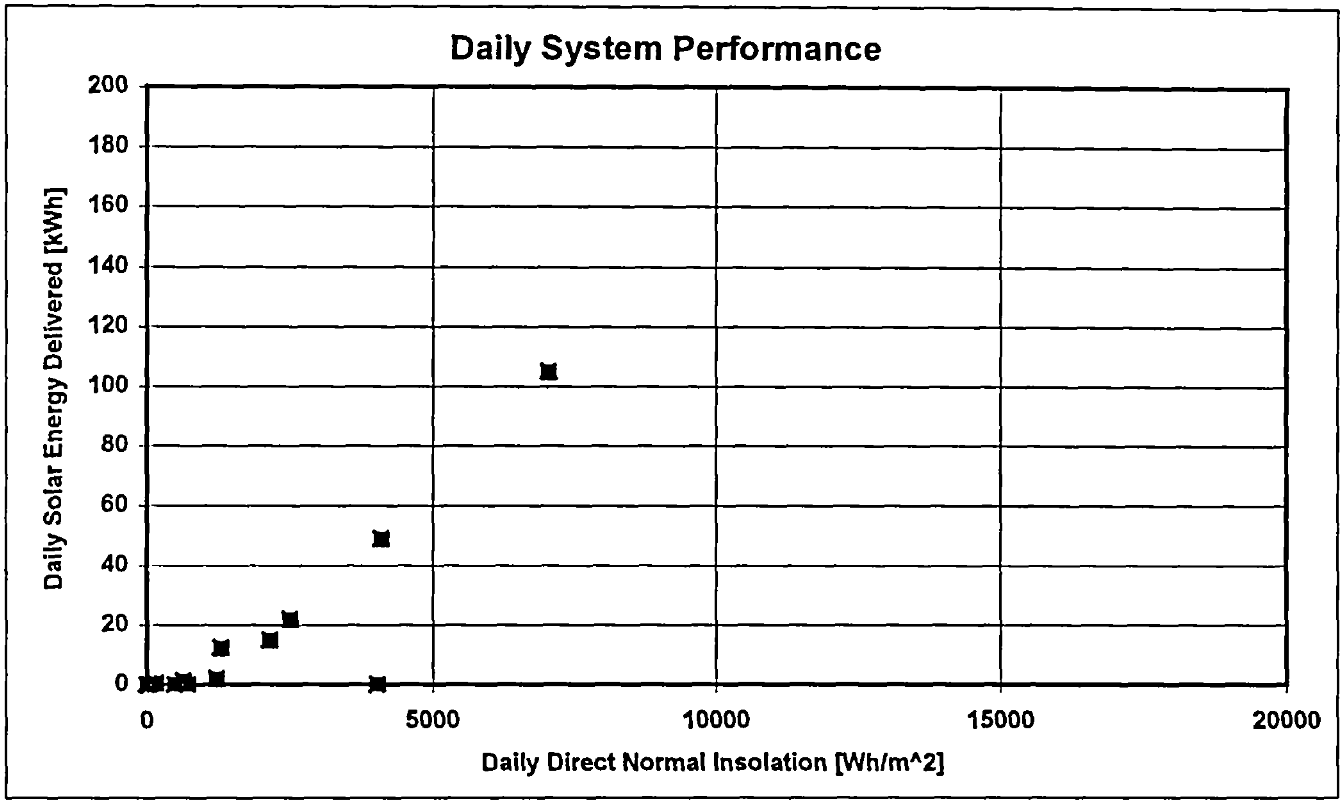
Peak Solar Power:	19.0 kW
Peak Solar Efficiency:	16%
Peak Gas Power:	19.4 kW

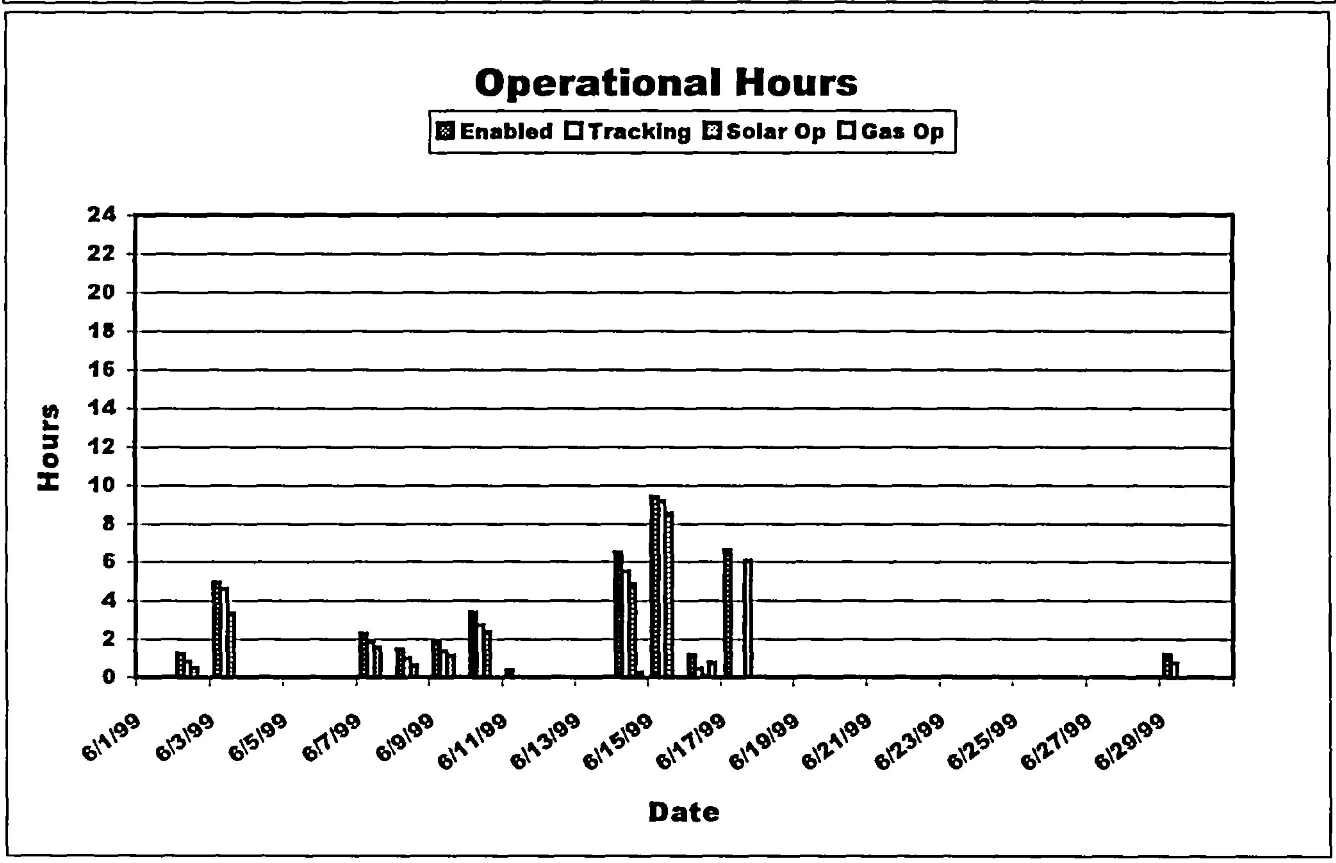
Operational/Reliability Data:

	Availability	Utilization	Capacity Factor
Controls	100%	6%	n/a
Solar	36%	9%	1%
Gas	37%	2%	0%

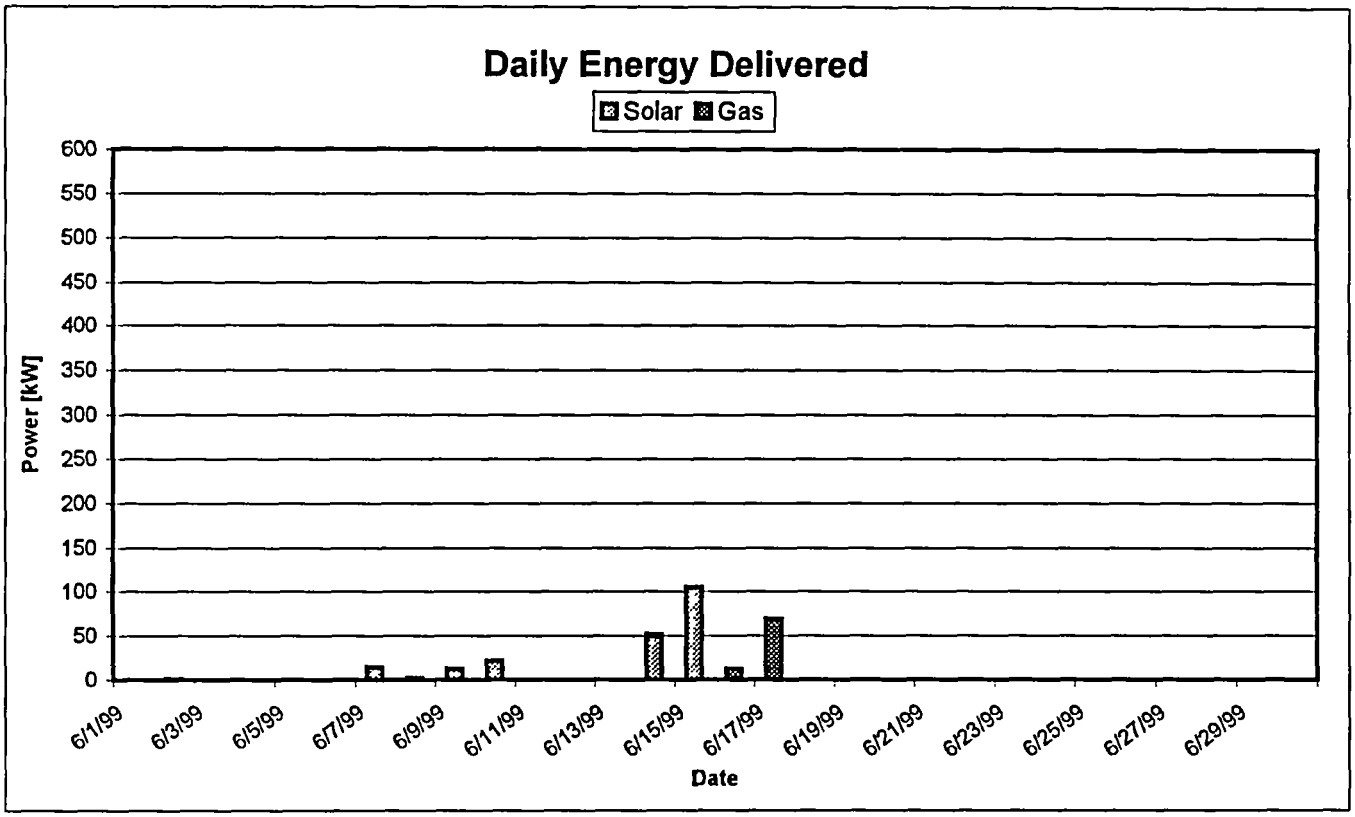
Day	Operational Summary
1	Not Operated
2	Operated 1600 to 1700
3	Operated 0730 to 1245; no power data file
4	Not operated
5	Not Operated
6	Not operated
7	Operated 0800 to 1015; Incidents #326, 327
8	Operated 0730 to 0840; Incidents #328 & 329
9	Operated 1420 to 1605; Incidents #330 &331
10	Operated 1230 to 1420, 1440 to 1645; Incident #332 (grid loss)
11	Not operated; Incident #333
12	Not operated; weekend and down due to Incident #333
13	Not operated; weekend and down due to Incident #333
14	Operated 1315 to 1900 on sun; Operated 1925 to 1940 on gas; Incident #334
15	Operated 0600 to 1530; Incident #335
16	Operated on gas/solar 0615 to 0705
17	Operated on gas 0700 to 1310; Incident #336
18	Not operated; engine and focus valves down
19	Not operated; engine and focus valves down
20	Not operated; engine and focus valves down
21	Not operated; engine and focus valves down
22	Not operated; engine and focus valves down
23	Not operated; engine and focus valves down
24	Not operated; engine and focus valves down
25	Not operated; engine and focus valves down
26	Not operated; engine and focus valves down
27	Not operated; engine and focus valves down
28	Not operated; engine and focus valves down
29	Not operated; manually moved and washed mirrors
30	Not operated; focus valves down

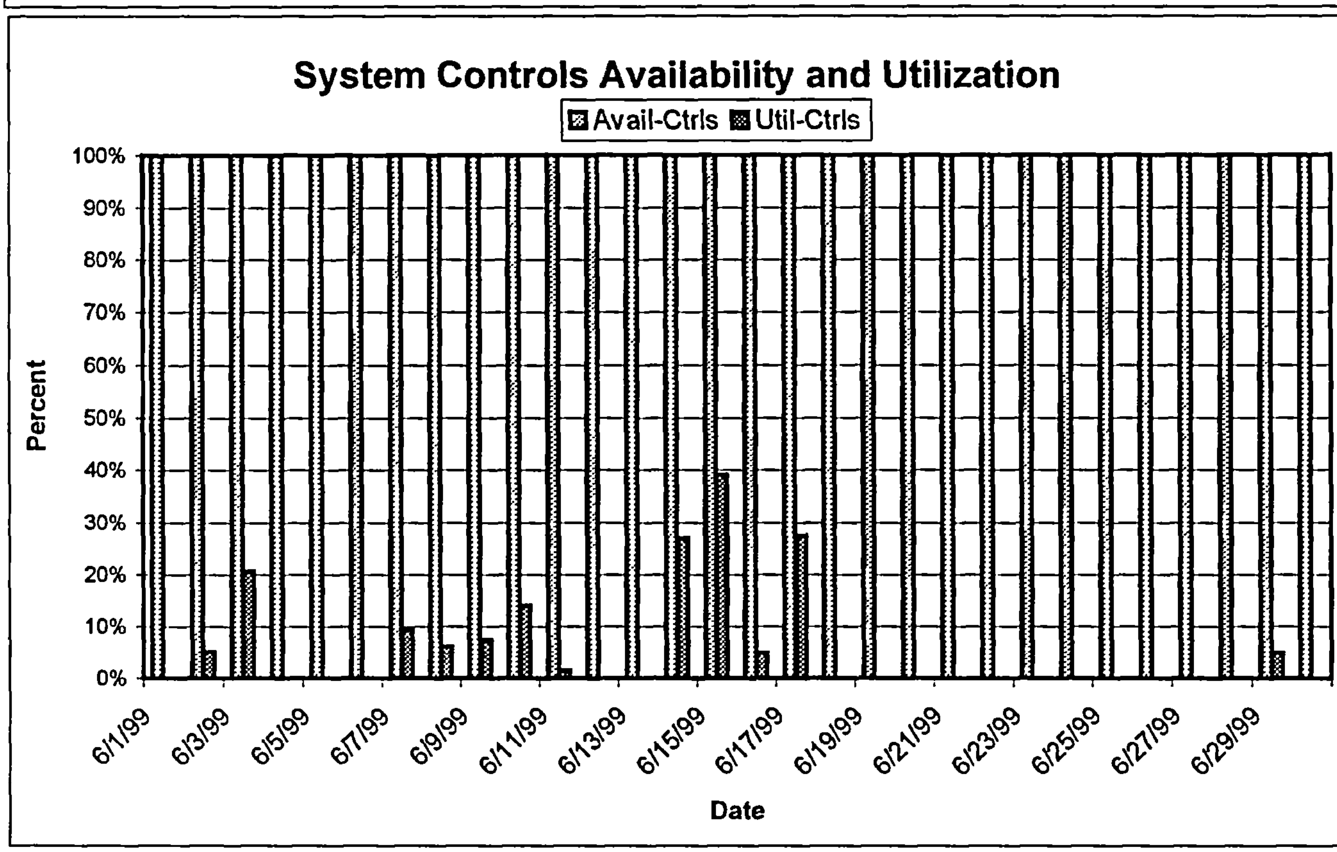
APS-West Dish Monthly Performance Summary



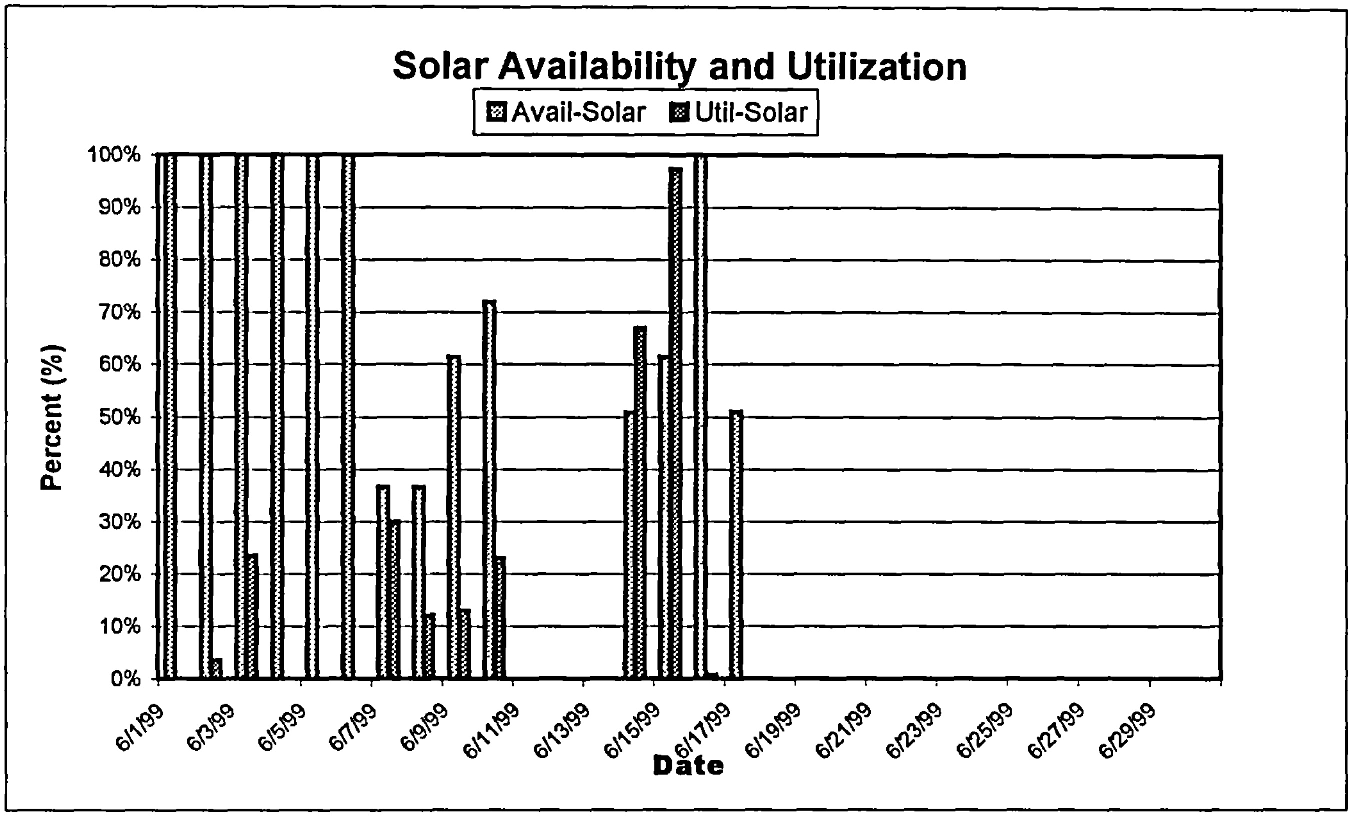


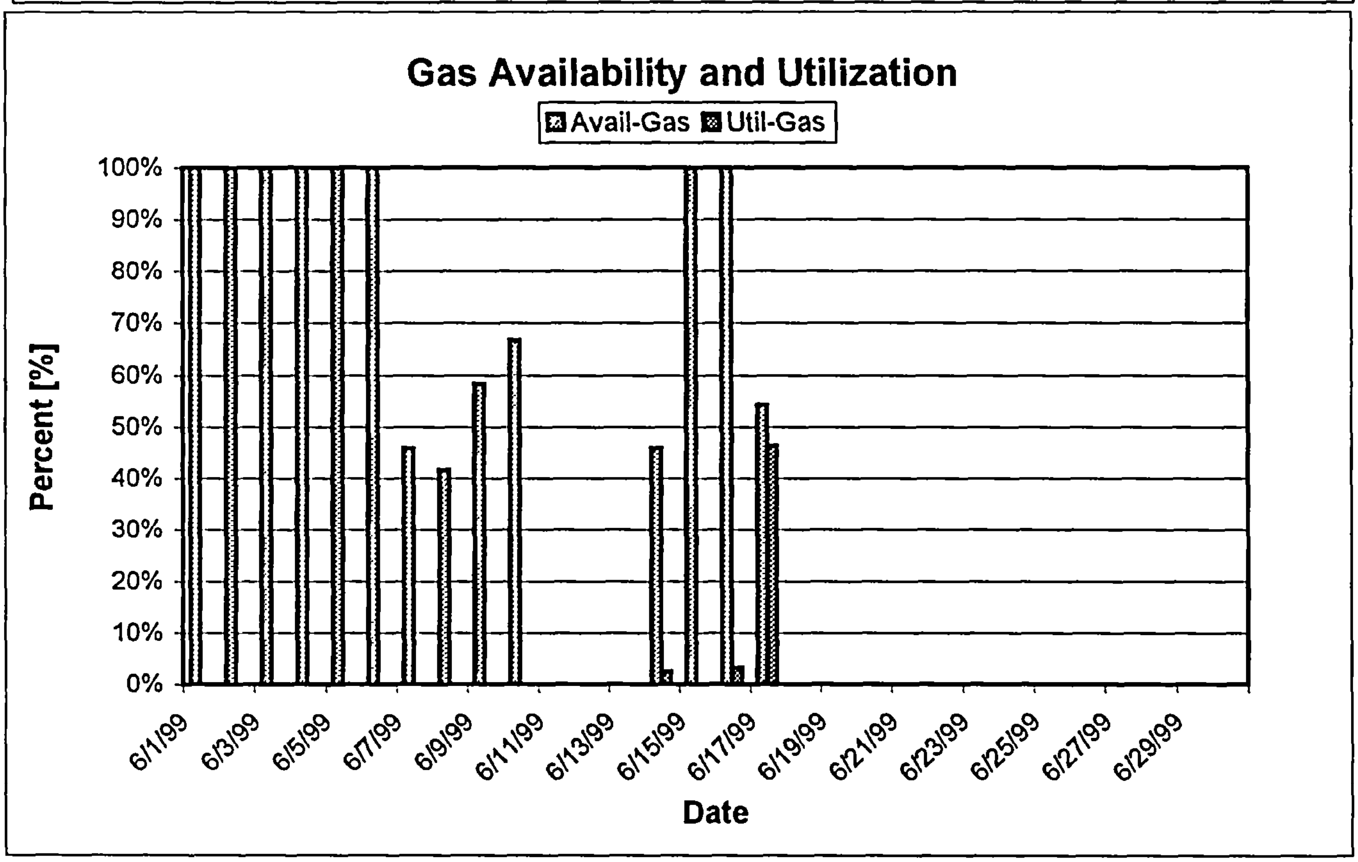
APS-West Dish Monthly Performance Summary





APS-West Dish Monthly Performance Summary





APS-West Dish

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	Monthly Total Hours					Downtimes [hr]			Insolation$_{DN}$		Power [kW]				Energy [kWh]	
	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Pk [W/m^2]	Total [Wh/m^2]	Solar Peak	Solar Avg	Gas Peak	Gas Avg	Consumed	Solar
Jun-99	427.0	40.2	28.2	23.0	7.1	0.0	275.5	453.0	942.0	24444.4	19.0	1.8	19.4	1.8	-13.2	206.4
	720 Month Total															

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	Hours					Downtimes [hr]			Daily Insolation$_{DN}$		Power [kW]				Energy [kWh]	
Day	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Peak [W/m^2]	Total [Wh/m^2]	Solar Peak	Solar Avg	Gas Peak	Gas Avg	Consumed	Solar
01-Jun-99	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0
02-Jun-99	14.2	1.2	0.8	0.5	0.0	0.0	0.0	0.0	747.0	631.3	4.2	2.6			-0.9	1.3
03-Jun-99	14.2	4.9	4.6	3.3	0.0	0.0	0.0	0.0	912.0	4030.2	0.0	0.0			0.0	0.0
04-Jun-99	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0			0.0	0.0
05-Jun-99	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	21.7	0.0	0.0			0.0	0.0
06-Jun-99	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	40.8	0.0	0.0			0.0	0.0
07-Jun-99	14.2	2.3	1.8	1.6	0.0	0.0	9.0	13.0	942.0	2144.9	19.0	9.4			-0.4	14.7
08-Jun-99	14.2	1.5	1.0	0.6	0.0	0.0	9.0	14.0	906.0	1210.4	5.8	3.2			-0.2	2.0
09-Jun-99	14.2	1.8	1.4	1.1	0.0	0.0	5.5	10.0	895.0	1289.0	14.3	10.9			-0.5	12.3
10-Jun-99	14.2	3.4	2.7	2.4	0.0	0.0	4.0	8.0	916.0	2499.3	16.0	9.3			-1.5	22.0
11-Jun-99	14.0	0.4	0.0	0.0	0.0	0.0	14.0	24.0	7.0	31.6	0.0	0.0			0.0	0.0
12-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	7.0	49.5	0.0	0.0			0.0	0.0
13-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	7.0	30.7	0.0	0.0			0.0	0.0
14-Jun-99	14.3	6.5	5.5	4.9	0.3	0.0	7.0	13.0	868.0	4094.2	13.7	7.0			-1.1	48.9
15-Jun-99	14.3	9.4	9.2	8.5	0.0	0.0	5.5	0.0	834.0	7043.3	15.0	8.3			-1.5	104.9
16-Jun-99	14.2	1.2	0.5	0.1	0.8	0.0	0.0	0.0	528.0	149.4	2.3	2.2	19.4	16.0	-6.4	0.4
17-Jun-99	14.3	6.6	0.0	0.0	6.0	0.0	7.0	11.0	371.0	477.2	0.0	0.0	14.8	11.5	-0.8	0.0
18-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	4.0	-10.5	0.0	0.0	0.0	0.0	0.0	0.0
29-Jun-99	14.2	1.2	0.7	0.0	0.0	0.0	14.3	24.0	731.0	711.2	0.0	0.0	0.0	0.0	0.0	0.0
30-Jun-99	14.3	0.0	0.0	0.0	0.0	0.0	14.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gas	Efficiency [%] Peak Eff	Average	Capacity Factor CF_{-Solar}	CF_{-Gas}	Availability and Utilization $Avail_{Auto}$	$Util_{Auto}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$
84.4	16.2%	7.4%	1%	0%	100%	6%	36%	9%	37%	2%

Gas	Efficiency [%] Peak Daily	Average	Capacity Factor Solar	Gas	Availability and Utilization $Avail_{Ctrls}$	$Util_{Ctrls}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$	Operational Summary
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not Operated
0.0	0%	2%	0%	0%	100%	5%	100%	4%	100%	0%	Operated 1600 to 1700
0.0	0%	0%	0%	0%	100%	21%	100%	23%	100%	0%	Operated 0730 to 1245; no power data file
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not Operated
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated
0.0	16%	6%	4%	0%	100%	9%	37%	30%	46%	0%	Operated 0800 to 1015; Incidents #326, 327
0.0	6%	1%	1%	0%	100%	6%	37%	12%	42%	0%	Operated 0730 to 0840; Incidents #328 & 329
0.0	14%	8%	3%	0%	100%	7%	61%	13%	58%	0%	Operated 1420 to 1605; Incidents #330 &331
0.0	16%	8%	6%	0%	100%	14%	72%	23%	67%	0%	Operated 1230 to 1420, 1440 to 1645; Incident #332 (grid loss)
0.0	0%	0%	0%	0%	100%	2%	0%	0%	0%	0%	Not operated; Incident #333
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; weekend and down due to Incident #333
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; weekend and down due to Incident #333
2.8	12%	7%	10%	0%	100%	27%	51%	67%	46%	2%	Operated 1315 to 1900 on sun; Operated 1925 to 1940 on gas; Incident #334
0.0	14%	9%	20%	0%	100%	39%	61%	97%	100%	0%	Operated 0600 to 1530; Incident #335
12.3	1%	1%	0%	1%	100%	5%	100%	1%	100%	3%	Operated on gas/solar 0615 to 0705
69.3	0%	0%	0%	9%	100%	27%	51%	0%	54%	46%	Operated on gas 0700 to 1310; Incident #336
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; engine and focus valves down
0.0	0%	0%	0%	0%	100%	5%	0%	0%	0%	0%	Not operated; manually moved and washed mirrors
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; focus valves down

APS-West Dish Monthly Performance Summary

July-99

Monthly Totals:

nergy Delivered on Solar:	664.4	kWh
Energy Delivered on Gas:	50.2	kWh
Net Energy Delivered:	596.4	kWh
Automated Operation:	179.7	hours
Tracking Operation:	126.7	hours
Solar Operation:	63.1	hours
Gas Operation:	3.0	hours

Monthly Records:

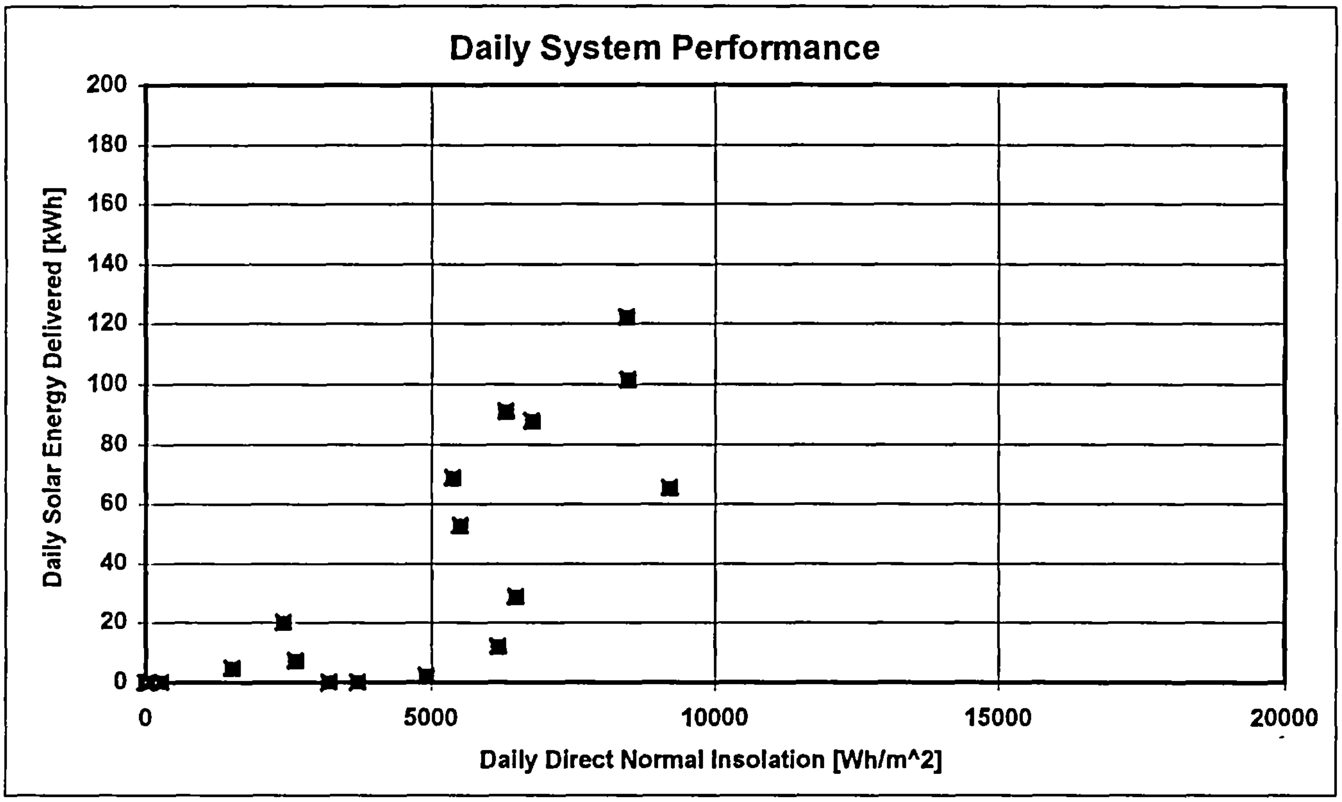
Peak Solar Power:	16.6	kW
Peak Solar Efficiency:	17.1%	

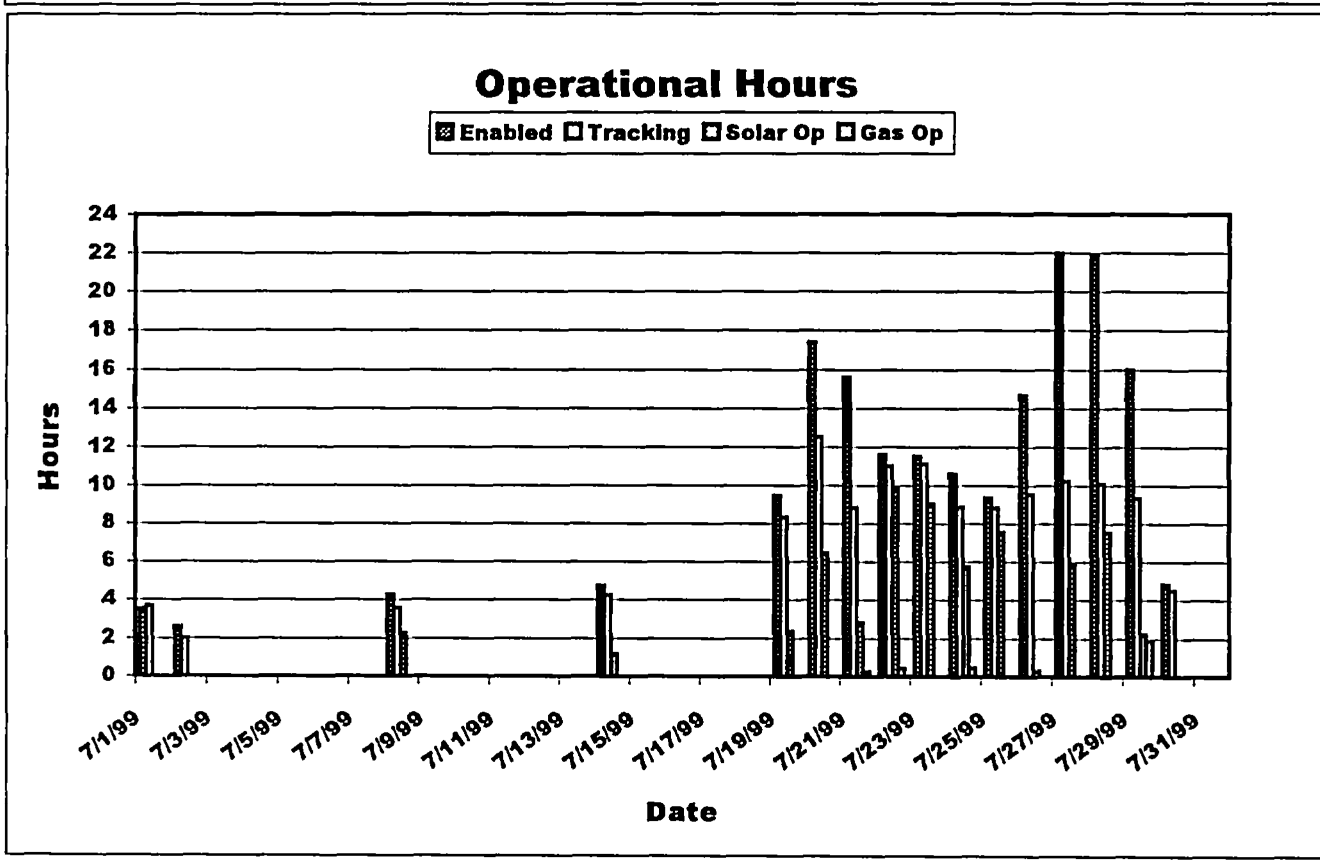
Operational/Reliability Data:

	Availabilit	Utilization	Capacity Factor
Controls	89%	27%	
Solar	51%	29%	6%
Gas	56%	1%	0%

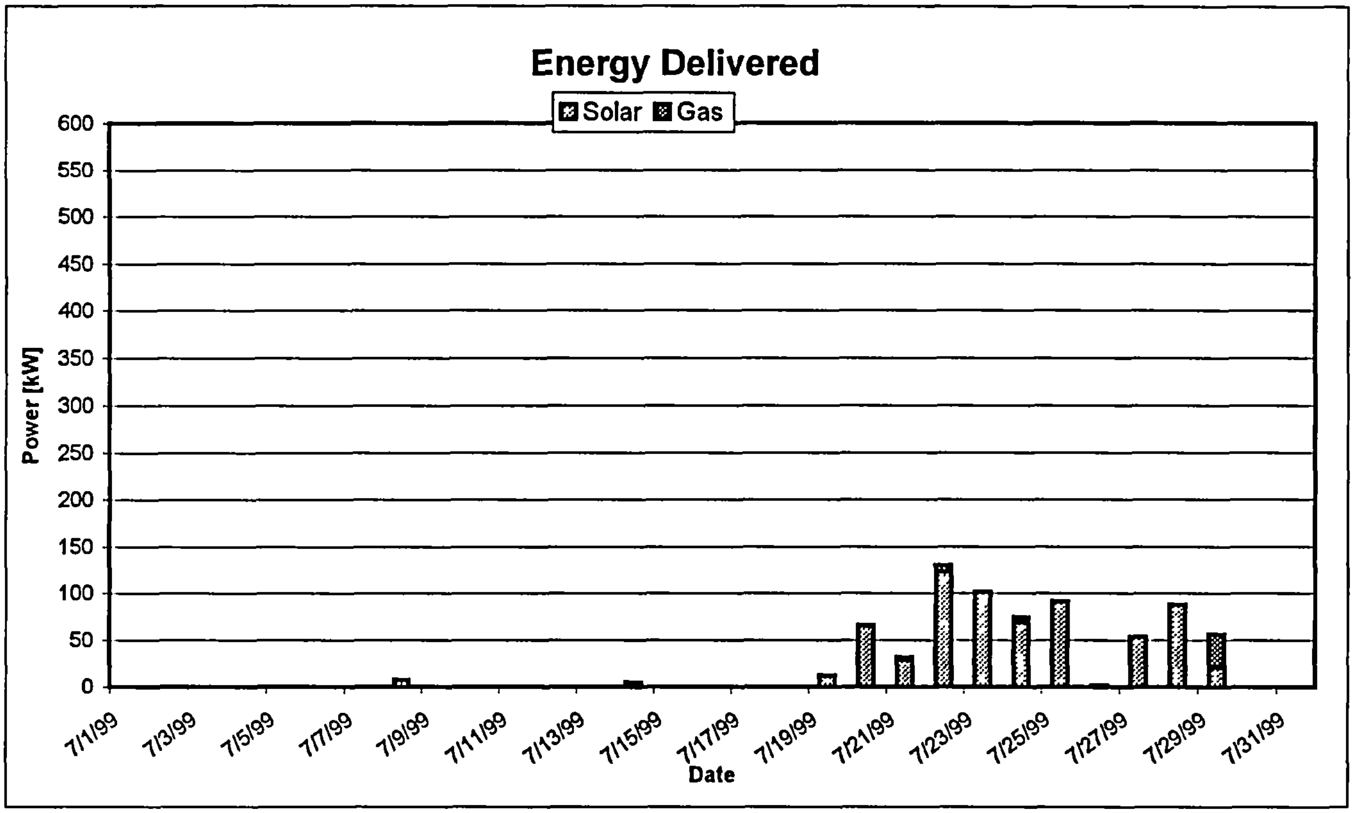
Day	Operational Summary
1	Tracked 1300-1700 for BCS focus adjustment
2	Tracked 0600-0900 for BCS focus tests; cloudy
3	Not operated - weekend
4	not operated - holiday
5	Not operated: holiday
6	Not operated
7	Not operated
8	Solar op 0700 to 1100
9	Not operated
10	Not operated
11	Not operated
12	Not operated
13	Not operated
14	Solar op 0600 to 1100
15	Not operated; Comm fault in PM
16	Not operated: Comm fault
17	Not operated: Comm fault
18	Not operated: Comm fault
19	Operated on gas 0935-1000; on sun 1010-1100; defocused 1100-1600; calibration 1620-1640
20	Operated on sun
21	Operated on sun 0600-1020, 1030-1615; adjusted focus; operated on gas 1710-1730
22	Operated on sun; SSR failed in PM; calibration 0700-1400, 1600-1700
23	Gas op 0600-0620; solar op 0620-1800; some calibration tracking
24	Solar op 0600-1700
25	Solar op 0610-1530; cloudy in PM
26	Cleaned mirrors; tracked mostly defocused 0930-1900 (cloudy); PCS faults @ 0958 & 1309
27	PCS Maint. 0645-0800; solar op 0800-1900; cloudy
28	Solar op 0911-2400
29	Gas op 0600-0715; Gas/Solar op 0730-1400; PCS fault 1400; tracked defocused 1400-1700
30	Tracked defocused 1000-1400
31	Not operated; PCS down, weekend

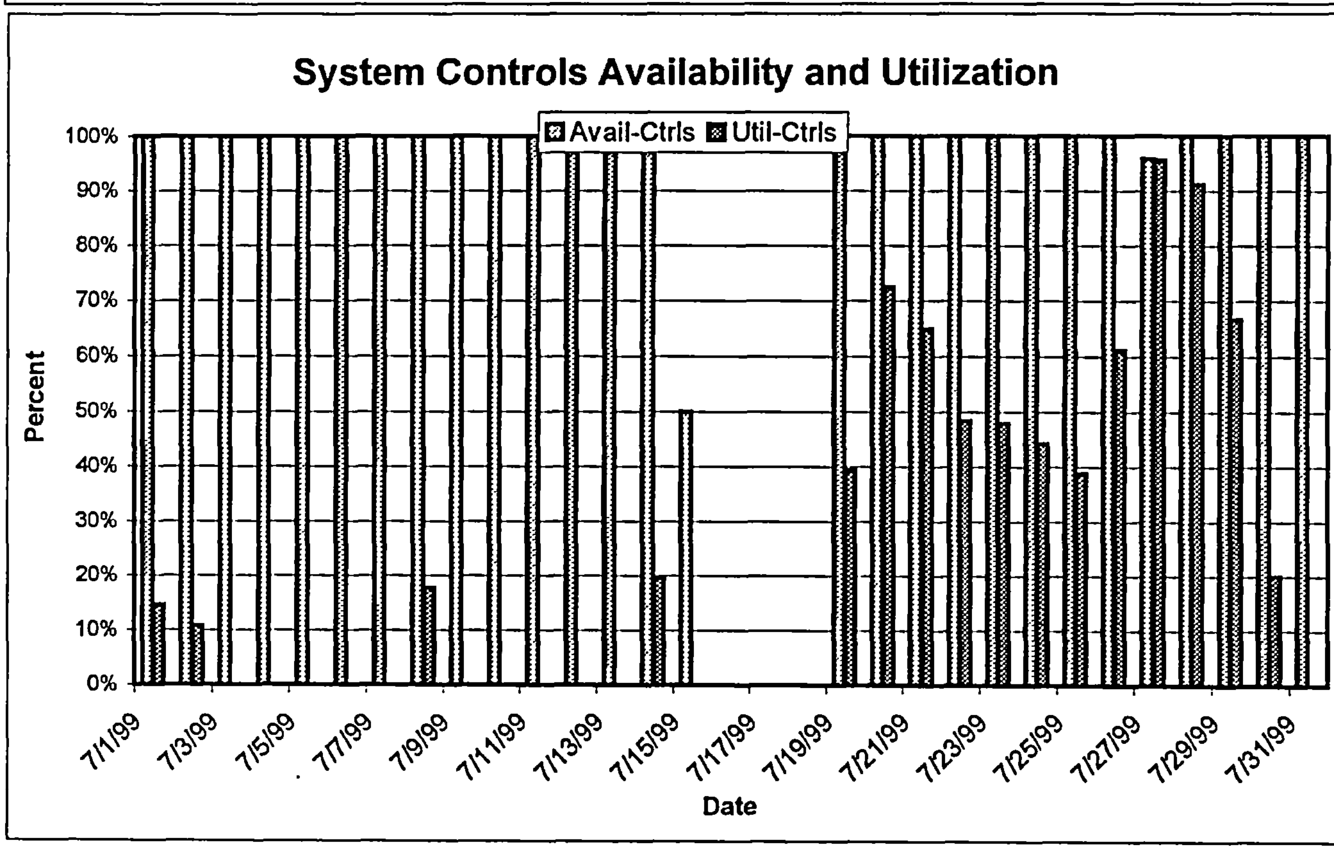
APS-West Dish Monthly Performance Summary



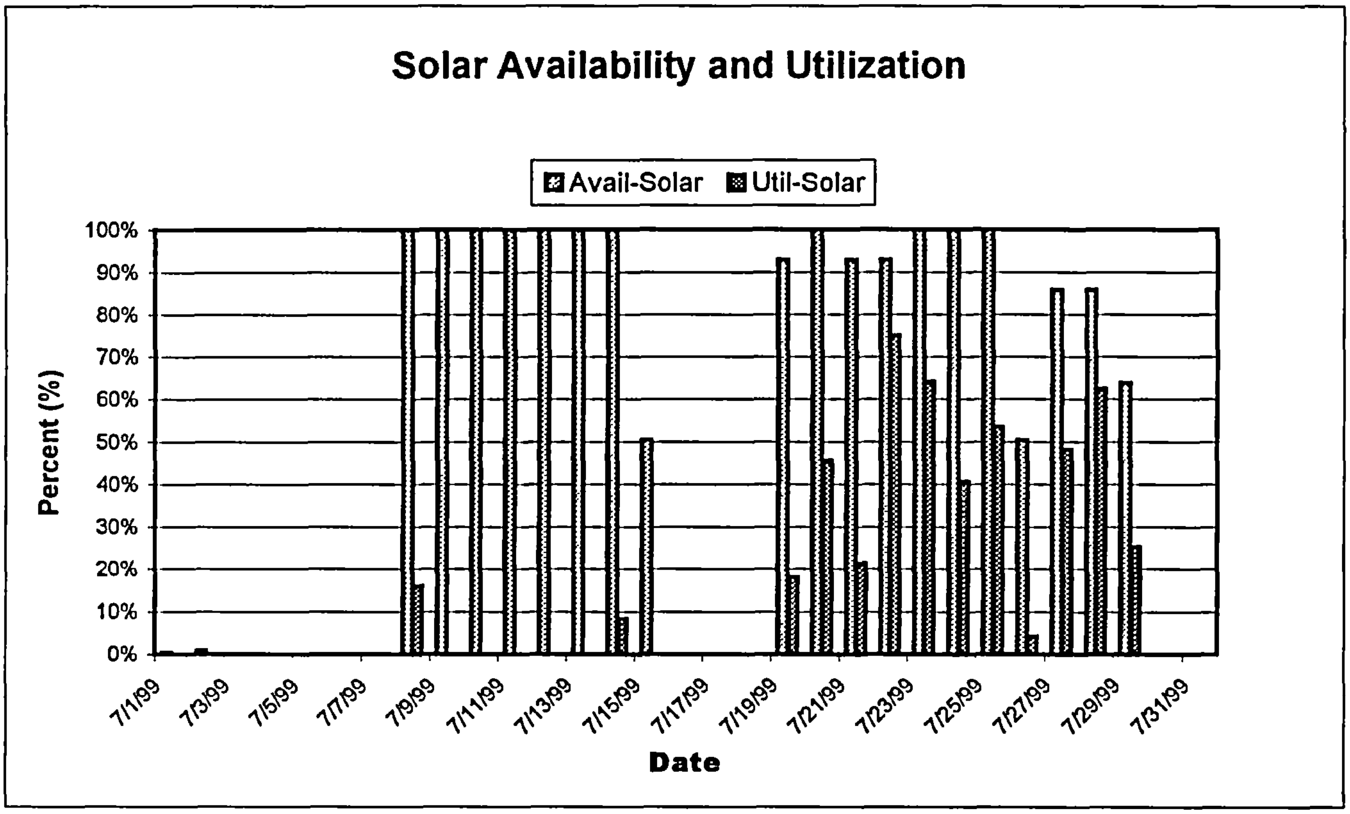


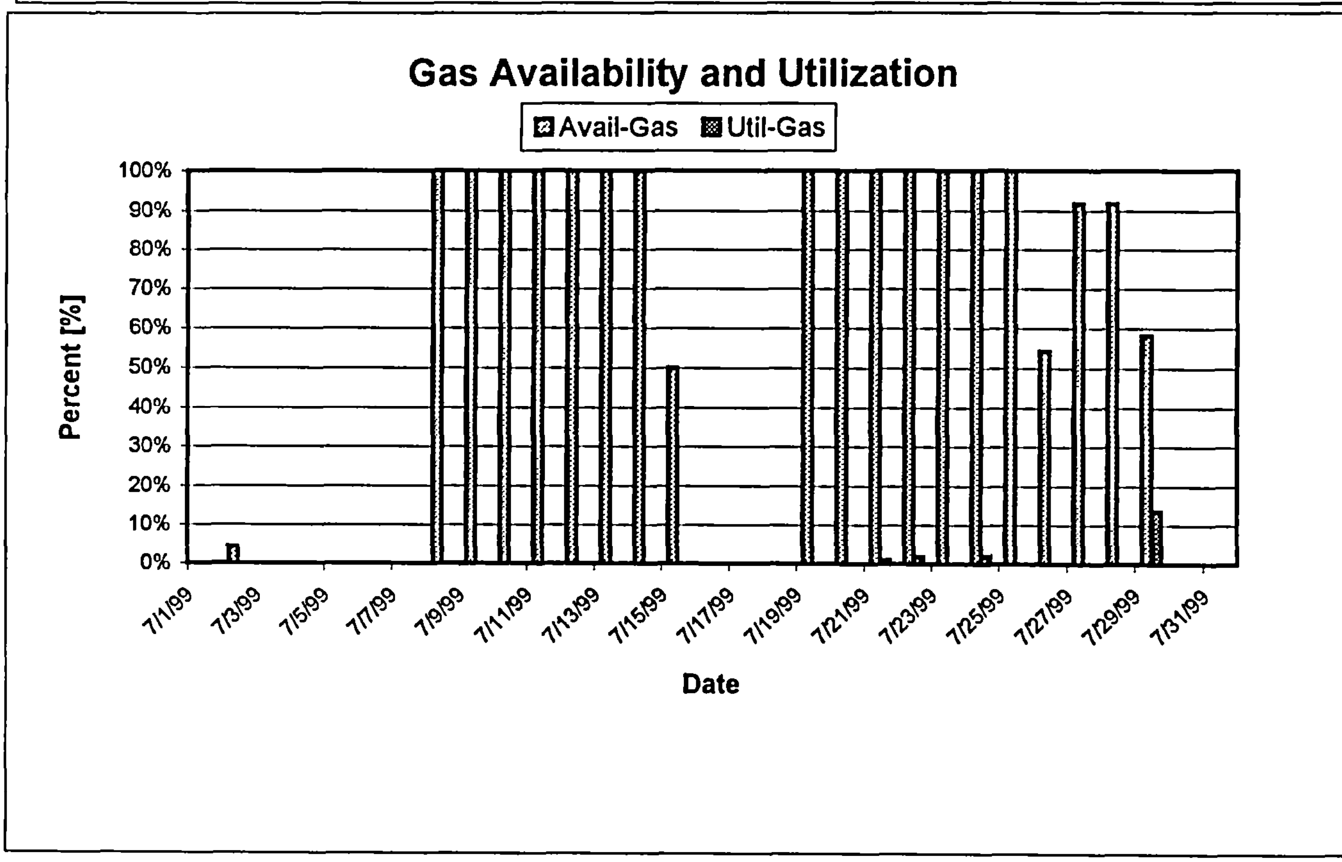
APS-West Dish Monthly Performance Summary





