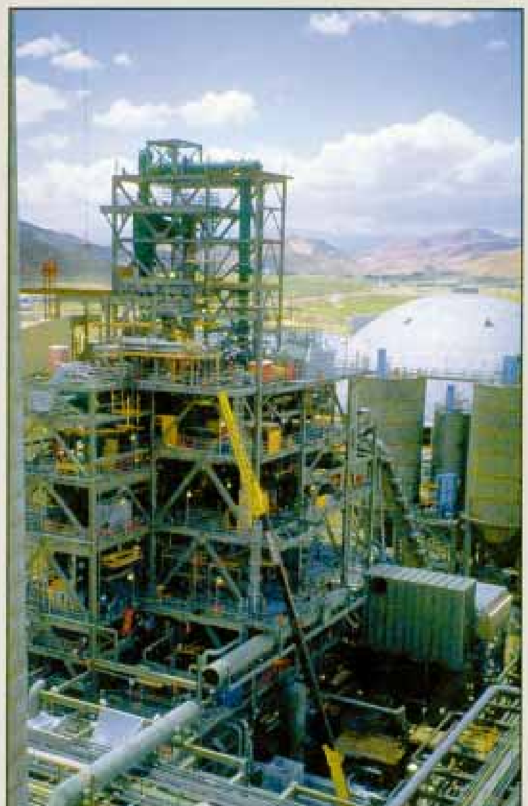
TOPICAL REPORT NUMBER 8

DECEMBER 1996

CLEAN COAL TECHNOLOGY



The Piñon Pine Power Project

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Demonstration of an Advanced Integrated Gasification Combined Cycle Power Plant

A report on a project conducted jointly under
a cooperative agreement between:

The U.S. Department of Energy and Sierra Pacific Power Company

Sierra Pacific
POWER COMPANY

Cover image: Photo of the Piñon Pine Power Project during construction.

Preparation and printing of this document conforms to the general funding provisions of a cooperative agreement between Sierra Pacific Power Company and the U.S. Department of Energy. The funding contribution of the industrial participant permitted inclusion of multicolored artwork and photographs at no additional expense to the U.S. Government.

CLEAN COAL TECHNOLOGY

The Piñon Pine Power Project

Introduction and Executive Summary

Coal is America's most abundant fossil fuel. Its combustion creates the steam that produces 65 percent of this country's electricity. The burning of coal, however, liberates two types of gases that have been linked to the formation of acid rain: nitrogen oxides (NO_X) and sulfur dioxide ($S0_2$).

With the passage of each successive piece of clean air legislation over the years, the electric utility industry has been made increasingly aware that it would eventually have to reduce both types of emissions from existing and new power plants to environmentally acceptable levels.

The Clean Coal Technology (CCT) Demonstration Program is a government and industry co-funded program to furnish the U.S. energy marketplace with advanced, more efficient and environmentally responsible coal-utilizing technologies.

A multi-phased effort consisting of five separate solicitations was administered by the U.S. Department of Energy (DOE). Projects selected are a new generation of innovative coal utilization processes that are being demonstrated in "showcase" projects conducted across the country.

These projects are on a scale sufficiently large to demonstrate commercial worthiness and generate data for design, construction, operation and technical/economic evaluation of full-scale commercial applications.

Integrated Gasification Combined Cycle

Among the technologies being demonstrated in the CCT program is Integrated Gasification Combined Cycle (IGCC). IGCC is an innovative electric power generation technology that combines modern coal gasification with gas turbine and steam power generation technologies. Fuel gas produced by a gasifier is cleaned and burned in a gas turbine to produce electric power. Heat recovered from the hot turbine's exhaust produces steam that turns a steam turbine generator to produce more electricity.

IGCC power plants are environmentally acceptable and easily sited. Atmospheric emissions of pollutants are low. Water use is lower than conventional coal-based generation because gas turbine units require no cooling water, an especially important consideration in areas of limited water resources.

Due to their high efficiency, less coal is used per megawatt-hour of output, causing IGCC power plants to emit less carbon dioxide ($C0_2$) to the atmosphere, thereby decreasing global warming concerns. Less coal use also reduces disposal requirements for ash or slag if there is no market for these materials.

Repowering is an excellent application for IGCC. Such applications utilize an existing power plant site and are more economical than greenfield applications Costs are lower because an existing steam turbine is used, less site development is required, and the permitting process is accelerated.