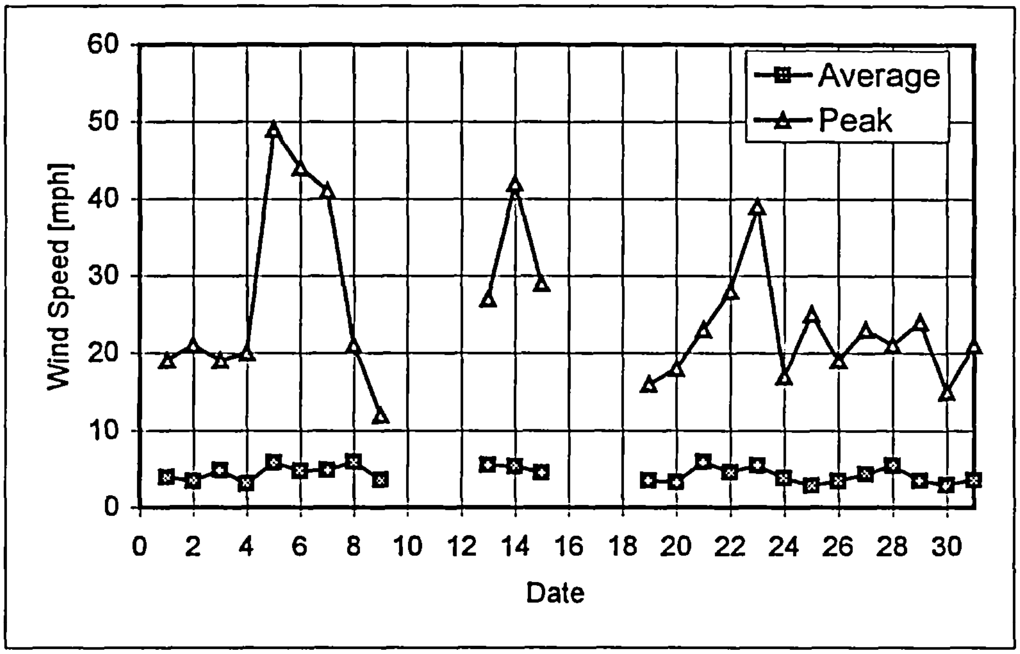
APS-West Dish Monthly Performance Summary





Weather Data for APS STAR Site July-99

	Wind Speed [mph]	
Day	Average	Peak
1	4.0	19
2	3.5	21
3	4.9	19
4	3.1	20
5	5.9	49
6	4.8	44
7	4.9	41
8	6.0	21
9	3.7	12
10		
11		
12		
13	5.5	27
14	5.4	42
15	4.6	29
16		
17		
18		
19	3.6	16.0
20	3.3	18.0
21	6.0	23.0
22	4.7	28.0
23	5.5	39.0
24	3.9	17.0
25	2.9	25.0
26	3.4	19.0
27	4.4	23.0
28	5.5	21.0
29	3.6	24.0
30	2.9	15.0
31	3.6	21.0



APS-West Dish Monthly Performance Summary

August-99

Monthly Totals:

Energy Delivered on Solar:	542.6 kWh
Energy Delivered on Gas:	2.5 kWh
Net Energy Delivered:	430.5 kWh
Automated Operation:	165.2 hours
Tracking Operation:	122.6 hours
Solar Operation:	42.9 hours
Gas Operation:	0.2 hours

Monthly Records:

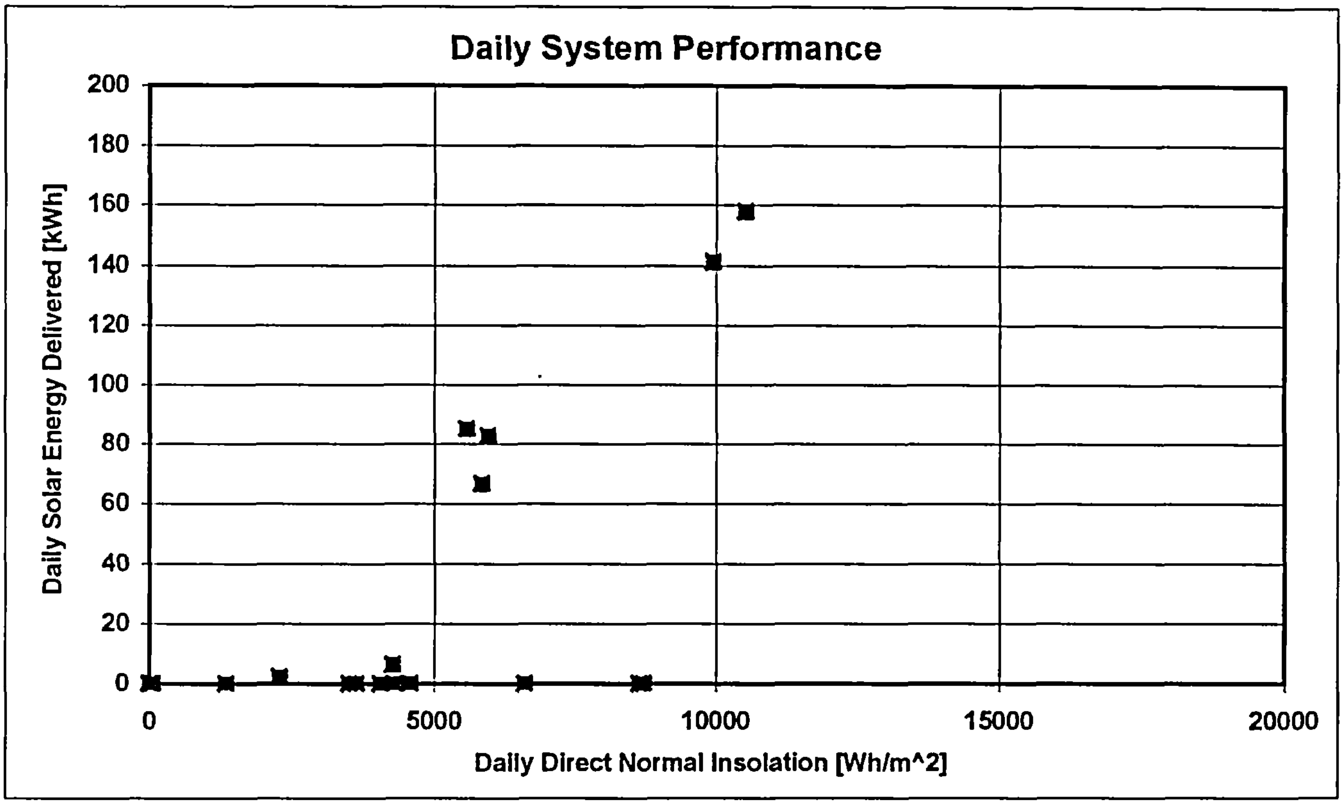
Peak Solar Power:	17.9
Peak Solar Efficiency:	16.6%

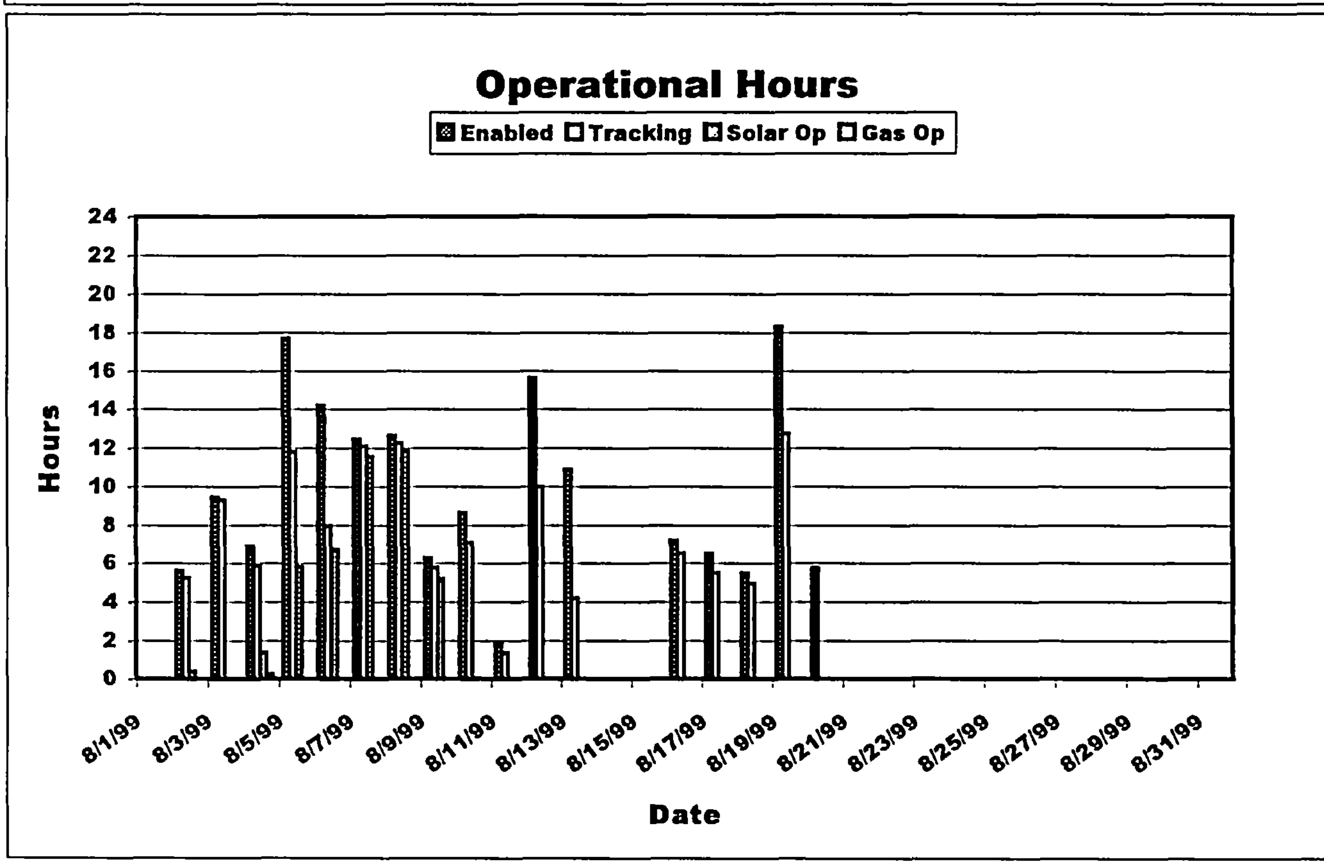
Operational/Reliability Data:

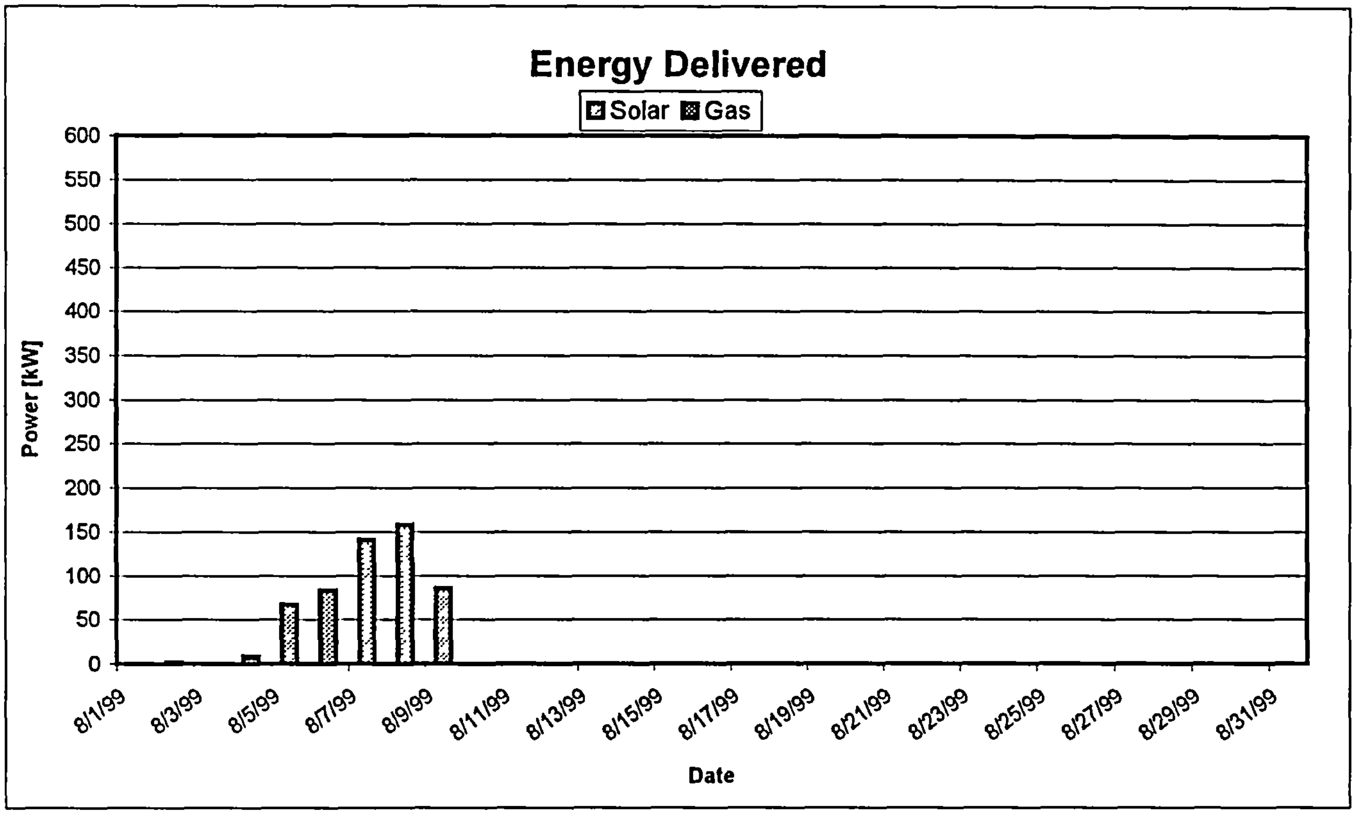
	Availability	Utilization	Capacity Factor
Controls	98%	23%	n/a
Solar	24%	12%	5%
Gas	21%	0%	0%

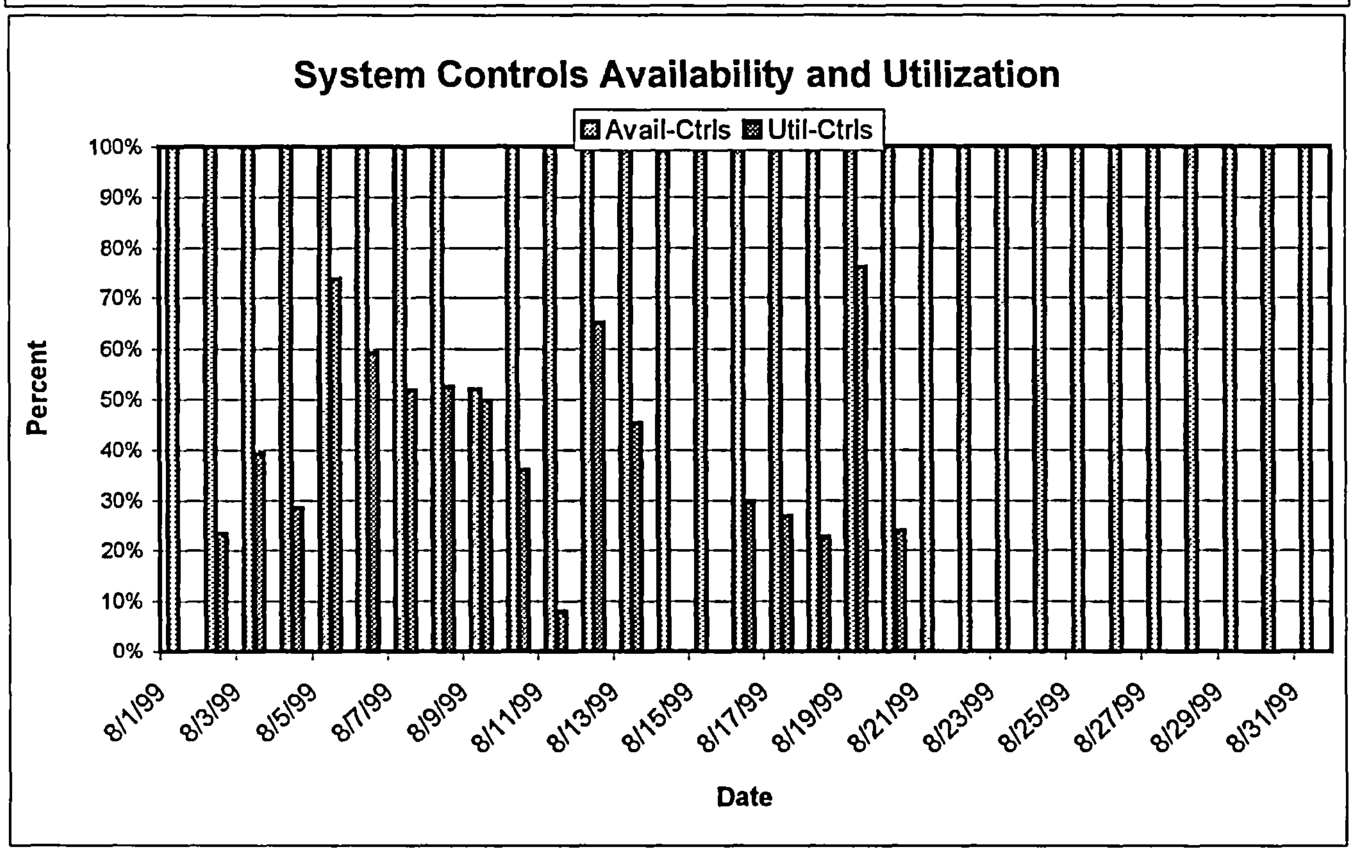
Day	Operational Summary
1	Not operated; PCS down
2	Solar op 0630-1200; PCS blower fault ~1250
3	BCS Alignment; power meter disconnected
4	BCS 0600-1220; Gas op 1540-1600; PCS fault 1554; Solar op 1600-1830; high wind stow
5	Solar op 0600-1900; Operator error 1700 (changed latitude)
6	Solar op 0600-1430;
7	Solar Op 0630-1900
8	Solar op 0600-1900
9	Solar op 0600-1230; motor protection relay failed 1225
10	Tracked defocused 0600-1600; PCS faults 1234, 1454.
11	Tracked Defocused 0600-0700, 1530-1630; PCS Fault 0737 (Max Press Diff)
12	Tracked defocused
13	Tracked defocused
14	Weekend - not operated
15	Weekend -- not operated
16	Operated 0700-1415; cloudy
17	Operated on sun; cloudy
18	Tracked defocused
19	Tracked Defocused
20	Removed engine
21	System not operated
22	System not operated
23	System not operated
24	System not operated
25	System not operated
26	System not operated
27	System not operated
28	System not operated
29	System not operated
30	System not operated
31	System not operated

APS-West Dish Monthly Performance Summary

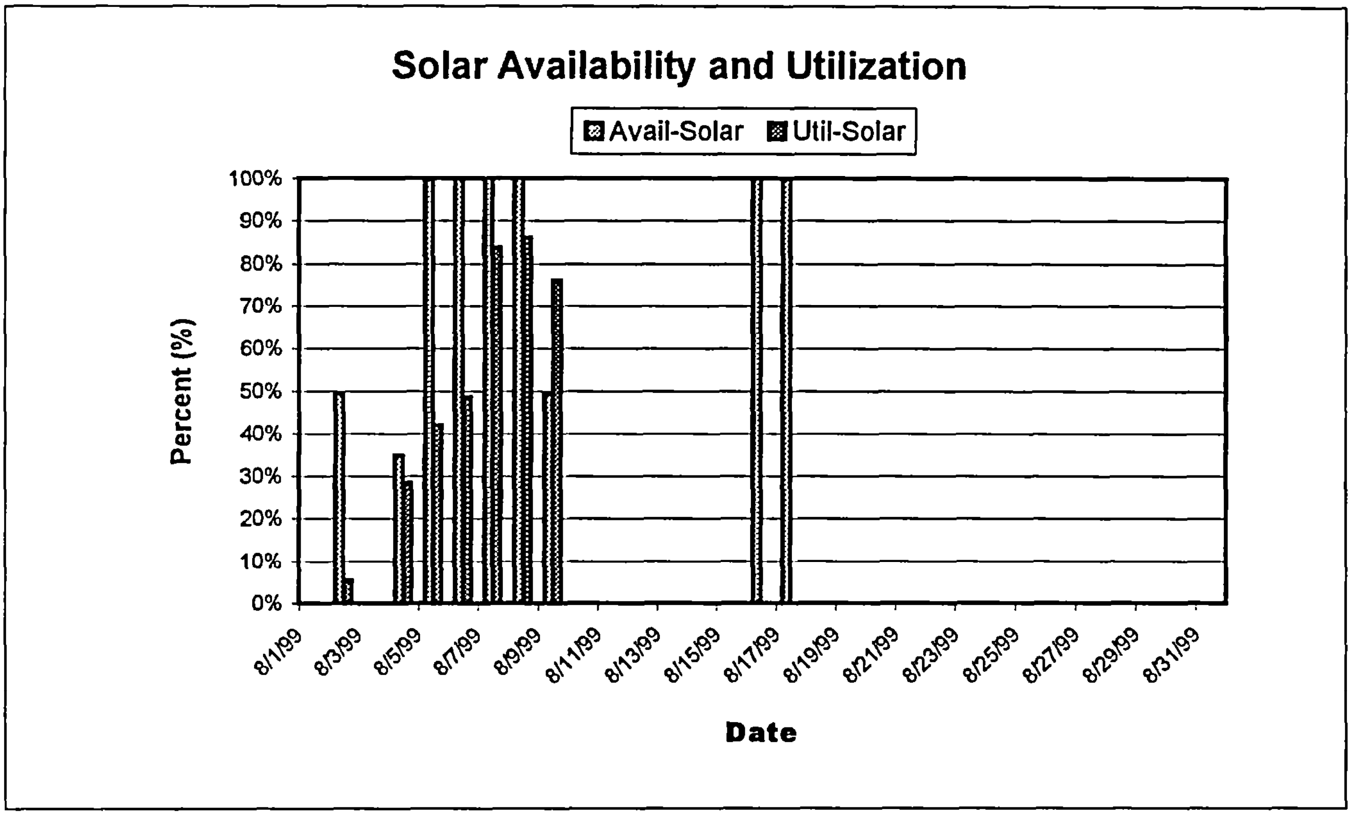


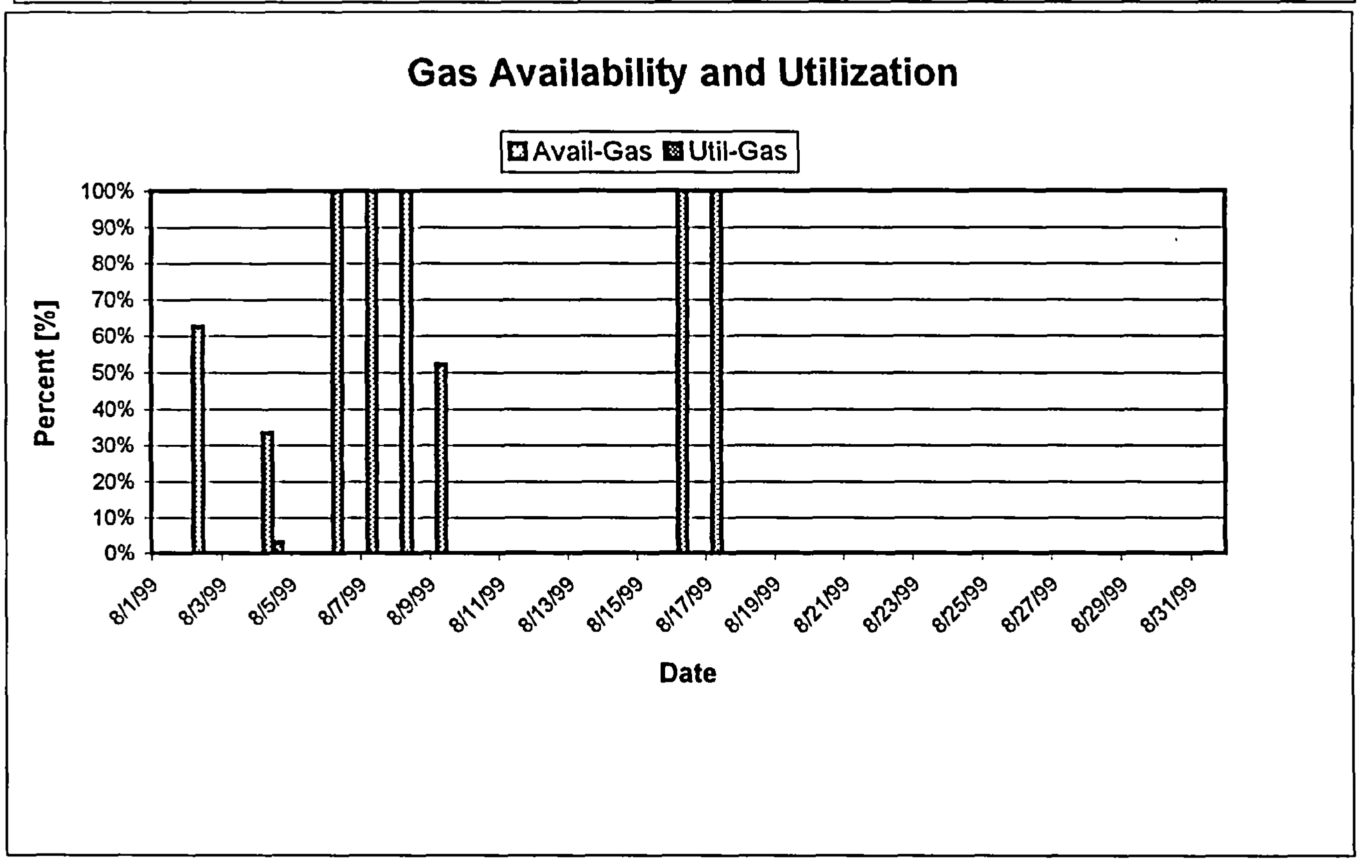



Energy Delivered
Solar
Gas
Power [kW]
600
550
500
450
400
350
300
250
200
150
100
50
0
8/1/99
8/3/99
8/5/99
8/7/99
8/9/99
8/11/99
8/13/99
8/15/99
8/17/99
8/19/99
8/21/99
8/23/99
8/25/99
8/27/99
8/29/99
8/31/99
Date


System Controls Availability and Utilization
Avail-Ctrls
Util-Ctrls
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
8/1/99
8/3/99
8/5/99
8/7/99
8/9/99
8/11/99
8/13/99
8/15/99
8/17/99
8/19/99
8/21/99
8/23/99
8/25/99
8/27/99
8/29/99
8/31/99
Date

APS-West Dish Monthly Performance Summary





APS-West Dish

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	Monthly Total Hours					Downtimes [hr]			Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		Energy [kWh]	
.	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Pk [W/m^2]	Total [Wh/m^2]	Peak Pwr	Average	Gas Peak	Average	Consumed	Solar
Aug-99	427.9	165.2	122.6	42.9	0.2	11.5	326.7	588.5	995.0	89937.8	17.9	2.5	13.4	0.3	-114.5	542.6

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	Hours					Downtimes [hr]			Daily Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		Energy [kWh]	
Day	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Peak [W/m^2]	Total [Wh/m^2]	Peak	Average	Gas Peak	Average	Consumed	Solar
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06-Aug-99	13.8	14.2212	7.9601	6.6939	0.0001	0	0	0	922	9958.601628	16.1	12.384494	0	0	4.990305	82.900553
07-Aug-99	13.8	12.4559	12.0895	11.5564	0.0001	0	0	0	931	9945.109544	16.679	12.222014	0	0	-2.31171375	141.24247
08-Aug-99	13.8	12.6223	12.2559	11.8875	0.0001	0	0	0	959	10520.2278	17.875	13.282257	0	0	-2.58750944	157.91870
09-Aug-99	13.8	6.23030	5.76427	5.16473	0.0001	11.5	7	11.5	932	5579.098711	18.561	16.486344	0	0	-5.53202403	85.147553
10-Aug-99	13.8	8.63049	7.08121	0.03334	0.0001	0	13.8	24	943	4578.233156	0.453	0.4528641	0	0	-11.6912461	0.0151
11-Aug-99	13.8	1.93204	1.3651	0.00001	0.0001	0	13.8	24	809	1335.626489	0	0	0	0	-0.56642810	0
12-Aug-99	13.8	15.6195	9.99121	0.00001	0.0001	0	13.8	24	995	8710.564633	0	0	0	0	-0.53871778	0
13-Aug-99	13.8	10.8584	4.19732	0.00001	0.0001	0	13.8	24	973	3926.678017	0	0	0	0	-2.68984069	0
14-Aug-99	13.8	0.0001	0.0001	0.00001	0.0001	0	13.8	24	7	41.38921111	0	0	0	0	-0.01622296	0
15-Aug-99	13.8	0.0001	0.0001	0.00001	0.0001	0	13.8	24	8	61.10662778	0	0	0	0	-3.15963238	0
16-Aug-99	13.8	7.16121	6.4951	0.00001	0.0001	0	0	0	915	3507.010017	0	0	0	0	-3.37739972	0
17-Aug-99	13.8	6.46149	5.4051	0.00001	0.0001	0	0	0	930	4060.270767	0	0	0	0	-13.3440799	0
18-Aug-99	13.8	5.40177	4.96232	0.00001	0.0001	0	13.8	24	985	4309.021211	0	0	0	0	-6.66078075	0
19-Aug-99	13.8	18.284	12.7554	0.00001	0.0001	0	13.8	24	800	6600.063572	0	0	0	0	-7.71855230	0
20-Aug-99	13.8	5.72571	0.0001	0.00001	0.0001	0	13.8	24	5	7.757261111	0	0	0	0	0.95462347	0
21-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
22-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
23-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
24-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
25-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
26-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
27-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
28-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
29-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
30-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0
31-Aug-99	13.8	0	0	0	0	0	13.8	24	0	0	0	0	0	0	0	0

Gas	Efficiency [%]		Capacity Factor		Availability and Utilization					
Gas	Peak Eff	Average	CF_{Solar}	CF_{Gas}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$
2.5	16.6%	5.3%	5%	0%	98%	23%	24%	12%	21%	0%

	Efficiency [%]		Capacity Factor		Availability and Utilization						Operational Summary
Gas	Peak Daily	Average	Solar	Gas	$Avail_{Ctrls}$	$Util_{Ctrls}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$	
0	0	0	0%	0%	100%	0%	0%	0%	0%	0%	Not operated, PCS down
0	0.1259831	0.00612159	0.0066	0	1	0.2341	0.43275	0.0559	0.925	7E-06	Solar op 0630-1205, PCS blower fault ~1250
0	0	0	0	0	1	0.3027	0	0	0	0	Fault A gen ent, power meter disconnected
2.4922657	0.0863263	0.01325057	0.0150	0.0941	1	0.2855	0.34793	0.7344	0.33333	0.0292	PCS 0800-1220, Gas op 1540-1600; PCS fault 1554; Solar op 1600-1830; high wind stow
0	0.1549653	0.10055905	0.1633	0	1	0.7367	1	0.4199	0	0	Solar op 0600-1900. Operator error 1700 (changed latitude)
0	0.1663279	0.12257932	0.2403	0	1	0.5928	1	0.4551	1	4E-06	Solar op 0600-1430
0	0.1503605	0.12512955	0.4294	0	1	0.519	1	0.6374	1	4E-06	Solar Op 0630-1900
0	0.165303	0.13225522	0.4577	0	1	0.5257	1	0.7916	1	4E-06	Solar op 0800-1500
0	0.1574023	0.13445593	0.2466	0	0.52083	0.4364	0.43275	0.7595	0.52083	5E-06	Solar op 0600-1230, motor protection relay failed 1225
0	0.0043524	2.9059E-05	4E-05	0	1	0.3599	0	0	0	0	Tracked defocused 0900-1600; PCS faults 1234, 1454.
0	0	0	0	0	1	0.0005	0	0	0	0	Tracked Defocused 0500-0700, 1530-1630; PCS Fault 0737 (Max Press Diff)
0	0	0	0	0	1	0.6525	0	0	0	0	Tracked defocused
0	0	0	0	0	1	0.4524	0	0	0	0	Tracked defocused
0	0	0	0	0	1	4E-09	0	0	0	0	Weekend - not operated
0	0	0	0	0	1	4E-05	0	0	0	0	Weekend -- not operated
0	0	0	0	0	1	0.2954	1	7E-07	1	4E-06	Operated 0700-1415, cloudy
0	0	0	0	0	1	0.2692	1	7E-07	1	4E-06	Operated on sun, cloudy
0	0	0	0	0	1	0.2279	0	0	0	0	Tracked defocused
0	0	0	0	0	1	0.7815	0	0	0	0	Tracked Defocused
0	0	0	0	0	1	0.2357	0	0	0	0	Removed engine
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated
0	0	0	0	0	1	0	0	0	0	0	System not operated

APS-West Dish Monthly Performance Summary

September-99

Monthly Totals:

Energy Delivered on Solar:	129.4	kWh
Energy Delivered on Gas:	1.1	kWh
Net Energy Delivered:	136.0	kWh
Automated Operation:	117.8	hours
Tracking Operation:	49.6	hours
Solar Operation:	14.5	hours
Gas Operation:	0.2	hours

Monthly Records:

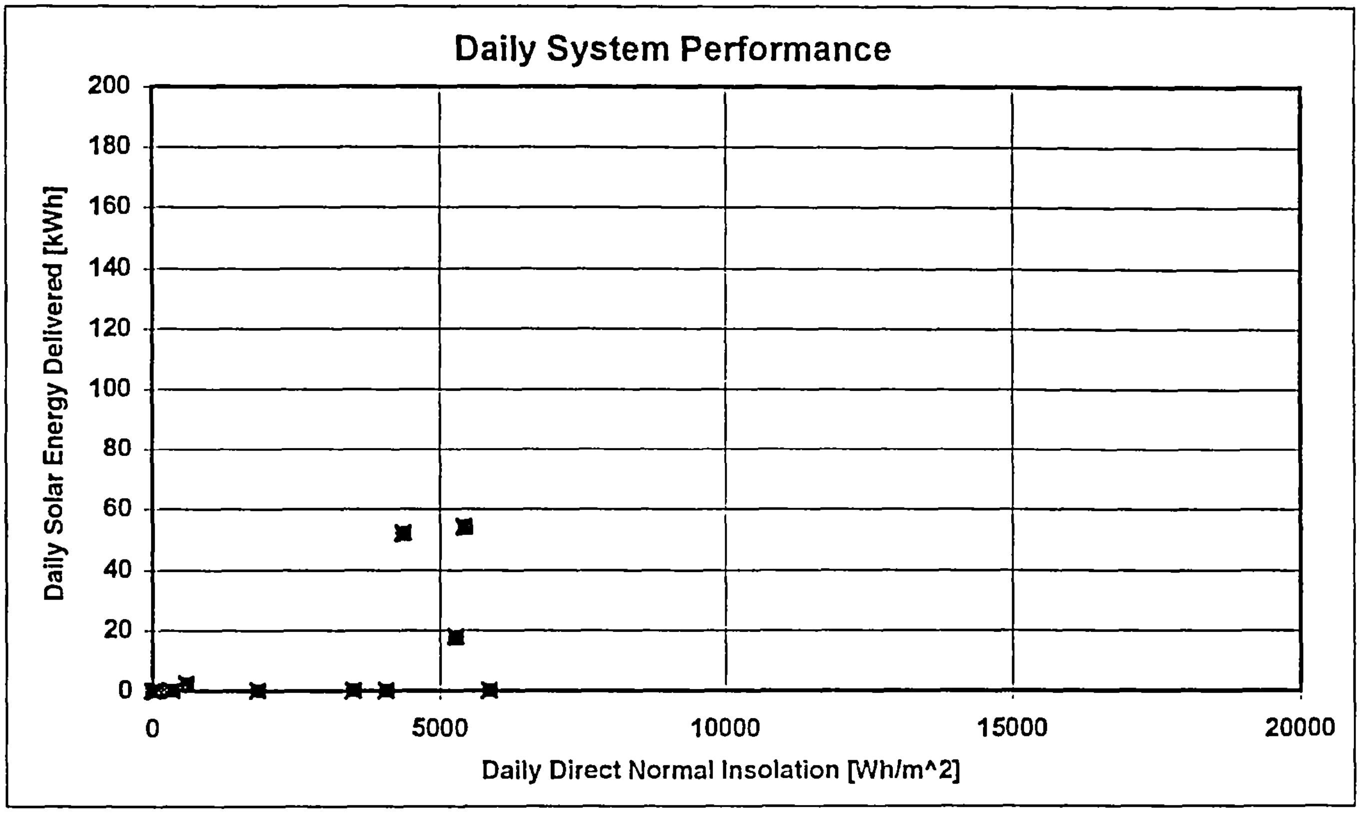
Peak Solar Power:	15.4 kW
Peak Solar Efficiency:	13.7%

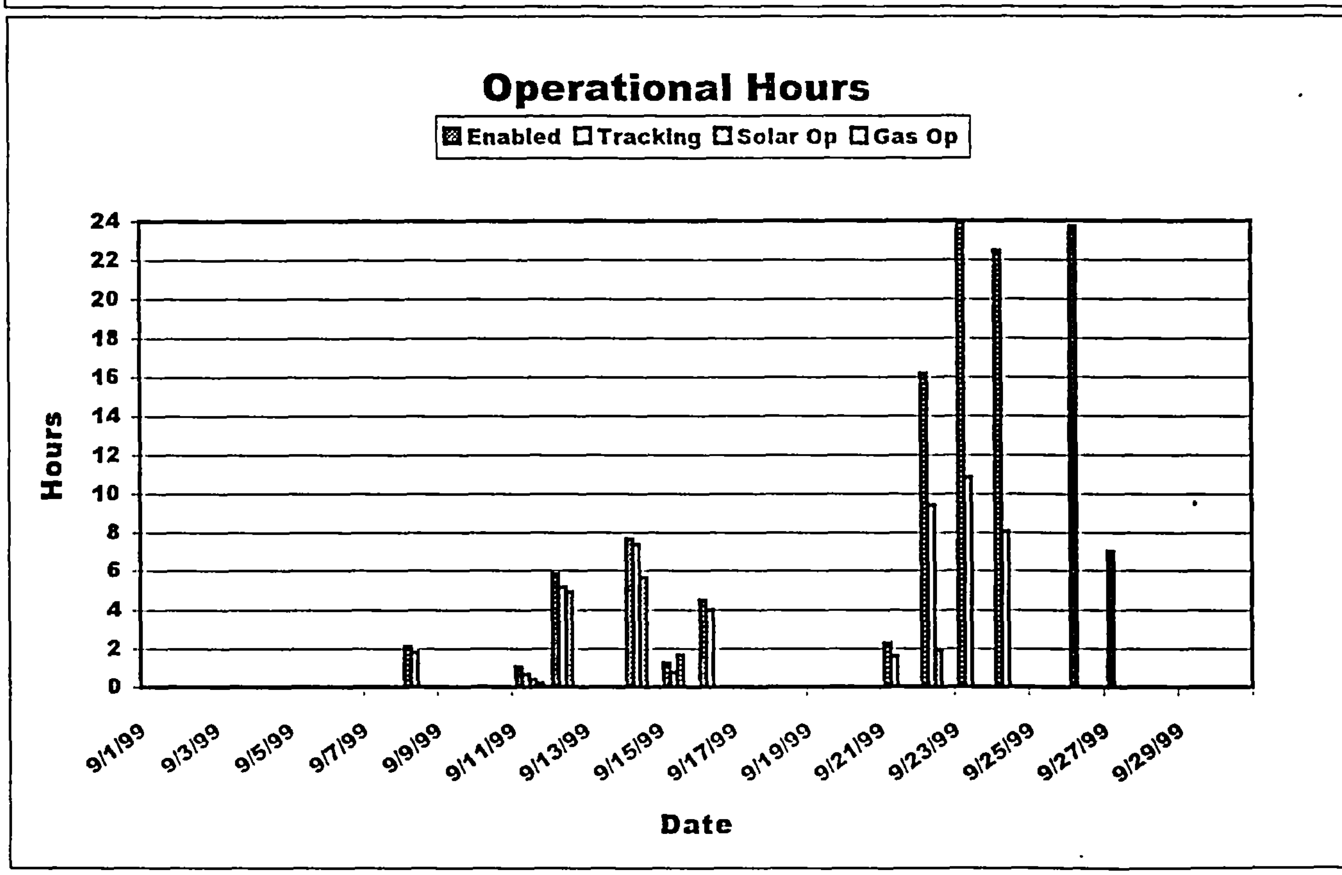
Operational/Reliability Data:

	Availabilit	Utilizati	Capacity Factor
Controls	88%	19%	n/a
Solar	52%	5%	1%
Gas	53%	0%	0%

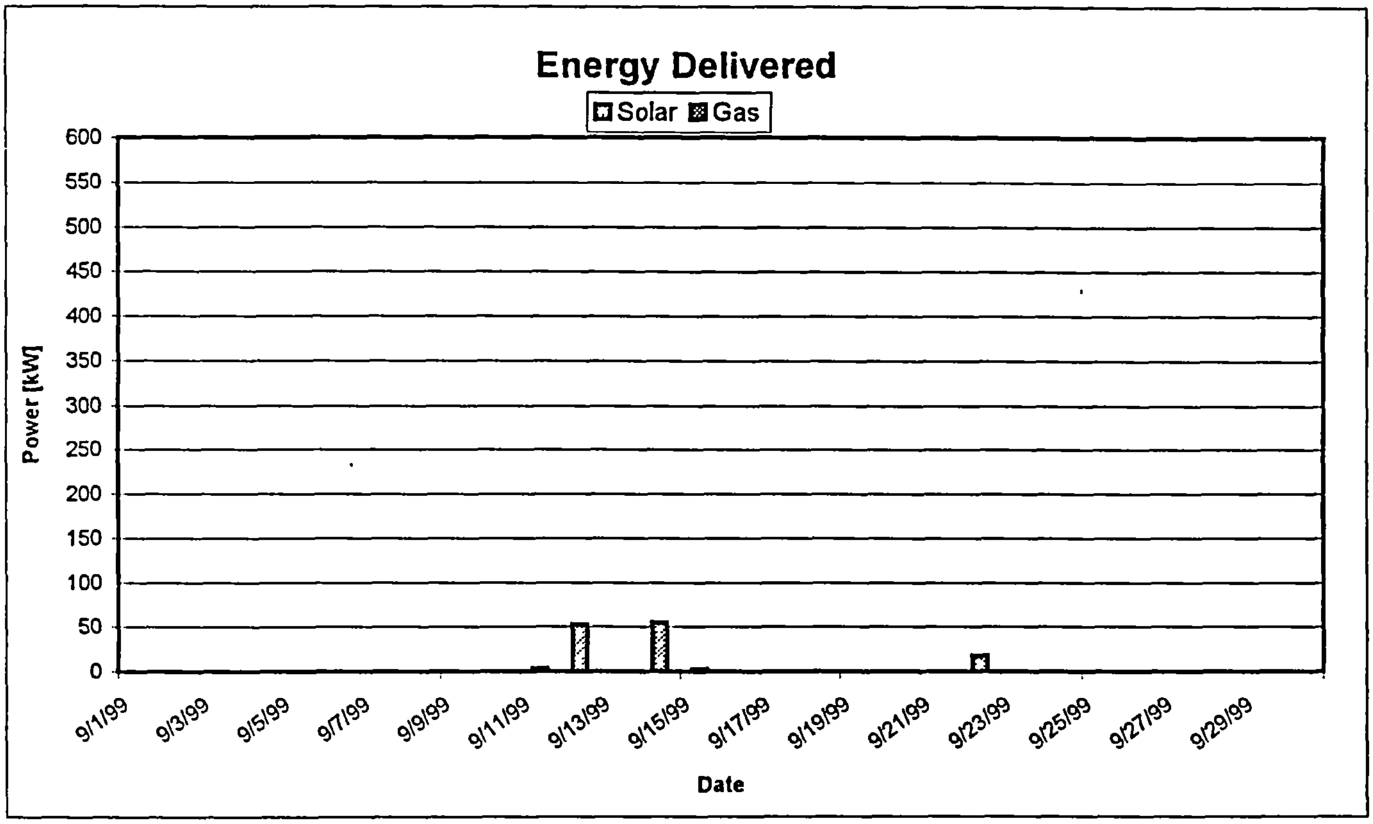
Day	Operational Summary
1	System down - engine; no data
2	System down - engine; no data
3	System down - engine; no data
4	System down - engine; no data
5	System down - engine; no data
6	System down - engine; no data
7	System down - engine; no data
8	Calorimetry
9	Not operated
10	Not operated
11	Operated briefly on hydrogen and solar
12	Operated on sun; PCS faults 0824, 1526 (bad TC)
13	Not operated - PCS TC bad
14	Operated on sun 0700-1300
15	Operated on sun; data missing
16	Tracked defocused?
17	Not operated
18	Not operated
19	No data
20	No Data
21	Defocused Tracking
22	Operated on sun
23	Tracked defocused
24	Tracked defocused
25	Weekend -- not operated
26	Weekend -- not operated
27	Not operated -- wiring upgrade
28	Not operated -- wiring upgrade
29	Not operated -- wiring upgrade
30	Not operated -- wiring upgrade

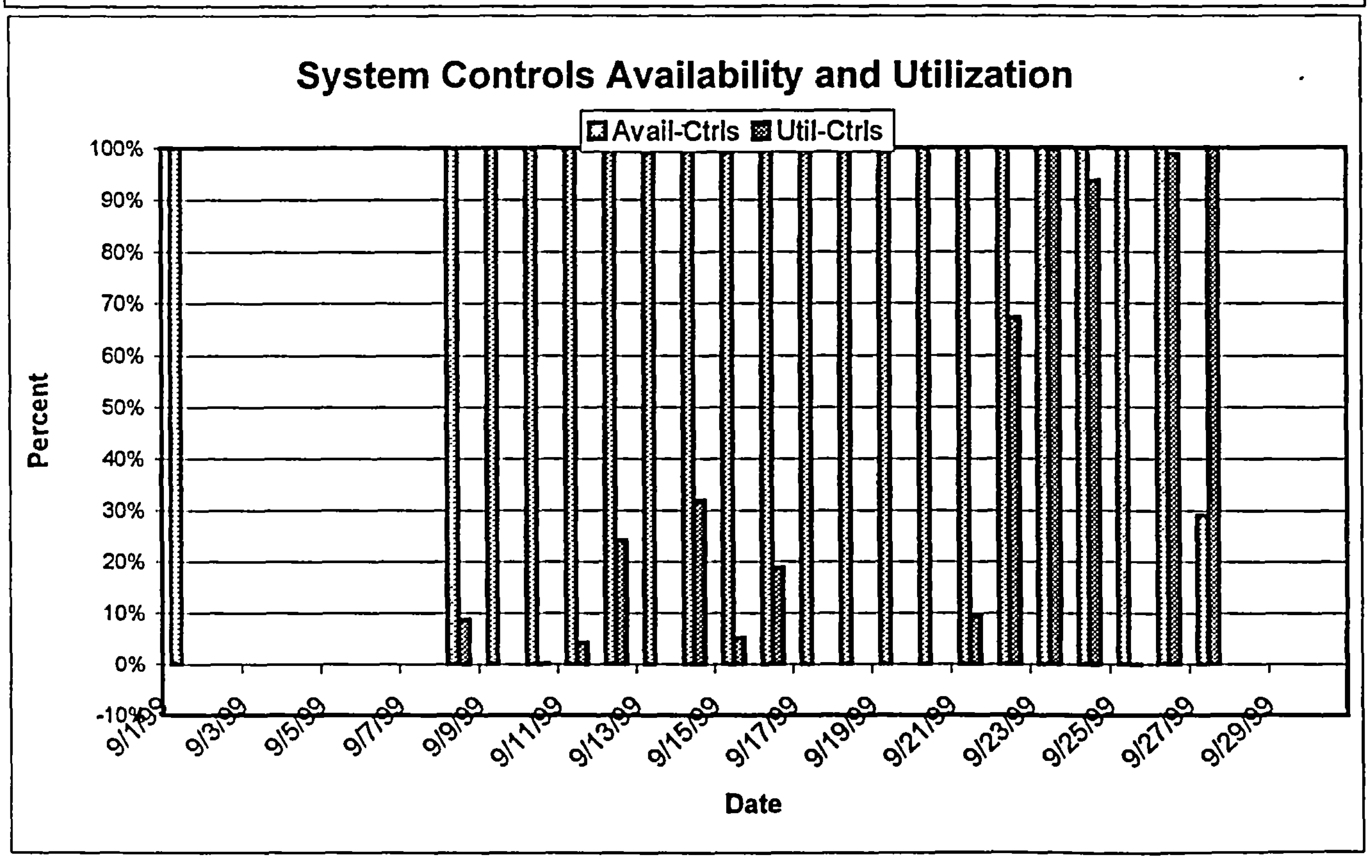
APS-West Dish Monthly Performance Summary



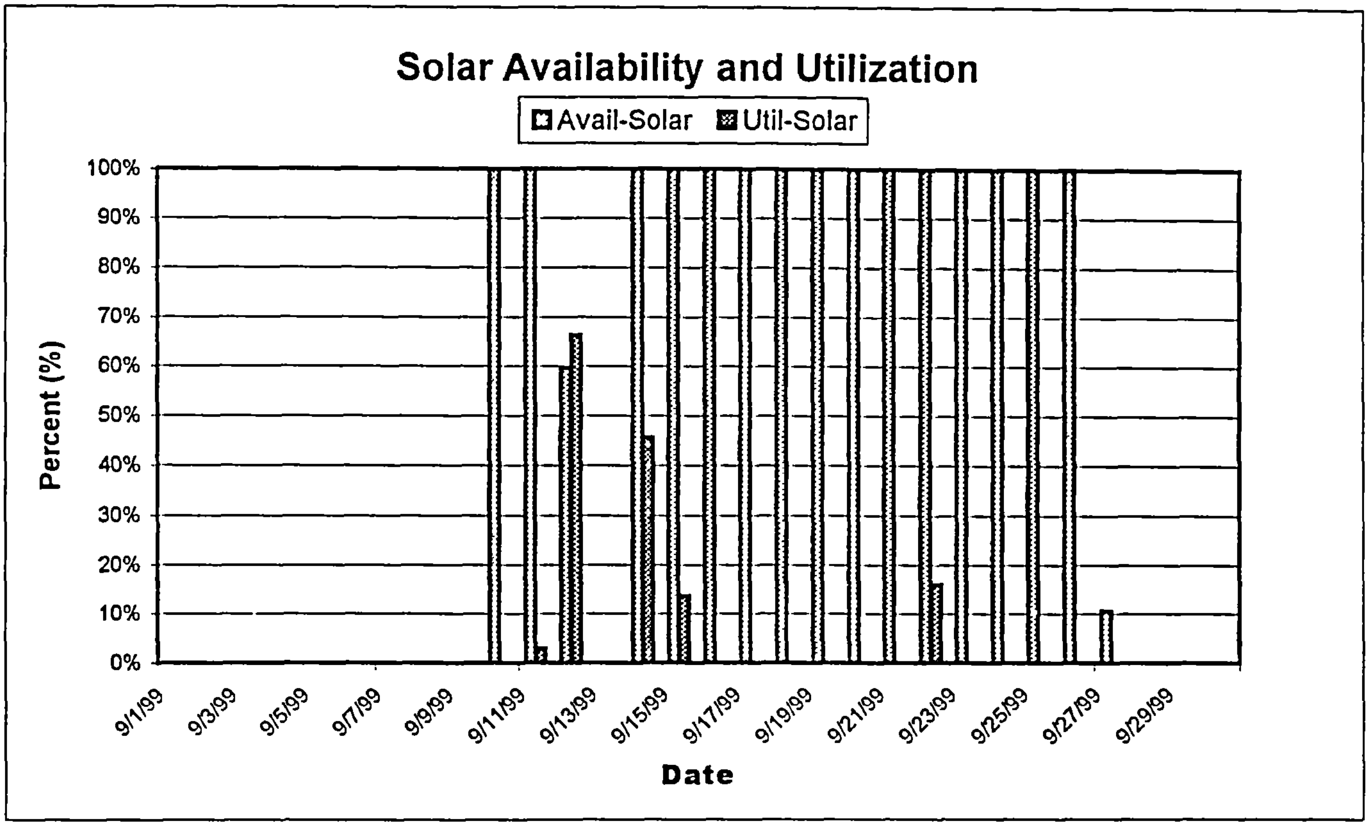


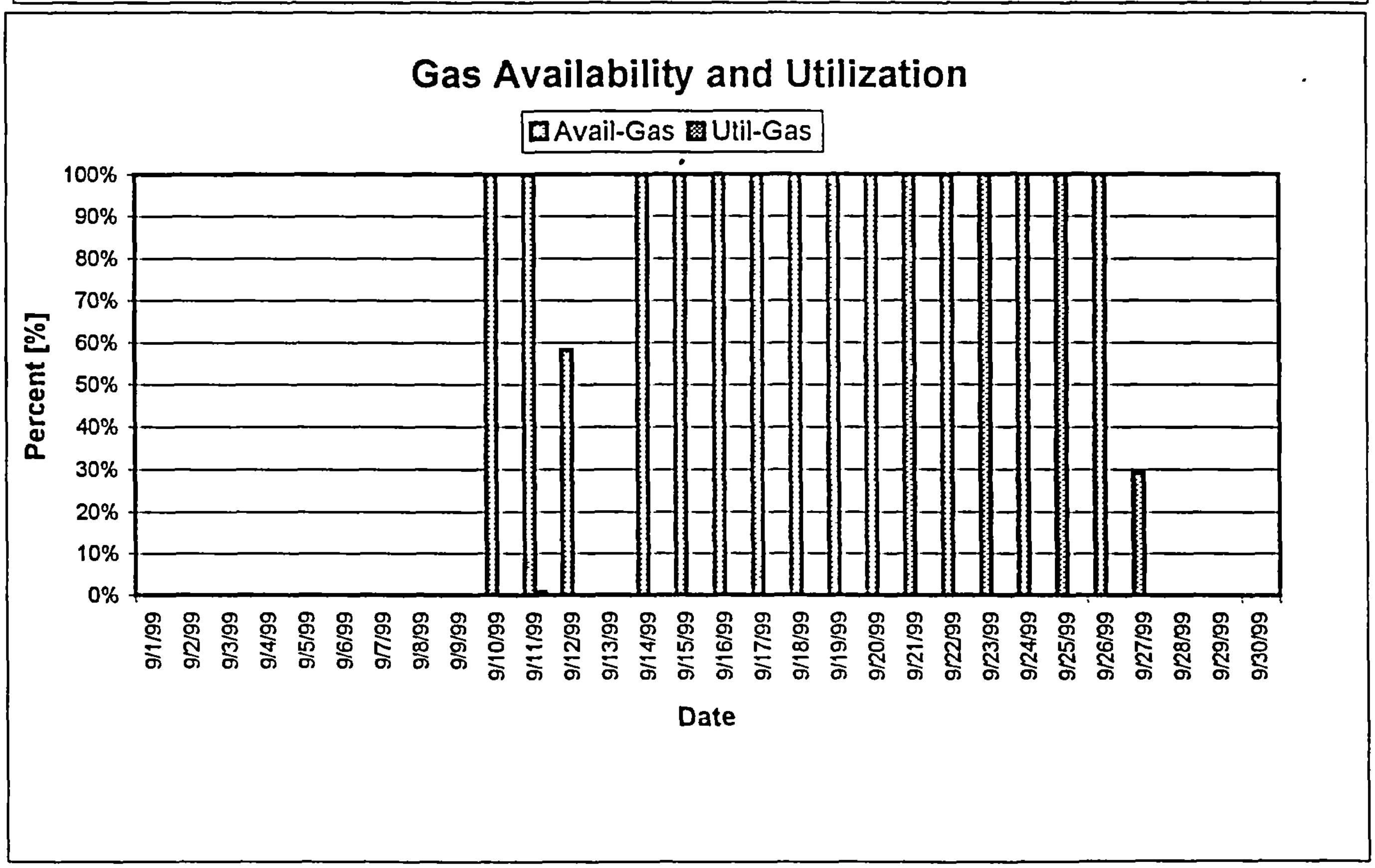
APS-West Dish Monthly Performance Summary





APS-West Dish Monthly Performance Summary





APS-West Dish

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	Monthly Total Hours					Downtimes [hr]			Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		E
	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Pk [W/m^2]	Total [Wh/m^2]	Peak Pwr	Average	Gas Peak	Average	Consumed
Sep-99	368.2	117.8	49 6	14 5	0.2	89 0	177.2	339.0	1000 0	25333 8	15.4	1.3	12 6	0 2	5.4
	720														

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	Hours					Downtimes [hr]			Daily Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		E
Day	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Peak [W/m^2]	Total [Wh/m^2]	Peak	Average	Gas Peak	Average	Consumed
01-Sep-99	12.8	0 0	0.0	0 0	0.0	0 0	12.8	24.0	0.0	0	0	0	0	0	0
01-Sep-99	12.8	0.0	0.0	0.0	0.0	0.0	12.8	24.0	0 0	0	0	0	0	0	0
01-Sep-99	12.7	0.0	0.0	0.0	0.0	0.0	12.7	24.0	0.0	0	0	0	0	0	0
01-Sep-99	12.7	0.0	0.0	0.0	0.0	0.0	12.7	24.0	0.0	0	0	0	0	0	0
01-Sep-99	12.7	0.0	0.0	0 0	0.0	0.0	12.7	24.0	0 0	0	0	0	0	0	0
01-Sep-99	12.6	0.0	0.0	0.0	0.0	0.0	12.6	24.0	0.0	0	0	0	0	0	0
01-Sep-99	12.6	0.0	0.0	0.0	0.0	0.0	12.6	24 0	0 0	0	0	0	0	0	0
08-Sep-99	12.6	2.1	1.8	0.0	0.0	0.0	12.6	24.0	1000	1824	0	0	0	0	0
09-Sep-99	12.5	0.0	0.0	0.0	0.0	0.0	12.5	24.0	7	35	0	0	0	0	0
10-Sep-99	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0 0	5	-1	0	0	0	0	0
11-Sep-99	12.4	1.0	0.7	0.4	0.2	0.0	0.0	0.0	792	573	7.262	6.3666208	12.564	6.784929	-7.30279792
12-Sep-99	12.4	5.8	5.2	4.9	0.0	0.0	5.0	10.0	979	4365	15.388	10.626996	0	0	-5.05208472
13-Sep-99	12.4	0.0	0.0	0.0	0.0	0.0	12.4	24.0	8	56	0	0	0	0	-1.92129778
14-Sep-99	12.3	7.7	7.4	5 6	0.0	0.0	0.0	0.0	923	5424	13.944	9.6507646	0	0	28.8233975
15-Sep-99	12.3	1.2	0.7	1.7	0.0	0.0	0.0	0.0	853	-6170	8.769	1.7077271	0	0	25.72338486
16-Sep-99	12.2	4.5	4.0	0.0	0.0	0.0	0.0	0.0	925	3494	0	0	0	0	-4.20536278
17-Sep-99	12.2	0.0	0 0	0.0	0.0	0.0	0.0	0.0	8	49	0	0	0	0	-2.43910403
18-Sep-99	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0 0	7	50	0	0	0	0	-2.61597347
19-Sep-99	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0
20-Sep-99	12.1	0.0	0.0	0.0	0 0	0.0	0.0	0.0	0	0	0	0	0	0	0
21-Sep-99	12.1	2.2	1.6	0.0	0.0	0.0	0.0	0 0	720	335	0	0	0	0	0.766424167
22-Sep-99	12.0	16.2	9.4	1.9	0.0	0.0	0.0	0.0	864	5276	11.456	9.2901033	0	0	-10.7168208
23-Sep-99	12.0	23 9	10.8	0.0	0.0	0.0	0.0	0.0	820	4066	0	0	0	0	-5.38157361
24-Sep-99	12.0	22.5	8.1	0.0	0.0	0.0	0.0	0.0	905	5862	0	0	0	0	-7.07148917
25-Sep-99	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	29	0	0	0	0	-0.05490625
26-Sep-99	11.9	23.7	0.0	0.0	0.0	0 0	0.0	0.0	8	66	0	0	0	0	-2.53525681
27-Sep-99	11.8	7.0	0.0	0.0	0.0	17.0	10.6	17.0	3	1	0	0	0	0	-0.60101736
28-Sep-99	11.8	0.0	0.0	0.0	0.0	24.0	11.8	24.0	0	0	0	0	0	0	0
29-Sep-99	11.8	0.0	0.0	0.0	0.0	24 0	11.8	24.0	0	0	0	0	0	0	0
30-Sep-99	11.7	0.0	0.0	0.0	0.0	24.0	11.7	24.0	0	0	0	0	0	0	0

ergy [kWh]		Efficiency [%]		Capacity Factor		Availability and Utilization					
Solar	Gas	Peak Eff	Average	CF_{-Solar}	CF_{-Gas}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$
129 4	1.1	13 7%	4 5%	1%	0%	88%	19%	52%	5%	53%	0%

ergy [kWh]		Efficiency [%]		Capacity Factor		Availability and Utilization						Operational Summary
Solar	Gas	Peak Daily	Average	Solar	Gas	$Avail_{Ctrls}$	$Util_{Ctrls}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$	
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - engine; no data
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - engine; no data
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - engine; no data
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - engine; no data
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - engine; no data
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - engine; no data
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - engine; no data
0	0	0%	0%	0%	0%	100%	9%	0%	0%	0%	0%	Calorimetry
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated
0	0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated
2.3327228	1.1315	8%	4%	1%	0%	100%	4%	100%	3%	100%	1%	Operated briefly on hydrogen and solar
52.134377	0		11%	17%	0%	100%	24%	60%	66%	58%	0%	Operated on sun; PCS faults 0824, 1526 (bad TC)
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated - PCS TC bad
54 317817	0	14%	9%	18%	0%	100%	32%	100%	46%	100%	0%	Operated on sun 0700-1300
2 8353185	0		0%	1%	0%	100%	5%	100%	14%	100%	0%	Operated on sun; data missing
0	0	0%	0%	0%	0%	100%	19%	100%	0%	100%	0%	Tracked defocused?
0	0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated
0	0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated
0	0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	No data
0	0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	No Data
0	0	0%	0%	0%	0%	100%	9%	100%	0%	100%	0%	Defocused Tracking
17.790641	0	12%	3%	6%	0%	100%	67%	100%	16%	100%	0%	Operated on sun
0	0	0%	0%	0%	0%	100%	100%	100%	0%	100%	0%	Tracked defocused
0	0	0%	0%	0%	0%	100%	94%	100%	0%	100%	0%	Tracked defocused
0	0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Weekend -- not operated
0	0	0%	0%	0%	0%	100%	99%	100%	0%	100%	0%	Weekend -- not operated
0	0	0%	0%	0%	0%	29%	100%	11%	0%	29%	0%	Not operated -- wiring upgrade
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated -- wiring upgrade
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated -- wiring upgrade
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated -- wiring upgrade

APS-West Dish Monthly Performance Summary

October-99

Monthly Totals:

Energy Delivered on Solar:	843.7 kWh
Energy Delivered on Gas:	9.9 kWh
Net Energy Delivered:	773.0 kWh
Automated Operation:	285.3 hours
Tracking Operation:	117.0 hours
Solar Operation:	100.2 hours
Gas Operation:	0.9 hours

Monthly Records:

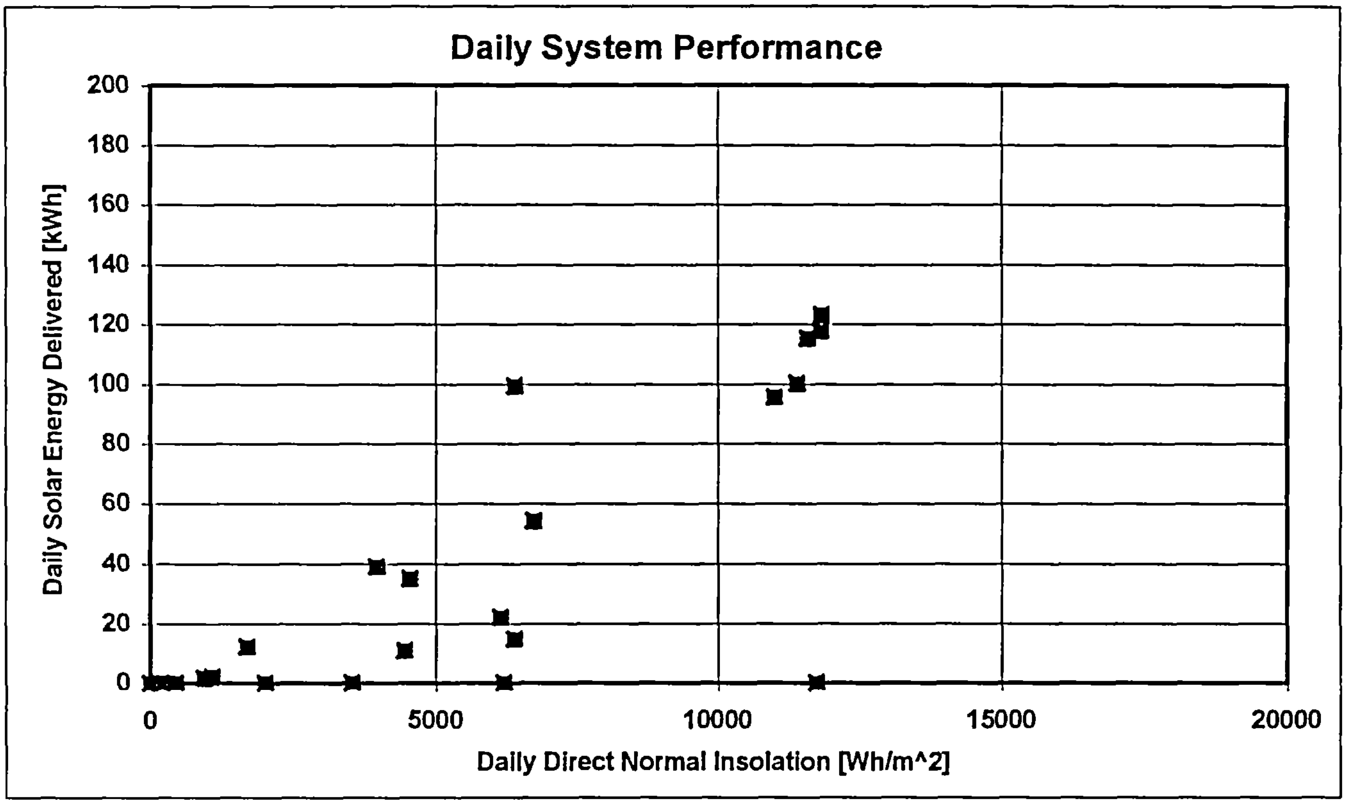
Peak Solar Power [kW]:	18.7
Peak Solar Efficiency:	17.7%

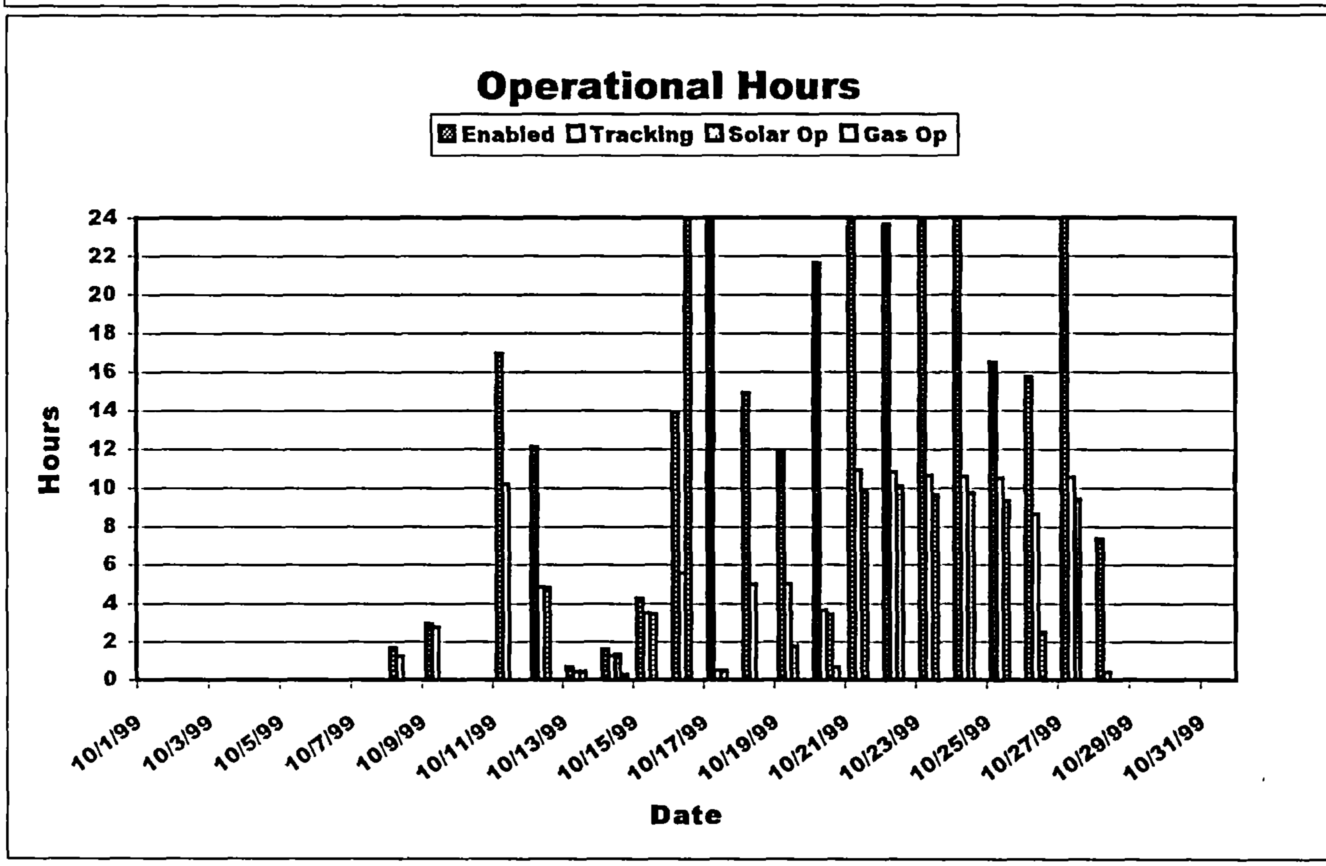
Operational/Reliability Data:

	Avail.	Util.	Capacity Factor
Controls	74%	39%	n/a
Solar	51%	31%	10%
Gas	52%	0%	0%

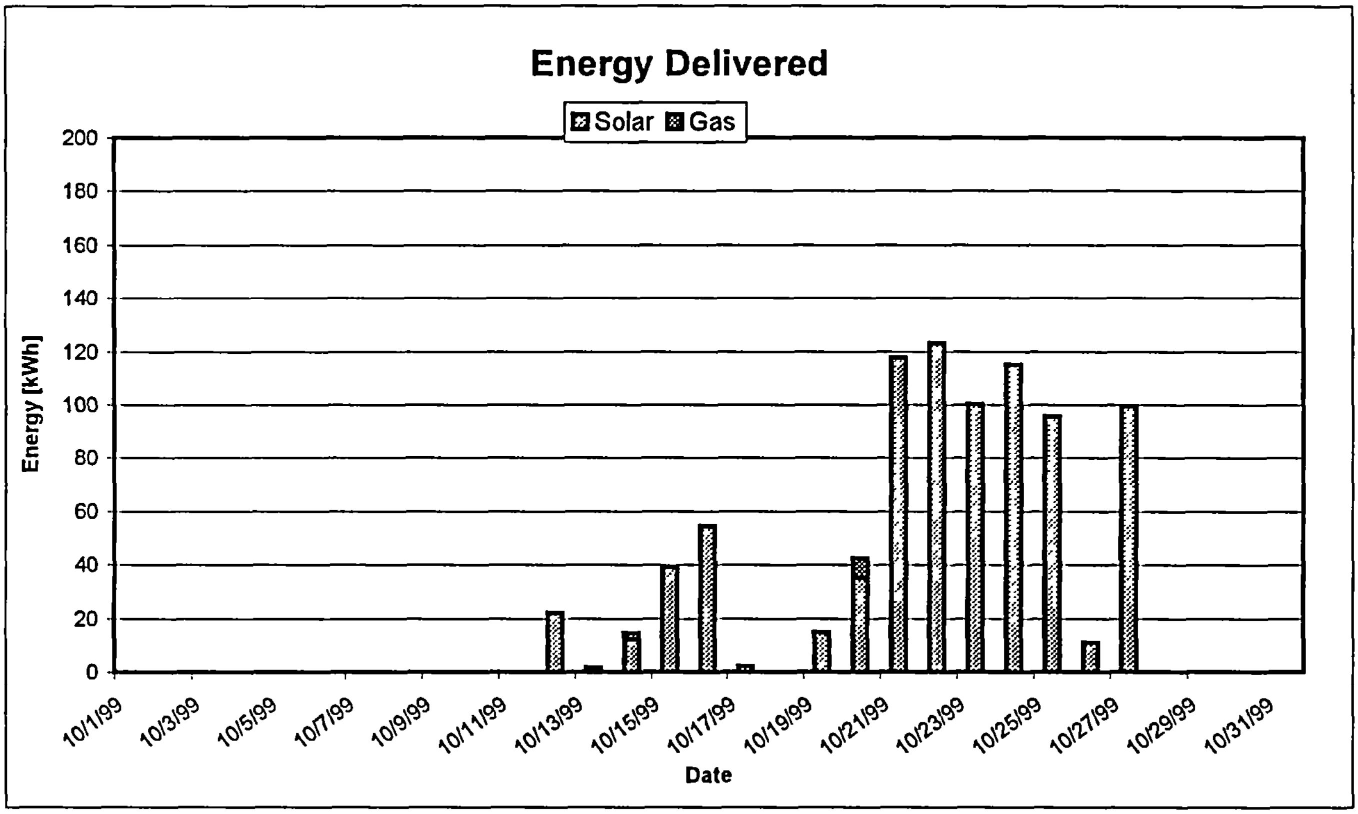
Day	Operational Summary
1	Not operated - down for maintenance
2	Not operated - down for maintenance
3	Not operated - down for maintenance
4	Not operated - down for maintenance
5	Not operated - down for maintenance
6	Not operated - down for maintenance
7	Not operated - down for maintenance
8	New control system checkout
9	tracking defocused
10	Not operated -- weekend
11	tracked defocused
12	Operated on sun; power meter not calibrated
13	Maintenance in AM; elev. Motor fault in PM
14	Ran on hydrogen and solar; power meter not calibrated
15	Operated on sun; power meter not calibrated
16	Tracked defocused
17	Tracked defocused; high winds
18	Tracked defocused, then stowed face-up
19	Operated on solar; demo for Philippines group
20	hydrogen operation in AM; solar operation in PM
21	Operated on sun
22	Operated on sun
23	Operated on sun
24	Operated on sun
25	Operated on sun
26	Operated on sun till 14:40; calibrated power meter, replaced sun sensor; cloudy
27	Operated on sun; calibration tracking
28	PCS Fault about 07:30
29	Not Operated; engine Removed
30	Not Operated; engine Removed
31	Not Operated; engine Removed

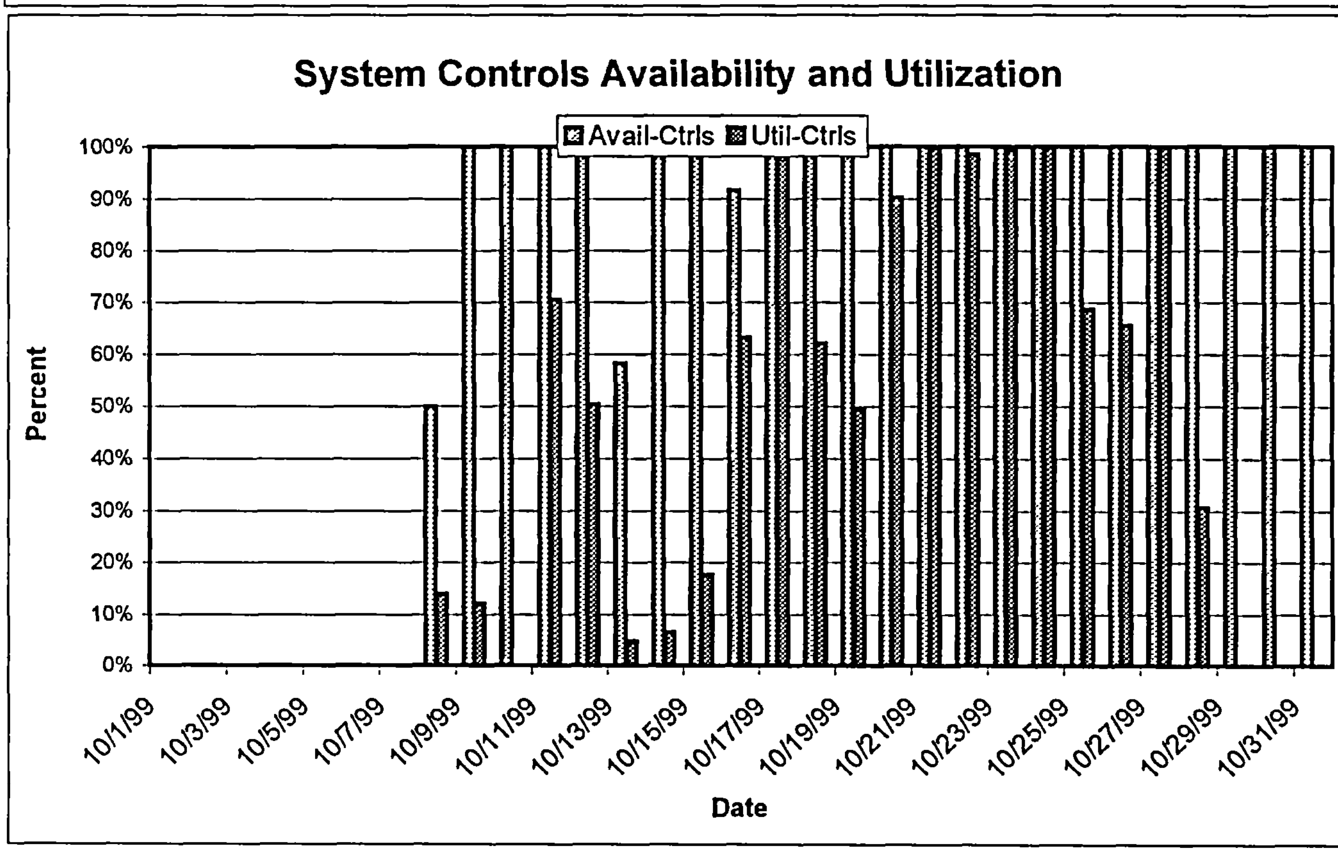
APS-West Dish Monthly Performance Summary



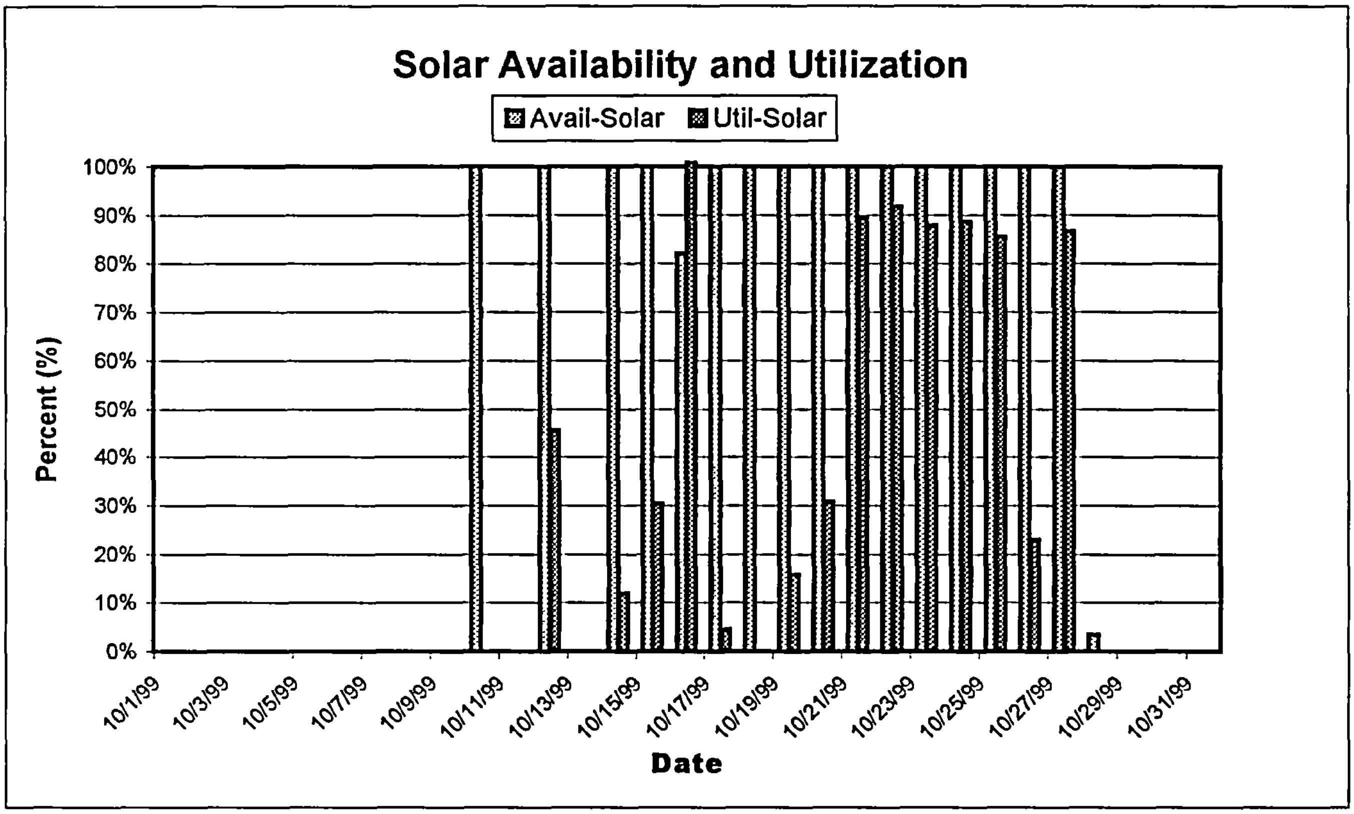


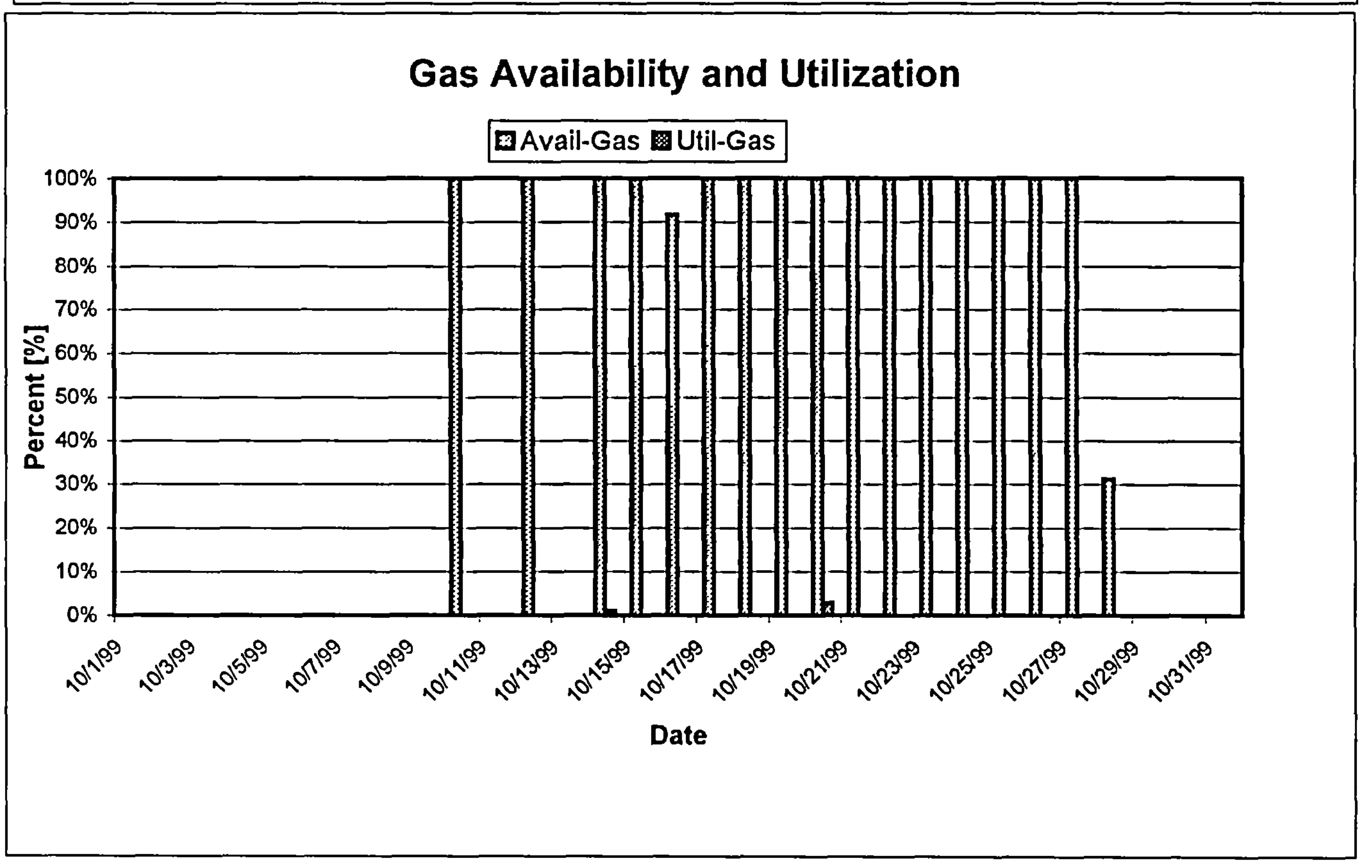
APS-West Dish Monthly Performance Summary





APS-West Dish Monthly Performance Summary





APS-West Dish

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	Monthly Total Hours					Downtimes [hr]			Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		Energy [kWh]	
	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Pk [W/m^2]	Total [Wh/m^2]	Peak Pwr	Average	Gas Peak	Average	Consumed	Solar
Oct-99	345 8	285.3	117.0	100.2	0.9	192.0	169 8	354.5	1180.0	123501.5	18.7	4.05941	15.8	0.7	-80.7	843.7

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	Hours					Downtimes [hr]			Daily Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		Energy [kWh]	
Day	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Peak [W/m^2]	Total [Wh/m^2]	Peak	Average	Gas Peak	Average	Consumed	Solar
01-Oct-99	11.5	0 0	0.0	0.0	0.0	24	11.5	24	36	-78	0.0	0.0	0.0	0.0	0.0	0.0
02-Oct-99	11.5	0.0	0.0	0.0	0 0	24	11.5	24	36	-78	0 0	0.0	0.0	0.0	0.0	0.0
03-Oct-99	11.5	0.0	0.0	0.0	0.0	24	11.5	24	36	-78	0.0	0.0	0.0	0.0	0.0	0.0
04-Oct-99	11.5	0.0	0.0	0.0	0.0	24	11.5	24	36	-78	0.0	0.0	0.0	0.0	0.0	0.0
05-Oct-99	11.5	0.0	0.0	0.0	0.0	24	11.5	24	36	-78	0.0	0.0	0.0	0.0	0.0	0.0
06-Oct-99	11.5	0.0	0.0	0.0	0.0	24	11.5	24	36	-78	0.0	0.0	0.0	0.0	0.0	0.0
07-Oct-99	11.5	0.0	0.0	0.0	0.0	24	11.5	24	36	-78	0.0	0.0	0.0	0.0	0.0	0 0
08-Oct-99	11.5	1.7	1.2	0.0	0.0	12	11.5	24	1158	2005	0.0	0.0	0.0	0.0	0.0	0.0
09-Oct-99	11.4	2.9	2.7	0.0	0.0	0	11.4	24	1171	3527	0.0	0.0	0.0	0.0	0.0	0.0
10-Oct-99	11.4	0.0	0.0	0.0	0.0	0	0	0	41	430	0.0	0.0	0.0	0.0	0.0	0.0
11-Oct-99	11.4	16.9	10.2	0 0	0 0	0	11.4	24	1170	11746	0.0	0.0	0 0	0.0	0.0	0.0
12-Oct-99	11.3	12.1	4.8	4.8	0.0	0	0	0	1173	6146	5.0	4.3	0.0	0.0	0.0	22.2
13-Oct-99	11.3	0.7	0.4	0.4	0.0	10	11.3	24	1166	943	4.3	4.1	0.0	0 0	0.0	1.7
14-Oct-99	11.2	1.6	1.2	1.3	0.2	0	0	0	1138	1681	12.7	9.2	14.7	9.4	0.0	12.3
15-Oct-99	11.2	4.2	3.5	3.4	0.0	0	0	0	1155	3967	18.7	11.4	0.0	0.0	0.0	39.0
16-Oct-99	11.2	13.9	5.6	23.9	0.0	2	2	2	1159	6734	5.0	2.3	0.0	0.0	0.0	54.3
17-Oct-99	11.2	23.9	0.5	0.5	0.0	0	0	0	1169	1079	4.9	4.4	0 0	0.0	0.0	2.2
18-Oct-99	11.1	14.9	5.0	0.0	0.0	0	0	0	1180	6213	0.0	0 0	0.0	0.0	-12.4	0.0
19-Oct-99	11.1	11.9	5.0	1.8	0.0	0	0	0	1178	6394	13.8	8.5	0.0	0.0	-11.1	14.9
20-Oct-99	11.1	21.6	3.7	3.4	0.7	0	0	0	1173	4545	14.8	10.2	15.8	11.4	-6.6	35.0
21-Oct-99	11.1	24.0	10.9	9.9	0.0	0	0	0	1144	11811	16.1	11.9	0.0	0.0	-4.5	117.7
22-Oct-99	11.0	23.6	10.8	10.1	0.0	0	0	0	1146	11829	16.3	12.2	0.0	0.0	-4.2	123.0
23-Oct-99	11.0	23.8	10.7	9.7	0.0	0	0	0	1144	11394	15.6	10.4	0.0	0.0	-4.4	100.2
24-Oct-99	11.0	23.9	10.6	9.8	0.0	0	0	0	1142	11584	15.7	11.8	0.0	0.0	-4.4	115.2
25-Oct-99	10.9	16.5	10.5	9.3	0.0	0	0	0	1137	10994	15.2	10.2	0 0	0.0	-2.5	95.7
26-Oct-99	10.9	15.7	8.7	2.5	0.0	0	0	0	1124	4451	13.1	4.4	0.0	0.0	-23.2	10.9
27-Oct-99	10.9	24.0	10.5	9.4	0.0	0	0	0	714	6400	14.3	10.5	0.0	0.0	-5.0	99.5
28-Oct-99	10.9	7.4	0.4	0.0	0.0	0	10.5	16.5	434	173	0.0	0.0	0.0	0.0	-2.3	0.0
29-Oct-99	10.5	0.0	0.0	0.0	0.0	0	10.5	24	0	0	0 0	0.0	0.0	0.0	0.0	0.0
30-Oct-99	10.5	0.0	0.0	0.0	0.0	0	10.5	24	0	0	0.0	0.0	0.0	0.0	0.0	0.0
31-Oct-99	10.5	0.0	0.0	0.0	0 0	0	10.5	24	0	0	0.0	0 0	0.0	0.0	0.0	0 0

Gas	Efficiency [%] Peak Eff	Average	Capacity Factor CF_{-Solar}	CF_{-Gas}	Availability and Utilization $Avail_{Auto}$	$Util_{Auto}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$
9.9	17.7%	6 0%	10%	0%	74%	39%	51%	31%	52%	0%

	Efficiency [%]		Capacity Factor		Availability and Utilization						Operational Summary
Gas	Peak Daily	Average	Solar	Gas	$Avail_{Ctrls}$	$Util_{Ctrls}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$	
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0.0	0%	0%	0%	0%	50%	14%	0%	0%	0%	0%	New control system checkout
0.0	0%	0%	0%	0%	100%	12%	0%	0%	0%	0%	tracking defocused
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated — weekend
0.0	0%	0%	0%	0%	100%	71%	0%	0%	0%	0%	tracked defocused
0.0	5%	3%	8%	0%	100%	50%	100%	46%	100%	0%	Operated on sun; power meter not calibrated
0.0	3%	2%	1%	0%	58%	5%	0%	0%	0%	0%	Maintenance in AM; elev. Motor fault in PM
2.4	10%	6%	4%	0%	100%	7%	100%	12%	100%	1%	Ran on hydrogen and solar; power meter not calibrated
0.0	14%	9%	14%	0%	100%	18%	100%	30%	100%	0%	Operated on sun; power meter not calibrated
0.0		7%	19%	0%	92%	63%	82%	261%	92%	0%	Tracked defocused
0.0	4%	2%	1%	0%	100%	100%	100%	4%	100%	0%	Tracked defocused; high winds
0.0	0%	0%	0%	0%	100%	62%	100%	0%	100%	0%	Tracked defocused, then stowed face-up
0.0	10%	2%	5%	0%	100%	50%	100%	16%	100%	0%	Operated on solar; demo for Philippines group
7.6	11%	7%	13%	1%	100%	90%	100%	31%	100%	3%	hydrogen operation in AM; solar operation in PM
0.0	12%	9%	43%	0%	100%	100%	100%	89%	100%	0%	Operated on sun
0 0	13%	9%	45%	0%	100%	99%	100%	92%	100%	0%	Operated on sun
0 0	12%	8%	36%	0%	100%	99%	100%	88%	100%	0%	Operated on sun
0.0	12%	9%	42%	0%	100%	100%	100%	89%	100%	0%	Operated on sun
0.0	12%	8%	35%	0%	100%	69%	100%	85%	100%	0%	Operated on sun
0.0	10%	2%	4%	0%	100%	66%	100%	23%	100%	0%	Operated on sun till 14:40; calibrated power meter, replaced sun sensor; cloudy
0.0	18%	14%	37%	0%	100%	100%	100%	87%	100%	0%	Operated on sun; calibration tracking
0.0	0%	0%	0%	0%	100%	31%	3%	0%	31%	0%	PCS Fault about 07:30
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not Operated; engine Removed
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not Operated; engine Removed
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not Operated; engine Removed

APS-West Dish Daily Performance Summary

Daily Summary: **14-Apr-99**

Hours of Operation

Hours of Automated Operation	23.93
Hours of Tracking Operation	12.56
Hours of Solar Operation	12.26
Hours of Gas Operation	0.00
Hours of Hybrid Operation	0.00

Net Power [kW]

Peak Power	20.0
Average Power	14.8

Energy Delivered (total) [kWh]:	**173.8**
Energy Delivered (Solar)	173.8
Energy Delivered (Gas)	0
Energy Delivered (Hybrid)	0

Efficiency [%]

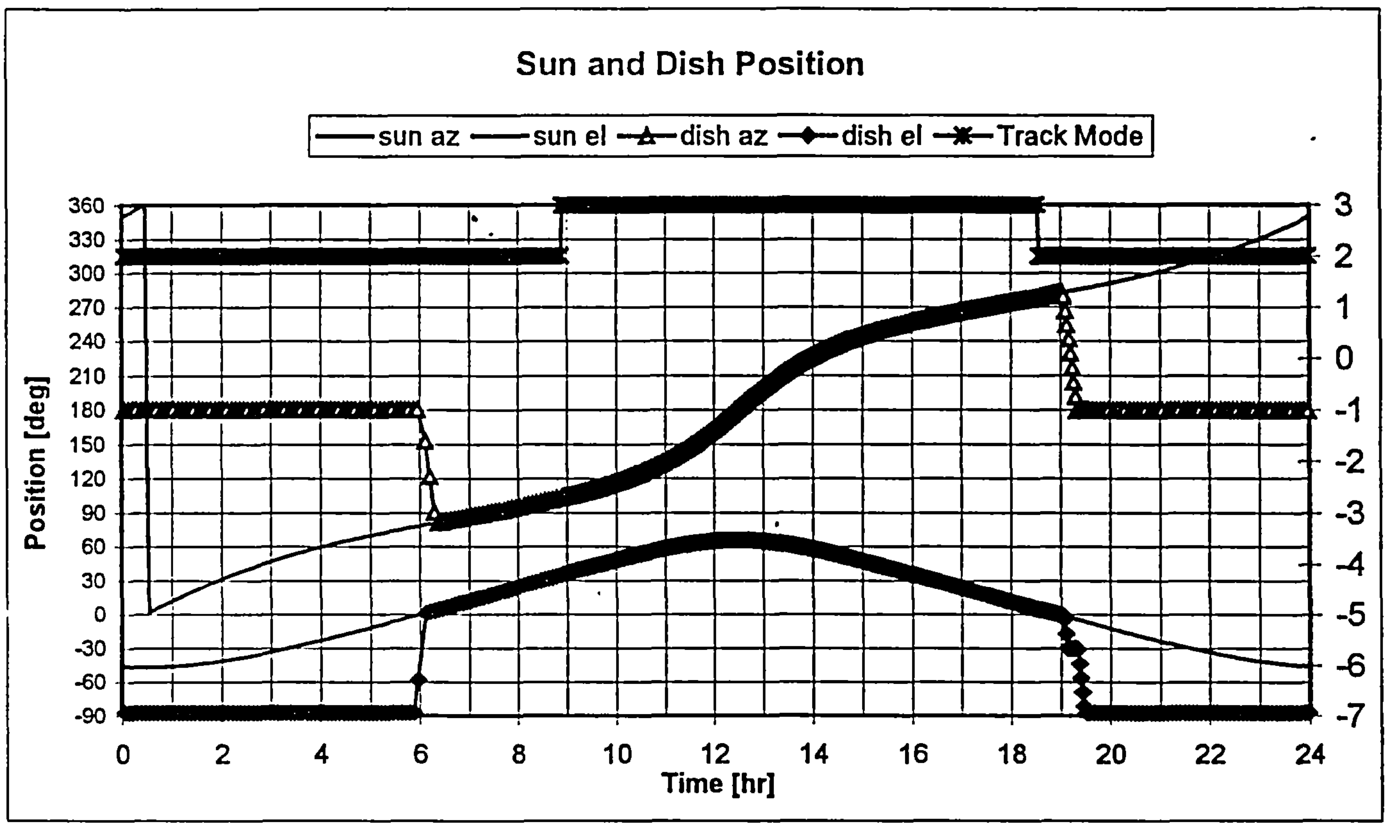
Peak Efficiency	22%
Average Efficiency	15%

Availability and Utilization [%]

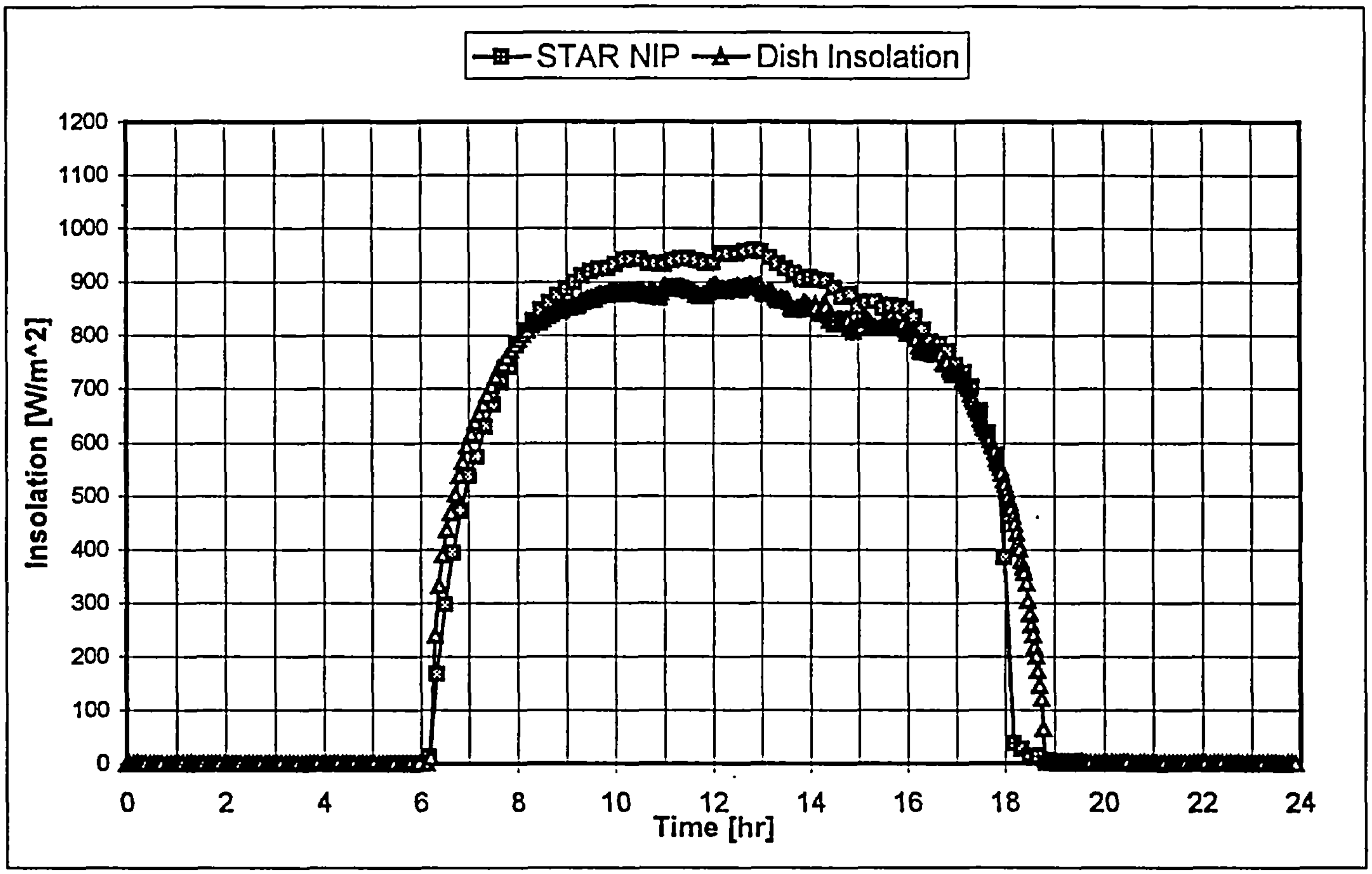
Auto Availability	100%
Auto Utilization	100%
Tracking Availability	100%
Tracking Utilization	98%
Solar Availability	100%
Solar Utilization	96%
Gas Availability	100%
Gas Utilization	0%
Hybrid Availability	0%
Hybrid Utilization	0%

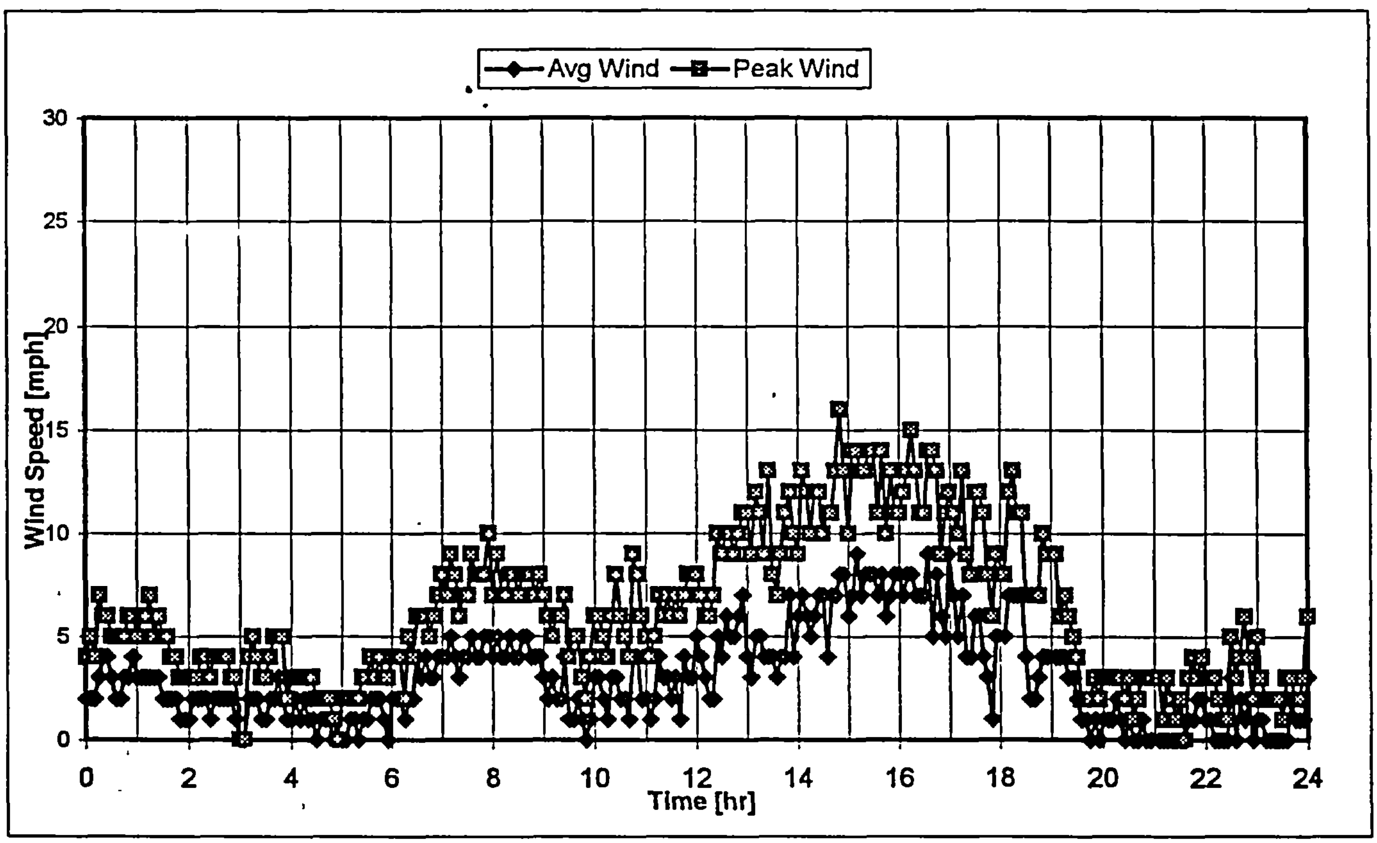
Capacity Factor

CF_{Solar}	56%
CF_{Gas}	0%
CF_{Hybrid}	0%

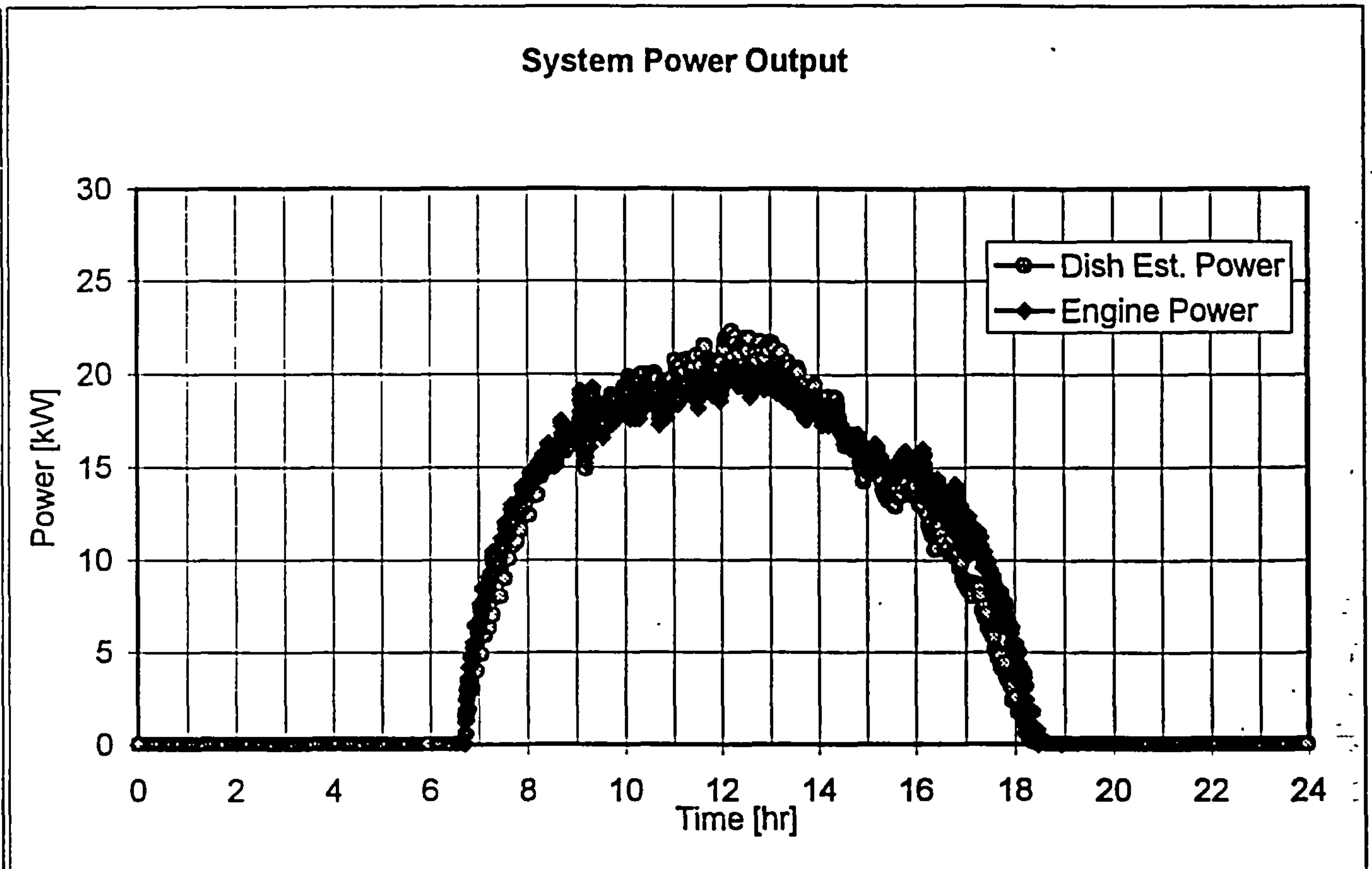


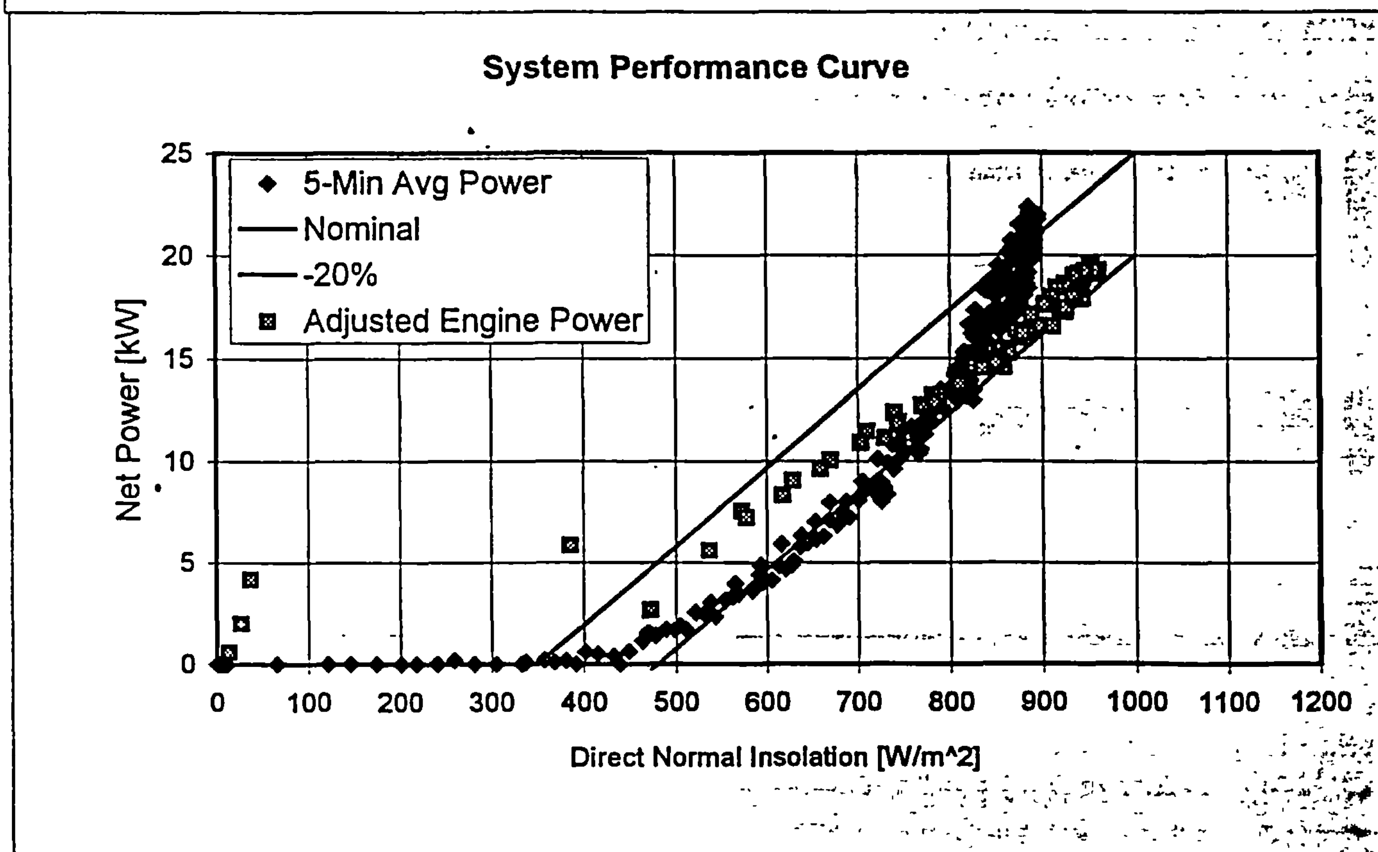
APS-West Dish Daily Performance Summary





APS-West Dish Daily Performance Summary





Appendix I:
Cumulative Performance of the APS East Dish/Stirling System

APS-East Dish Cumulative Performance Summary

Monthly Data:

	Total Hours Month	Daylight	Solar Op.	Gas Op.	Solar Down	Gas Down	System Records: Power	Efficiency	Energy [kWh]: Solar	Gas	Monthly Availability/Utilization Solar Availability	Solar Utilization	Gas Availability	Gas Utilization
Feb-99	228 8	116	0 0	0 0	0 0	0 0	0 0	0%	0	0				
Mar-99	558 4	267	0 0	0 0	0 0	0 0	0 0	0%	0	0				
Apr-99	681.7	384	0 0	0 0	0 0	0 0	0 0	0%	0	0				
May-99	744 0	427	0 0	0 0	0 0	0 0	0 0	0%	0	0				
Jun-99	720 0	427	0 0	0 0	0 0	0 0	0 0	0%	0	0				
Jul-99	744 0	433	23 6	5 8	105 6	171 5	17.3	21%	228	90	76%	7%	77%	1%
Aug-99	744 0	412	7.3	0 9	404 2	704 0	15 9	18%	90	0	2%	90%	5%	2%
Sep-99	720 0	370	23 4	2 2	110 1	219 0	20 5	17%	771	122	70%	9%	70%	0%
Oct-99	744 0	350	0 0	0 0	349 0	744 0	0 0	0%	0	0	0%	0%	0%	~~#DIV/0!~~ 0%
Nov-99	720 0	314	0 0	0 0	0 0	0 0	0 0	0%	0	0				
Dec-99	744 0	312	0 0	0 0	0 0	0 0	0 0	0%	0	0				
Maximums:			23 6	5 8			20 5	21%	771	122	76%	90%	77%	#DIV/0!

Cumulative Values:

	Total Hours Data	Daylight	Solar Op.	Gas Op.	Solar Down	Gas Down	System Records: Power	Efficiency	Energy [kWh] Solar	Gas	Cumulative Availability/Utilization Solar Avail	Solar Util	Gas Avail	Gas Util
Feb-99	228 8	115 9	0 0	0 0	0 0	0 0	0 0	0%	0	0	100%	0%	100%	0%
Mar-99	787.2	383 4	0 0	0 0	0 0	0 0	0 0	0%	0	0	100%	0%	100%	0%
Apr-99	1468 9	767.6	0 0	0 0	0 0	0 0	0 0	0%	0	0	0 100%	0%	0 100%	0%
May-99	2212.9	1194 6	0 0	0 0	0 0	0 0	0 0	0%	0	0	100%	0%	100%	0%
Jun-99	2932 9	1621.6	0 0	0 0	0 0	0 0	0 0	0%	0	0	100%	0%	100%	0%
Jul-99	3676 9	2054 6	23 6	5 8	105 6	171 5	17.3	21%	228	90	95%	1%	95%	0%
Aug-99	4420 9	2466 9	30 9	6 8	509 8	875 5	17.3	21%	319	90	79%	2%	80%	0%
Sep-99	5140 9	2836 7	54 3	8 9	619 9	1094 5	20 5	21%	1090	212	78%	2%	79%	0%
Oct-99	5884 9	3187.0	54 3	8 9	968 8	1838 5	20 5	21%	1090	212	70%	2%	69%	0%
Nov-99	6604.9	3500 5									37%	2%	38%	1%
Dec-99	7348 9	3812 0												
Totals:	7348 9	3812.0	54 3	8 9	968 8	1838.5			1089 7	212 4				

Cumulative Performance Summary - APS East Dish

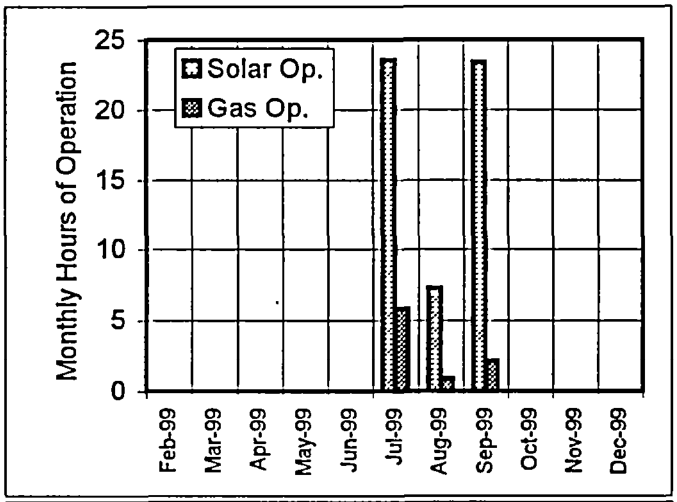
through October 1999

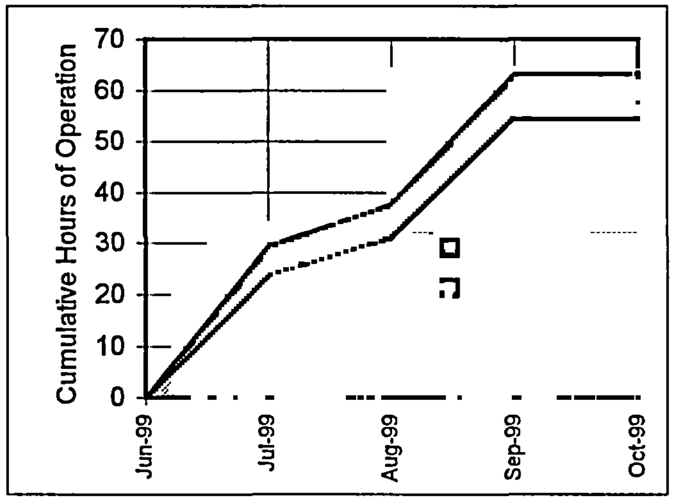
System Records:

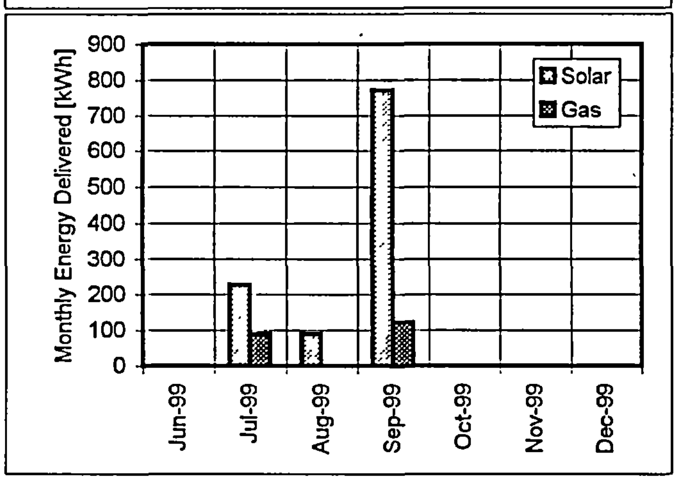
20.5 kW Peak Power Delivered
21% Peak Instantaneous Efficiency
90% Monthly Solar Utilization
771 kWh Monthly Solar Energy Delivery
122 kWh Monthly Gas Energy Delivery
23.6 hours Monthly Solar Operation
5.8 hours Monthly Gas Operation

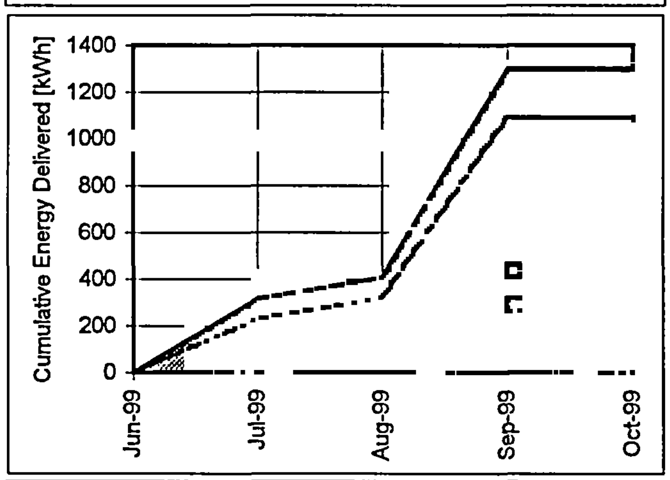
Totals:

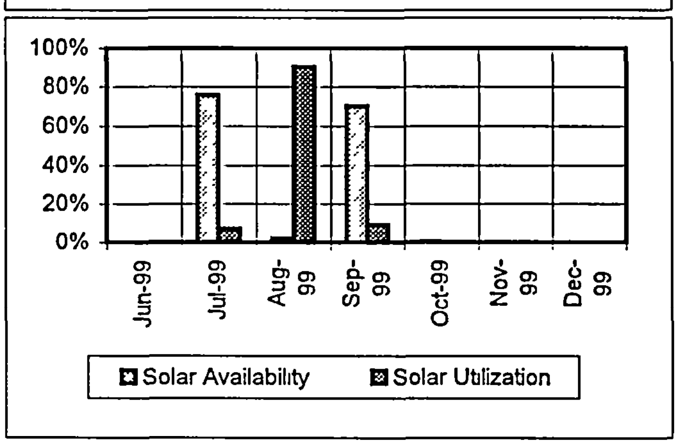
54	Hours of Solar Operation
9	Hours of Gas Operation
63	Hours of System Operation
1,090	kWh Solar
212	kWh Gas
1,302	kWh Delivered by System

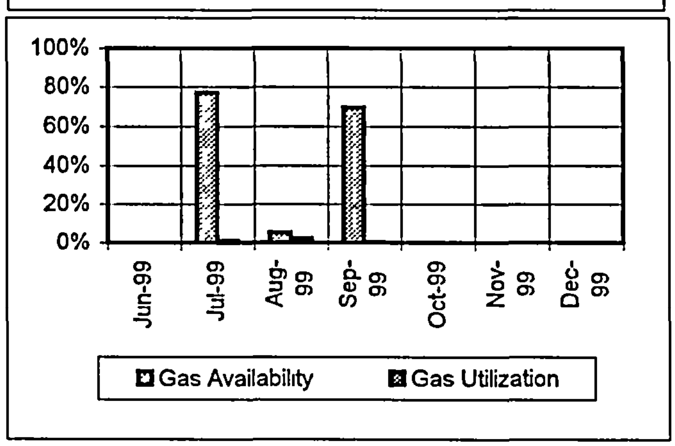












Appendix J:

Month-by-Month Performance Summaries for the APS East Dish/Stirling System

APS-East Dish Monthly Performance Summary

July-99

Monthly Totals:

Energy Delivered on Solar:	228.4	kWh
Energy Delivered on Gas:	90.4	kWh
Net Energy Delivered:	91.0	kWh
Automated Operation:	138.3	hours
Tracking Operation:	99.1	hours
Solar Operation:	23.6	hours
Gas Operation:	5.8	hours

Monthly Records:

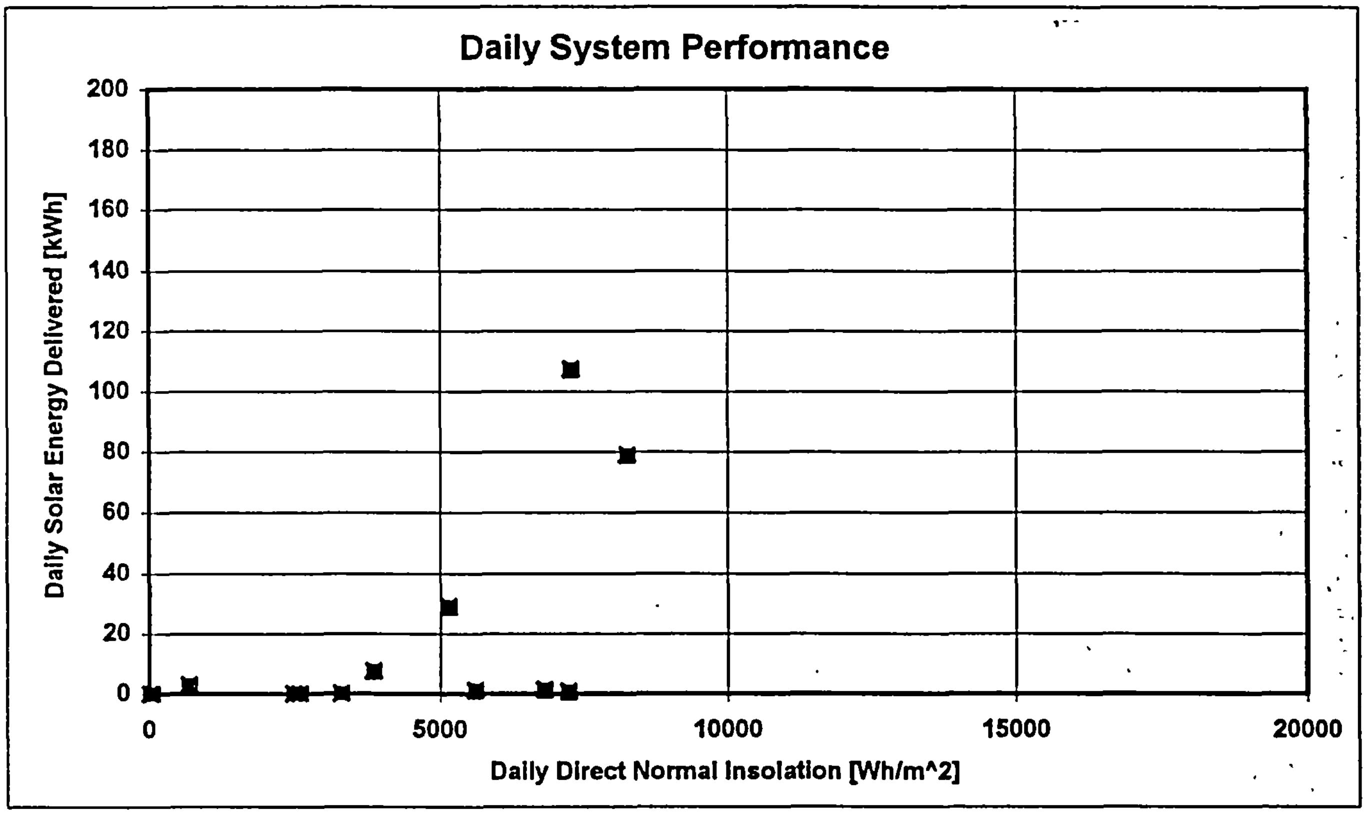
Peak Solar Power:	17.3 kW
Peak Solar Efficiency:	21.2%

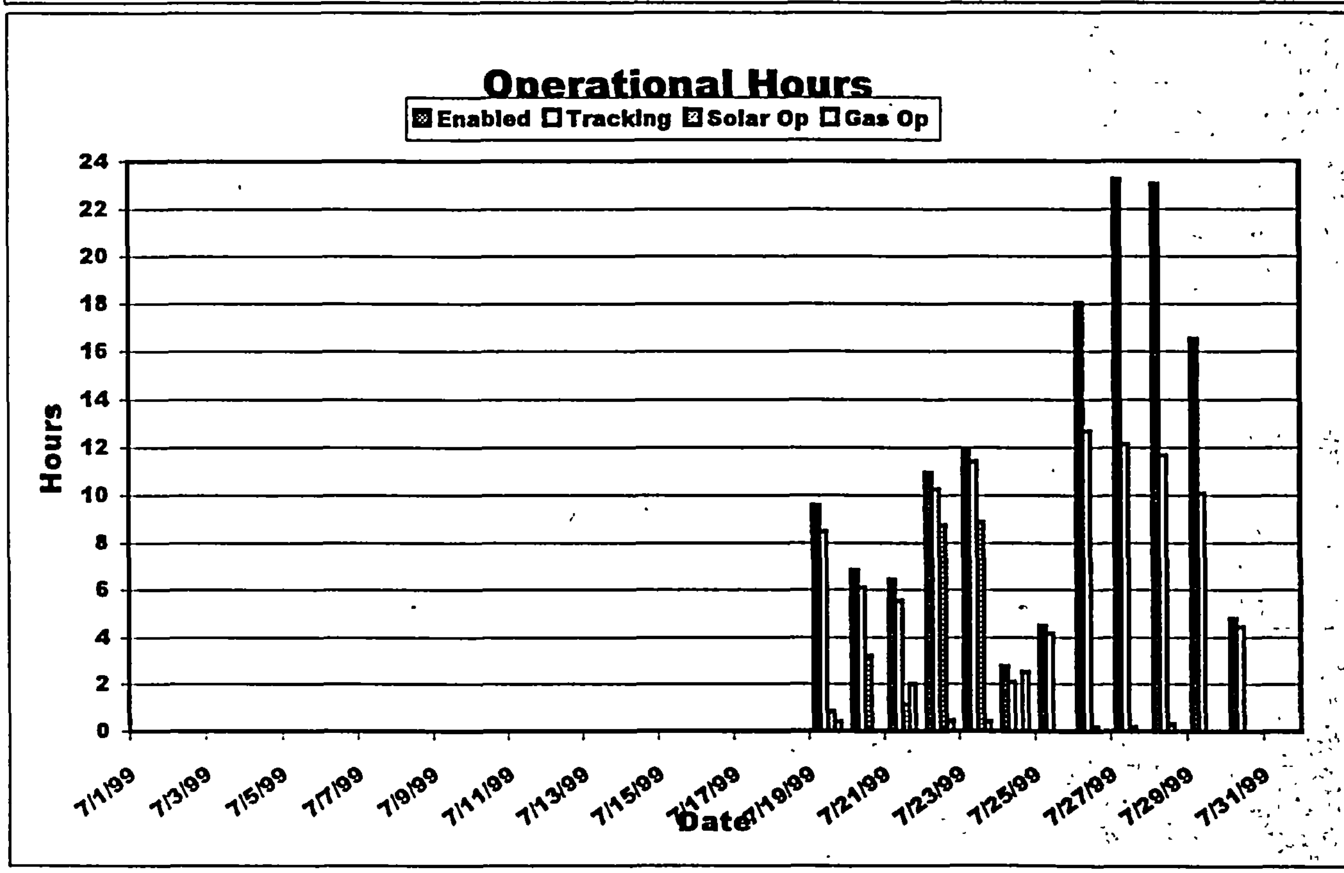
Operational/Reliability Data:

	Availabilit	Utilization	Capacity Factor
Controls	99%	19%	n/a
Solar	42%	31%	5%
Gas	77%	1%	1%

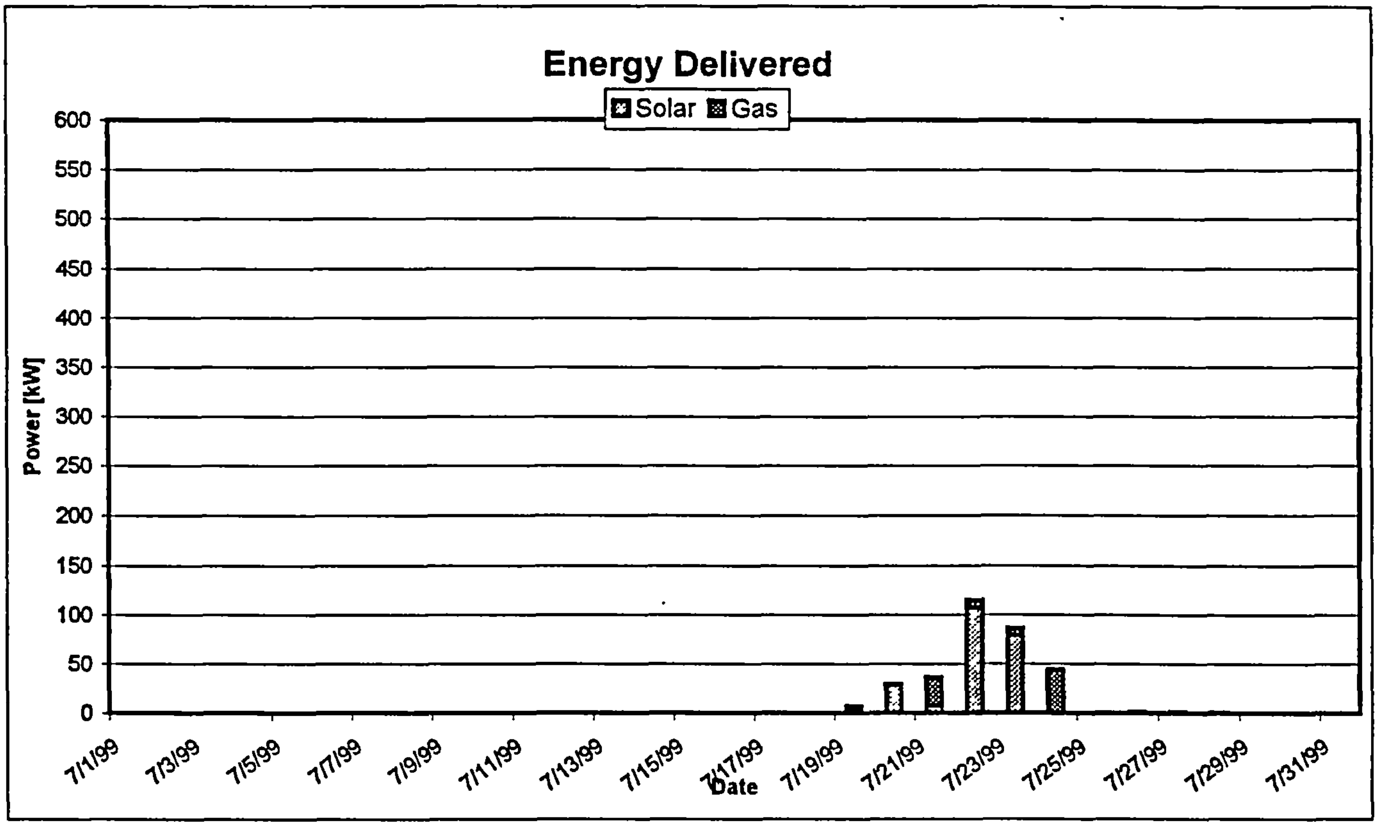
Day	Operational Summary
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	Operated on gas 0930 to 1000, solar 1000-1100; tracked defocused; solar op 1740-1940
20	Operated on sun 0600-0830; sealed focus valve assy's; Tracked 1300-1700
21	Solar op 0700-0810, 1630-1745; PCS Actuator Fault; gas op 1200-1545; adjusted focus
22	Operated on Sun; TC 1-3 failed ~0720; calibration 1000-1700
23	Solar op 0600-1800; power meter rough calibration
24	Gas/Solar op 0600-0830; PCS fault-actuator 0858
25	Washed mirrors; tracked 1100-1530 defocused
26	Tracked defocused 0600-1900; solar op 1220, 1500-1515
27	Solar op 0600-1900 (cloudy); Actuator fault @1123; tracked defocused 1205-1900
28	Tracked defocused 0700-1900; solar op 0800-0930 for tests
29	Tracked defocused; PCS down (actuator fault)
30	Tracked defocused 0930-1400
31	Not operated

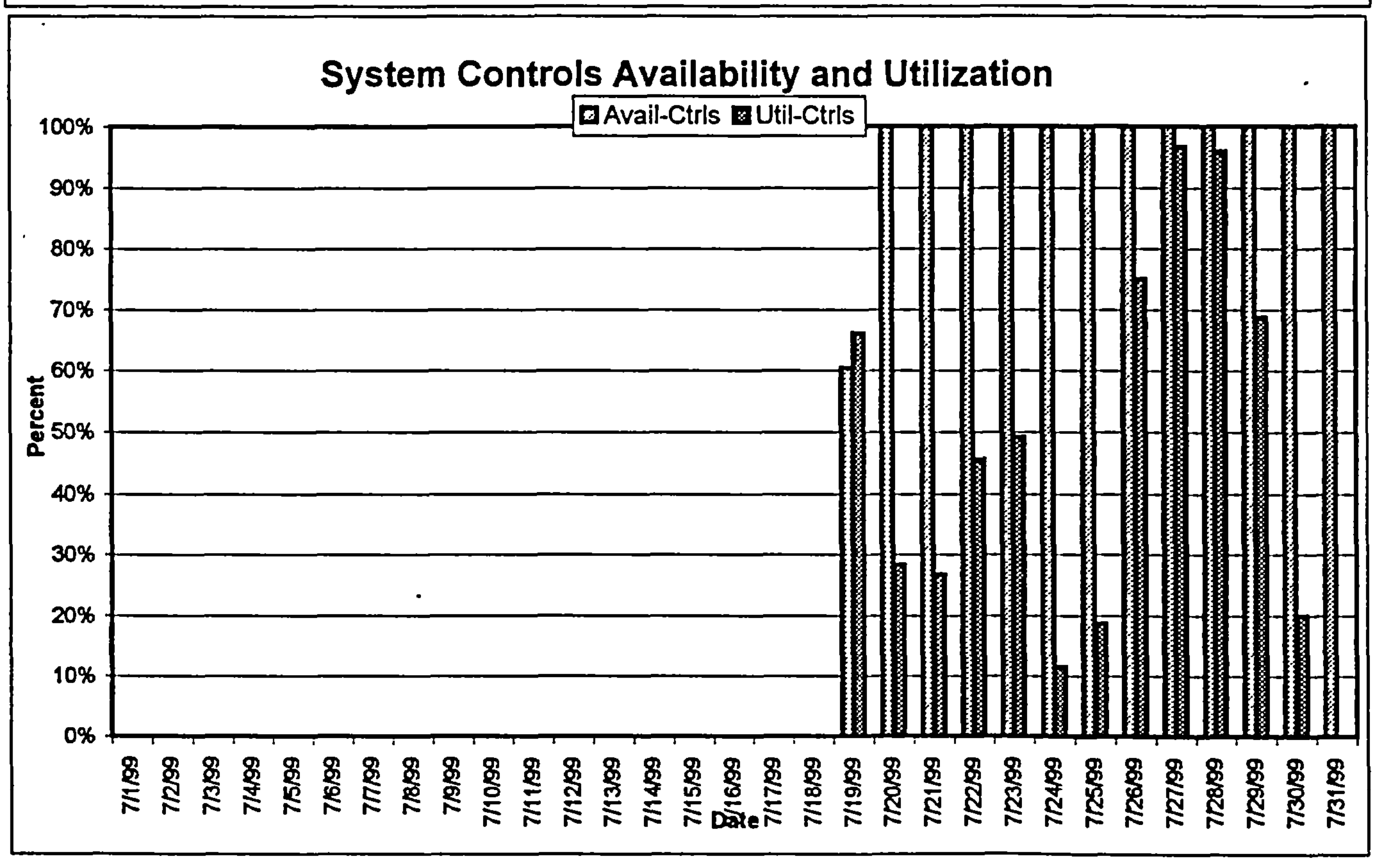
APS-East Dish Monthly Performance Summary



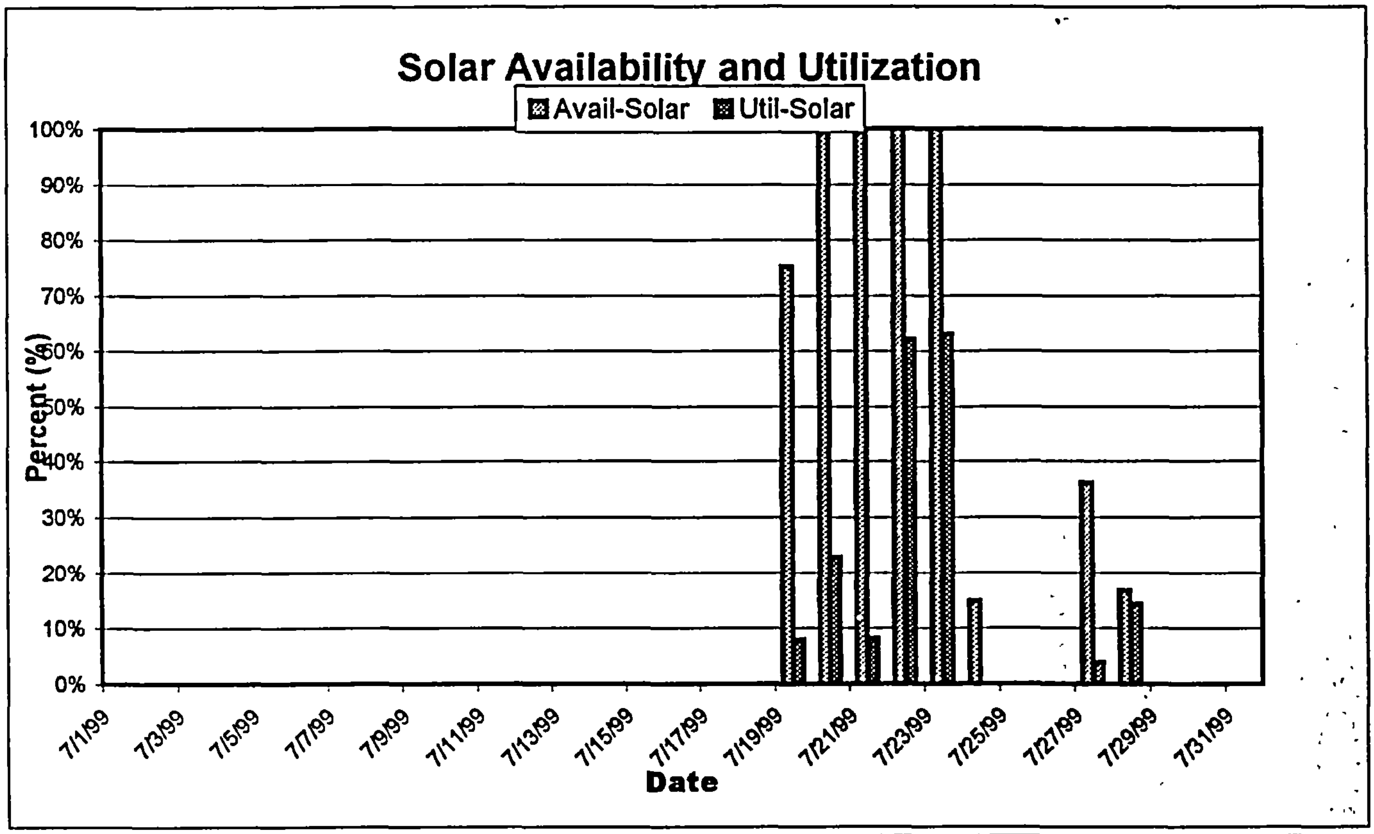


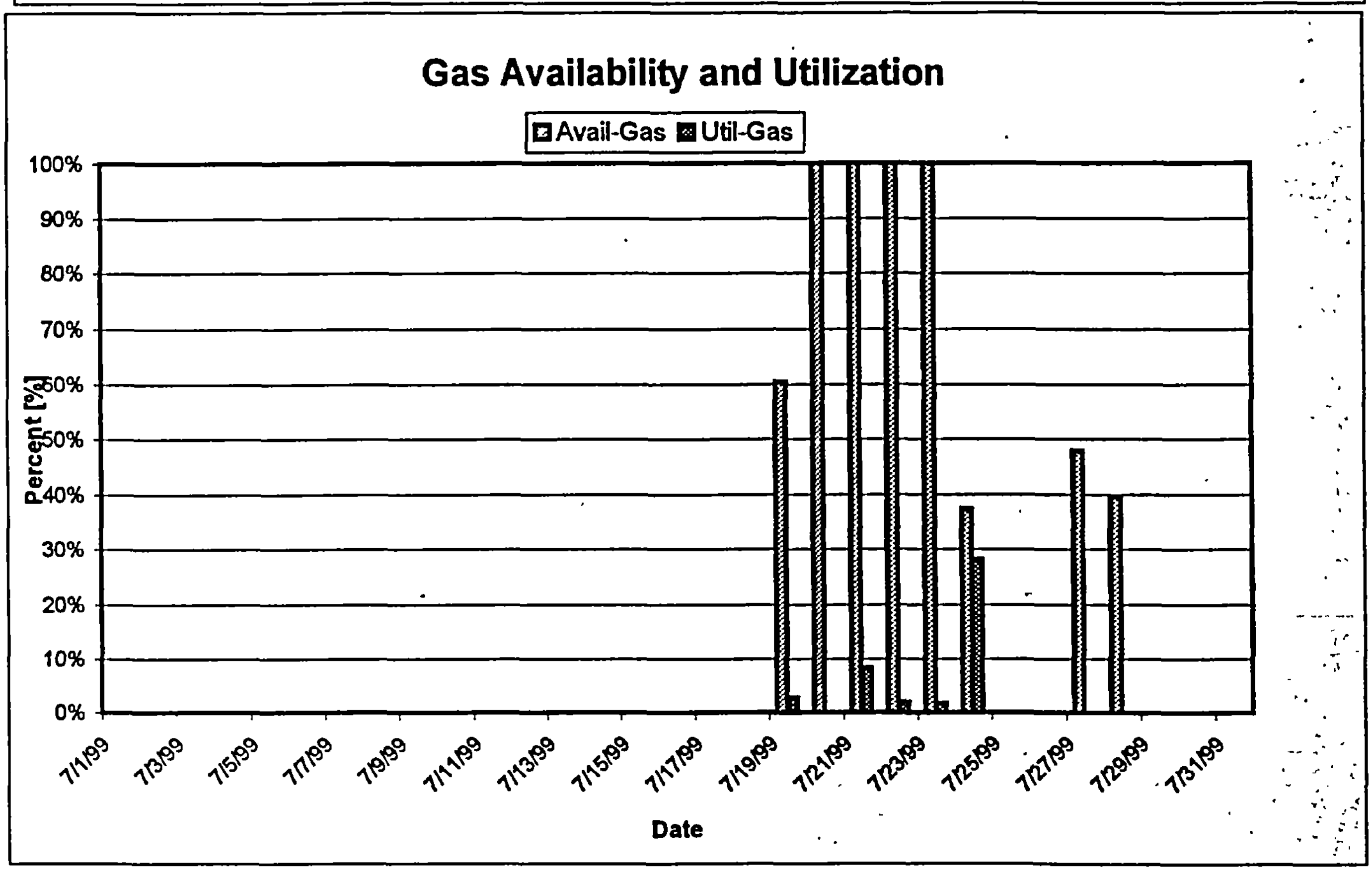
APS-East Dish Monthly Performance Summary





APS-East Dish Monthly Performance Summary





APS-East Dish Monthly Performance Summary

August-99

Monthly Totals:

Energy Delivered on Solar:	90.3 kWh
Energy Delivered on Gas:	0.0 kWh
Net Energy Delivered:	-128.1 kWh
Automated Operation:	156.2 hours
Tracking Operation:	133.0 hours
Solar Operation:	7.3 hours
Gas Operation:	0.9 hours

Monthly Records:

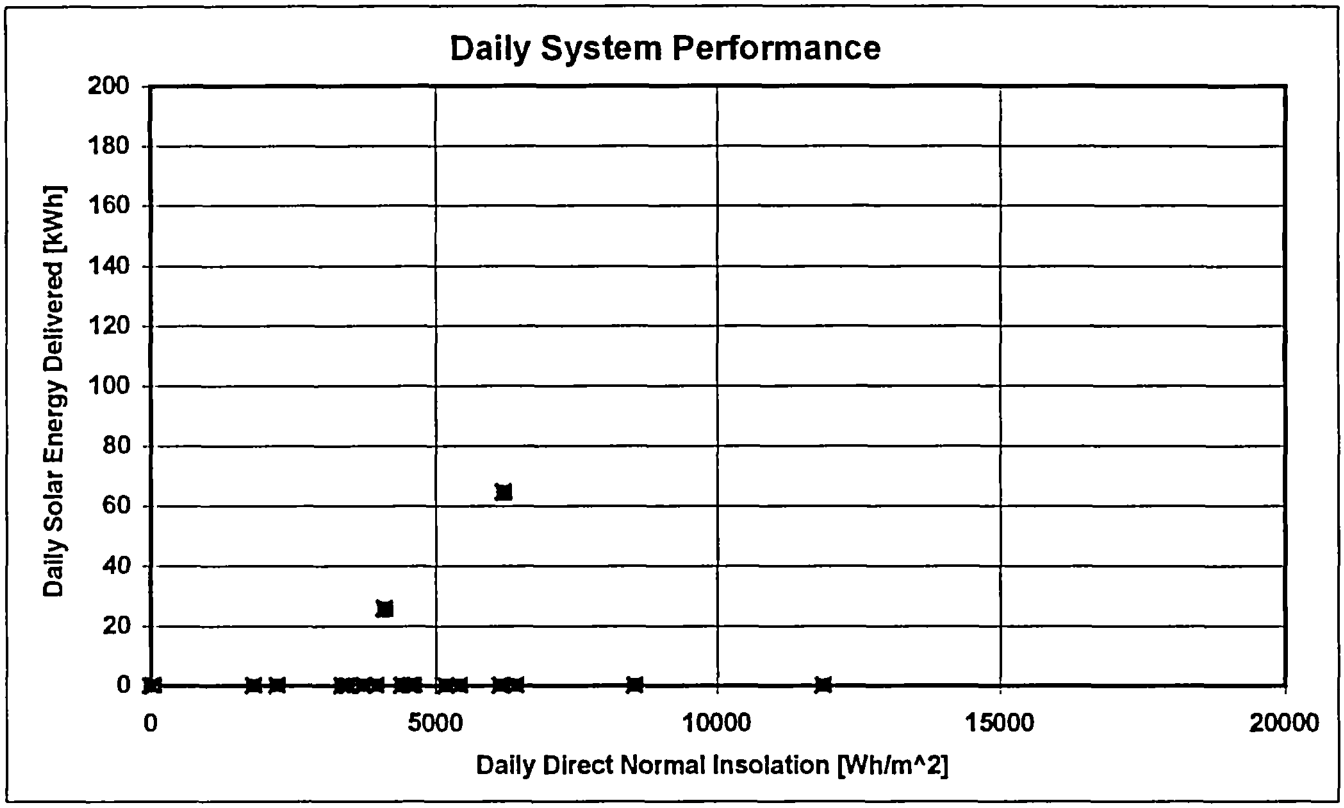
Peak Solar Power:	15.9 kW
Peak Solar Efficiency:	18.5%

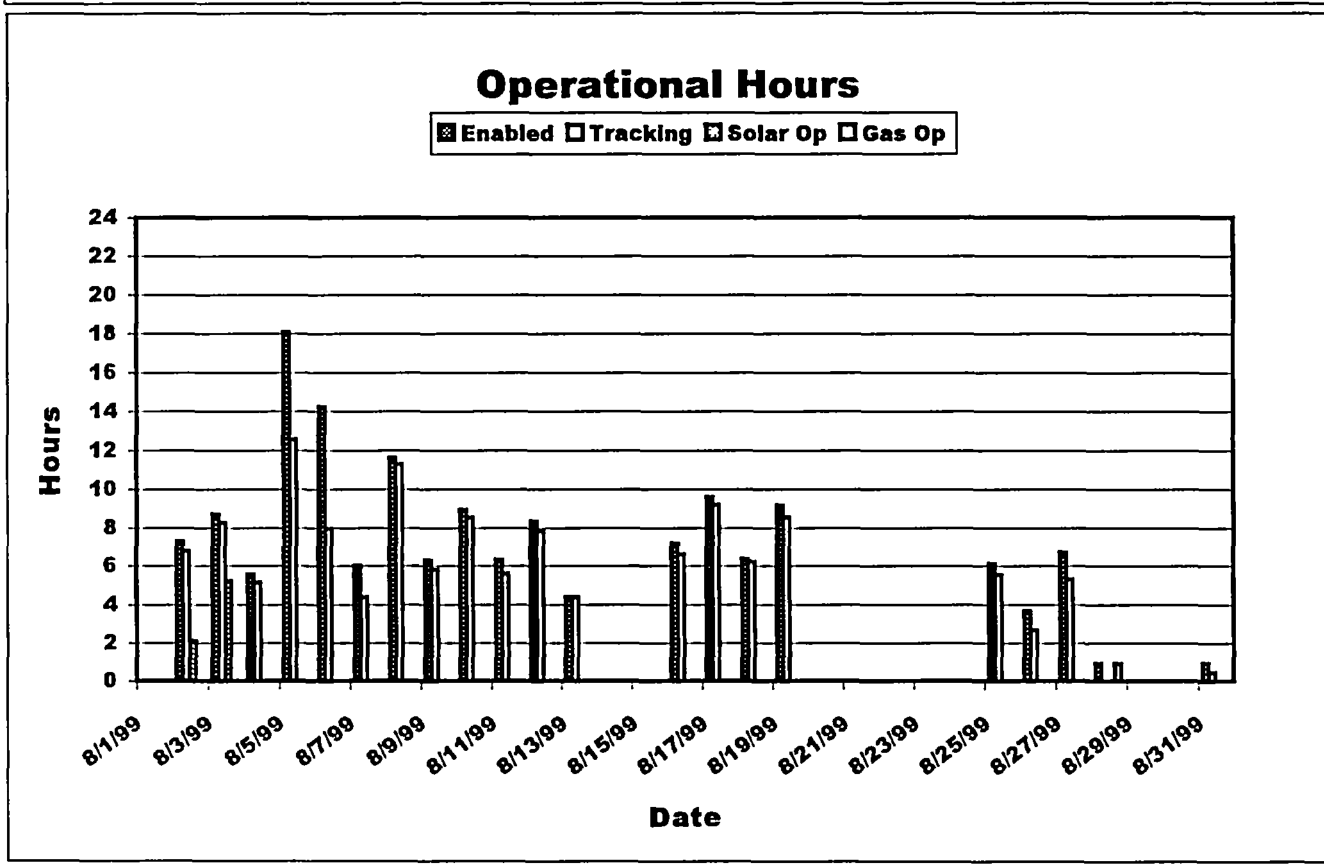
Operational/Reliability Data:

	Availability	Utilization	Capacity Factor
Controls	100%	21%	n/a
Solar	9%	3%	1%
Gas	9%	1%	0%

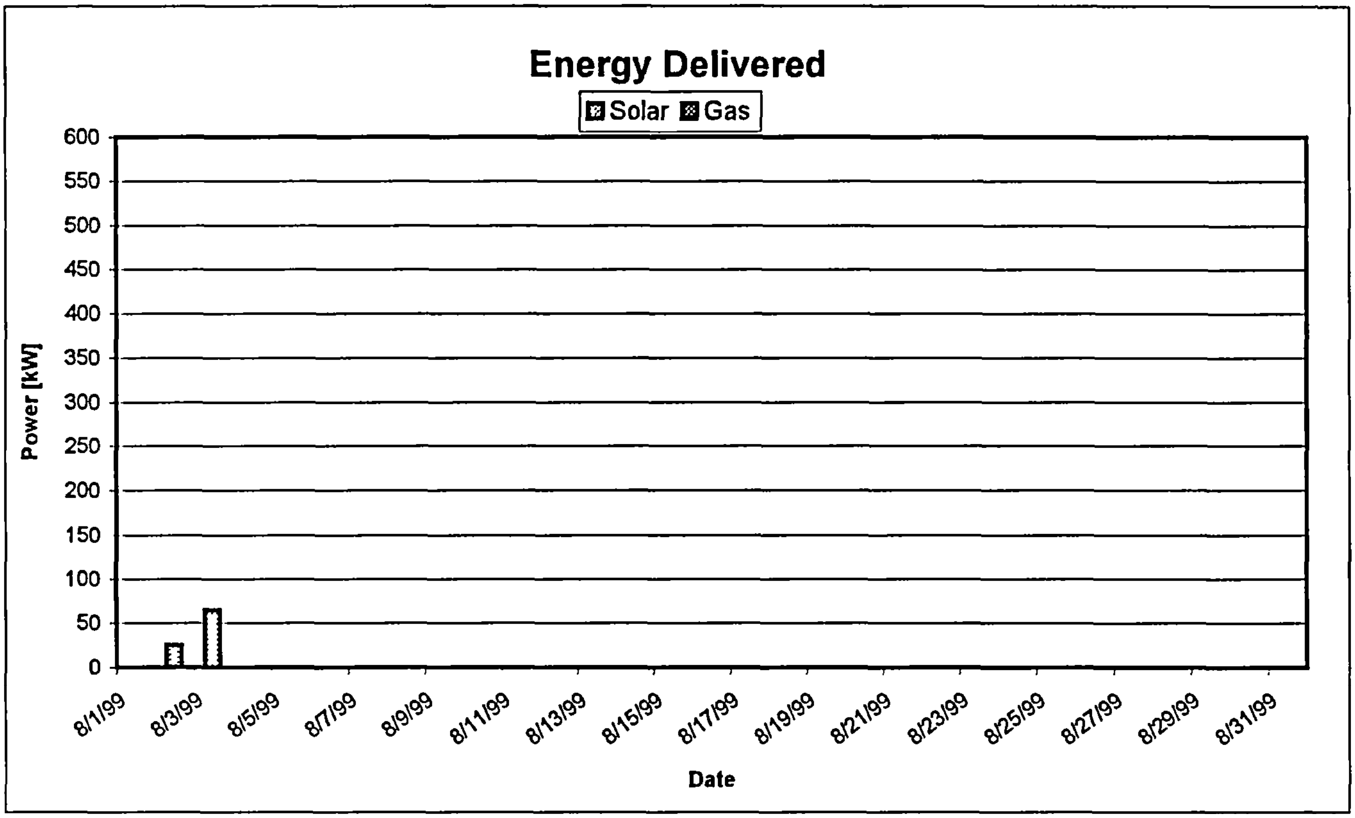
Day	Operational Summary
1	Not operated; PCS down
2	Solar op 0730-1300, 1400-1600
3	Solar op 0600-1200; defocused track 1200-1420; PCS fault 1420
4	BCS 1300-1800
5	BCS Tracking
6	BCS Tracking
7	BCS Tracking
8	BCS Tracking
9	BCS Tracking
10	Tracked defocused 0600-1530
11	BCS Adjustment
12	BCS Testing
13	BCS Testing
14	Weekend - not operated
15	Weekend - not operated
16	BCS Testing
17	BCS Testing
18	BCS Testing
19	BCS Testing
20	BCS Testing
21	System Idle
22	System Idle
23	System Idle
24	System Idle
25	BCS and Calorimetry
26	Calorimetry
27	Calorimetry and BCS
28	Re-installed PCS; actuator stall fault
29	System powered down
30	System powered down
31	On sun 0.4 hr for tests

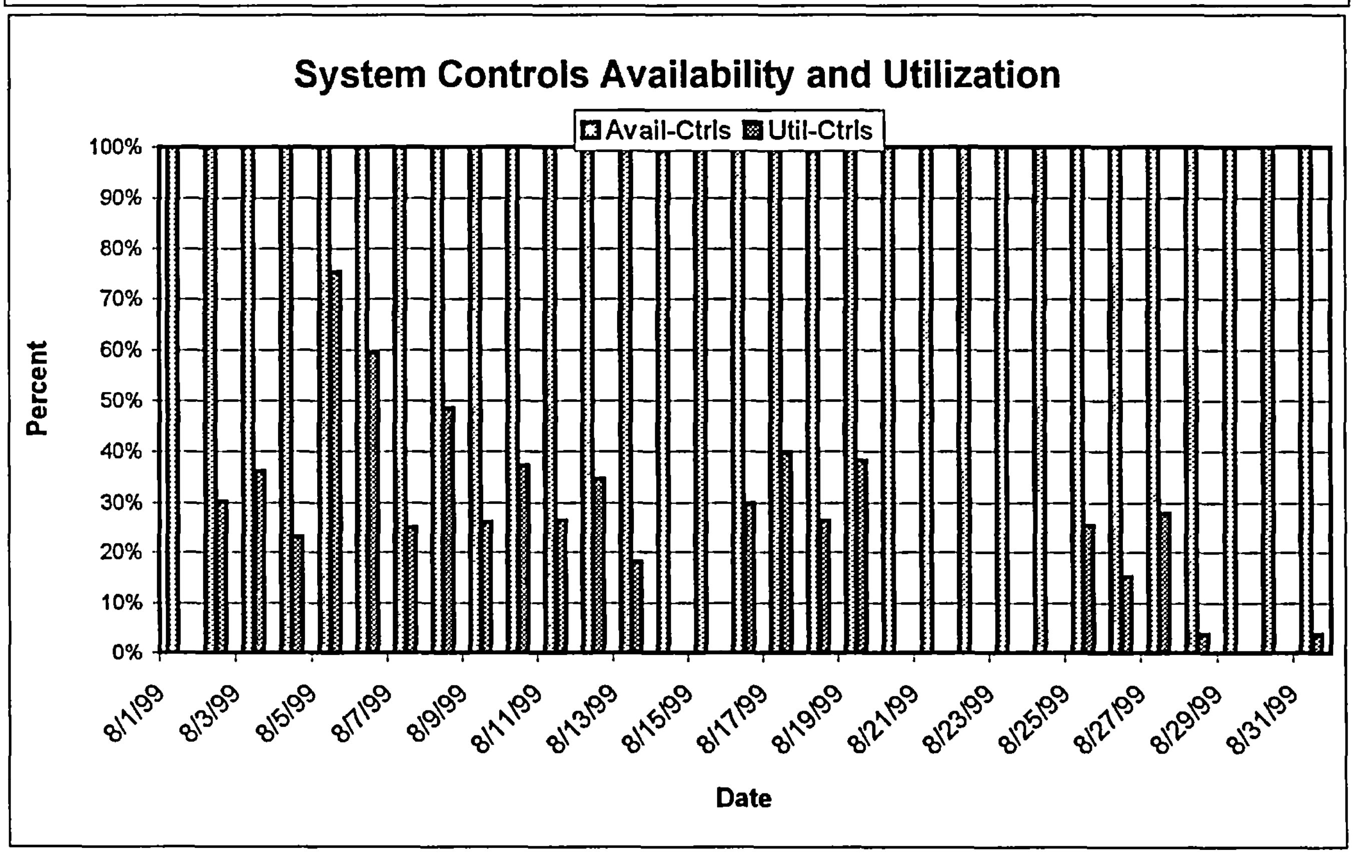
APS-East Dish Monthly Performance Summary



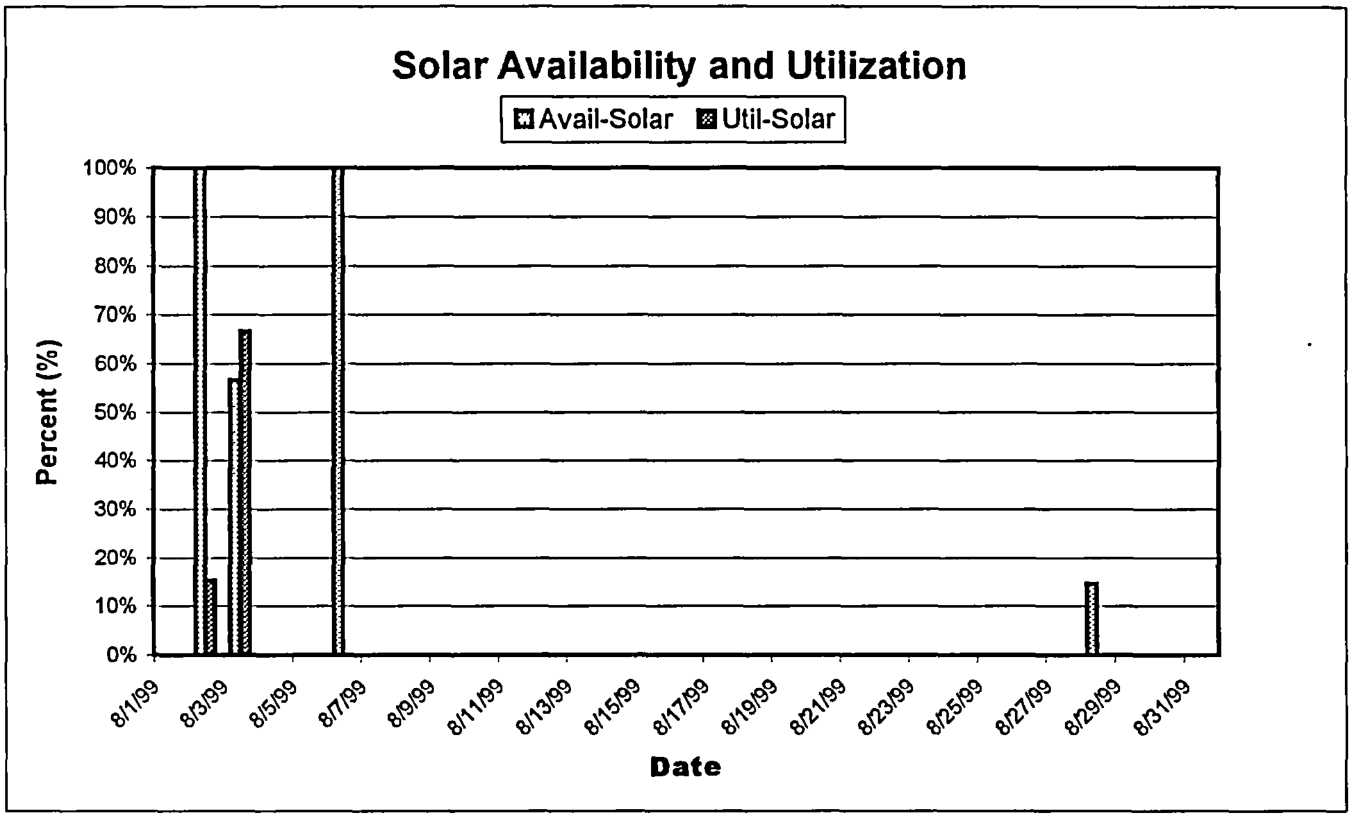


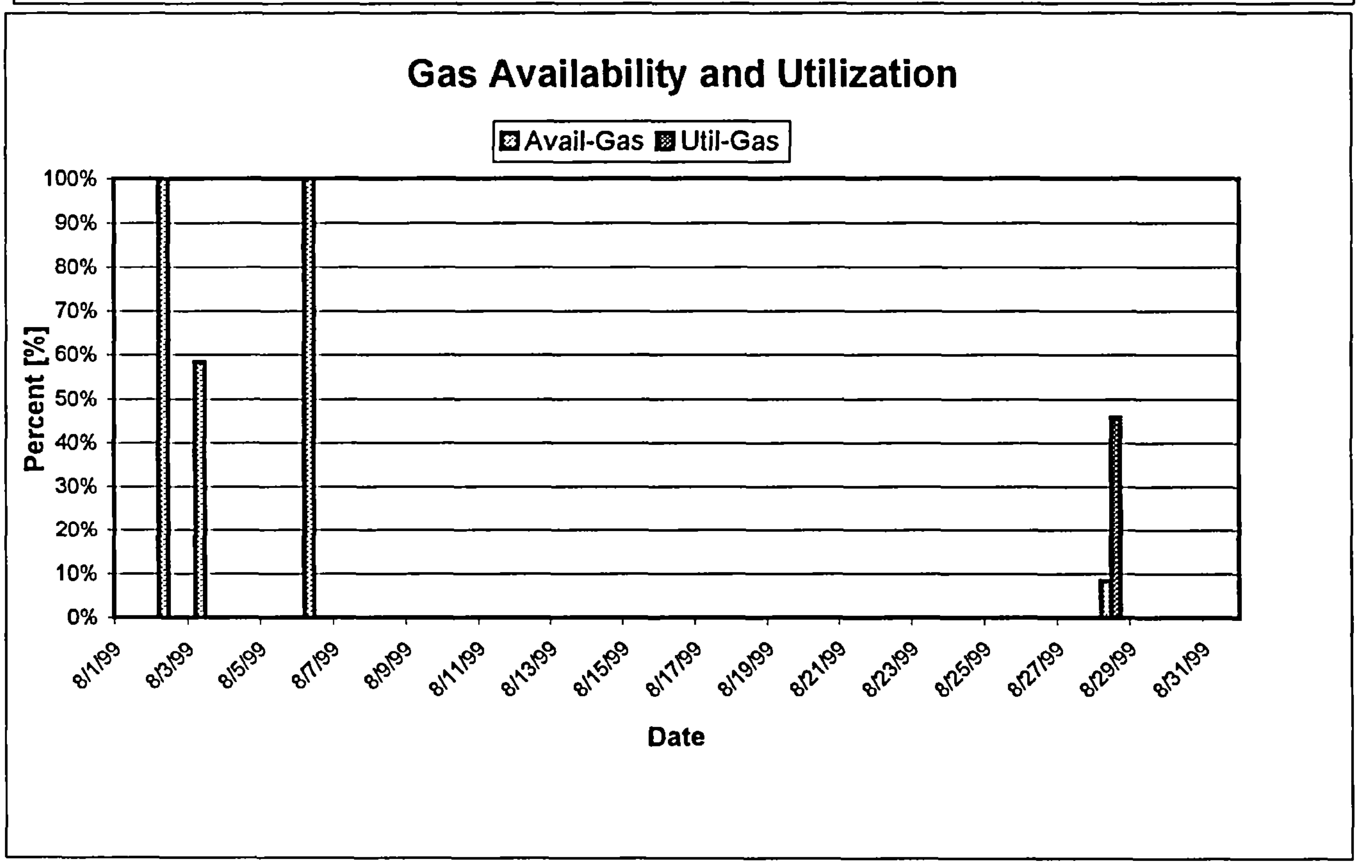
APS-East Dish Monthly Performance Summary





APS-East Dish Monthly Performance Summary





ergy [kWh]		Efficiency [%]		Capacity Factor		Availability and Utilization					
Solar	Gas	Peak Eff	Average	CF_{Solar}	CF_{Gas}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$
90.3	0.0	18.5%	0.8%	1%	0%	100%	21%	9%	3%	9%	1%

ergy [kWh]		Efficiency [%]		Capacity Factor		Availability and Utilization						Operational Summary
Solar	Gas	Peak Daily	Average	Solar	Gas	$Avail_{Ctrls}$	$Util_{Ctrls}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$	
0	0	0	0	0%	0%	100%	0%	0%	0%	0%	0%	Not operated, PCS down
25.[illegible]	0	0.1[illegible]	0.00510519	0.074[illegible]	0	1	[illegible]	1	0.152	1	4E-06	Solar op 0730-1300, 1400-1600
54.[illegible]	0	0.1[illegible]	0.00[illegible]	0.187[illegible]	0	1	[illegible]	[illegible]	[illegible]	0.56533	7E-06	Solar op 0650-1200, defocused track 1200-1420; PCS fault 1420
0	0	0	0	0	0	1	0.2703	0	0	0	0	BCS 1300-1600
0	0	0	0	0	0	1	0.752	0	0	0	0	BCS Tracking
0	0	0	0	0	0	1	0.5039	1	7E-07	1	4E-06	BCS Tracking
0	0	0	0	0	0	1	0.24[illegible]	0	0	0	0	BCS Tracking
0	0	0	0	0	0	1	0.434[illegible]	0	0	0	0	BCS Tracking
0	0	0	0	0	0	1	0.261[illegible]	0	0	0	0	BCS Tracking
0	0	0	0	0	0	1	0.3721	0	0	0	0	Tracked defocused 0900-1530
0	0	0	0	0	0	1	0.2634	0	0	0	0	BCS Adjustment
0	0	0	0	0	0	1	0.347	0	0	0	0	BCS Testing
0	0	0	0	0	0	1	0.187[illegible]	0	0	0	0	BCS Testing
0	0	0	0	0	0	1	4E-06	0	0	0	0	Weekend - not operated
0	0	0	0	0	0	1	4E-06	0	0	0	0	Weekend - not operated
0	0	0	0	0	0	1	0.2087	0	0	0	0	BCS Testing
0	0	0	0	0	0	1	0.2091	0	0	0	0	BCS Testing
0	0	0	0	0	0	1	0.2042	0	0	0	0	BCS Testing
0	0	0	0	0	0	1	0.3022	0	0	0	0	BCS Testing
0	0	0	0	0	0	1	4E-06	0	0	0	0	BCS Testing
0	0	0	0	0	0	1	0	0	0	0	0	System idle
0	0	0	0	0	0	1	0	0	0	0	0	System idle
0	0	0	0	0	0	1	0	0	0	0	0	System idle
0	0	0	0	0	0	1	0	0	0	0	0	System idle
0	0	0	0	0	0	1	0.2541	0	0	0	0	BCS and Calorimetry
0	0	0	0	0	0	1	0.1526	0	0	0	0	Calorimetry
0	0	0	0	0	0	1	0.2709	0	0	0	0	Calorimetry and BCS
0		0	0	0	0.137	1	0.0322	0.14[illegible]	5E-[illegible]	0.565[illegible]	0.448	Reinstalled PCS, actuator stall fault
0	0	0	0	0	0	1	0	0	0	0	0	System powered down
0	0	0	0	0	0	1	0	0	0	0	0	System powered down
0	0	0	0	0	0	1	[illegible]	0	0	0	0	On sun [illegible] hr for tests

APS-East Dish

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	Monthly Total Hours					Downtimes [hr]			Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		E
	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Pk [W/m^2]	Total [Wh/m^2]	Peak Pwr	Average	Gas Peak	Average	Consumed
Aug-99	427.8	156.2	133.0	7.3	0.9	0.0	404.2	704.0	6699.0	100568.9	15.9	0.7959865	18.2	-	-218 5

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	Hours					Downtimes [hr]			Daily Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		E
Day	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Peak [W/m^2]	Total [Wh/m^2]	Peak	Average	Gas Peak	Average	Consumed
01-Aug-99	13 8	0 0	0 0	0 0	0 0	0	13 8	24	5 0	40 8	0	0	0	0	-10 8991885
02 Aug 99	13 6	7 25932	6 76066	2 09779	0 0001	0	0	[illegible]	769	4100 217044	15 383	12 224571	0	0	-21.4664735
03 Aug 99	13 [illegible]	[illegible]	3 2[illegible]	5 1[illegible]	0 000[illegible]	0	[illegible]	1[illegible]	755	[illegible]	15 [illegible]	12 4[illegible]	0	0	2 [illegible]
04 Aug 99	13 [illegible]	[illegible]52[illegible]16	5 [illegible]2[illegible]71	0 00001	0 0001	0	13 8	24	765	3[illegible] 47[illegible]	0	0	0	0	12 3[illegible]
05 Aug 99	13 [illegible]	16 0[illegible]73	12 5551	0 00001	0 0001	0	13 8	24	764	64[illegible] 50[illegible]	0	0	0	0	-8 352[illegible]
06-Aug-99	13 3	14 255[illegible]	7 [illegible]	0 00001	0 0001	0	13 5	24	760	5435 072183	0	0	0	0	15 0[illegible]
07-Aug-99	13 8	5 [illegible]	4 [illegible]21	0 00001	0 0001	0	13 [illegible]	24	7[illegible]	3353 1[illegible]	0	0	0	0	11 [illegible]
08 Aug-99	13 8	11 [illegible]22[illegible]	11 2[illegible]	0 00001	0 0001	0	13 [illegible]	24	7[illegible]	[illegible]531 351[illegible]	0	0	0	0	-4 [illegible]
09-Aug-99	13 8	5 [illegible]8[illegible]	5 [illegible]	0 00001	0 0001	0	13 [illegible]	24	7[illegible]	45[illegible] 5[illegible]	0	0	0	0	-13 [illegible]
10-Aug-99	13 6	8 02932	8 [illegible]2371	0 00001	0 0001	0	13 [illegible]	24	761	[illegible]191 [illegible]572	0	0	0	0	9 [illegible]69
11-Aug-99	13 [illegible]	8 32204	5 [illegible]	0 00001	0 0001	0	13 [illegible]	24	76[illegible]	440[illegible]	0	0	0	0	-1[illegible]
12 Aug-99	13 [illegible]	[illegible] 32[illegible]83	7 [illegible]21	0 00001	0 0001	0	13 8	24	765	61[illegible] 4[illegible]	0	0	0	0	-10 5[illegible]
13-Aug-99	13 8	4 370[illegible]	4 3[illegible]732	0 00001	0 0001	0	13 8	24	77[illegible]	34[illegible] 6[illegible]433	0	0	0	0	[illegible]
14-Aug-99	13 8	0 0001	0 0001	0 00001	0 0001	0	13 8	24	7	25 1[illegible]	0	0	0	0	-8 5[illegible]
15-Aug-99	13 8	0 0001	0 0001	0 00001	0 0001	0	13 [illegible]	24	7	34 7[illegible]	0	0	0	0	-1 29224[illegible]
16 Aug-99	13 8	7 [illegible]84[illegible]	5 60516	0 00001	0 0001	0	13 [illegible]	24	7[illegible]	[illegible]	0	0	0	0	9 81125137
17 Aug 99	13 8	[illegible]	3 20[illegible]	0 00001	0 0001	0	13 5	24	7[illegible]	[illegible]420 [illegible]	0	0	0	0	9 [illegible]498722
18 Aug-99	13 [illegible]	[illegible]	[illegible]	0 00001	0 0001	0	13 [illegible]	24	7[illegible]	4[illegible] 13[illegible]	0	0	0	0	9 5774[illegible]
19-Aug 99	13 [illegible]	9 [illegible]	8 [illegible]	0 00001	0 0001	0	13 8	24	74[illegible]	4[illegible]	0	0	0	0	-8 5[illegible]
20 Aug-99	13 [illegible]	0 0001	0 0001	0 00001	0 0001	0	13 3	24	[illegible]	[illegible]	0	0	0	0	[illegible] 03[illegible]
21-Aug-99	13 [illegible]	0	0	0	0	0	13 [illegible]	24	0	0	0	0	0	0	[illegible]
22 Aug 99	13 [illegible]	0	0	0	0	0	13 [illegible]	24	0	0	0	0	0	0	0
23 Aug 99	13 3	0	0	0	0	0	13 [illegible]	24	0	0	0	0	0	0	0
24-Aug 99	13 8	0	0	0	0	0	13 [illegible]	24	0	0	0	0	0	0	0
25 Aug-99	13 8	5 10427	5 [illegible]	0	0	0	13 [illegible]	24	7[illegible]	[illegible]	0	0	0	0	6 [illegible]325[illegible]
26 Aug-99	13 [illegible]	3 [illegible]	2 [illegible]	0 00001	0 0001	0	13 8	24	75[illegible]	[illegible]799 857[illegible]	0	0	0	0	[illegible] 0595[illegible]71
27-Aug-99	13 [illegible]	[illegible]	[illegible]	0 00001	0 0001	0	13 3	24	73[illegible]	[illegible] 1[illegible]	0	0	0	0	-1[illegible]
28-Aug-99	13 [illegible]	[illegible]93	[illegible]	0 0000[illegible]	[illegible]	0	[illegible] 8	22	35		0	0	1[illegible] 22		[illegible]
29-Aug-99	13 [illegible]	0	0	0	0	0	[illegible] 6	24	0	0	0	0	0	0	[illegible]
30-Aug-99	13 [illegible]	0	0	0	0	0	13 [illegible]	24	0	0	0	0	0	0	[illegible]
31-Aug-99	13 [illegible]	[illegible]	[illegible]	0 [illegible]	0 [illegible]	0	13 [illegible]	24	6[illegible]	[illegible]	0	0	0	0	-[illegible]

APS-East Dish Monthly Performance Summary

September-99

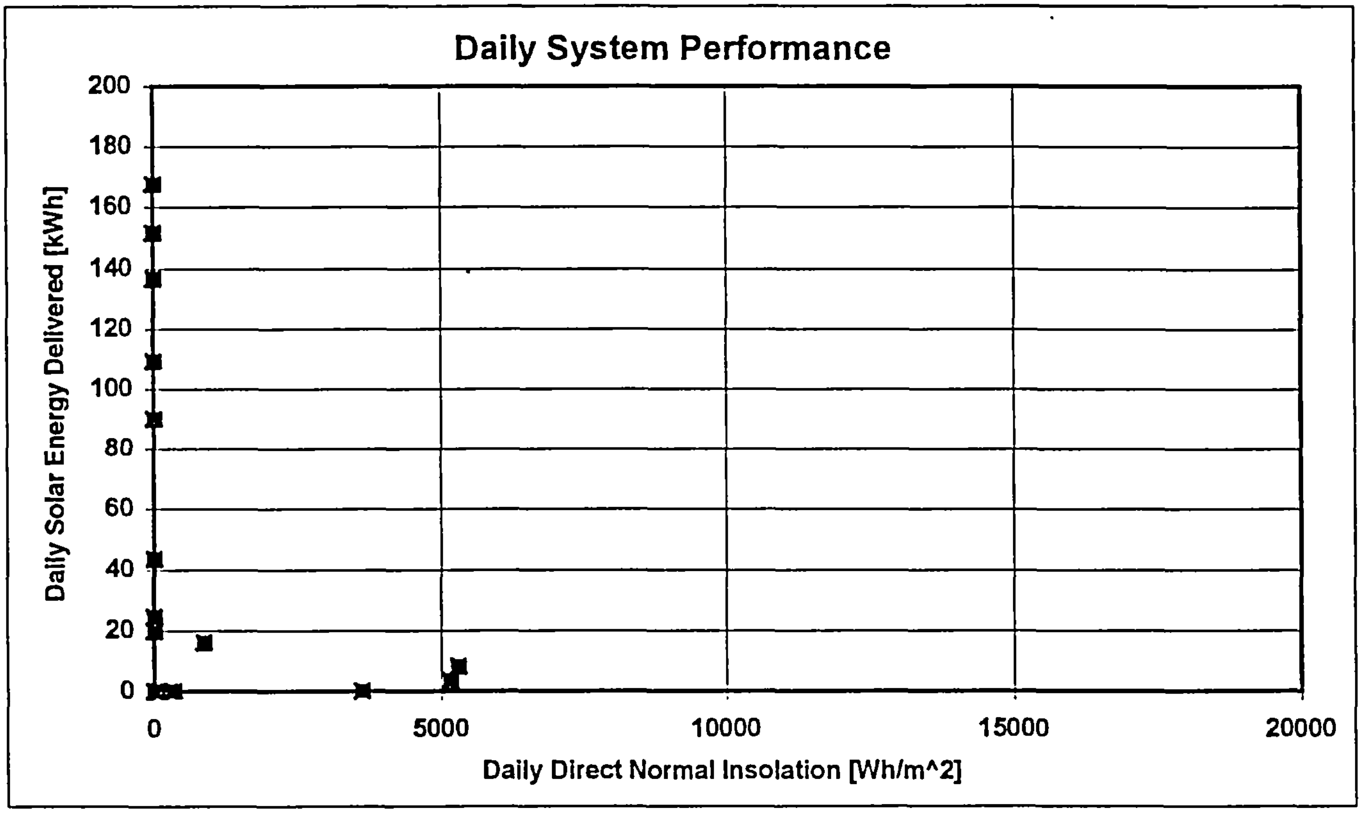
Monthly Totals:		**Monthly Records:**	
Energy Delivered on Solar:	771.0 kWh	Peak Solar Power:	20.5 kW
Energy Delivered on Gas:	122.0 kWh	Peak Solar Efficiency:	17.0%
Net Energy Delivered:	794.5 kWh		
Automated Operation:	178.0 hours		
Tracking Operation:	110.6 hours		
Solar Operation:	23.4 hours		
Gas Operation:	2.2 hours		

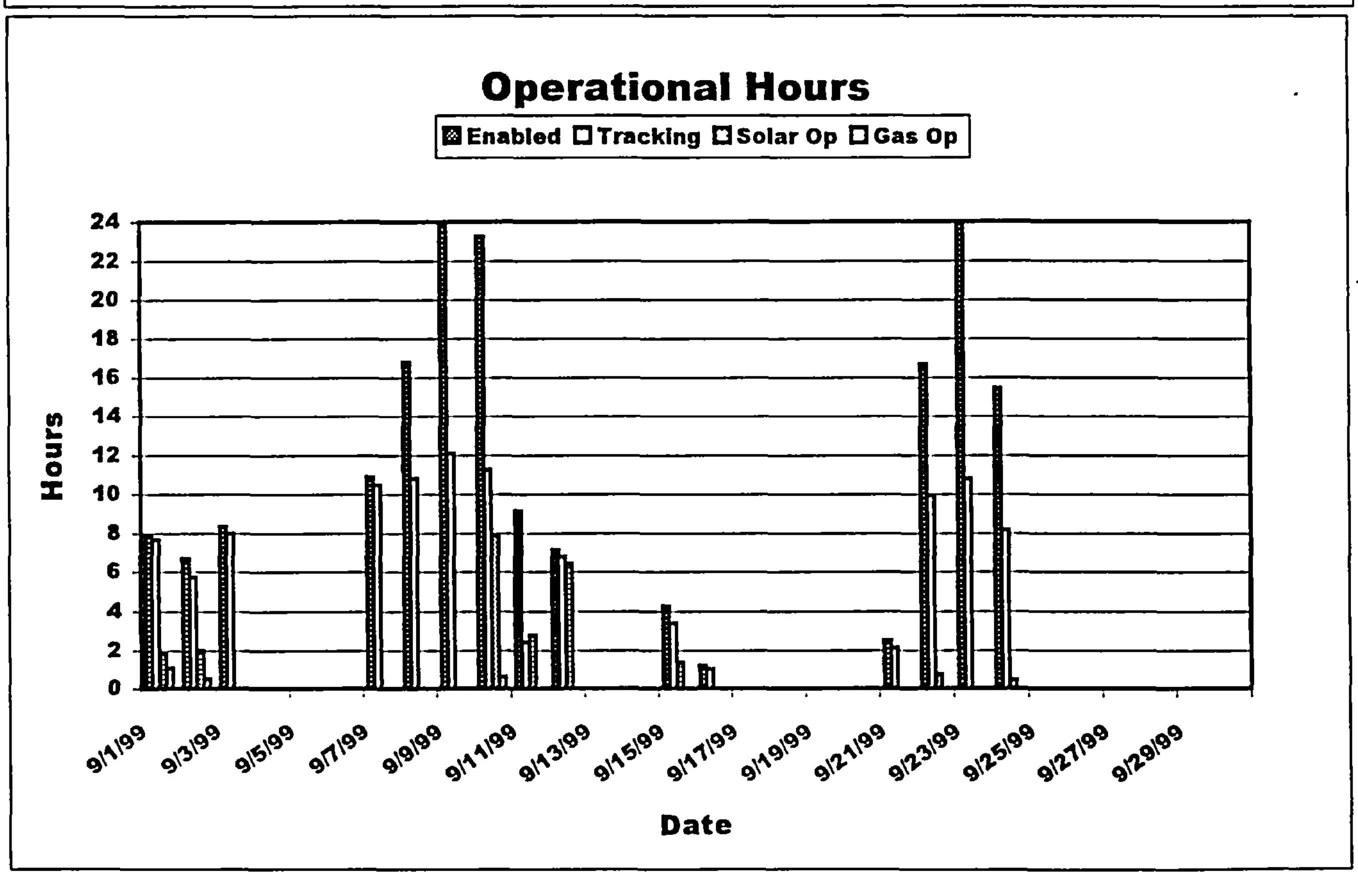
Operational/Reliability Data:

	Availabilit	Utilizati	Capacity Factor
Controls	90%	25%	n/a
Solar	70%	9%	3%
Gas	70%	0%	0%

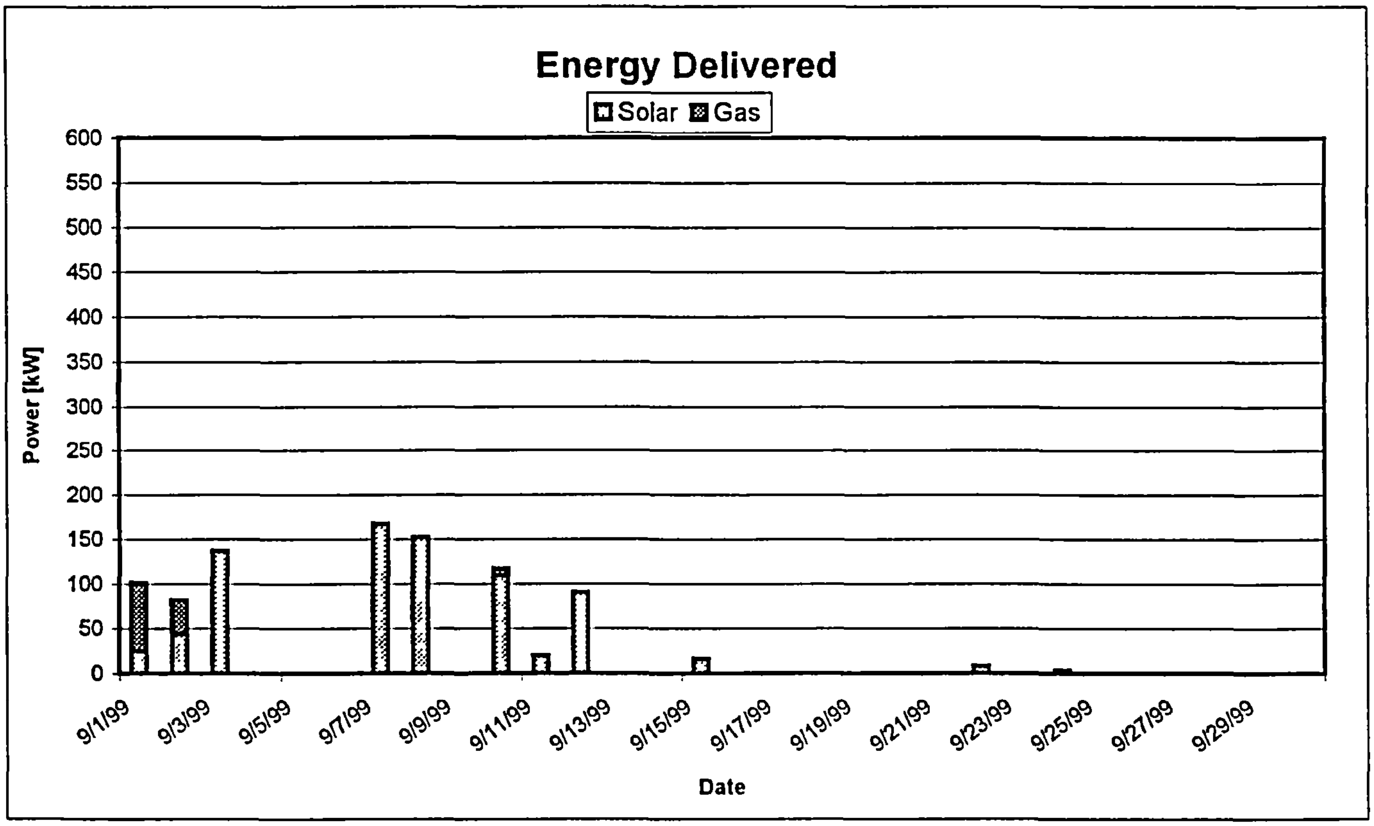
Day	Operational Summary
1	Operated 0600-1400; power meter not connected properly
2	Operated 0625-1250; Actuator fault; Gas op 1348-1427
3	Operated 0620-1440; power meter not connected correctly (data from El Meter)
4	Not operated - Labor Day holiday weekend
5	Not Operated - Labor Day Holiday Weekend
6	Not operated - Labor Day Weekend Holiday
7	Operated 0600-1720; power meter not connected (values from El Meter)
8	Operated 0715-1822; calibrated power meter after 1835 (data from El Meter)
9	Operated 0600-1900; cloudy day
10	Operated on sun 0700-1900; on gas 0650-0730
11	Operated 0550-0750; Actuator stall fault 0750
12	Operated on sun 0600-1320; TC failure 1320
13	System down
14	System down - no data
15	Operated on sun
16	Operated on sun briefly
17	Not operated
18	Not operated
19	System down - PCS
20	No Data
21	Tracked defocused - PCS down
22	Operated on sun 0630-1800
23	Tracked defocused
24	Tracked defocused; operated 1630-1700
25	Weekend -- not operated
26	Weekend -- not operated
27	Not operated - PCS down
28	Not operated - PCS down
29	Not operated - PCS down
30	Not operated - PCS down

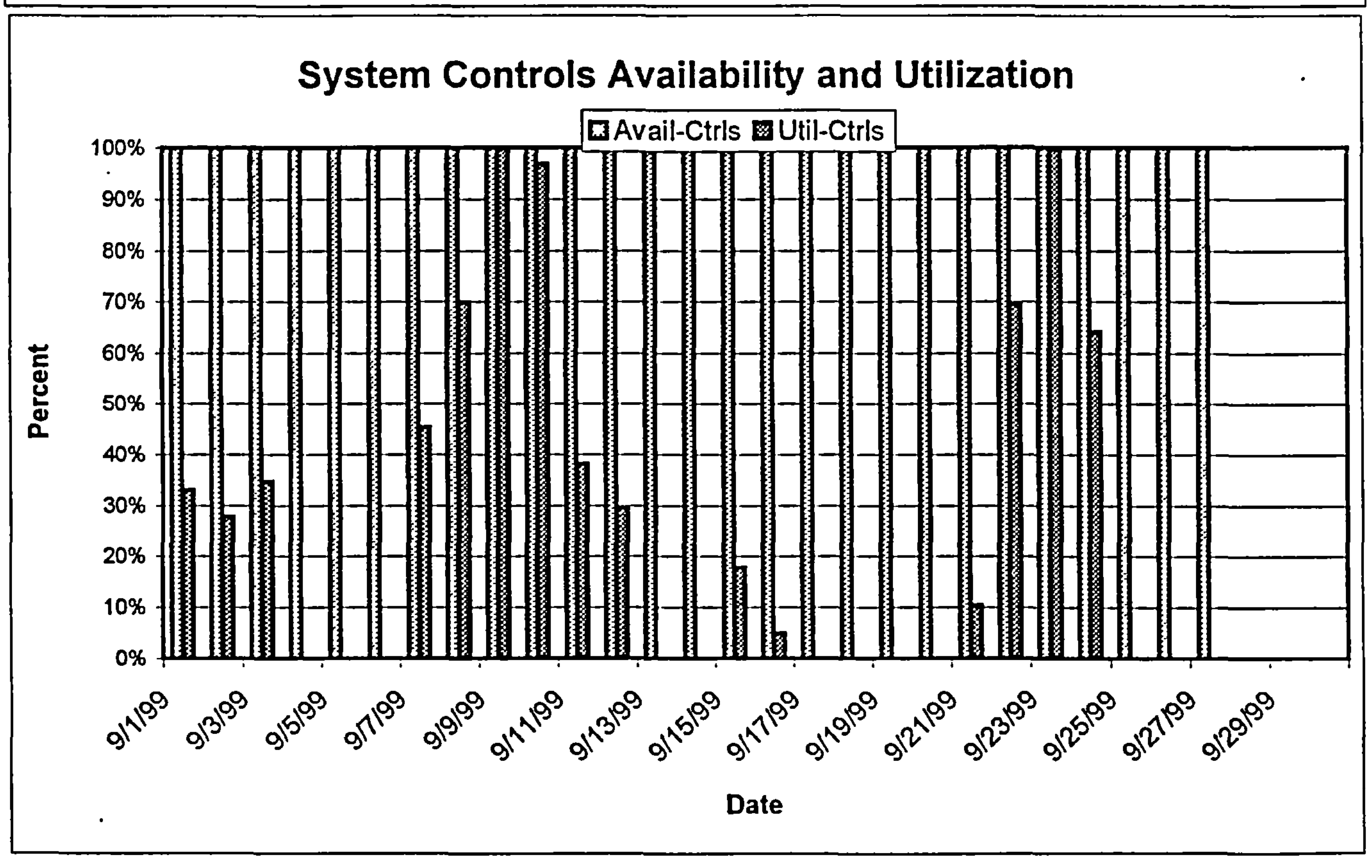
APS-East Dish Monthly Performance Summary



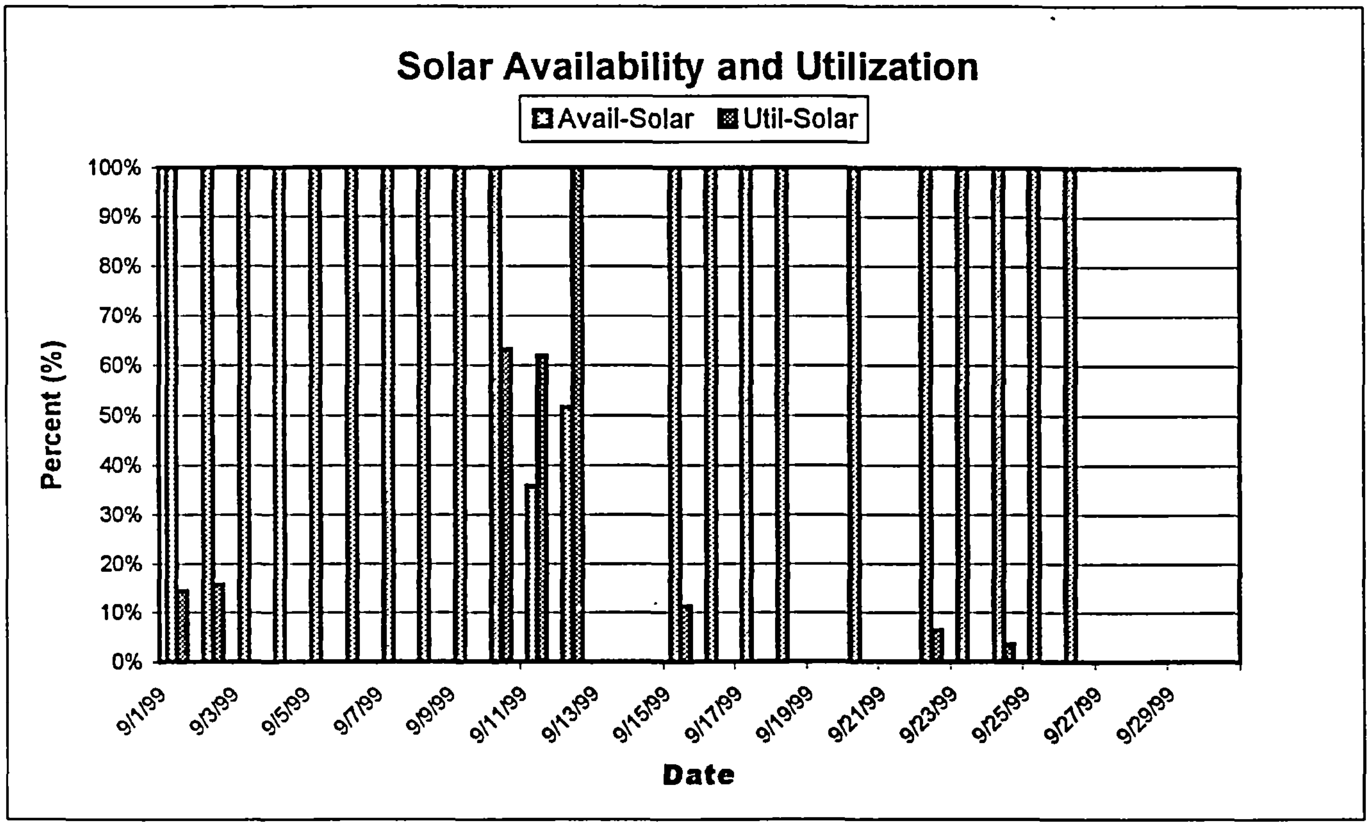


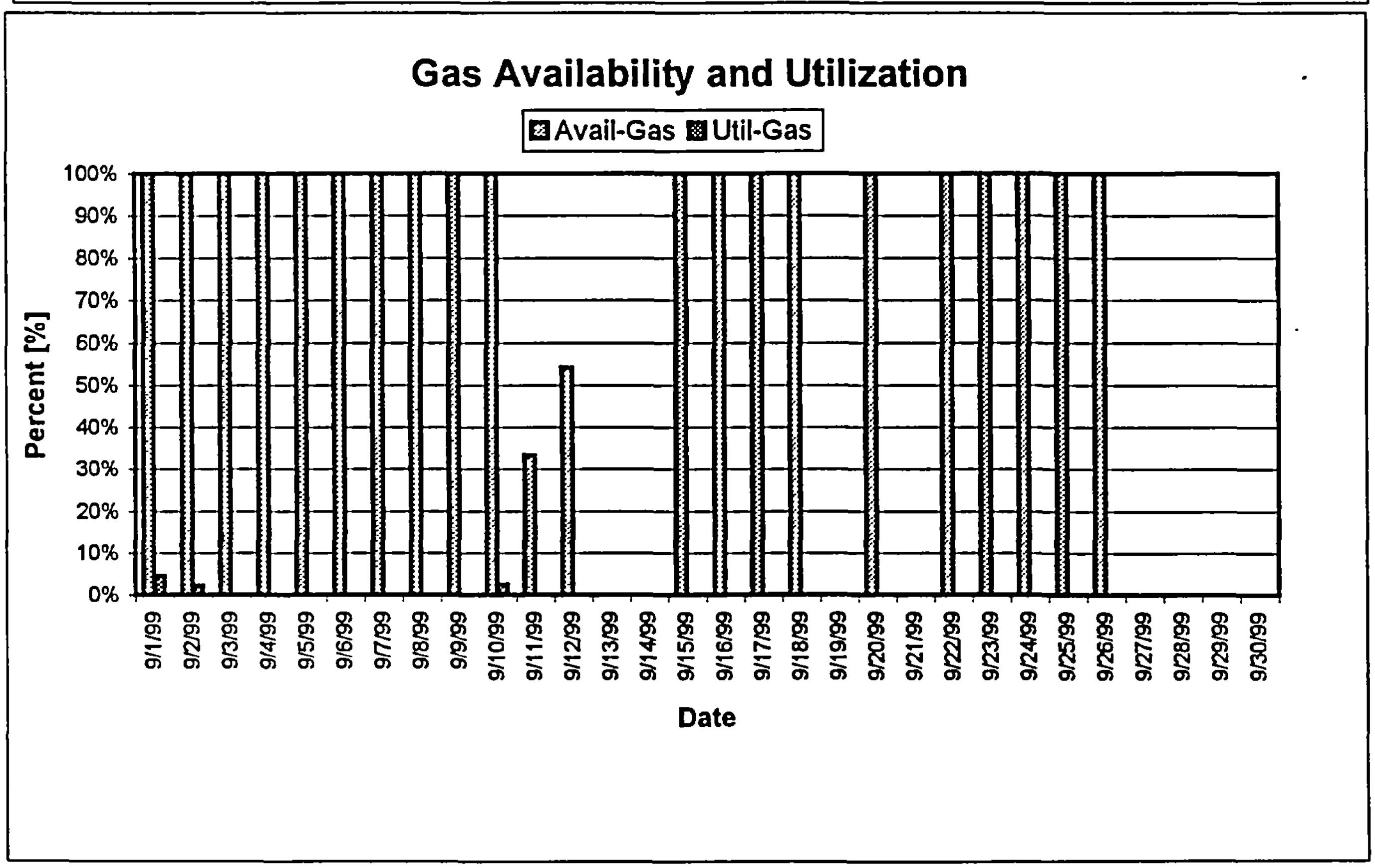
APS-East Dish Monthly Performance Summary





APS-East Dish Monthly Performance Summary





APS-East Dish

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	Monthly Total Hours					Downtimes [hr]			Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		Energy [kWh]	
	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Pk [W/m^2]	Total [Wh/m^2]	Peak Pwr	Average	Gas Peak	Average	Consumed	Solar
Sep-99	368.4	178.0	110 6	23.4	2.2	72.0	110.1	219.0	1307.0	15831.0	20.5	2.2	16.8	0.5	-98 5	771.0

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	Hours					Downtimes [hr]			Daily Insolation$_{DN}$		Solar Power [kW]		Gas Power [kW]		Energy [kWh]	
Day	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Peak [W/m^2]	Total [Wh/m^2]	Peak	Average	Gas Peak	Average	Consumed	Solar
01-Sep-99	12.8	7.9	7.7	1.8	1.1	0.0	0.0	0 0	0.0	0.0	0.0	0.0	16 8	0.0	-17.7	24.4
02-Sep-99	12.8	6.7	5.7	2.0	0.5	0.0	0.0	0 0	0.0	0.0	16.3	0 0	16.3	0.0	0.0	43.7
03-Sep-99	12.7	8.3	8 0	0 0	0.0	0.0	0.0	0.0	0.0	0.0	20.5	0 0	0 0	0 0	0.0	136 8
04-Sep-99	12.7	0.0	0.0	0.0	0.0	0.0	0 0	0.0	0.0	0 0	0.0	0 0	0 0	0.0	0.0	0 0
05-Sep-99	12.7	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0.0	0.0	0 0	0 0	0 0	0.0	0.1	0 0
06-Sep-99	12.6	0.0	0.0	0.0	0.0	0 0	0 0	0.0	0.0	0.0	0.0	0 0	0 0	0.0	0.0	0.0
07-Sep-99	12.6	10.9	10.4	0.0	0.0	0 0	0.0	0.0	0.0	0.0	19.3	0 0	0 0	0.0	0.0	167.6
08-Sep-99	12.6	16.8	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	0 0	0.0	0.0	151.8
09-Sep-99	12.5	24.0	12.1	0.0	0.0	0.0	0 0	0.0	186.0	257.0	0 0	0.0	0.0	0.0	-7.8	0 0
10-Sep-99	12.5	23.2	11.2	7.9	0.6	0.0	0 0	0.0	0.0	0.0	15.9	13.9	16.1	13.7	-8.4	109.3
11-Sep-99	12.4	9.1	2.4	2.7	0.0	0.0	8.0	16.0	0.0	0.0	12.4	7.2	0.0	0.0	-5.4	19.8
12-Sep-99	12.4	7.1	6.8	6.4	0.0	0.0	6.0	11.0	0.0	0.0	17.6	14.1	0.0	0.0	-3.2	90.0
13-Sep-99	12.4	0.0	0.0	0.0	0.0	0.0	12.4	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14-Sep-99	12.3	0.0	0.0	0.0	0.0	0.0	12.3	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-Sep-99	12.3	4.3	3.4	1.4	0.0	0.0	0.0	0.0	250.0	855.8	14.1	11.8	0.0	0.0	-5.2	16.1
16-Sep-99	12.2	1.2	1.0	0.0	0.0	0.0	0.0	0.0	248.0	337.5	0.0	0.0	0.0	0 0	1.6	0.0
17-Sep-99	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	82.3	0.0	0 0	0.0	0.0	-6.4	0.0
18-Sep-99	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	94.2	0.0	0.0	0.0	0.0	-6.0	0.0
19-Sep-99	12.1	0.0	0.0	0.0	0.0	0.0	12.1	24.0	15.0	41.5	0.0	0.0	0.0	0.0	-3.0	0 0
20-Sep-99	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0 0	0.0	0.0	0.0	0.0
21-Sep-99	12.1	2.5	2.1	0.0	0.0	0.0	12.1	24.0			0.0	0.0	0.0	0.0	-1.8	0.0
22-Sep-99	12.1	16.7	9.9	0.8	0.0	0.0	0.0	0.0	1307.0	5308.1	11.6	10.6	0.0	0.0	-12.2	8.1
23-Sep-99	12.0	23.9	10.8	0.0	0.0	0.0	0.0	0.0	720.0	3620.7	0.0	0.0	0.0	0.0	-11.6	0.0
24-Sep-99	12.0	15.4	8.2	0.4	0.0	0.0	0.0	0.0	740.0	5166.5	9 6	8.0	0.0	0.0	-9.3	3.5
25-Sep-99	11.9	0.0	0.0	0 0	0.0	0.0	0.0	0 0	7.0	43.0	0.0	0.0	0.0	0.0	-0.3	0.0
26-Sep-99	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	43.7	0 0	0 0	0.0	0.0	0.3	0.0
27-Sep-99	11.8	0.0	0.0	0.0	0.0	0.0	11.8	24.0	6.0	-19.3	0.0	0.0	0.0	0.0	-2.2	0.0
28-Sep-99	11.8	0.0	0.0	0.0	0.0	24.0	11.8	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0.0
29-Sep-99	11.8	0.0	0.0	0.0	0.0	24.0	11.8	24.0	0.0	0.0	0.0	0 0	0.0	0.0	0.0	0.0
30-Sep-99	11.7	0.0	0.0	0.0	0.0	24.0	11.7	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Gas	Efficiency [%]		Capacity Factor		Availability and Utilization					
	Peak Eff	Average	CF_{-Solar}	CF_{-Gas}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$
122.0	17.0%		3%	0%	90%	25%	70%	9%	70%	0%

Gas	Efficiency [%]		Capacity Factor		Availability and Utilization						Operational Summary
	Peak Daily	Average	Solar	Gas	$Avail_{Ctrls}$	$Util_{Ctrls}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$	
76.4	0%	0%	1%	2%	100%	33%	100%	14%	100%	5%	Operated 0600-1400; power meter not connected properly
37.5	0%	0%	1%	1%	100%	28%	100%	16%	100%	2%	Operated 0625-1250; Actuator fault; Gas op 1348-1427
0.0	0%	0%	0%	0%	100%	35%	100%	0%	100%	0%	Operated 0620-1440; power meter not connected correctly *(data from El Meter)*
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated - Labor Day holiday weekend
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not Operated - Labor Day Holiday Weekend
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated - Labor Day Weekend Holiday
0.0	0%	0%	0%	0%	100%	45%	100%	0%	100%	0%	Operated 0600-1720; power meter not connected (values from El Meter)
0.0	0%	0%	0%	0%	100%	70%	100%	0%	100%	0%	Operated 0715-1822; calibrated power meter after 1835 (data from El Meter)
0.0	0%	0%	0%	0%	100%	100%	100%	0%	100%	0%	Operated 0600-1900; cloudy day
8.1	0%	0%	35%	1%	100%	97%	100%	63%	100%	2%	Operated on sun 0700-1900; on gas 0650-0730
0.0	0%	0%	6%	0%	100%	38%	36%	62%	33%	0%	Operated 0550-0750; Actuator stall fault 0750
0.0	0%	0%	29%	0%	100%	30%	52%	100%	54%	0%	Operated on sun 0600-1320; TC failure 1320
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - no data
0.0	17%	17%	5%	0%	100%	18%	100%	11%	100%	0%	Operated on sun
0.0	0%	0%	0%	0%	100%	5%	100%	0%	100%	0%	Operated on sun briefly
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Not operated
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	System down - PCS
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	No Data
0.0	0%	0%	0%	0%	100%	10%	0%	0%	0%	0%	Tracked defocused - PCS down
0.0		1%	3%	0%	100%	69%	100%	6%	100%	0%	Operated on sun 0630-1800
0.0	0%	0%	0%	0%	100%	100%	100%	0%	100%	0%	Tracked defocused
0.0	12%	1%	1%	0%	100%	64%	100%	4%	100%	0%	Tracked defocused; operated 1630-1700
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Weekend -- not operated
0.0	0%	0%	0%	0%	100%	0%	100%	0%	100%	0%	Weekend -- not operated
0.0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated - PCS down
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - PCS down
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - PCS down
0.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - PCS down

APS-East Dish Monthly Performance Summary

October-99

Monthly Totals:

nergy Delivered on Solar:	0.0	kWh
Energy Delivered on Gas:	0.0	kWh
Net Energy Delivered:	0.0	kWh
Automated Operation:	208.8	hours
Tracking Operation:	63.5	hours
Solar Operation:	0.0	hours
Gas Operation:	0.0	hours

Monthly Records:

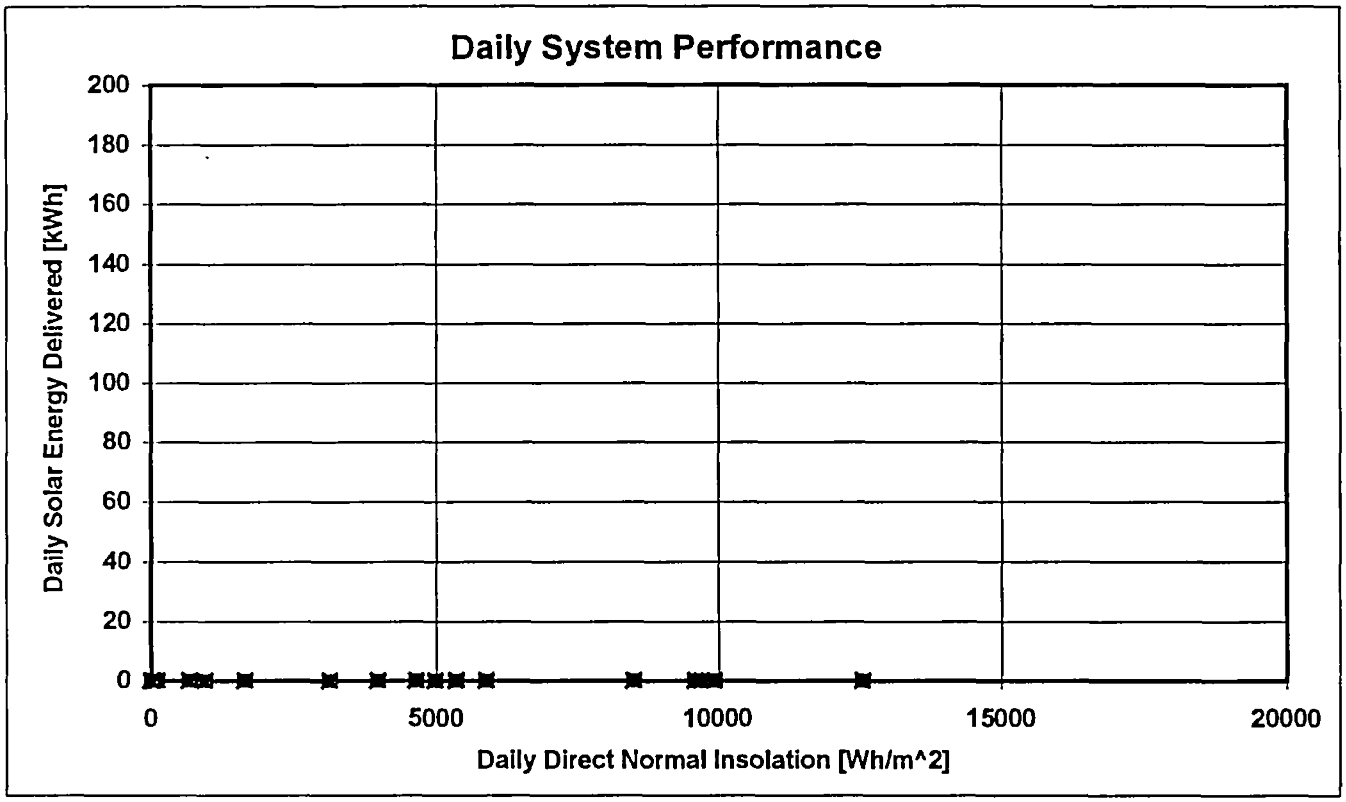
Peak Solar Power [kW]:	0.0
Peak Solar Efficiency:	0.0%

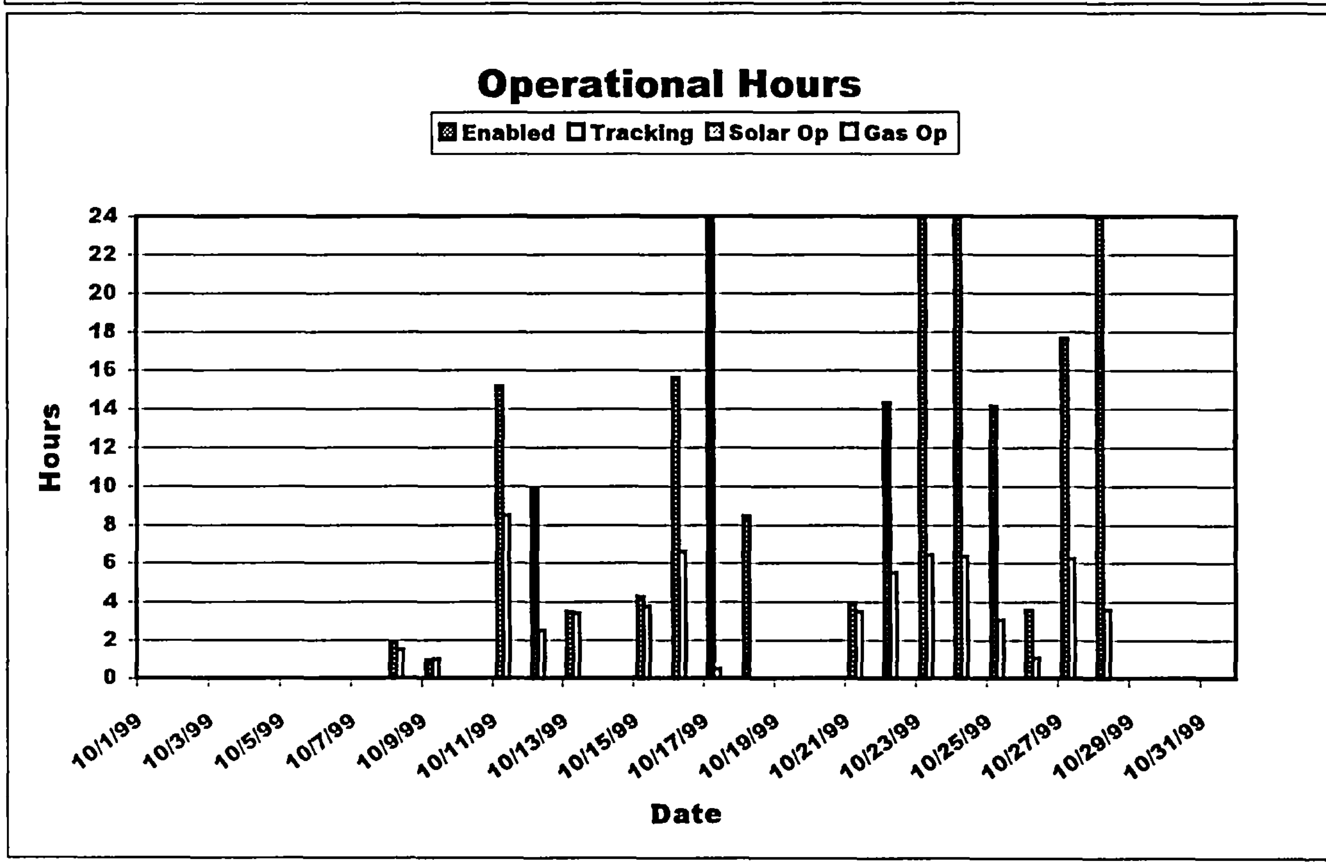
Operational/Reliability Data:

	Availabilit	Utilization	Capacity Factor
Controls	74%	28%	n/a
Solar	0%	0%	0%
Gas	0%	0%	0%

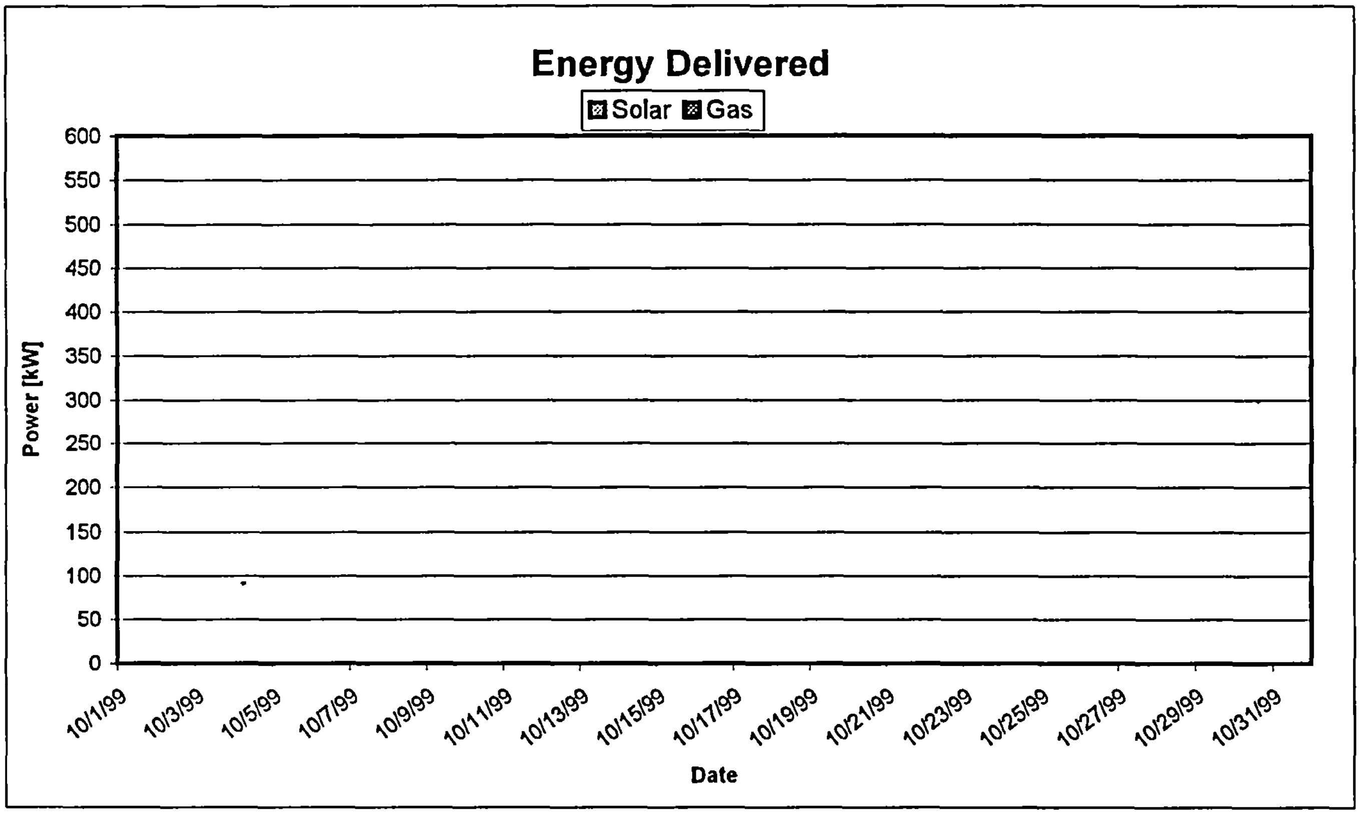
Day	Operational Summary
1	Not operated - down for maintenance
2	Not operated - down for maintenance
3	Not operated - down for maintenance
4	Not operated - down for maintenance
5	Not operated - down for maintenance
6	Not operated - down for maintenance
7	Not operated - down for maintenance
8	Maintenance and Testing
9	Control and BCS testing
10	Not operated - PCS off
11	BCS Testing
12	BCS Testing
13	BCS Testing
14	Not operated
15	BCS Testing
16	Tracked defocused; BCS Image at 10:12
17	Tracked defocused; high winds
18	Moved to upward stow for facet hardware replacement
19	Facet maintenance
20	Facet Maintenance
21	BCS Alignment
22	BCS Alignment
23	BCS Tracking
24	BCS Tracking
25	BCS Tracking
26	BCS Tracking
27	BCS Alignment
28	BCS Alignment
29	Not operated; PCS off
30	Not operated; PCS off
31	Not operated; PCS off

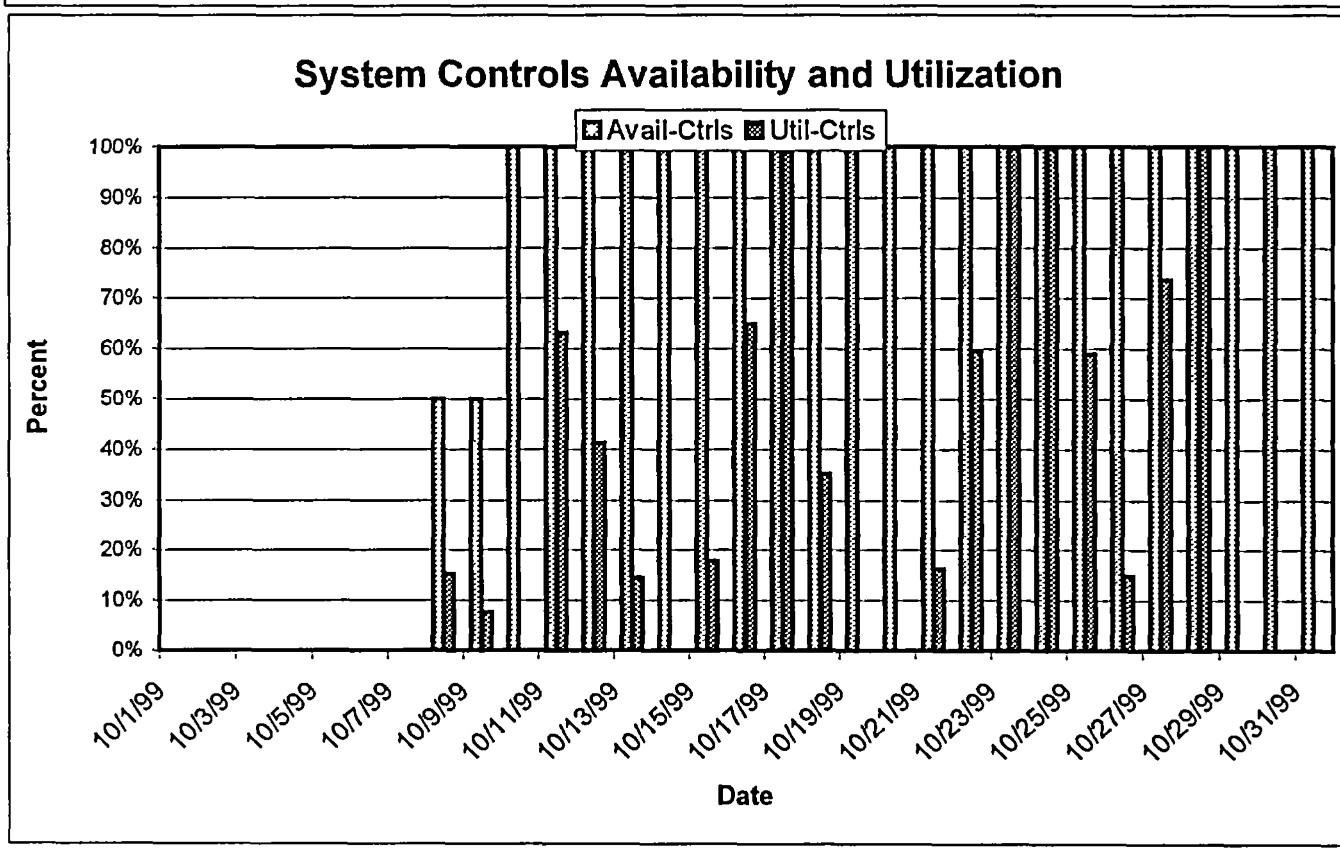
APS-East Dish Monthly Performance Summary



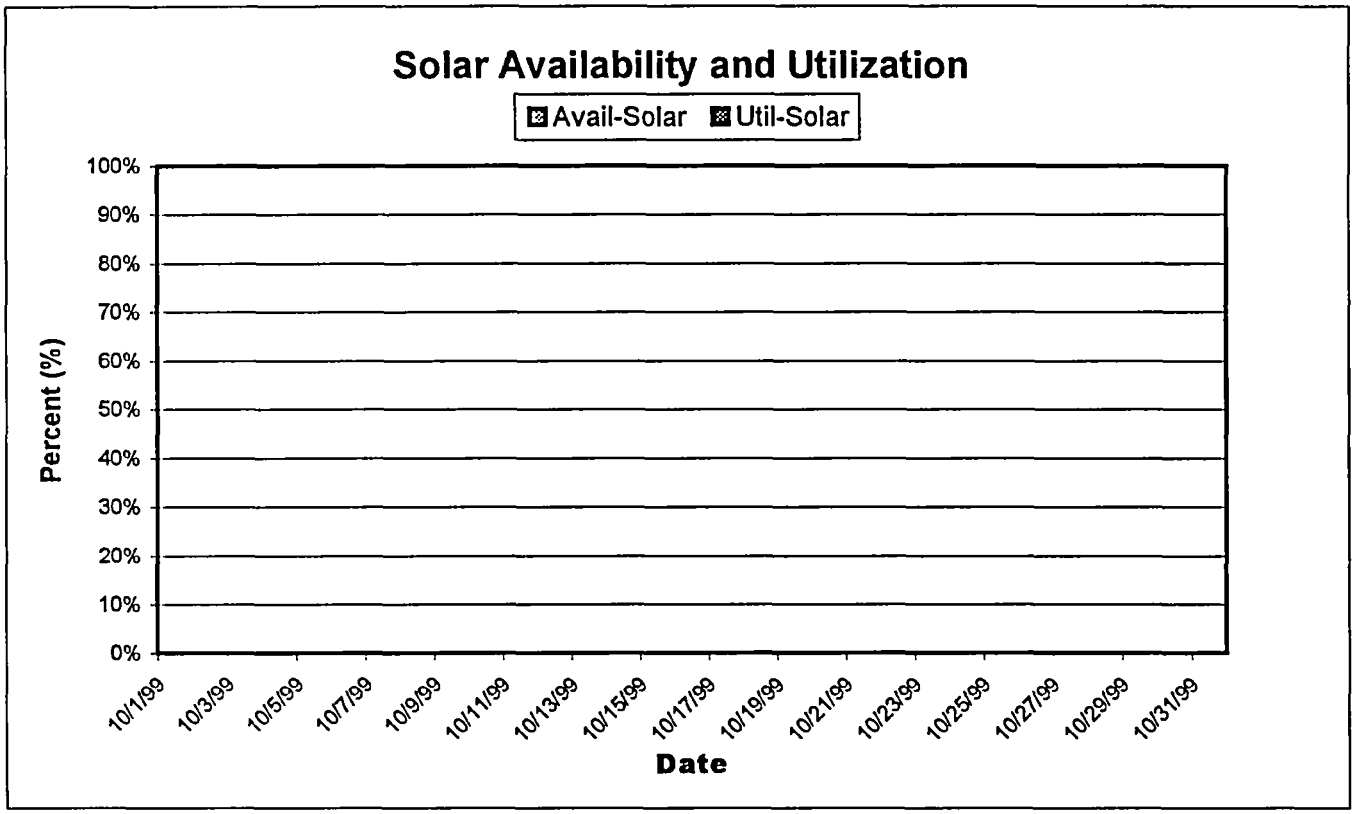


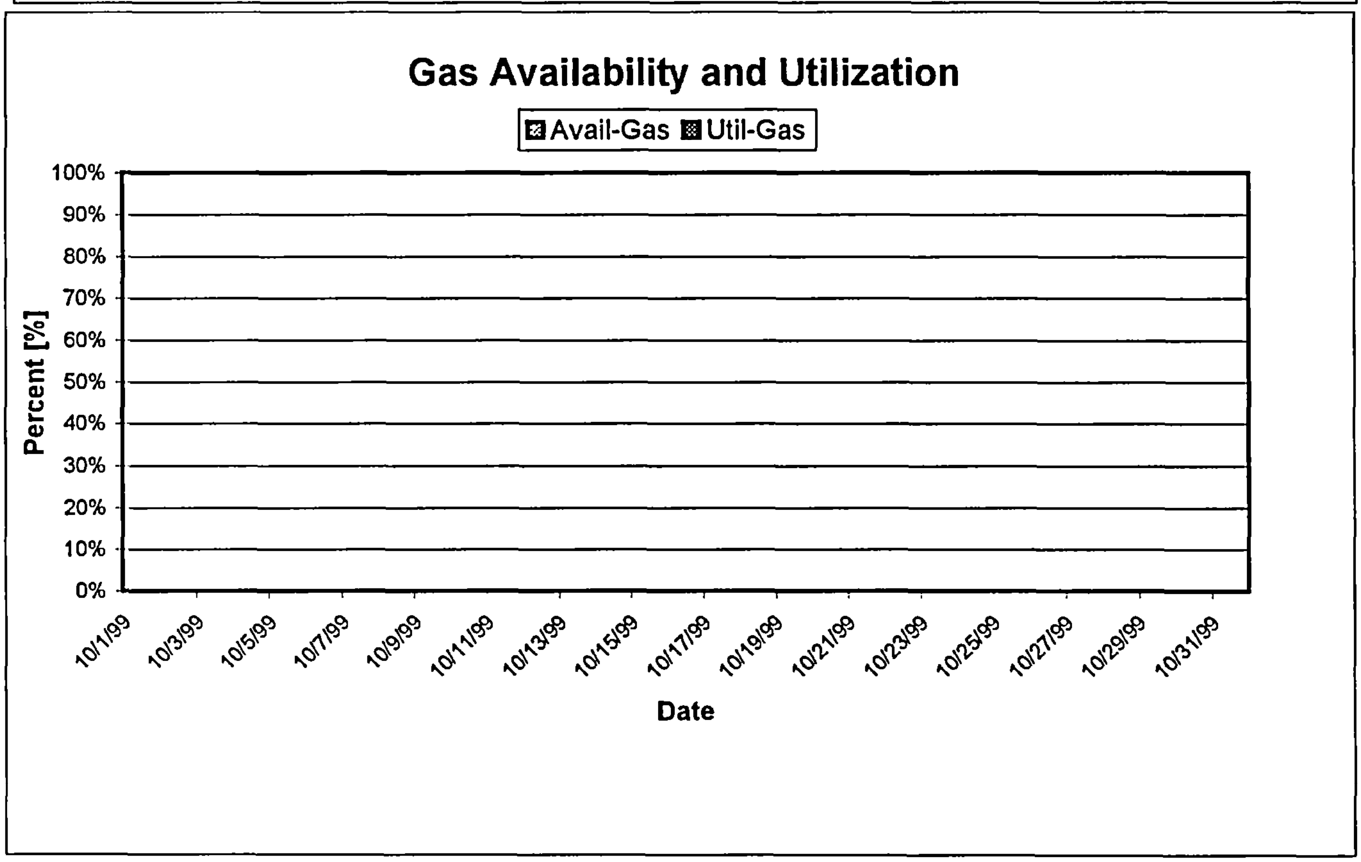
APS-East Dish Monthly Performance Summary





APS-East Dish Monthly Performance Summary





APS-East Dish

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	Monthly Total Hours					Downtimes [hr]			$Insolation_{DN}$		Solar Power [kW]		Gas Power [kW]		E
	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Pk [W/m^2]	Total [Wh/m^2]	Peak Pwr	Average	Gas Peak	Average	Consumed
Oct-99	277.0	208.8	63.5	0.0	0.0	192.0	349 0	744 0	1519 0	84496 3	0.0	0	0.0	-	0.0

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

	Hours					Downtimes [hr]			Daily $Insolation_{DN}$		Solar Power [kW]		Gas Power [kW]		E
Day	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Peak [W/m^2]	Total [Wh/m^2]	Peak	Average	Gas Peak	Average	Consumed
01-Oct-99						24	12	24	0	0	0	0	0	0	0
02-Oct-99						24	12	24	0	0	0	0	0	0	0
03-Oct-99						24	12	24	0	0	0	0	0	0	0
04-Oct-99						24	12	24	0	0	0	0	0	0	0
05-Oct-99						24	12	24	0	0	0	0	0	0	0
06-Oct-99						24	12	24	0	0	0	0	0	0	0
07-Oct-99	11.45084	0.0	0.0	0.0	0.0	24	11.45	24	4.0	9.5	0	0	0	0	0
08-Oct-99	11.43556	1.83177	1.49871	0.00001	0.0001	12	11.44	24	745	-2610.185594	0	0	0	0	0
09-Oct-99	11.3855	0.91593	0.99899	0.00001	0.0001	12	11.39	24	1501	3129.969406	0	0	0	0	0
10-Oct-99	11.40639	0.0001	0.0001	0.00001	0.0001	0	11.41	24	14	100.2414889	0	0	0	0	0
11-Oct-99	11.4075	15.1529	8.49232	0.00001	0.0001	0	11.41	24	1504	12552.03579	0	0	0	0	0
12-Oct-99	11.40611	9.90732	2.49788	0.00001	0.0001	0	11.41	24	1500	3970.157739	0	0	0	0	0
13-Oct-99	11.33833	3.46343	3.38093	0.00001	0.0001	0	11.34	24	1504	5344.449544	0	0	0	0	0
14-Oct-99	11.22359	0.0001	0.0001	0.00001	0.0001	0	11.22	24	7	48.85746111	0	0	0	0	0
15-Oct-99	11.26389	4.2551	3.75454	0 00001	0.0001	0	11.26	24	1486	4985.537461	0	0	0	0	0
16-Oct-99	11.17972	15.602	6.59149	0.00001	0.0001	0	11.18	24	1492	9930.123433	0	0	0	0	0
17-Oct-99	11.18	23.8618	0.50066	0.00001	0.0001	0	11.18	24	1499	938.5359333	0	0	0	0	0
18-Oct-99	11.18	8.42677	0.0001	0.00001	0.0001	0	11.18	24	7	49.68371111	0	0	0	0	0
19-Oct-99	11.14056	0.0001	0.0001	0.00001	0.0001	0	11.14	24	10	50.65898889	0	0	0	0	0
20-Oct-99	11.02098	0.0001	0 0001	0.00001	0.0001	0	11.02	24	6	-5.0149	0	0	0	0	0
21-Oct-99	11.05278	3.90621	3.49066	0.00001	0.0001	0	11.05	24	1496	5888.013017	0	0	0	0	0
22-Oct-99	11.04028	14.3023	5.52038	0.00001	0 0001	0	11.04	24	1519	8497.5076	0	0	0	0	0
23-Oct-99	10.95694	23.9212	6.44038	0.00001	0.0001	0	10.96	24	1502	9592.781906	0	0	0	0	0
24-Oct-99	10.95694	23.9218	6.35677	0.00001	0.0001	0	10.96	24	1496	9705.618017	0	0	0	0	0
25-Oct-99	10.94472	14.1523	3.06788	0.00001	0.0001	0	10.94	24	1489	4647.728572	0	0	0	0	0
26-Oct-99	10.86333	3.56538	1.07788	0.00001	0.0001	0	10.86	24	1207	669.1132944	0	0	0	0	0
27-Oct-99	10.82333	17.6507	6.24427	0 00001	0.0001	0	10.82	24	890	5363.970933	0	0	0	0	0
28-Oct-99	10 82361	23.979	3.5801	0.00001	0.0001	0	10.82	24	705	1637.041072	0	0	0	0	0
29-Oct-99	10.5	0	0	0	0	0	10.5	24	0	0	0	0	0	0	0
30-Oct-99	10.5	0	0	0	0	0	10.5	24	0	0	0	0	0	0	0
31-Oct-99	10.5	0	0	0	0	0	10.5	24	0	0	0	0	0	0	0

ergy [kWh]		Efficiency [%]		Capacity Factor		Availability and Utilization					
Solar	Gas	Peak Eff	Average	CF_{-Solar}	CF_{-Gas}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$
0.0	0.0	0 0%	0 0%	0%	0%	74%	28%	0%	0%	0%	0%

ergy [kWh]		Efficiency [%]		Capacity Factor		Availability and Utilization						Operational Summary
Solar	Gas	Peak Daily	Average	Solar	Gas	$Avail_{Ctrls}$	$Util_{Ctrls}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$	
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Not operated - down for maintenance
0	0	0%	0%	0%	0%	50%	15%	0%	0%	0%	0%	Maintenance and Testing
0	0	0%	0%	0%	0%	50%	8%	0%	0%	0%	0%	Control and BCS testing
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated - PCS off
0	0	0%	0%	0%	0%	100%	63%	0%	0%	0%	0%	BCS Testing
0	0	0%	0%	0%	0%	100%	41%	0%	0%	0%	0%	BCS Testing
0	0	0%	0%	0%	0%	100%	14%	0%	0%	0%	0%	BCS Testing
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated
0	0	0%	0%	0%	0%	100%	18%	0%	0%	0%	0%	BCS Testing
0	0	0%	0%	0%	0%	100%	65%	0%	0%	0%	0%	Tracked defocused; BCS Image at 10:12
0	0	0%	0%	0%	0%	100%	99%	0%	0%	0%	0%	Tracked defocused; high winds
0	0	0%	0%	0%	0%	100%	35%	0%	0%	0%	0%	Moved to upward stow for facet hardware replacement
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Facet maintenance
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Facet Maintenance
0	0	0%	0%	0%	0%	100%	16%	0%	0%	0%	0%	BCS Alignment
0	0	0%	0%	0%	0%	100%	60%	0%	0%	0%	0%	BCS Alignment
0	0	0%	0%	0%	0%	100%	100%	0%	0%	0%	0%	BCS Tracking
0	0	0%	0%	0%	0%	100%	100%	0%	0%	0%	0%	BCS Tracking
0	0	0%	0%	0%	0%	100%	59%	0%	0%	0%	0%	BCS Tracking
0	0	0%	0%	0%	0%	100%	15%	0%	0%	0%	0%	BCS Tracking
0	0	0%	0%	0%	0%	100%	74%	0%	0%	0%	0%	BCS Alignment
0	0	0%	0%	0%	0%	100%	100%	0%	0%	0%	0%	BCS Alignment
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; PCS off
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; PCS off
0	0	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	Not operated; PCS off

Appendix K:
October 1999 Monthly Performance Summary for the SRP Dish/Stirling System

SRP Dish Monthly Performance Summary

October-99

Monthly Totals:

Energy Delivered on Solar:	202.8 kWh
Energy Delivered on Gas:	0.0 kWh
Net Energy Delivered:	33.6 kWh
Automated Operation:	239.3 hours
Tracking Operation:	86.5 hours
Solar Operation:	17.1 hours
Gas Operation:	0.0 hours

Monthly Records:

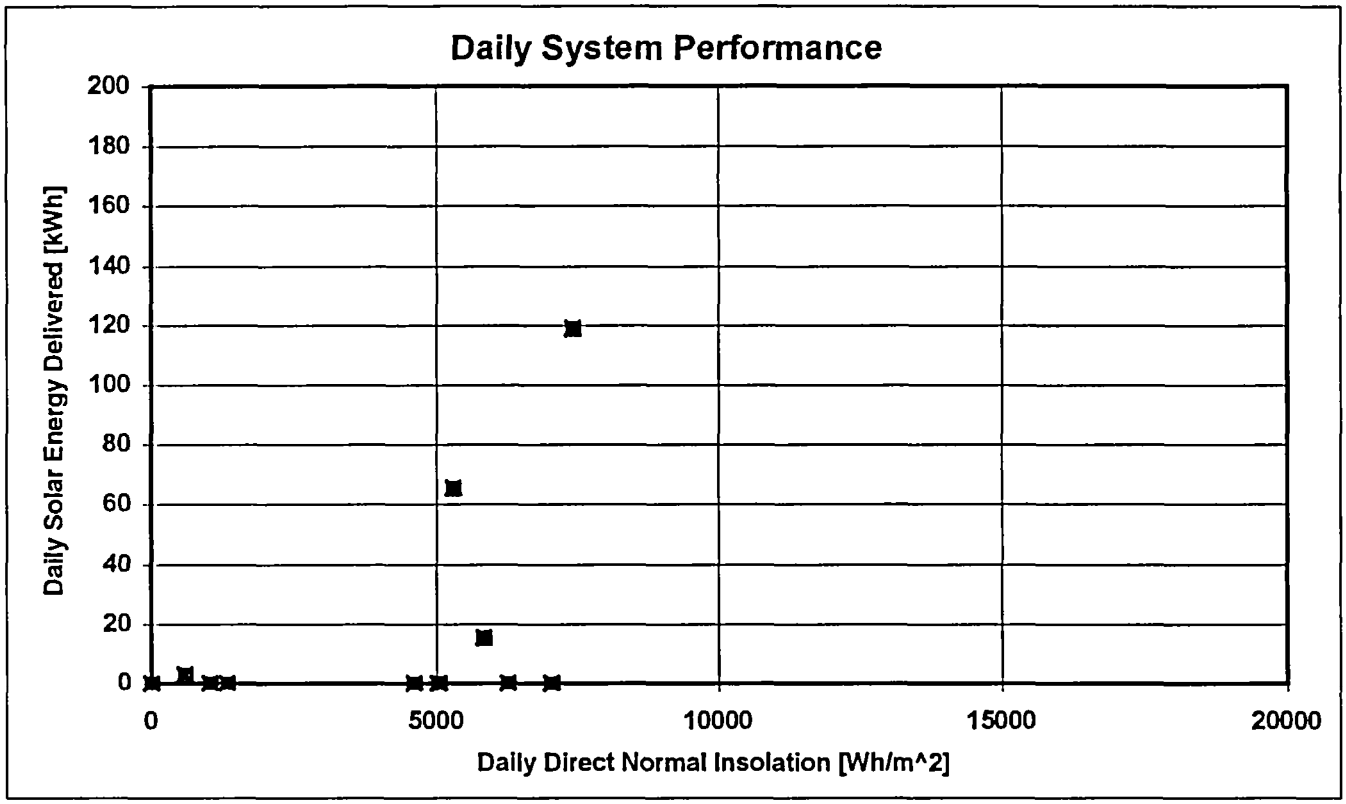
Peak Solar Power:	17.0 kW
Peak Solar Efficiency:	20.1%

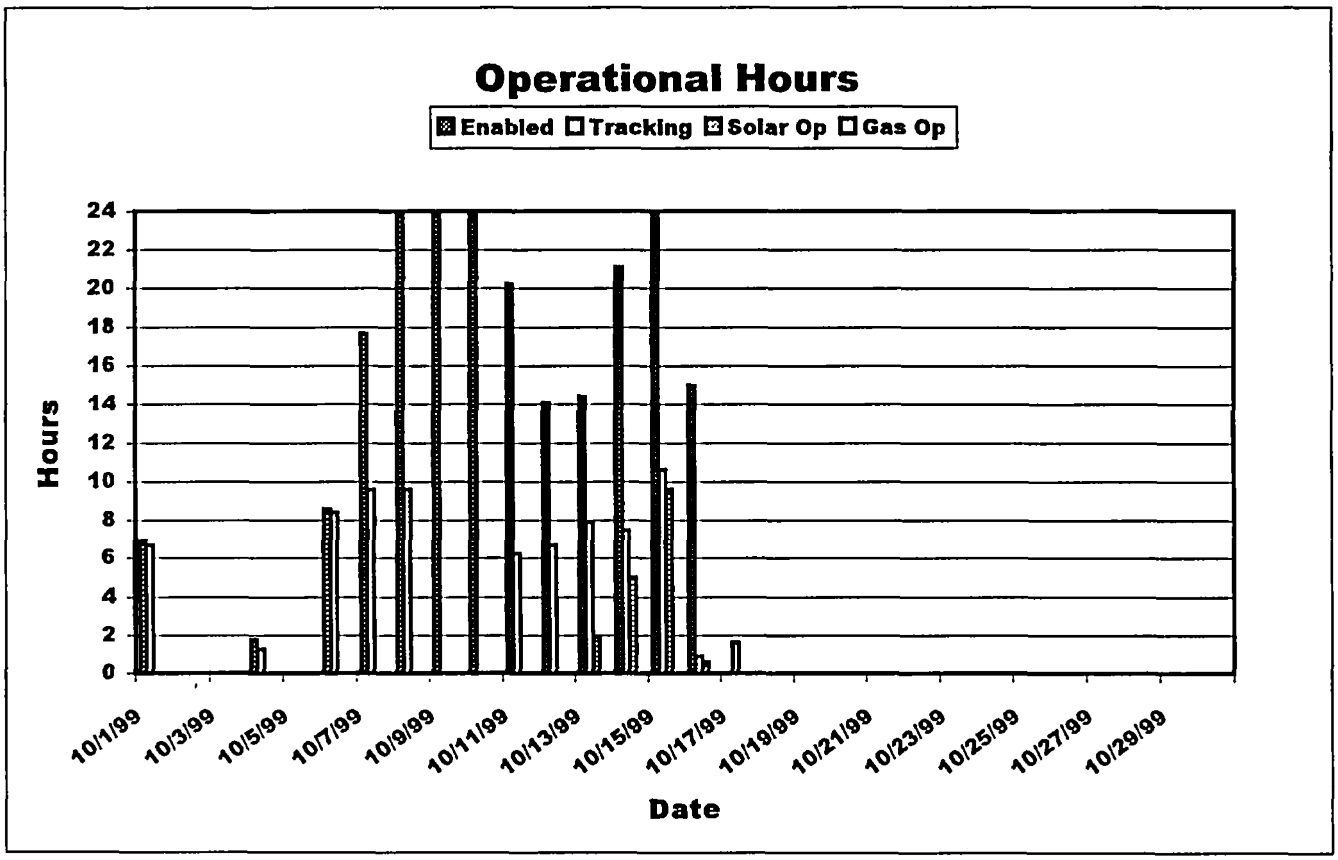
Operational/Reliability Data:

	Availabilit	Utilization	Capacity Factor
Controls	100%	55%	n/a
Solar	16%	10%	4%
Gas	19%	0%	0%

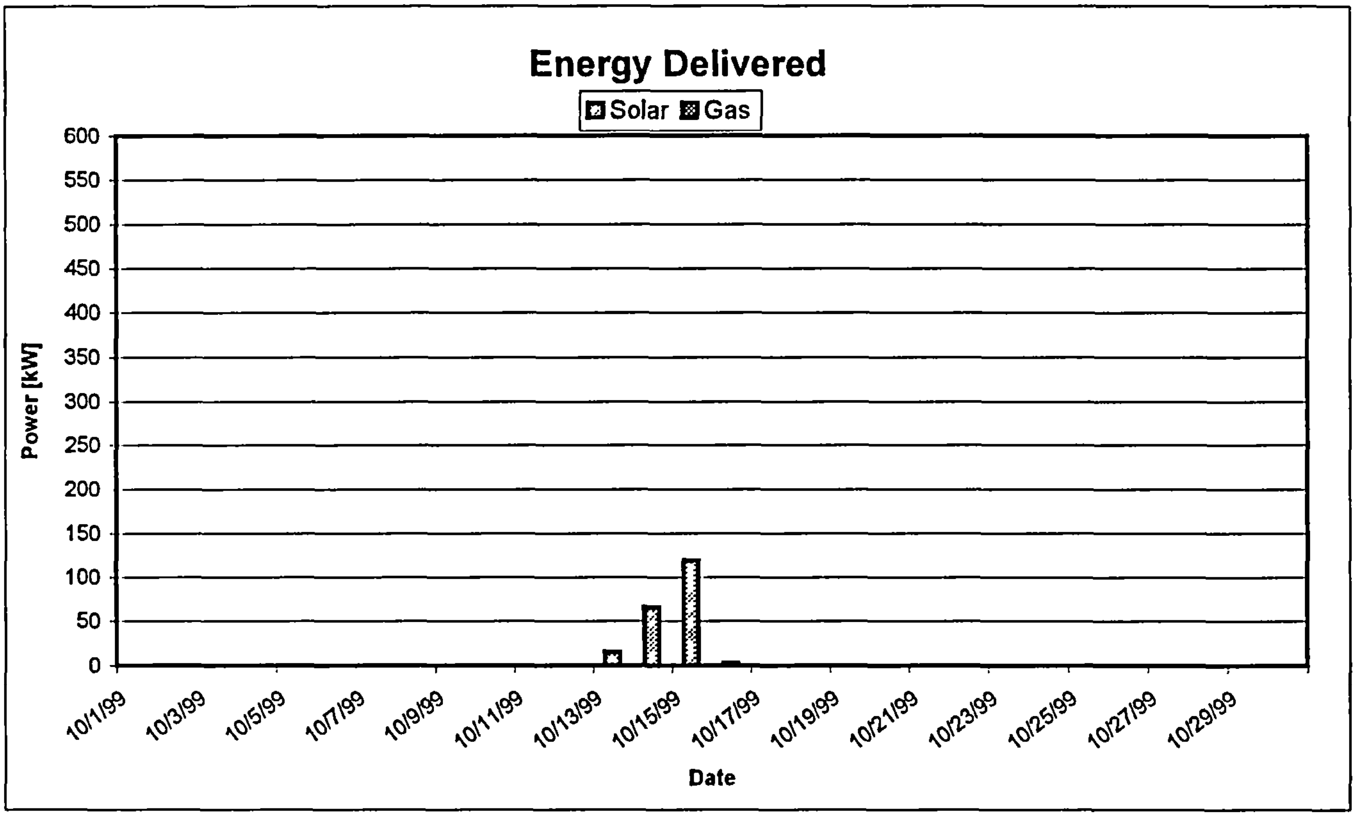
Day	Operational Summary
1	Tracked defocused
2	Not operated - weekend
3	Not operated - weekend
4	Tracked defocused
5	Not operated
6	0
7	Tracked defocused
8	Tracked Defocused
9	Tracked defocused
10	Not operated - weekend
11	Not operated - weekend
12	Tracked Defocused
13	Tracked defocused; maintenance in PM
14	Tracked defocused; solar op in PM
15	Operated on sun
16	Operated on sun
17	Operated on sun until PCS Fault at about 0800
18	Not operated - PCS down, weekend
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	0
28	0
29	0
30	0
31	0

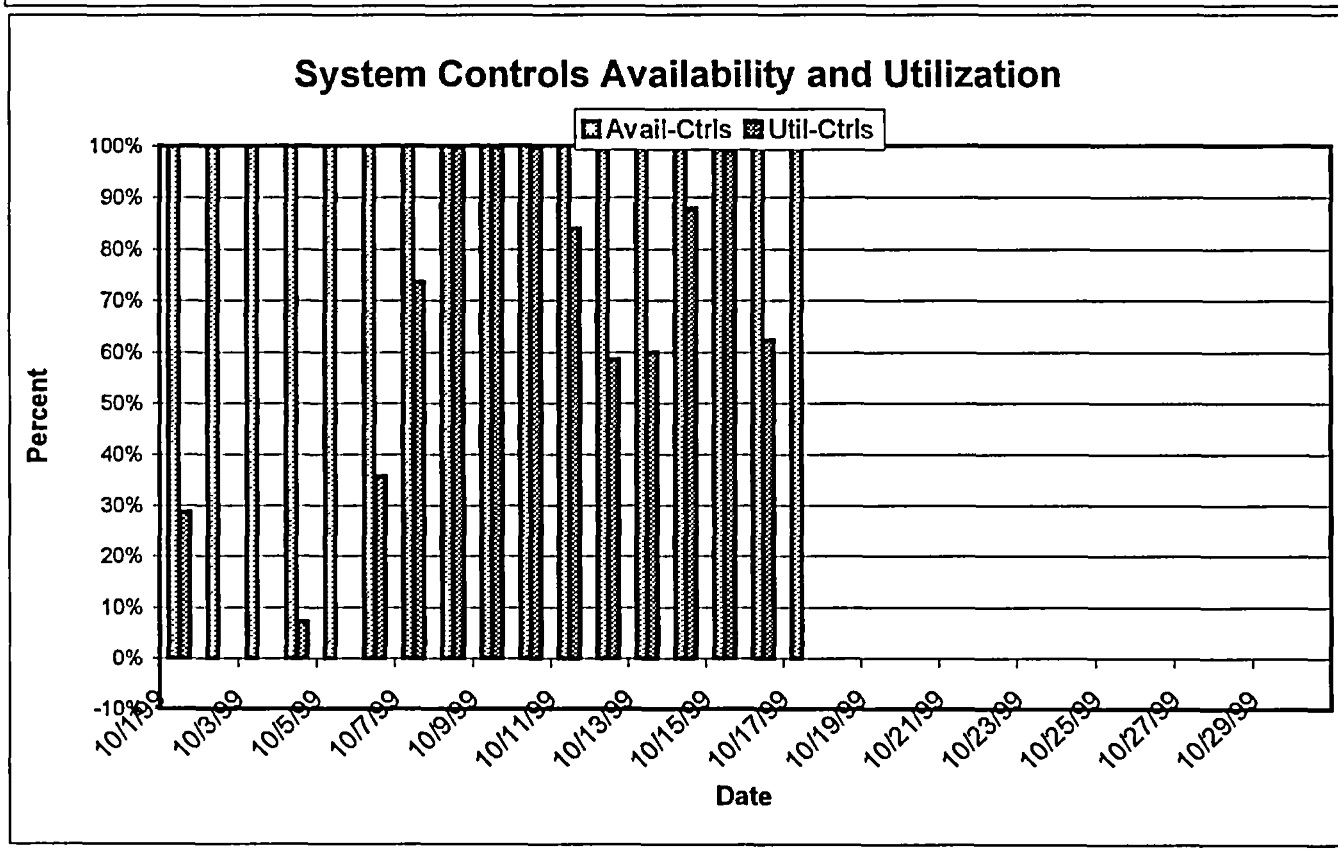
SRP Dish Monthly Performance Summary



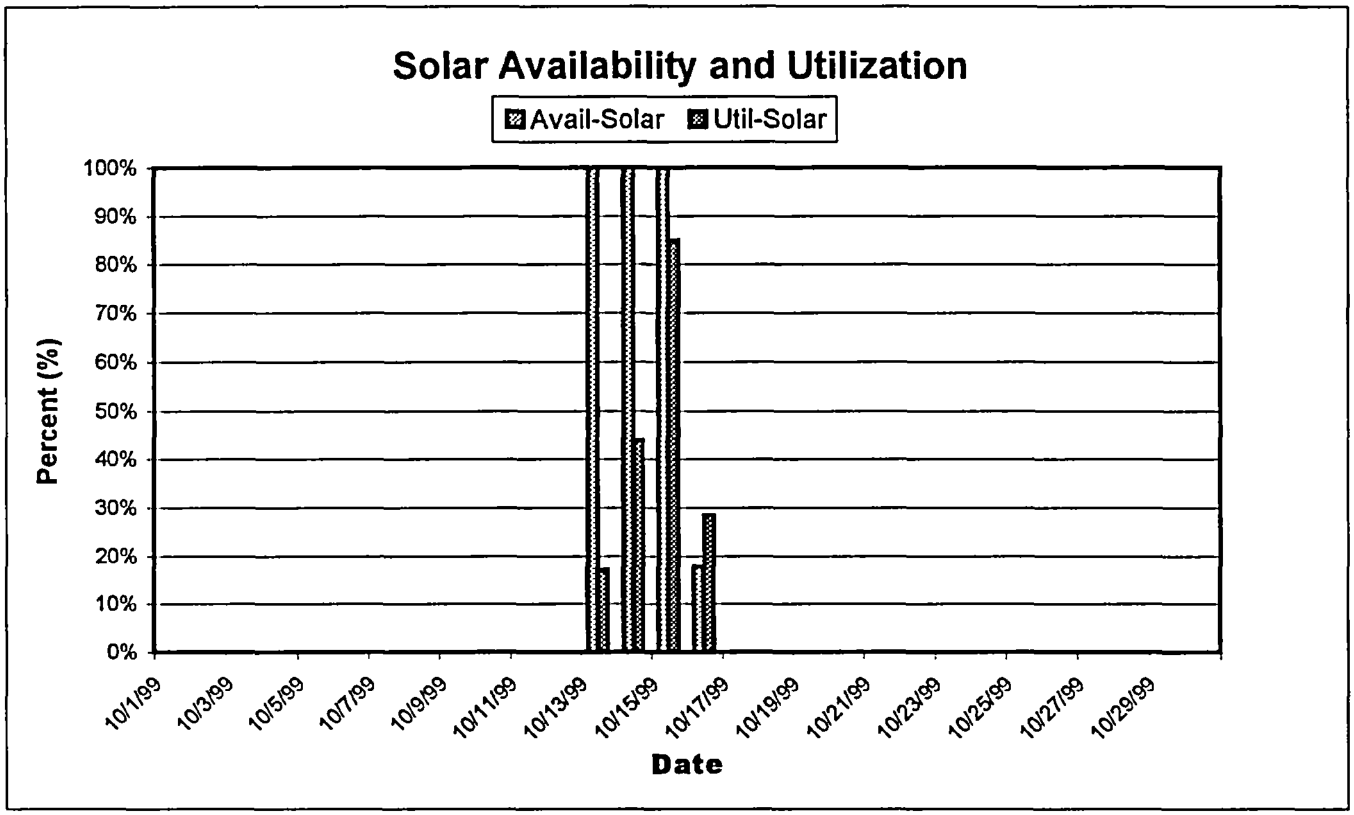


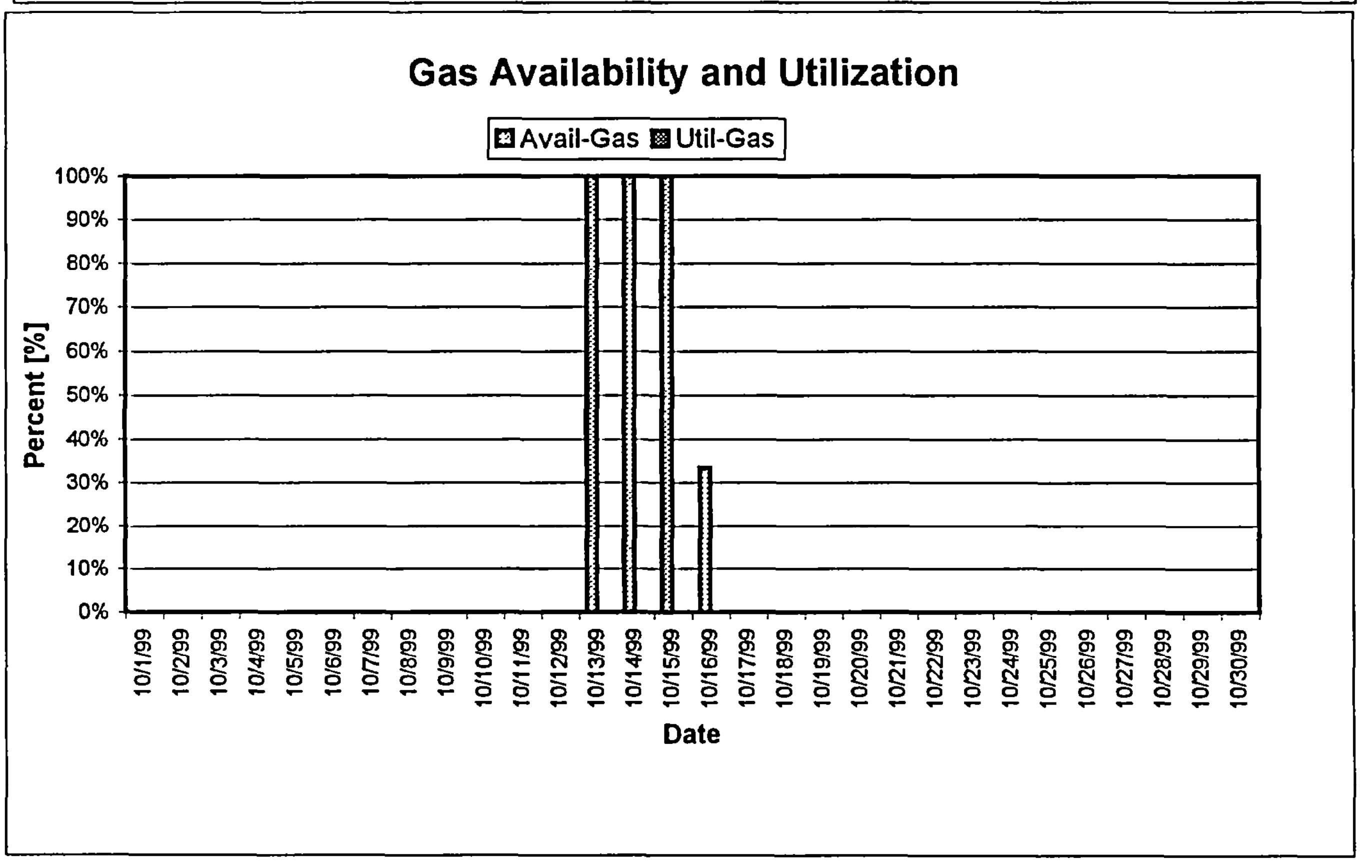
SRP Dish Monthly Performance Summary





SRP Dish Monthly Performance Summary





SRP Dish

Copy and paste row 7 to appropriate row in cumulative spreadsheet

	Monthly Total Hours					Downtimes [hr]			$Insolation_{DN}$		Solar Power [kW]		Gas Power [kW]		E
	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Pk [W/m^2]	Total [Wh/m^2]	Peak Pwr	Average	Gas Peak	Average	Consumed
Oct-99	206.1	239.3	86.5	17.1	0.0	0.0	170.3	352.0	759.0	63544.2	17.0	2.1651684	0.0	-	-169.2

Paste daily data here in appropriate row, using "Edit/Paste Special/Values"

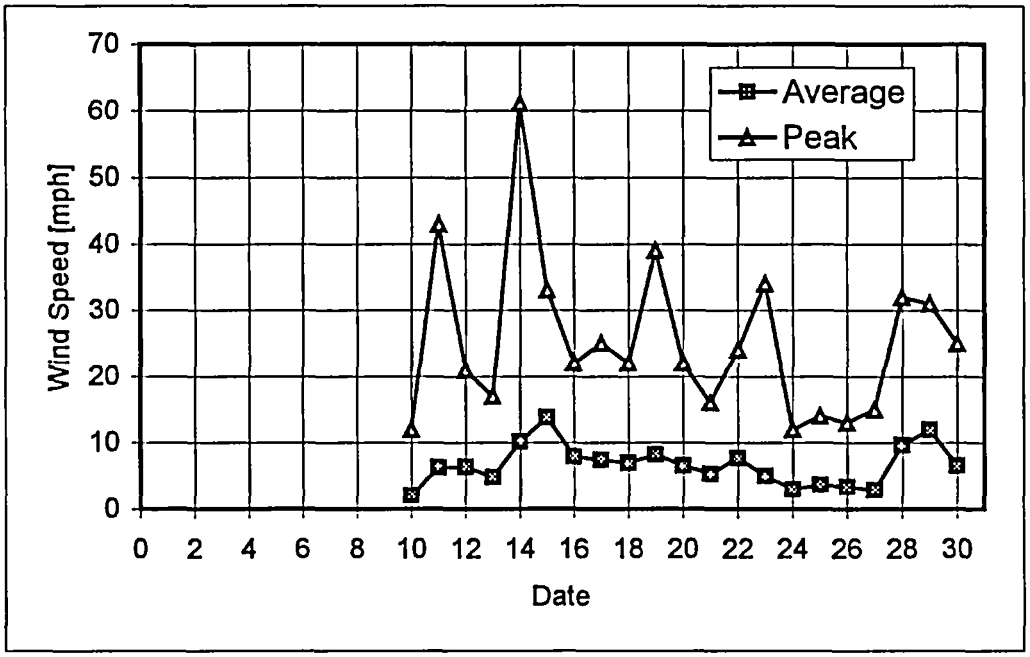
	Hours					Downtimes [hr]			Daily $Insolation_{DN}$		Solar Power [kW]		Gas Power [kW]		E
Day	Sun Up	Enabled	Tracking	Solar Op	Gas Op	Controls	Solar	Gas	Peak [W/m^2]	Total [Wh/m^2]	Peak	Average	Gas Peak	Average	Consumed
01-Oct-99	11.73[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	11.74	24	754	[illegible]	0	0	0	0	[illegible]
02-Oct-99	11.65[illegible]	0.0001	0.0001	0.0001	0.0001	0	11.66	24	3	-2.906844444	0	0	0	0	9.[illegible]
03-Oct-99	11.65[illegible]	0.0001	0.0001	0.0001	0.0001	0	11.64	24	3	[illegible]	0	0	0	0	-9.444[illegible]
04-Oct-99	11.659722	1.74843	1.248711	0.0001	0.0001	0	11.6[illegible]	24	711	1016.315[illegible]	0	0	0	0	12.324[illegible]
05-Oct-99	11.5442[illegible]	0.0001	0.0001	0.0001	0.0001	0	11.54	24	2	-7.5424	0	0	0	0	-5.[illegible]
06-Oct-99	11.436073	8.5756[illegible]	4.40[illegible]	0.0001	0.0001	0	11.[illegible]	24	752	625[illegible]	0	0	0	0	-10.5605[illegible]
07-Oct-99	11.42[illegible]	17.[illegible]	9.574544	0.0001	0.0001	0	11.4[illegible]	24	754	[illegible]	0	0	0	0	-12.[illegible]
08-Oct-99	11.509444	23.9[illegible]	9.[illegible]	0.0001	0.0001	0	11.5[illegible]	24	753	7042.4540[illegible]	0	0	0	0	-11.[illegible]
09-Oct-99	11.509444	23.9[illegible]	9.[illegible]	0.0001	0.0001	0	11.5[illegible]	24	753	7042.454[illegible]	0	0	0	0	11.[illegible]
10-Oct-99	11.42[illegible]	23.9[illegible]	0.0001	0.0001	0.0001	0	11.43	24	3	-3.54712[illegible]	0	[illegible]	[illegible]	0	-6.[illegible]
11-Oct-99	11.42[illegible]	23.[illegible]	0.0001	0.0001	0.0001	0	11.43	24	3	-3.4[illegible]	0	0	0	0	-1.[illegible]
12-Oct-99	11.356[illegible]	20.167	6.[illegible]	0.0001	0.0001	0	11.36	24	742	6[illegible]	0	0	0	0	-12.501[illegible]
12-Oct-99	11.293224	14.[illegible]	0.6[illegible]	0.0001	0.0001	0	11.29	24	75[illegible]	[illegible]	0	0	0	0	-1[illegible]
13-Oct-99	11.244544	14.4034	7.909544	1.91501	0.0001	0	0	0	755	5845.602322	13.116	9.0422524	0	0	-12.9247122
14-Oct-99	11.305333	21.9825	7.476433	4.95413	0.0001	0	0	0	759	5309.045794	17.019	15.182957	0	0	-10.836086
15-Oct-99	11.308889	23.9751	11.5751	9.60779	0.0001	0	0	0	749	7427.874822	16.221	12.366152	0	0	-5.27371542
16-Oct-99	11.275556	14.9743	3.900933	0.58723	0.0001	0	9.276	16	712	562.9091276	5.384	5.3716705	0	0	-8.73543026
17-Oct-99	11.24222	[illegible]	1.634544	0.0001	0.0001	0	11.[illegible]	24	750	1312.107491	0	0	0	0	-3.[illegible]
18-Oct-99															
19-Oct-99															
20-Oct-99															
21-Oct-99															
22-Oct-99															
23-Oct-99															
24-Oct-99															
25-Oct-99															
26-Oct-99															
27-Oct-99															
28-Oct-99															
29-Oct-99															
30-Oct-99															

ergy [kWh]		Efficiency [%]		Capacity Factor		Availability and Utilization					
Solar	Gas	Peak Eff	Average	CF_{-Solar}	CF_{-Gas}	$Avail_{Auto}$	$Util_{Auto}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$
202.8	0.0	20.1%	2.8%	4%	0%	100%	55%	16%	10%	19%	0%

ergy [kWh]		Efficiency [%]		Capacity Factor		Availability and Utilization						Operational Summary
Solar	Gas	Peak Daily	Average	Solar	Gas	$Avail_{Ctrls}$	$Util_{Ctrls}$	$Avail_{Solar}$	$Util_{Solar}$	$Avail_{Gas}$	$Util_{Gas}$	
0	0	0	0	0%	0%	100%	29%	0%	0%	0%	0%	Tracked defocused
0	0	0	0	0	0	1	4E-06	0	0	0	0	Not operated - weekend
0	0	0	0	0	0	1	4E-06	0	0	0	0	Not operated - weekend
0	0	0	0	0	0	1	0.0729	0	0	0	0	Tracked defocused
0	0	0	0	0	0	1	4E-06	0	0	0	0	Not operated
0	0	0	0	0	0	1	0.3573	0	0	0	0	0
0	0	0	0	0	0	1	0.7354	0	0	0	0	Tracked defocused
0	0	0	0	0	0	1	0.9969	0	0	0	0	Tracked Defocused
0	0	0	0	0	0	1	0.7389	0	0	0	0	Tracked defocused
0	0	0	0	0	0	1	0.9074	0	0	0	0	Not operated - weekend
0	0	0	0	0	0	1	0.9074	0	0	0	0	Not operated - weekend
0	0	0	0	0	0	1	0.8403	0	0	0	0	Tracked Defocused
0	0	0	0	0	0	1	0.5863	-0.24594	0	0	0	Tracked defocused, maintenance in PM
15.400994	0	0.1560662	0.07321259	0.0548	0	1	0.6001	1	0.1703	1	4E-06	Tracked defocused, solar op in PM
65.49217	0	0.2007324	0.10[illegible]	0.2317	0	1	0.8764	1	0.439	1	4E-06	Operated on sun
118.81132	0	0.1913203	0.14092806	0.4202	0	1	0.959	1	0.8496	1	4E-06	Operated on sun
3.0460946	0	0.105132	0.04805406	0.0108	0	1	0.6241	0.17737	0.2856	0.53335	1E-05	Operated on sun until PCS Fault at about 0800
0	0	0	0	0	0	1	-0.0006	0	0	0	0	Not operated - PCS down, weekend

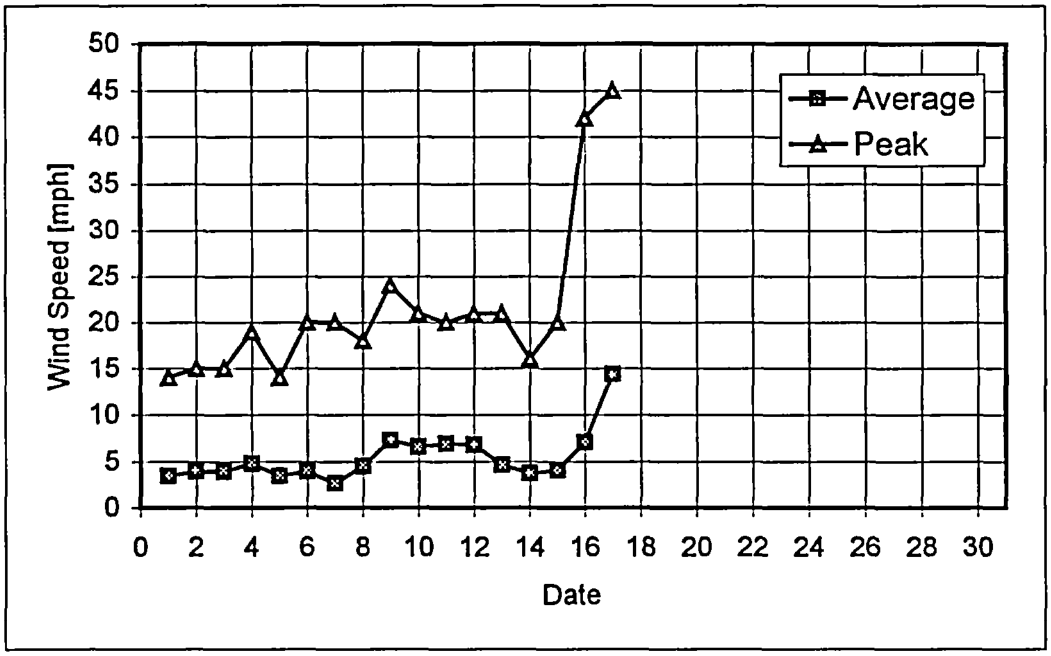
Weather Data for SRP Site   September-99

	Wind Speed [mph]	
Day	Average	Peak
1		
2		
3		
4		
5		
6		
7		
8		
9		
10	2.0	12.0
11	6.3	43.0
12	6.4	21.0
13	4.8	17.0
14	10.1	61.0
15	13.8	33.0
16	7.9	22.0
17	7.5	25.0
18	6.9	22.0
19	8.2	39.0
20	6.5	22.0
21	5.3	16.0
22	7.8	24.0
23	5.0	34.0
24	3.0	12.0
25	3.6	14.0
26	3.4	13.0
27	2.9	15.0
28	9.7	32.0
29	12.0	31.0
30	6.6	25.0



Weather Data for SRP Site October-99

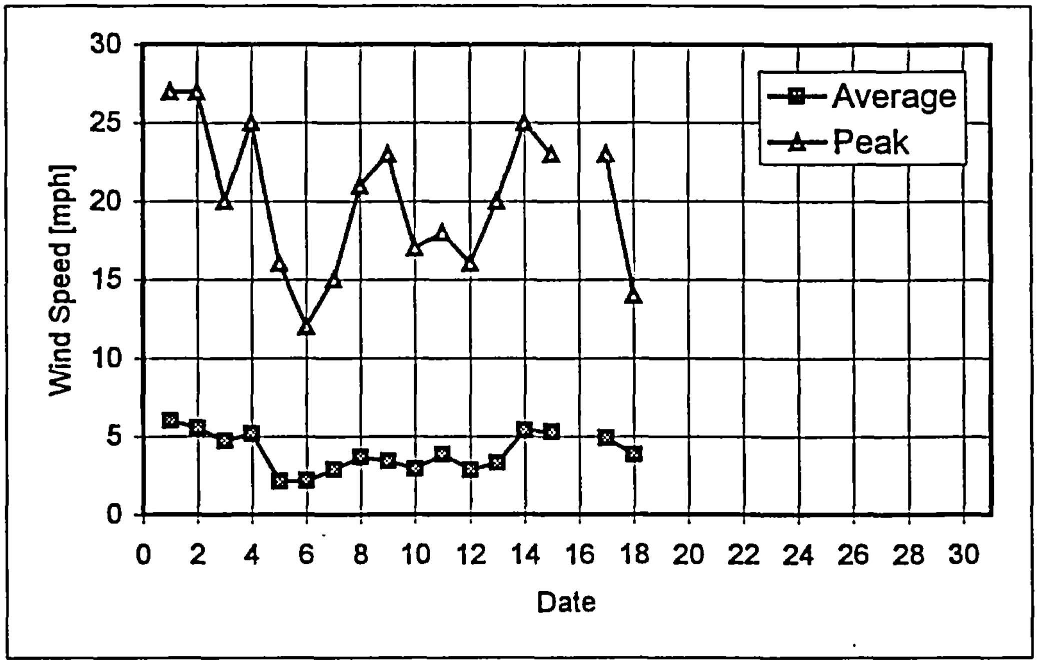
Day	Wind Speed [mph] Average	Peak
1	3.4	14.0
2	3.9	15.0
3	3.9	15.0
4	4.8	19.0
5	3.5	14.0
6	3.9	20.0
7	2.7	20.0
8	4.5	18.0
9	7.3	24.0
10	6.6	21.0
11	6.9	20.0
12	6.8	21.0
13	4.6	21.0
14	3.7	16.0
15	4.1	20.0
16	7.0	42.0
17	14.4	45.0
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		



Appendix L:
Weather Data from APS Dish/Stirling Network Interface

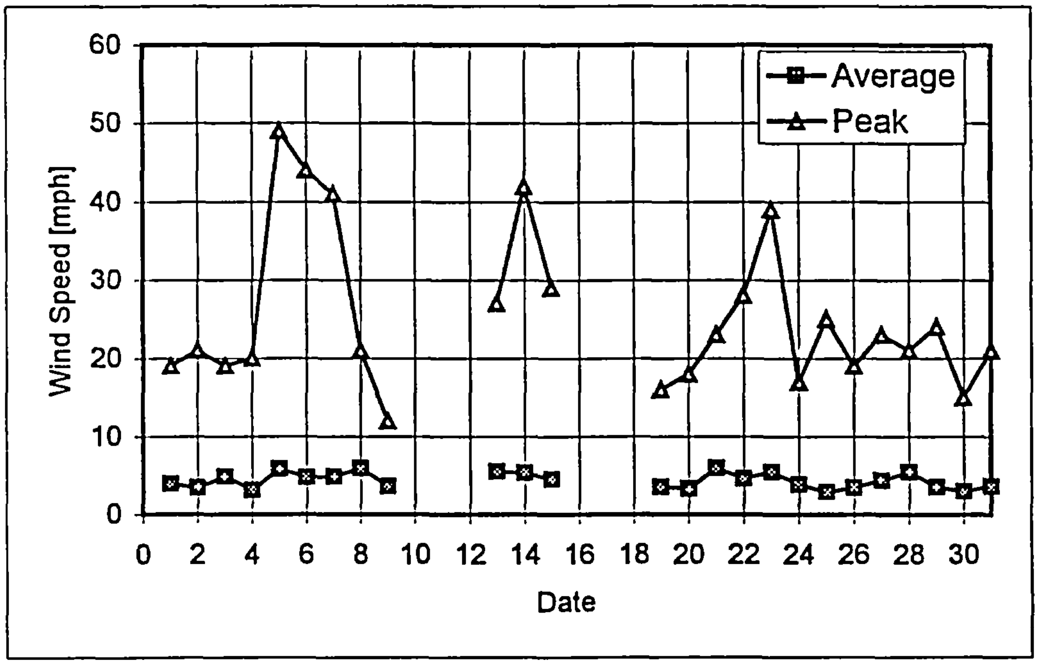
Weather Data for APS STAR Site June-99

Day	Wind Speed [mph] Average	Peak
1	6.0	27
2	5.6	27
3	4.7	20
4	5.2	25
5	2.1	16
6	2.2	12
7	2.9	15
8	3.7	21
9	3.5	23
10	2.9	17
11	3.9	18
12	2.9	16
13	3.3	20
14	5.4	25
15	5.3	23
16		
17	4.9	23
18	3.8	14
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		



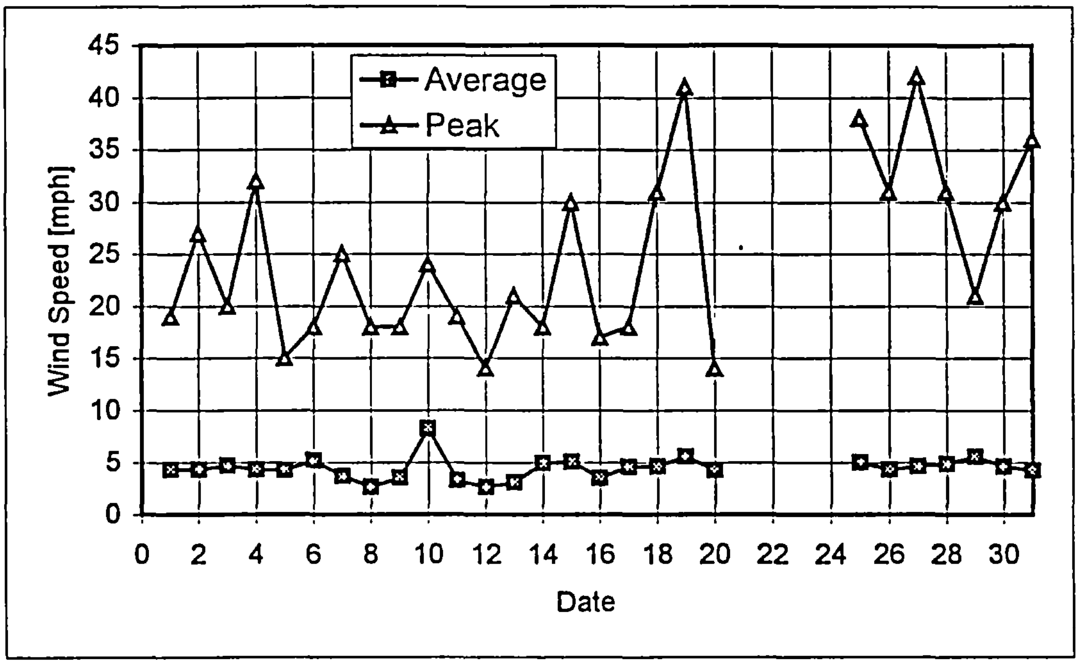
Weather Data for APS STAR Site July-99

	Wind Speed [mph]	
Day	Average	Peak
1	4.0	19
2	3.5	21
3	4.9	19
4	3.1	20
5	5.9	49
6	4.8	44
7	4.9	41
8	6.0	21
9	3.7	12
10		
11		
12		
13	5.5	27
14	5.4	42
15	4.6	29
16		
17		
18		
19	3.6	16.0
20	3.3	18.0
21	6.0	23.0
22	4.7	28.0
23	5.5	39.0
24	3.9	17.0
25	2.9	25.0
26	3.4	19.0
27	4.4	23.0
28	5.5	21.0
29	3.6	24.0
30	2.9	15.0
31	3.6	21.0



Weather Data for APS STAR Site   August-99

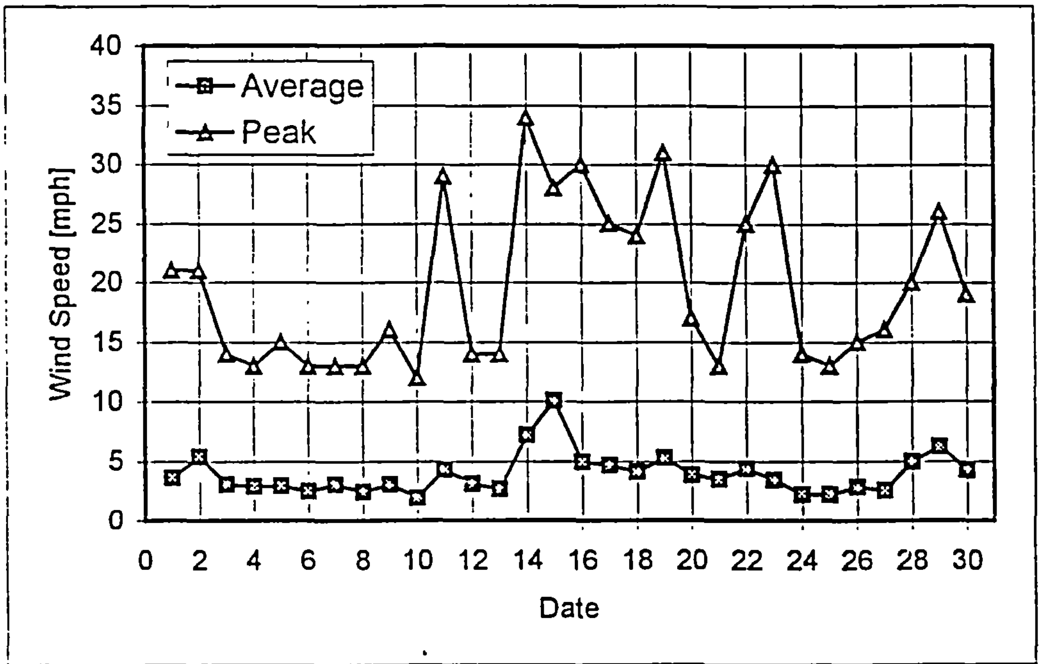
Day	Wind Speed [mph] Average	Peak
1	4.3	19.0
2	4.4	27.0
3	4.7	20.0
4	4.4	32.0
5	4.3	15.0
6	5.2	18.0
7	3.7	25.0
8	2.7	18.0
9	3.5	18.0
10	8.2	24.0
11	3.3	19.0
12	2.6	14.0
13	3.1	21.0
14	4.9	18.0
15	5.1	30.0
16	3.6	17.0
17	4.6	18.0
18	4.7	31.0
19	5.6	41.0
20	4.3	14.0
21		
22		
23		
24		
25	5.1	38.0
26	4.4	31.0
27	4.7	42.0
28	4.9	31.0
29	5.6	21.0
30	4.7	30.0
31	4.3	36.0



Weather Data for APS STAR Site

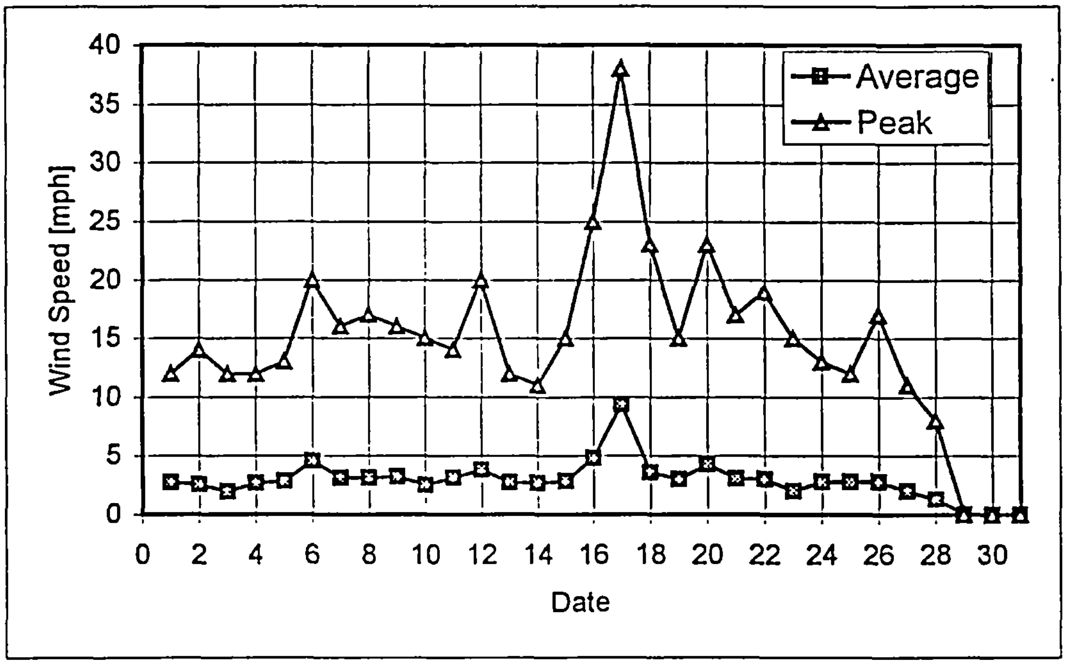
September-99

Day	Wind Speed [mph] Average	Peak
1	3.6	21.0
2	5.4	21.0
3	3.0	14.0
4	2.9	13.0
5	2.9	15.0
6	2.5	13.0
7	3.0	13.0
8	2.4	13.0
9	3.1	16.0
10	2.0	12.0
11	4.2	29.0
12	3.1	14.0
13	2.6	14.0
14	7.2	34.0
15	10.1	28.0
16	4.9	30.0
17	4.6	25.0
18	4.1	24.0
19	5.3	31.0
20	3.8	17.0
21	3.5	13.0
22	4.4	25.0
23	3.4	30.0
24	2.2	14.0
25	2.2	13.0
26	2.8	15.0
27	2.5	16.0
28	4.9	20.0
29	6.2	26.0
30	4.2	19.0



Weather Data for APS STAR Site — October-99

	Wind Speed [mph]	
Day	Average	Peak
1	2.7	12.0
2	2.6	14.0
3	2.0	12.0
4	2.7	12.0
5	2.9	13.0
6	4.6	20.0
7	3.2	16.0
8	3.1	17.0
9	3.3	16.0
10	2.5	15.0
11	3.1	14.0
12	3.8	20.0
13	2.8	12.0
14	2.7	11.0
15	2.9	15.0
16	4.8	25.0
17	9.3	38.0
18	3.6	23.0
19	3.0	15.0
20	4.2	23.0
21	3.1	17.0
22	3.1	19.0
23	2.0	15.0
24	2.8	13.0
25	2.8	12.0
26	2.8	17.0
27	2.1	11.0
28	1.3	8.0
29	0.0	0.0
30	0.0	0.0
31	0.0	0.0



Appendix M:
Dish/Stirling System Production Cost Estimates

Science Applications International Corporation

an Employee-Owned Company

DATE: 12 December 1997

TO: Barry Butler
PHONE: 619-546-6004 **FAX:** 619-546-6335

CC: Kelly Beninga, Stefan Johansson, Bud Brittingham, Mike Taylor, Tom Mullens, Pat Hodges

FROM: Roger L. Davenport
SAIC Energy Projects Division, Golden, CO
PHONE: 303-279-1928 **FAX:** 303-384-0320

SUBJECT: JVP Cost Estimates and Projections

Attached are updated cost estimates and projections for production of dish/Stirling systems. I have used the actual costs from the dishes now being produced to try and tie down a baseline single-unit and five-unit-batch cost for the systems. Then Kelly and I worked up a cost projection methodology based on those estimates for higher production rates and including such things as marketing and general engineering costs. The attached pages contain the following:

- A detailed cost estimate for the first Phase 2 unit, including materials, labor for fabrication of parts and installation, and installation-related costs such as foundation engineering. The materials costs are based where possible on the quotes we have for the first unit being installed on the NREL mesa. (4 pages)

- A detailed material cost estimate for the fifth Phase 2 unit. This is also based as much as possible on the actual quotes and estimates we have for the Phase 2 dish/Stirling system components. The same labor and other costs as for the single-unit build are assumed for the five-unit build during Phase 2 of the JVP. (2 pages)

- A detailed cost projection for a "commercial production" unit occurring as the first unit produced after an investment of $2.2 million in capital equipment is made, and following the 50 systems after JVP Phase 2. The costs are projected from the single-unit build labor costs, and the fifth-unit Phase 2 material costs. (4 pages)

  Assumptions are shown for each of the individual items. Generally, the following assumptions have been applied:
  - Materials costs are assumed to be about 30% less due to volume purchasing and increased efficiency of usage;
  - Fabrication hours are reduced by 40% due to increased automation and production efficiency;
  - Installation hours are reduced 20% due to increased efficiency and specialization;
  - Engineering and design activities are greatly reduced due to simplification of designs and amortization over 50-unit installations; and

- Labor rates are reduced 40% for fabrication and installation direct labor

- A projection and comparison of the costs of systems starting from the bare production and installation costs and including factors such as marketing and general engineering costs, profit, and facilities costs. (1 page)

The cost estimates and projections are discussed in more detail in the following paragraphs.

Single-Unit Build
The single-unit cost estimate is divided into a summary page, two pages of material cost estimate, and a single-page labor cost estimate. The summary page refers to the materials and labor estimates as detail pages. Costs are presented in terms of the dish concentrator fabrication costs, the PCS, installation costs, engineering costs for the installation, and overhead costs associated with the installation. In the materials cost estimate, parts are identified by assemblies and sub-assemblies, and references are made to the part numbers/drawing numbers of many of the parts. In the labor estimate, tasks are divided into fabrication tasks and installation tasks, by subsystem.

Five-Unit Build
Only the two-page materials estimate is included for the five-unit build. The fabrication and installation labor and the other costs were not judged to change significantly between the first and fifth units, and are handled using a simple multiplier in the cost estimate. The materials costs do not show a tremendous drop going from the single unit to the fifth unit of production. The total cost for materials dropped only about $2K from a total of $54K, or about 4%. Because the fifth unit had separate estimates for shipping costs to different sites, I used the five-unit build material costs and generically-estimated shipping costs as a basis for the projections described below, rather than the single-unit costs (for which parts were shipped to Golden).

Commercial Production Scenario
The next four pages are an estimate for a "commercial production" system, as described above. The changes from the single-unit and five-unit build estimates are noted for each line. In the labor estimate, the man-hours hours were reduced due to the assumption of more automation in fabrication and more specialization in installation, as well as increased efficiency overall due to more continuous production and installation. In addition, the hourly labor rates were reduced in anticipation of a change in overhead structure from the standard SAIC overhead burdens to lower rates. Note that in the materials estimate, the reductions were sometimes applied only to the final sub-assembly costs, not to each individual item, in order to reduce the amount of work I had to do in modifying the spreadsheet.

System Sales Price and Cost Projections
The final attached sheet shows system sales price calculations and cost projections for several production scenaria. Each scenario occupies two columns on the spreadsheet, separated by vertical bars. The first column contains individual cost items, and the second column contains cost sub-totals. The system cost estimates described in the preceding paragraphs are summarized in the upper section of each scenario.

The first scenario is the single-unit production scenario. The production and installation costs are identical to those given in the earlier cost estimates down to the sub-total line labeled **"Installed System Cost"**. Following that line are overhead items labeled "Management and

Marketing" and "Engineering, General". These are overhead activities that are not directly related to the installation of the system. Note that at this point, no capital equipment investments or facilities costs are assessed – these costs were already paid by the earlier Phase of the JVP and the SolMaT program in order to build the production equipment we are now using. The warrantee cost is estimated as 15% of the Installed System Cost, and the total of these values with that cost is termed the "**Loaded System Cost**". Finally, a profit of 15% on the Loaded System Cost is added to obtain the final "**System Selling Price**" at the bottom of the column.

The second scenario is that of the first five-unit build of systems, now taking place as part of the JVP Phase 2 program. A reduction of 10% in the labor factors of the first system is included to account for efficiency improvements during the course of the JVP Phase 2 program. Also, an amortization of costs such as foundation designs is included, assuming that all five systems could be placed in the same location and would therefore share similar if not identical designs. Finally, management and marketing costs of $500K, and general engineering costs of $500K, are amortized over the five units.

The next scenario presented is for following batches of five unit builds anticipated for the JVP Phase 3 program. A total of perhaps 10 such batches may be built. These are anticipated to have a 20% reduction in labor values relative to the single-unit build, and the foundations and other shared items are amortized assuming five-unit builds at single sites. For each batch of five units, management and marketing costs of $400K and engineering costs of $400K are assumed to be incurred, and these are amortized over those five units.

The next scenario is for a 50-unit build. At this level, the labor costs are assumed to be reduced by 30% from the single-unit build, and materials costs for the dish are assumed to be reduced by 20% due to high-volume purchases. The PCS cost for this scenario is that given by STM in their JVP Phase 3 ROM. Finally, shared site expenses, $750K in management and marketing expenses, and $600K of engineering costs, are amortized over the fifty units.

The following scenario is a first commercial production scenario. The first build is assumed to be a batch of 150 systems, installed at three 50-unit sites. Therefore, shared site costs are amortized over 50 units. In this scenario, an investment of $2.2 million in capital costs is assumed, along with $300K in facilities costs. These, along with $1 million in management and marketing and $750K in engineering costs, are amortized over the 150-unit build.

Finally, the last scenario is for a 500-unit build occurring after the first 150-unit commercial production run. The Installed System Cost was generated by applying a learning curve to the 150-unit commercial production figures, with a learning curve coefficient of 90%. An additional $1.65 million investment in capital equipment is assumed. Again, shared site costs are amortized over 50-unit builds, and capital equipment, facility, management and marketing, and general engineering costs are amortized over the 500-system batch.

Evaluation and Caveats

The system cost projections show that once we are past the JVP Phase 3 five-unit batch production mode, the full costs of our systems to a customer should be about $300K. As we make investments in capital equipment and get out from under SAIC labor overhead burdens, the cost should drop to about $157K at 150 units and to $108K at production of 500 units.

Obviously, the projections at 150 and 500 units are quite uncertain, but they appear to be in the right order of magnitude for a continued business.

One reason the low-production system costs are so high is that the only estimate I have for the PCS cost is the one given to me over the phone by Stefan in November. Not having any further information, I used that same PCS price ($180,000) for all of the estimates up to the 50-unit build. Therefore, for those cases, the PCS is a significant fraction of the system installed cost (61% to 65% of the total). Clearly, if STM can give us a better numbers for these low production rates, the costs of the systems would drop dramatically. In the 50-unit build, I used the Phase 3 ROM value that was given us by STM at the start of the JVP, and for the commercial scenario I proposed that the cost of the PCS would drop by 80% from the single-unit cost. This gave a PCS cost approximately 1/3 of the total installed system cost, which seemed reasonable to me. Hopefully, we will soon be receiving updated cost estimates from STM to include in these calculations, based on the "Request for Standard Pricing for STM Power Conversion Systems", dated 3 December, which I have seen in draft form.

Until then, and until I can corner Bud and Mike Taylor to get their comments on the details and projections of labor costs for production and installation, this is all I can do. Please feel free to contact me with any questions or comments, and I will do my best to respond. If anyone would like the spreadsheet with the cost estimates and projections, let me know and I will e-mail it to you.

Cheers!

JVP Phase 2 Dish/Stirling System Cost Estimate

Single-Unit Build

$ 293,292 Total Cost

Component	Cost	Sub-Total	Basis
Dish Concentrator		$ 76,092	
Dish Materials	$ 54,252		see detail sheet
Fabrication Labor	$ 20,640		see detail sheet
Fabrication Supervision	$ 1,200		est. 1 hr/facet@$75/hr
PCS Cost	$ 180,000	$ 180,000	est. by Stefan J., 11/21/97 (phone)
Installation Costs		$ 25,200	see detail sheet
Soil Samples	$ 1,000		est. (Sandi D.)
Soil Analysis	$ 2,000		est. (Sandi D.)
Drill Hole and Set Pedestal	$ 3,000		Patrick & Henderson Quote, 2/22/1996 + 9%
Wiring to Pedestal	$ 1,500		Donald Keef Quote, 4/17/96 + 6%
Boom Truck Rental	$ 1,600		est. (4 days, $50/hr)
Crane to Install System	$ 800		est. ($400 mobilization, $100/hr for 4 hrs)
Installation Labor	$ 12,300		
Installation Supervision	$ 3,000		est. 40 hr/system @ $75/hr
Engineering		$ 6,000	
Foundation Design	$ 2,000		est. 20hrs @ $100/hr
Electrical Interface Design	$ 2,000		est. 20hrs @ $100/hr
Planning and Permits	$ 2,000		est. 20hrs @ $100/hr
Overhead		$ 6,000	
Project Management	$ 1,000		est. 10 hr/system @ $100/hr
Bookkeeping	$ 2,000		est. 40 hr/system @ $50/hr
Purchasing	$ 3,000		est. 40 hr/system @ $75/hr

JVP Phase 2 Dish Materials Cost Estimate

Single-Unit Build

Total Dish System Cost $ 54,252

Part Number/ Assembly Level	Description	Quantity Required/ Assembly Level System	Assy	Sub-Assy	Unit Cost	Total Cost	Cost Basis
D2-0101-1	**Drive Unit**	1			8261	8261	
D2-0101-?	Flenders Drive		1		7500		Actual cost of refurbished drives for JVP Phase 2
D2-0101-?	Drive Motors		2		125		MMC 6135K12
D2-0101-?	Encoders		2		150		est. (Machined Parts ~ 90, elec. 15, assy 45)
D2-0101-?	Limit Switches		4		12		DigiKey 59066-030-ND, 57065-000-ND, 4/30/97
D2-0101-?	Junction Box		1		64		MMC 6918K75+6917K15
D2-0101-?	Misc. Hardware		1		100		MMC 7527K53x2; est.
D2-0130-1	**Spool Plate, Pedestal-to-Drive**	1			800	800	Silver Weibull quote, 4/30/97
D2-0???-?	**Assembly Hardware**	1			500	500	wag
D2-1000-1	**Hub/Transition**	1			11345	12845	Quote #12235B, 10/27/97, Vertex-NM
	Hub Shipping to Golden	1			1500		
D2-2000-1	**Trusswork**	1			9431	9431	
D2-2100-1	Radial Truss Assembly		6		441		QTN-1197-08, 11/12/97, SFI
D2-2200-1	Circumferential Truss Assembly		5		483		QTN-1197-08, 11/12/97, SFI
D2-2300-1	Long Cantilever Truss Assembly		10		225		QTN-1197-08, 11/12/97, SFI
D2-2400-1	Short Cantilever Truss Assembly		2		184		QTN-1197-08, 11/12/97, SFI
D2-2500-1	Truss Brackets		6		292		QTN-1197-10, 11/19/97, SFI
	Shipping to Golden		1		0		included in quote
D2-3100 and D2-3200	**PCS Arm**	1			6160	6160	QTN-1197-09, 11/13/97, SFI
?	Shipping to Golden	1			0		included in quote
D2-4000-1	**Mirror Facet**	16			623	9964	
D2-4000-2	Facet Trim		66		0.26		Actual JVP Phase 1; $/ft
D2-4001-1	Mirror Tile Set		1		250		Naugatuck Glass Quote, 10/26/95
D2-4000-10	Mirror Adhesive		1		43		Est. from 3M phone Quote, 4/97
D2-4100-1	Facet Ring Assembly		1		168		
D2-41??-?	Facet Ring Segments			4	30		Roadrunner Quote, 11/97 (per Lem Tingley)
D2-41??-?	Mounting Brackets			3	11		United Machining Quote, 12/12/96

D2-41??-?	Captive Nut			3	5		United Machining Quote, 1/20/97
D2-4200-1	Membrane Assembly		2		43		
D2-42??-?	201 SS foil			9	4.76		Actual JVP Phase 1; $/m^2
D2-4300-1	Facet Focus Control Assembly		1		59		Qual. Machine Shop Quote, 4/28/97
D2-5000-1	**Control System**	1			1492	1492	
D2-5100	Control Box Assembly		1		594		
D2-51??-?	Enclosure			1	100		est.
D2-51??-?	Little PLC Controller			1	183		Zworld Actual, 4/30/97
D2-51??-?	Little PLC ADC-4 Expansion Board			1	95		Zworld Actual, 1/97
D2-51??-?	Solid-State Relays			3	13		DigiKey CC1066-ND
D2-51??-?	Reversing Relays (3PDT)			2	19		MMC
D2-51??-?	24 VDC Power Supply			1	40		est.
D2-51??-?	Connectors			1	50		est.
D2-51??-?	Misc. Parts			1	50		est.
D2-5???-?	Sun Sensor		1		200		wag
D2-5???-?	Signal Wiring		1		100		est.
D2-5???-?	Power Wiring		1		200		est.
D2-5???-?	NEMA 3R 60Amp Disconnect		1		398		Grainger, 1H355
D2-6000-1	**Focus Control System**	1			759	759	
D2-6100-1	Focus Blower Assembly		1		409		
D2-61??-?	Blower - Gast R1102			1	265		Actual JVP Phase 1 (Gast Regenair R1)
D2-61??-?	Defocus Valve			1	122		Actual JVP Phase 1 (Lakeland, Red Hat 8030G83)
D2-61??-?	Check Valve			1	9		MMC 4616K32
D2-61??-?	Misc. Fittings			1	13		Memo 4/25/97
D2-6???-?	Flex Hoses		300		1		MMC 5304K45
D2-6???-?	Vacuum Regulator Assembly		1		14		
	Vacuum Regulator Valve			1	8		MMC 4616K31
	Misc. Fittings			1	6		Memo 4/25/97
D2-7000-1	**Pedestal**	1			4040	4040	QTN-997-04, 10/2/97, SFI
D2-7000-2	Pedestal Shipping	1			0		included in quote

JVP Phase 2 Dish/Stirling System Labor Estimate

Single-Unit Build

$ 60 Loaded Labor Rate

Assembly/Task	Man-hrs	Qty Req'd	Cost	Total Cost $	32,940
Fabrication Labor				$	20,640
Drive System					
Wire Drive Motors & Limits	40	1	2400		
Attach Spool Plate to Drive	4	1	240		
Inner PCS Arm					
Fabricate Latch	2	1	120		
Assemble Latch	2	1	120		
Mirror Facets					
Manufacture Mirror Facet	12	16	11520		
Apply Mirrors	4	16	3840		
Controls					
Assemble Control Box	20	1	1200		
Assemble Blower Assembly	20	1	1200		
Installation Labor				$	12,300
Pedestal					
Install Pedestal	4	1	240		
Drive					
Attach to Hub	4	1	240		
Install System on Pedestal	8	1	480		
Trusswork					
Assemble Radial Trusses	3	6	1080		
Assemble Circumferential Trusses	3	5	900		
Assemble Cantilever Trusses	3	12	2160		
PCS Support Arm					
Attach Outer Arm to Inner Arm	4	1	240		
Install on Hub	4	1	240		
Mirror Facets					
Install Facets	2	16	1920		
Adjust Facets	20	1	1200		
Controls					
Wire Control Box on Pedestal	20	1	1200		
Wire Focus Control	4	1	240		
Wire Arm Latch	4	1	240		
Wire Sun Sensor	4	1	240		
Wire PCS	4	1	240		
Install Focus Control Blower	4	1	240		
Install Focus Control Hoses	20	1	1200		

JVP Phase 2 Dish Materials Cost Estimate

Five-Unit Build

Total System Cost $ 52,342

Part Number/ Assembly Level	Description	Quantity Required/ Assembly Level System	Assy	Sub-Assy	Unit Cost	Total Cost	Cost Basis
D2-0101-1	**Drive Unit**	1			8261	8261	
D2-0101-?	Flenders Drive		1		7500		Actual cost of refurbished drives for JVP Phase 2
D2-0101-?	Drive Motors		2		125		MMC 6135K12
D2-0101-?	Encoders		2		150		est. (Machined Parts ~ 90, elec. 15, assy 45)
D2-0101-?	Limit Switches		4		12		DigiKey 59066-030-ND, 57065-000-ND, 4/30/97
D2-0101-?	Junction Box		1		64		MMC 6918K75+6917K15
D2-0101-?	Misc. Hardware		1		100		MMC 7527K53x2; est.
D2-0130-1	**Spool Plate, Pedestal-to-Drive**	1			800	800	Silver Weibull quote, 4/30/97
D2-0???-?	**Assembly Hardware**	1			500	500	wag
D2-1000-1	**Hub/Transition**	1			9395	11395	Quote #12235B, 10/27/97, Vertex-NM
	Hub Shipping	1			2000		Est. from values in Vertex Quote #12235B
D2-2000-1	**Trusswork**	1			9012	9012	
D2-2100-1	Radial Truss Assembly		6		387		QTN-1197-08, 11/12/97, SFI
D2-2200-1	Circumferential Truss Assembly		5		424		QTN-1197-08, 11/12/97, SFI
D2-2300-1	Long Cantilever Truss Assembly		10		197		QTN-1197-08, 11/12/97, SFI
D2-2400-1	Short Cantilever Truss Assembly		2		162		QTN-1197-08, 11/12/97, SFI
D2-2500-1	Truss Brackets		6		246		QTN-1197-10, 11/19/97, SFI
	Shipping to Golden		1		800		Est. from QTN-1197-08
D2-3100 and D2-3200	**PCS Arm**	1			5544	6344	QTN-1197-09, 11/13/97, SFI
?	Shipping to Golden	1			800		Est. from QTN-1197-09
D2-4000-1	**Mirror Facet**	16			623	9964	
D2-4000-2	Facet Trim		66		0.26		Actual JVP Phase 1; $/ft
D2-4001-1	Mirror Tile Set		1		250		Naugatuck Glass Quote, 10/26/95
D2-4000-10	Mirror Adhesive		1		43		Est. from 3M phone Quote, 4/97
D2-4100-1	Facet Ring Assembly		1		168		
D2-41??-?	Facet Ring Segments			4	30		Roadrunner Quote, 11/97 (per Lem Tingley)
D2-41??-?	Mounting Brackets			3	11		United Machining Quote, 12/12/96

D2-41??-?	Captive Nut			3	5		United Machining Quote, 1/20/97
D2-4200-1	Membrane Assembly		2		43		
D2-42??-?	201 SS foil			9	4.76		Actual JVP Phase 1; $/m^2
D2-4300-1	Facet Focus Control Assembly		1		59		Qual. Machine Shop Quote, 4/28/97
D2-5000-1	**Control System**	1			1492	1492	
D2-5100	Control Box Assembly		1		594		
D2-51??-?	Enclosure			1	100		est.
D2-51??-?	Little PLC Controller			1	183		Zworld Actual, 4/30/97
D2-51??-?	Little PLC ADC-4 Expansion Board			1	95		Zworld Actual, 1/97
D2-51??-?	Solid-State Relays			3	13		DigiKey CC1066-ND
D2-51??-?	Reversing Relays (3PDT)			2	19		MMC
D2-51??-?	24 VDC Power Supply			1	40		est.
D2-51??-?	Connectors			1	50		est.
D2-51??-?	Misc. Parts			1	50		est.
D2-5???-?	Sun Sensor		1		200		wag
D2-5???-?	Signal Wiring		1		100		est.
D2-5???-?	Power Wiring		1		200		est.
D2-5???-?	NEMA 3R 60Amp Disconnect		1		398		Grainger, 1H355
D2-6000-1	**Focus Control System**	1			759	759	
D2-6100-1	Focus Blower Assembly		1		409		
D2-61??-?	Blower - Gast R1102			1	265		Actual JVP Phase 1 (Gast Regenair R1)
D2-61??-?	Defocus Valve			1	122		Actual JVP Phase 1 (Lakeland, Red Hat 8030G83)
D2-61??-?	Check Valve			1	9		MMC 4616K32
D2-61??-?	Misc. Fittings			1	13		Memo 4/25/97
D2-6???-?	Flex Hoses		300		1		MMC 5304K45
D2-6???-?	Vacuum Regulator Assembly		1		14		
	Vacuum Regulator Valve			1	8		MMC 4616K31
	Misc. Fittings			1	6		Memo 4/25/97
D2-7000-1	**Pedestal**	1			3815	3815	QTN-997-04, 10/2/97, SFI
D2-7000-2	Pedestal Shipping	1			0		included in quote

JVP Phase 2 Dish/Stirling System Cost Estimate

Commercial Production Scenario

Changes from Single-Unit Build as noted

$ 97,302 Total Cost

Component	Cost	Sub-Total	Basis
Dish Concentrator		$ 43,398	
Dish Materials	$ 35,367		see detail sheet
Fabrication Labor	$ 7,430		see detail sheet
Fabrication Supervision	$ 600		-50% for efficiency
PCS Cost	$ 36,000	$ 36,000	-80% for volume production
Installation Costs		$ 11,904	
Soil Samples	$ 200		-80% for efficiency, simplified designs
Soil Analysis	$ 400		-80% for efficiency, simplified designs
Drill Hole and Set Pedestal	$ 1,500		-50% for efficiency, simplified designs
Wiring to Pedestal	$ 1,200		-20% for efficiency, simplified designs
Boom Truck Rental	$ 800		-50% for efficiency, simplified designs
Crane to Install System	$ 400		-50% for efficiency, simplified designs
Installation Labor	$ 5,904		see detail sheet
Installation Supervision	$ 1,500		-50% for efficiency, less supervision needed
Engineering		$ 3,000	
Foundation Design	$ 1,000		-50% for simplified designs
Electrical Interface Design	$ 1,000		-50% for simplified designs
Planning and Permits	$ 1,000		-50% for simplified designs
Overhead		$ 3,000	
Project Management	$ 500		-50% for less supervision needed
Bookkeeping	$ 1,000		-50% for less supervision needed
Purchasing	$ 1,500		-50% for volume purchasing

JVP Phase 2 Dish Materials Cost Estimate

Commercial Production Scenario

Modifications from 5-Unit Build costs

Total System Cost $ 35,367

Part Number/ Assembly Level	Description	Quantity Required/ Assembly Level System	Assy	Sub-Assy	Unit Cost	Total Cost	Cost Basis
D2-0101-1	**Drive Unit**	1			4511	4511	
D2-0101-?	Flenders Drive		1		3750		-50% for advanced drive
D2-0101-?	Drive Motors		2		125		
D2-0101-?	Encoders		2		150		
D2-0101-?	Limit Switches		4		12		
D2-0101-?	Junction Box		1		64		
D2-0101-?	Misc. Hardware		1		100		
D2-0130-1	**Spool Plate, Pedestal-to-Drive**	1			560	560	-30% for volume purchase
D2-0???-?	**Assembly Hardware**	1			350	350	-30% for volume purchase
D2-1000-1	**Hub/Transition**	1			6577	7977	-30% for volume purchase
	Hub Shipping	1			1400		-30% for volume purchase
D2-2000-1	**Trusswork**	1			6308	6308	-30% for volume purchase
D2-2100-1	Radial Truss Assembly		6		387		
D2-2200-1	Circumferential Truss Assembly		5		424		
D2-2300-1	Long Cantilever Truss Assembly		10		197		
D2-2400-1	Short Cantilever Truss Assembly		2		162		
D2-2500-1	Truss Brackets		6		246		
	Shipping to Golden		1		800		
D2-3100 and D2-3200	**PCS Arm**	1			3881	4441	-30% for volume purchase
?	Shipping to Golden	1			560		-30% for volume purchase
D2-4000-1	**Mirror Facet**	16			436	6975	-30% for volume purchase
D2-4000-2	Facet Trim		66		0.26		
D2-4001-1	Mirror Tile Set		1		250		

D2-4000-10	Mirror Adhesive		1		43		
D2-4100-1	Facet Ring Assembly		1		168		
D2-41??-?	Facet Ring Segments			4	30		
D2-41??-?	Mounting Brackets			3	11		
D2-41??-?	Captive Nut			3	5		
D2-4200-1	Membrane Assembly		2		43		
D2-42??-?	201 SS foil			9	4.76		
D2-4300-1	Facet Focus Control Assembly		1		59		
D2-5000-1	**Control System**	1			1044	1044	-30% for volume purchase
D2-5100	Control Box Assembly		1		594		
D2-51??-?	Enclosure			1	100		
D2-51??-?	Little PLC Controller			1	183		
D2-51??-?	Little PLC ADC-4 Expansion Board			1	95		
D2-51??-?	Solid-State Relays			3	13		
D2-51??-?	Reversing Relays (3PDT)			2	19		
D2-51??-?	24 VDC Power Supply			1	40		
D2-51??-?	Connectors			1	50		
D2-51??-?	Misc. Parts			1	50		
D2-5???-?	Sun Sensor		1		200		
D2-5???-?	Signal Wiring		1		100		
D2-5???-?	Power Wiring		1		200		
D2-5???-?	NEMA 3R 60Amp Disconnect		1		398		
D2-6000-1	**Focus Control System**	1			532	532	-30% for volume purchase
D2-6100-1	Focus Blower Assembly		1		409		
D2-61??-?	Blower - Gast R1102			1	265		
D2-61??-?	Defocus Valve			1	122		
D2-61??-?	Check Valve			1	9		
D2-61??-?	Misc. Fittings			1	13		
D2-6???-?	Flex Hoses		300		1		
D2-6???-?	Vacuum Regulator Assembly		1		14		
	Vacuum Regulator Valve			1	8		
	Misc. Fittings			1	6		
D2-7000-1	**Pedestal**	1			2671	2671	-30% for volume purchase
D2-7000-2	Pedestal Shipping	1			0		

JVP Phase 2 Dish/Stirling System Labor Estimate

Commercial Production Scenario

Fabrication hours reduced 40% from Single-Unit Build

Installation hours reduced 20% from Single-Unit Build

Labor Rate Reduced 40% from Single-Unit Build

$ 36 Loaded Labor Rate

Assembly/Task	Man-hrs	Qty Req'd	Cost	Total Cost $ 13,334
Fabrication Labor				$ 7,430
Drive System				
Wire Drive Motors & Limits	24	1	864	
Attach Spool Plate to Drive	2.4	1	86.4	
Inner PCS Arm				
Fabricate Latch	1.2	1	43.2	
Assemble Latch	1.2	1	43.2	
Mirror Facets				
Manufacture Mirror Facet	7.2	16	4147.2	
Apply Mirrors	2.4	16	1382.4	
Controls				
Assemble Control Box	12	1	432	
Assemble Blower Assembly	12	1	432	
Installation Labor				$ 5,904
Pedestal				
Install Pedestal	3.2	1	115.2	
Drive				
Attach to Hub	3.2	1	115.2	
Install System on Pedestal	6.4	1	230.4	
Trusswork				
Assemble Radial Trusses	2.4	6	518.4	
Assemble Circumferential Trusses	2.4	5	432	
Assemble Cantilever Trusses	2.4	12	1036.8	
PCS Support Arm				
Attach Outer Arm to Inner Arm	3.2	1	115.2	
Install on Hub	3.2	1	115.2	
Mirror Facets				
Install Facets	1.6	16	921.6	
Adjust Facets	16	1	576	
Controls				
Wire Control Box on Pedestal	16	1	576	
Wire Focus Control	3.2	1	115.2	
Wire Arm Latch	3.2	1	115.2	
Wire Sun Sensor	3.2	1	115.2	
Wire PCS	3.2	1	115.2	
Install Focus Control Blower	3.2	1	115.2	
Install Focus Control Hoses	16	1	576	

JVP Phase 2 System Cost Projections

			First Batch		Following Batches				Commercial Scenario		Projection with 90% learning curve	
Production Run Quantity ->	1		5		5		50		150		500	
	Cost	Sub-Total	Cost		Cost		Cost		Cost		Cost	
Dish Concentrator		$ 76,092		$ 71,998		$ 69,814		$ 57,161		$ 43,398		$ 34,524
Dish Materials	54252		52342		52342		41873		35367		28136	
Fabrication Labor	20640		18576		16512		14448		7430		5911	
Fabrication Supervision	1200		1080		960		840		600		477	
PCS Cost	180000	$180,000	180000	$ 180,000	180000	$ 180,000	125000	$ 125,000	36000	$ 36,000	28639	$ 28,639
Installation Costs		$ 25,200		$ 21,030		$ 19,260		$ 16,950		$ 11,904		$ 9,002
Soil Samples	1000		200		200		20		4		3	
Soil Analysis	2000		400		400		40		8		6	
Drill Hole and Set Pedestal	3000		3000		3000		3000		1500		1193	
Wiring to Pedestal	1500		1500		1500		1500		1200		955	
Boom Truck Rental	1600		1440		1280		1120		800		636	
Crane to Install System	800		720		640		560		400		318	
Installation Labor	12300		11070		9840		8610		5904		4697	
Installation Supervision	3000		2700		2400		2100		1500		1193	
Engineering		$ 6,000		$ 1,200		$ 1,200		$ 120		$ 60		$ 48
Foundation Design	2000		400		400		40		20		16	
Electrical Interface Design	2000		400		400		40		20		16	
Planning and Permits	2000		400		400		40		20		16	
Overhead		$ 6,000		$ 5,400		$ 4,800		$ 4,200		$ 3,000		$ 2,387
Project Management	1000		900		800		700		500		398	
Bookkeeping	2000		1800		1600		1400		1000		796	
Purchasing	3000		2700		2400		2100		1500		1193	
Installed System Cost		$293,292		$ 279,628		$ 275,074		$ 203,431		$ 94,362		$ 74,599
Management and Marketing	200000	$200,000	100000	$ 100,000	80000	$ 80,000	15000	$ 15,000	6667	$ 6,667	2000	$ 2,000
Engineering, General	200000	$200,000	100000	$ 100,000	80000	$ 80,000	12000	$ 12,000	5000	$ 5,000	1500	$ 1,500
Capital Equipment	0	$ -	0	$ -	0	$ -	0	$ -	14667	$ 14,667	3302	$ 3,302
Facilities Cost	0	$ -	0	$ -	0	$ -	0	$ -	2000	$ 2,000	1200	$ 1,200
Warrantee Cost (15% of Installed Cost)		$ 43,994		$ 41,944		$ 41,261		$ 30,515		$ 14,154		$ 11,190
Loaded System Cost		$737,285		$ 521,572		$ 476,335		$ 260,946		$ 136,849		$ 93,791
Profit (15% of Loaded System Cost)		$110,593		$ 78,236		$ 71,450		$ 39,142		$ 20,527		$ 14,069
System Selling Price		$847,878		$ 599,808		$ 547,785		$ 300,088		$ 157,377		$ 107,860

50-unit Amortization for installation, testing, engineering

First Batch: 90% Labor factor; 5 Amortization factor

Following Batches (5): 80% Labor factor; 5 Amortization factor

Following Batches (50): 70% Labor factor; 50 unit Amortization factor; 80% Material factor; PCS cost from Phase 3 ROM

Commercial Scenario: $2.2 million capital eqpt.

Projection with 90% learning curve: $1.65 million additional capital eqpt.

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

INTEROFFICE MEMORANDUM

DATE: May 21, 1998

TO: Distribution

FROM: Kelly Beninga
Golden, CO, Location 719

SUBJECT: Updated Costing for PNM Dish/Stirling Project - 40 and 68 Units

---

I have revised the project cost estimates for both the 40 and 68 unit projects in order to eliminate some redundancy and trim costs where possible. Although the cost of SAIC's portion of the project has gone down, the total cost has gone up because I used STM's latest verbal quote ($114k rather than $98k each for 40 PCS units). The project price is shown below. More detail on this estimate is attached.

	40 Units	68 Units
Total Project Price	$14,059,728	$21,389,740
Price per System	$351,493	$314,555

New assumptions used in this estimate are shown below:

- No central electrical equipment, wiring, or transmission lines are included here. It is assumed these costs are included elsewhere.
- The advanced drive costs have been elliminated.
- The length of the schedule has been reduced to allow completion of the project by the end of 1999 (40 units) and by July 2000 (68 units). To accomplish this, facet fabrication is started sooner, and may also require a 2nd production shift. More people were added to the installation team to complete installation in a shorter time period.
- The only project management charging this project will be directly related to building and installing systems.
- Engineering/QA support has been reduced.
- The dish material costs have gone up based on updated price information.
- The PCS price has gone up. We still do not have a written quote.

Original assumptions which are still used in this estimate are shown below:

- All components and subcontracts for 40 units are purchased at project initiation, and delivered/installed over the course of a year. Breaking up the purchases to smaller quantities will increase the price.
- The PCS price is for solar-only units.
- This estimate includes no money for dish design improvement. Improvements in manufacturing equipment are included to the extent that they will pay for themselves over the course of this project. I assume we will have a larger production facility for the project.
- A 15% of system cost factor was used to estimate the warranty cost. This will be inadequate if we have to warrant the performance of the system over the contract length.
- This is not a division coverage plan. Some people will only be partially covered or totally uncovered by this project.
- This is not costed as Phase III of USJVP. Sandia will require additional activities (such as reporting) that are not included here.
- All labor costs are based on JVP Phase II actuals with a 20% reduction factor for 40 units, and a 25% reduction factor for 68 units. No escalation is included.
- All materials costs are based on JVP Phase II actuals with a volume purchase reduction factor (20% for 40 units, 25% for 68 units), unless new quotes for the proper quantity have been received.

Attachments (for both 40 and 68 units):
1 - Project Cost Summary
2 - MS Project Resource Loaded Schedule
3 - Dish/Stirling System SAIC Production Labor Man-hrs
4 - Project ODC's and Small Subcontracts
5 - Non-recurring Capital Equipment Costs
6 - SAIC Dish Bill of Materials

Distribution: Barry Butler, Brian Hays, Rob Taylor, Tom Mullen, Corrie Garrow, Sheila Marble, Roger Davenport, Mike Taylor, Bud Brittingham, Elizabeth Rosenbeck

Attachment 1

PNM Project Cost Summary - 40 Dish/Stirling Systems

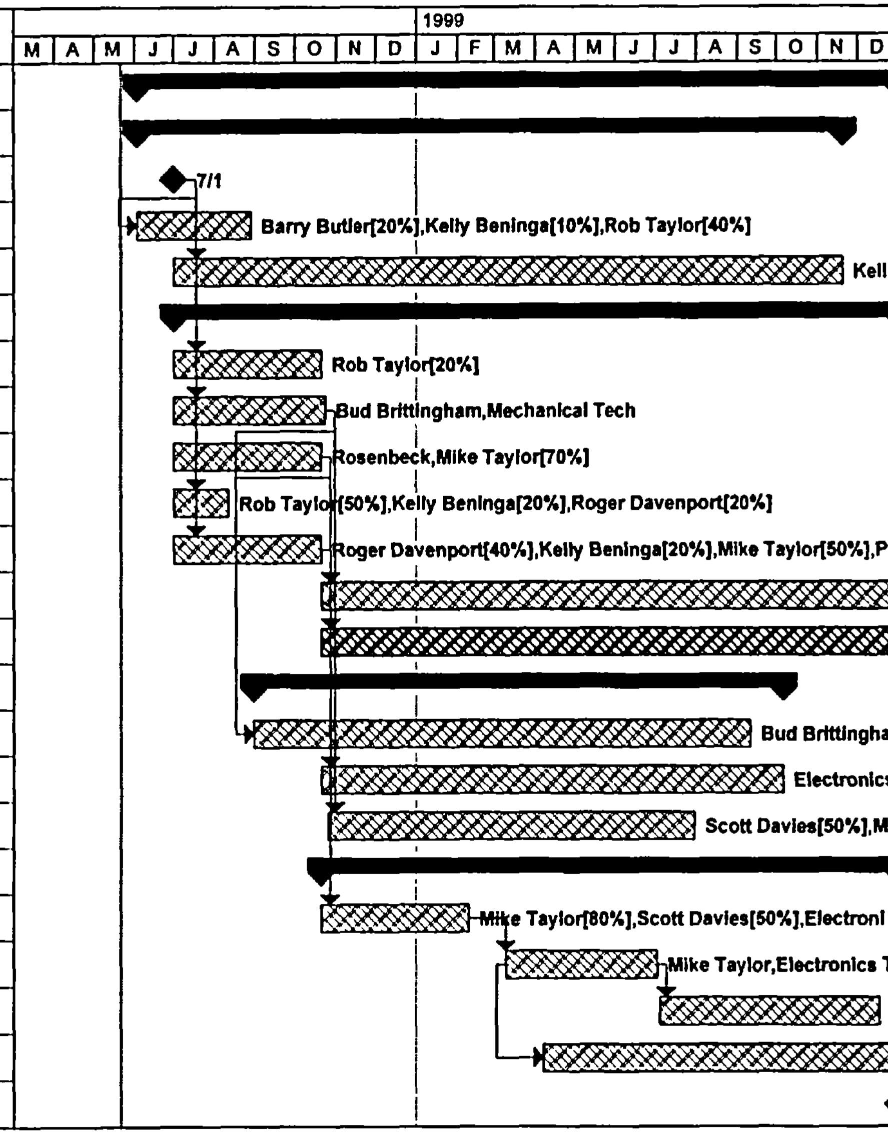
5/21/98

Item	Project Cost		Cost/system		Reference
SAIC Labor					
Project Management	$	343,106	$	8,578	Attachment 2
Non-recurring Engineering	$	419,161	$	10,479	Attachment 2
SAIC Dish Fabrication Labor	$	601,600	$	15,040	Attachment 2,3
System Installation and Checkout Labor	$	679,311	$	16,983	Attachment 2,3
SAIC Labor Subtotal	**$**	**2,043,178**	**$**	**51,079**	
Materials, Subcontracts, ODCs					
Dish Materials	$	2,719,160	$	67,979	Attachment 6
Power Conversion System (PCS)	$	4,560,000	$	114,000	verbal quote - revised
Spare Parts	$	545,937	$	13,648	
ODCs and Small Subcontracts	$	560,500	$	14,013	Attachment 4
Capital Equipment	$	386,400	$	9,660	Attachment 5
Subtotal	**$**	**8,771,997**	**$**	**219,300**	
Total Cost	**$**	**10,815,175**	**$**	**270,379**	
Warranty Cost @ 15%		1,622,276	$	40,557	
Profit @ 15%		1,622,276		40,557	
Total Price	**$**	**14,059,728**	**$**	**351,493**	

Attachment 2

PNM Dish/Stirling Project

ID	Work	Labor Cost	WBS	Task Name
1	**45,811.2 hrs**	**$2,043,178**	**1**	**Total SAIC Project Labor**
2	**3,278.4 hrs**	**$343,106**	**1.1**	**Management**
3	0 hrs	$0	1.1.1	Energy Purchase Agreement
4	352 8 hrs	$46,149	1.1 2	IPP Negotiations
5	2,925 6 hrs	$296,957	1.1.3	Project Management
6	**6,875.2 hrs**	**$419,161**	**1.2**	**Non-Recurring Engineering**
7	128 hrs	$14,197	1.2.1	Permitting
8	1,328 hrs	$59,561	1.2 2	Manufacturing Upgrades
9	1,088 hrs	$55,201	1.2 3	Vendor Negotiations
10	216 hrs	$23,202	1 2 4	Land/Interconnection Negotiations
11	2,112 hrs	$125,938	1.2 5	Site Plan/Electrical Interface Design
12	0 hrs	$0	1 2 6	Advanced Drive Development
13	2,003 2 hrs	$141,063	1.2 7	QA/Engineering Support
14	**17,104 hrs**	**$601,600**	**1.3**	**SAIC Manufacturing**
15	12,204 hrs	$446,040	1 3 1	Facet Manufacturing - see detail sheet
16	3,300 hrs	$99,000	1.3 2	Controls/Electrical Fabrication
17	1,600 hrs	$56,560	1 3 3	Miscellaneous Fabrication
18	**18,553.6 hrs**	**$679,311**	**1.4**	**Installation and Checkout**
19	1,472 hrs	$67,813	1.4.1	Site Preperation
20	2,988 hrs	$105,317	1 4 2	Phase I Installation (10 units) - see detail sheet
21	6,528 hrs	$205,219	1 4.3	Phase II Installation (30 units) - see detail sheet
22	7,565 6 hrs	$300,961	1 4 4	Checkout Testing
23	0 hrs	$0	1 4 5	Acceptance Test



Kelly Beninga
Project. PNM Fourty Dish Project
Date: Thu 5/21/98 Kelly Beninga

Task	Milestone	Rolled Up Split	External Tasks
Split	Summary	Rolled Up Milestone	Project Summary
Progress	Rolled Up Task	Rolled Up Progress	

Attachment 3

PNM 40 Dish/Stirling Systems SAIC Production Labor Estimate

5/21/98

Assembly/Task	Man-hrs/Unit from JVP Phase II	Fourty System Quantity Required	Total Man-hrs	*Total Man-hrs @ 80%
Facet Production Labor				
Inspect Segments	0.5	640	320	256
Grind ends of flanges	0.75	640	480	384
Load in welding fixture	0.75	640	480	384
Weld ring	1.5	640	960	768
Weld Brackets	1	640	640	512
Install focus control	0.5	640	320	256
Surface preparation	1	640	640	512
Clean ring	0.5	640	320	256
Load ring in tension fixture	0.75	640	480	384
Track welding heads	0.5	640	320	256
Weld Membranes	2	640	1280	1024
Cut membranes	1	640	640	512
Tension Membranes	1	640	640	512
Weld Membranes to ring	0.5	640	320	256
Remove from fixture	0.5	640	320	256
Apply lip trim	0.5	640	320	256
QA Measurement	0.75	640	480	384
Mirror Washing	1	640	640	512
Adhesive lamination	1.5	640	960	768
Mirror Install	3	640	1920	1536
Store Facets	0.5	640	320	256
Supervision	4	640	2560	2048
Facet Subtotal	**24**	**14080**	**15360**	**12288**
Dish controls assembly				
Dish control board/box	40	40	1600	1280
Motor encoder	4	80	320	256
Interface board/box	40	40	1600	1280
Sun Sensor	8	40	320	256
Cabling	8	40	320	256
Controls Subtotal	**100**	**240**	**4160**	**3328**
Miscellaneous				
Drive System				
Wire Drive Motors & Limits	16	40	640	512
Attach Spool Plate to Drive	4	40	160	128
Inner PCS Arm				
Fabricate Latch	2	80	160	128
Assemble Latch	2	80	160	128
Assemble Blower Assembly	20	40	800	640
Miscellaneous Subtotal	**44**	**280**	**1920**	**1536**

Installation Labor				
Installation Planning	400	2	800	640
Offload Truck	6	40	240	192
Set Pedestal	6	40	240	192
Set hub and hardware	12	40	480	384
Install Circumfrential Trusses	15	40	600	480
Install Vacuum System	6	40	240	192
Facet Installation	15	40	600	480
Attach drive to hub	4	40	160	128
Inner/outer support arms	6	40	240	192
Attach control box	4	40	160	128
Hang dish on pedestal	12	40	480	384
Power wiring to drive	2	40	80	64
Wire Control Box on Pedestal	20	40	800	640
Wire Focus Control	7	40	280	224
Wire Arm Latch	5	40	200	160
Wire Sun Sensor	5	40	200	160
Wire PCS	10	40	400	320
Wire Junction Boxes	10	40	400	320
Install Conduit	10	40	400	320
Pull wires	10	40	400	320
Install Hydrogen Line	5	40	200	160
Natural Gas Equipment	8	40	320	256
Controls Checkout	10	40	400	320
Install Alignment Equipment	4	40	160	128
Alignment	12	40	480	384
Remove Alignment Equipment	4	40	160	128
Tracking checkout	24	40	960	768
Install PCS	9	40	360	288
PCS operation checkout	30	40	1200	960
Install transformer	80	1	80	64
Install Grid Protection	100	1	100	80
Installation Subtotal	**851**	**1124**	**11820**	**9456**
TOTAL			**33260**	**26608**

* 80% labor reduction factor for 40 unit production

Attachment 4

5/21/98

PNM Project ODCs and Small Subcontracts - 40 Syst

	Quantity	Cost/Unit	Total Cost
Travel			
Denver - Albuquerque	30	$ 1,550	$ 46,500
San Diego - Albuquerque	5	$ 1,700	$ 8,500
San Diego - Denver	5	$ 1,700	$ 8,500
Shipping	40	$ 3,100	$ 124,000
Site Work			
Grading and fencing	1	$ 50,000	$ 50,000
Soil Samples	1	$ 1,000	$ 1,000
Soil Analysis	1	$ 2,000	$ 2,000
Pedestal hole, foundation	40	$ 4,500	$ 180,000
Crane Rental	1	$ 80,000	$ 80,000
Wiring to Pedestal	40	$ 1,500	$ 60,000
Grid Connection work	1	$ -	$ -
TOTAL		$ 147,050	$ 560,500

Attachment 5

5/21/98

PNM Project Non-recurring Capital Equipment - 40 Systems

Equipment	Quantity	Cost/Unit	Total Cost
Site Equipment			
Transformer (5 MW)	1	$ -	$ -
Grid Protection Panel	1	$ -	$ -
Electric Switchgear	1	$ -	$ -
Control/DAS Computers	2	$ 2,000	$ 4,000
Meters	2	$ 1,500	$ 3,000
Control Room	1	$ 20,000	$ 20,000
Maintenance Building	1	$ 30,000	$ 30,000
Water/Sewer	1	$ 40,000	$ 40,000
Facet Tooling			
Facet Cleaning Station	1	$ 20,000	$ 20,000
Glass Lamination Tooling	1	$ 25,000	$ 25,000
Ring Welding Fixture	1	$ 25,000	$ 25,000
Ring Roll Former	1	$ 35,000	$ 35,000
Membrane-Ring weld upgrades	1	$ 59,400	$ 59,400
Installation Equipment			
Alignment Equipment	1	$ 20,000	$ 20,000
Fork Lift	1	$ 20,000	$ 20,000
Man-Lift	2	$ 40,000	$ 80,000
Saftey Equipment	1	$ 5,000	$ 5,000
Totals		$ 342,900	$ 386,400

Attachment 1.

PNM Project Cost Summary - 68 Dish/Stirling Systems

5/21/98

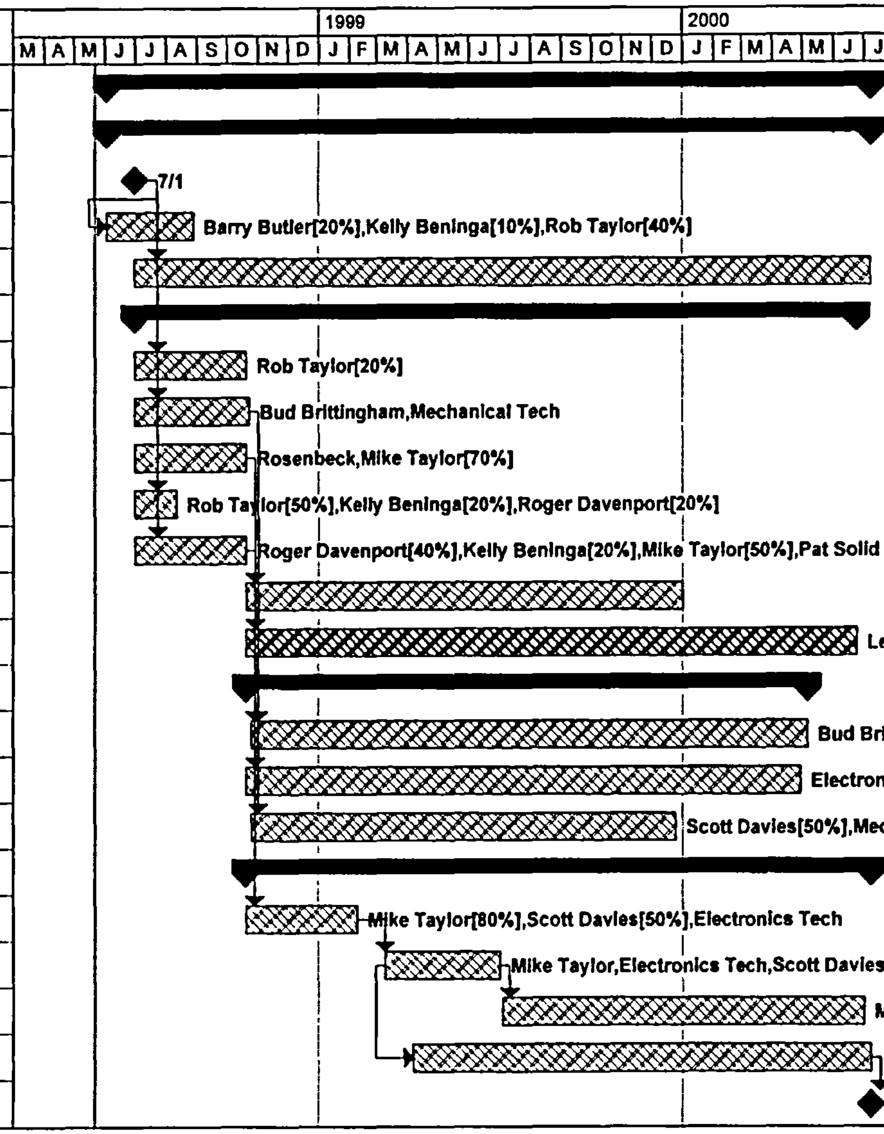
Item	Project Cost		Cost/system		Reference
SAIC Labor					
Project Management	$	462,358	$	6,799	Attachment 2
Non-recurring Engineering	$	475,496	$	6,993	Attachment 2
SAIC Dish Fabrication Labor	$	904,662	$	13,304	Attachment 2,3
System Installation and Checkout Labor	$	1,190,050	$	17,501	Attachment 2,3
SAIC Labor Subtotal	**$**	**3,032,566**	**$**	**44,597**	
Materials, Subcontracts, ODCs					
Dish Materials	$	4,333,640	$	63,730	Attachment 6 - 75% of Phas
Power Conversion System (PCS)	$	7,344,000	$	108,000	verbal quote - prorated (revi
Spare Parts	$	515,190	$	12,880	
ODCs and Small Subcontracts	$	885,350	$	13,020	Attachment 4
Capital Equipment	$	342,900	$	5,043	Attachment 5
Subtotal	**$**	**13,421,080**	**$**	**202,672**	
Total Cost	**$**	**16,453,646**	**$**	**247,269**	
Warranty Cost @ 15%		2,468,047	$	36,295	
Profit @ 15%		2,468,047		37,090	
Total Price	**$**	**21,389,740**	**$**	**314,555**	

Quantity = 68.00

Attachment 2

PNM Dish/Stirling Project

ID	Work	Labor Cost	WBS	Task Name
1	**70,720.8 hrs**	**$3,032,565**	**1**	**Total SAIC Project Labor**
2	**4,466.4 hrs**	**$462,358**	**1.1**	**Management**
3	0 hrs	$0	1.1.1	Energy Purchase Agreement
4	352 8 hrs	$46,149	1.1.2	IPP Negotiations
5	4,113 6 hrs	$416,209	1.1.3	Project Management
6	**7,291.2 hrs**	**$475,496**	**1.2**	**Non-Recurring Engineering**
7	128 hrs	$14,197	1 2 1	Permitting
8	1,328 hrs	$59,561	1.2 2	Manufacturing Upgrades
9	1,088 hrs	$55,201	1.2.3	Vendor Negotiations
10	216 hrs	$23,202	1 2 4	Land/Interconnection Negotiations
11	1,728 hrs	$125,938	1.2 5	Site Plan/Electrical Interface Design
12	0 hrs	$0	1.2 6	Advanced Drive Development
13	2,803 2 hrs	$197,398	1.2.7	QA/Engineering Support
14	**25,773.6 hrs**	**$904,662**	**1.3**	**SAIC Manufacturing**
15	18,080 hrs	$660,800	1.3.1	Facet Manufacturing - see detail sheet
16	5,253 6 hrs	$157,608	1 3 2	Controls/Electrical Fabrication
17	2,440 hrs	$86,254	1 3 3	Miscellaneous Fabrication
18	**33,189.6 hrs**	**$1,190,050**	**1.4**	**Installation and Checkout**
19	1,472 hrs	$67,813	1.4.1	Site Preperation
20	2,988 hrs	$105,317	1.4 2	Phase I Installation (10 units) - see detail sheet
21	14,560 hrs	$452,962	1.4.3	Phase II Installation (58 units) - see detail sheet
22	14,169 6 hrs	$563,958	1 4 4	Checkout Testing
23	0 hrs	$0	1.4 5	Acceptance Test



Kelly Beninga
Project PNM 68 Dish Project
Date: Thu 5/21/98 Kelly Beninga

Task		Milestone		Rolled Up Split		External Tasks	
Split		Summary		Rolled Up Milestone		Project Summary	
Progress		Rolled Up Task		Rolled Up Progress			

Attachment 3

PNM 68 Dish/Stirling Systems SAIC Production Labor Estimate

5/21/98

Assembly/Task	Man-hrs/Unit from JVP Phase II	68 System Quantity Required	Total Man-hrs	*Total Man-hrs @75%
Facet Production Labor				
Inspect Segments	0.5	1088	544	408
Grind ends of flanges	0.75	1088	816	612
Load in welding fixture	0.75	1088	816	612
Weld ring	1.5	1088	1632	1224
Weld Brackets	1	1088	1088	816
Install focus control	0.5	1088	544	408
Surface preparation	1	1088	1088	816
Clean ring	0.5	1088	544	408
Load ring in tension fixture	0.75	1088	816	612
Track welding heads	0.5	1088	544	408
Weld membranes	2	1088	2176	1632
Cut membranes	1	1088	1088	816
Tension Membranes	1	1088	1088	816
Weld Membranes to ring	0.5	1088	544	408
Remove from fixture	0.5	1088	544	408
Apply lip trim	0.5	1088	544	408
QA Measurement	0.75	1088	816	612
Mirror Washing	1	1088	1088	816
Adhesive lamination	1.5	1088	1632	1224
Mirror Install	3	1088	3264	2448
Store Facets	0.5	1088	544	408
Supervision	4	1088	4352	3264
Facet Subtotal	**24**	**23936**	**26112**	**19584**
Dish controls assembly				
Dish control board/box	40	68	2720	2040
Motor encoder	4	136	544	408
Interface board/box	40	68	2720	2040
Sun Sensor	8	68	544	408
Cabling	8	68	544	408
Controls Subtotal	**100**	**408**	**7072**	**5304**
Miscellaneous				
Drive System				
Wire Drive Motors & Limits	16	68	1088	816
Attach Spool Plate to Drive	4	68	272	204
Inner PCS Arm				0
Fabricate Latch	2	136	272	204
Assemble Latch	2	136	272	204
Assemble Blower Assembly	20	68	1360	1020
Miscellaneous Subtotal	**44**	**476**	**3264**	**2448**

Installation Labor				
Installation Planning	400	2	800	600
Offload Truck	6	68	408	306
Set Pedestal	6	68	408	306
Set hub and hardware	12	68	816	612
Install Circumfrential Trusses	15	68	1020	765
Install Vacuum System	6	68	408	306
Facet Installation	15	68	1020	765
Attach drive to hub	4	68	272	204
Inner/outer support arms	6	68	408	306
Attach control box	4	68	272	204
Hang dish on pedestal	12	68	816	612
Power wiring to drive	2	68	136	102
Wire Control Box on Pedestal	20	68	1360	1020
Wire Focus Control	7	68	476	357
Wire Arm Latch	5	68	340	255
Wire Sun Sensor	5	68	340	255
Wire PCS	10	68	680	510
Wire Junction Boxes	10	68	680	510
Install Conduit	10	68	680	510
Pull wires	10	68	680	510
Install Hydrogen Line	5	68	340	255
Natural Gas Equipment	8	68	544	408
Controls Checkout	10	68	680	510
Install Alignment Equipment	4	68	272	204
Alignment	12	68	816	612
Remove Alignment Equipment	4	68	272	204
Tracking checkout	24	68	1632	1224
Install PCS	9	68	612	459
PCS operation checkout	30	68	2040	1530
Install transformer	80	1	80	60
Install Grid Protection	100	1	100	75
Installation Subtotal	**851**	**1908**	**19408**	**14556**
TOTAL			**55856**	**41892**

* 75% labor reduction factor for 68 unit production

Attachment 4

PNM Project ODCs and Small Subcontracts - 68 Units

	Quantity	Cost/Unit	Total Cost
Travel			
Denver - Albuquerque	45	$ 1,550	$ 69,750
San Diego - Albuquerque	7	$ 1,700	$ 11,900
San Diego - Denver	7	$ 1,700	$ 11,900
Shipping	68	$ 3,100	$ 210,800
Site Work			
Grading and fencing	1	$ 50,000	$ 50,000
Soil Samples	1	$ 1,000	$ 1,000
Soil Analysis	1	$ 2,000	$ 2,000
Pedestal hole, foundation	68	$ 4,500	$ 306,000
Crane Rental	1	$ 120,000	$ 120,000
Wiring to Pedestal	68	$ 1,500	$ 102,000
Grid Connection work	1	$ -	$ -
TOTAL		$ 187,050	$ 885,350

Attachment 5

5/21/98

PNM Project Non-recurring Capital Equipment - 68 Systems

Equipment	Quantity	Cost/Unit	Total Cost
Site Equipment			
Transformer (5 MW)	1	$ -	$ -
Grid Protection Panel	1	$ -	$ -
Electric Switchgear	1	$ -	$ -
Control/DAS Computers	2	$ 2,000	$ 4,000
Meters	2	$ 1,500	$ 3,000
Control Room	1	$ 20,000	$ 20,000
Maintenance Building	1	$ 30,000	$ 30,000
Water/Sewer	1	$ 40,000	$ 40,000
Facet Tooling			
Facet Cleaning Station	1	$ 20,000	$ 20,000
Glass Lamination Tooling	1	$ 25,000	$ 25,000
Ring Welding Fixture	1	$ 25,000	$ 25,000
Ring Roll Former	1	$ 35,000	$ 35,000
Membrane-Ring weld upgrades	1	$ 59,400	$ 59,400
Installation Equipment			
Alignment Equipment	1	$ 20,000	$ 20,000
Fork Lift	1	$ 20,000	$ 20,000
Man-Lift	2	$ 40,000	$ 80,000
Saftey Equipment	1	$ 5,000	$ 5,000
Totals		$ 342,900	$ 386,400