Both greenfield and repowering IGCC could provide the flexibility needed for utility compliance planning for $S0_2$ emissions in the next century. Providing 25 percent of coal-based electricity by IGCC would result in emissions of less than 0.4 million of the 11.8 million tons/yr of $S0_2$ allowable under the Clean Air Act Amendments (CAAA).

Modularity and fuel flexibility are other important attributes of IGCC power plants. Before the gasifier is constructed, the combined cycle unit can be operated on other fuels, such as natural gas or fuel oil, to provide early power. The size of gas turbine units can be chosen to meet specific power

IGCC Advantages

- A Clean Environment
- High Efficiency
- Low Cost Electricity
- Potential for Low Capital Costs
- Repowering of Existing Plants
- Modularity
- Fuel Flexibility
- Phased Construction
- Low Water Use
- Low $C0_2$ Emissions
- Public Acceptability

requirements. The ability to operate on multiple fuels allows continued operation of the gas turbine unit if the gasifier island is shut down for maintenance or repairs, or if warranted by fuel costs.

IGCC power plants use plentiful and relatively inexpensive coal as their fuel. In the United States there are several hundred years of reserves, and use of coal helps to reduce dependence on foreign oil.

IGCC has potential for significant reduction in capital costs over today's technologies, per kW of generation. These, in part, arise from higher possible efficiencies compared to today's impressive IGCC values.

Efficiency improvements are expected to result from design improvements which increase overall steam and thermal integration, use of higher firing temperature gas turbines, and other technology enhancements such as hot-gas cleanup. Other contributors to reduced capital costs are: economies of scale, reduced engineering costs, and improvements resulting from operating experience.

Executive Summary

The Participant in the Piñon Pine Power Project is Sierra Pacific Power Company (SPCCo), Reno, Nevada, whose service area is primarily northern Nevada and northeast California. The Project will demonstrate an advanced IGCC technology at SPPCo's Tracy Power Station near Reno.

In The Piñon Pine Power Project, a KRW fluidized bed gasifier will operate on low sulfur coal from southern Utah. With hot-gas cleanup technology, it will provide a clean hot fuel gas for an advanced General Electric gas turbine generator. Gas turbine exhaust heat will be recovered to produce steam for generation of additional electricity. The net power output is 99.7 MWe. The net design efficiency of this power plant is 40.7 percent, or a heat rate of 8390 Btu/kWh, higher heating value basis; this IGCC power plant is expected to be one of the most efficient coal-based power plants in the U.S.

KRW gasification technology has been shown to be applicable to a broad range of coal grades-from lignite to anthracite. It is the only gasification technology being demonstrated in the CCT program that uses air instead of oxygen in the gasification step. Use of air eliminates the need for an air separation plant.

Use of hot-gas cleanup permits delivery of a hot fuel gas to the gas turbine, thereby lessening the fuel required to provide the required gas turbine energy and enhancing the power plant efficiency. KRW's advanced hot-gas cleanup technology is expected to be as effective as conventional cold-gas cleanup, but at lower overall capital cost.

KRW coal gasification technology was initially developed by Westinghouse Electric Corporation. Westinghouse was succeeded by Kellogg Rust, Inc. in 1984. Ownership was subsequently retained by The M.W. Kellogg Company in 1986.

KRW gasification is based on pressurized fluidized bed technology proven at the Waltz Mill, Pennsylvania Process Development Unit (PDU). A full size cold flow scaleup facility provided additional information needed for design of commercial size gasifiers.

Major support for PDU operations was provided by DOE and its predecessor organizations; additional support was provided by the Gas Research Institute. DOE supported the cold flow studies.

An advanced General Electric model MS 6001FA gas turbine generator is used at The Piñon Pine Power Project. This is a scaled down version of an advanced larger model. It can also operate on natural gas. Exhaust gas is delivered to a heat recovery steam generator (HRSG) that produces steam for additional power generation.

The Piñon Pine IGCC power plant is expected to use about 20 percent less water than a conventional modern pulverized coal-burning power plant of the same output. This is a desirable feature, especially for this project located in arid, water-scarce Nevada.

No process waste water is produced for treatment or disposal, because there is no condensation of water from the fuel gas which is always at a temperature of at least 1000°F (538°C).

Various other effluents, such as boiler blowdown, cooling tower blowdown, and storm drains flow to the evaporation pond. No waste water is discharged from the site.

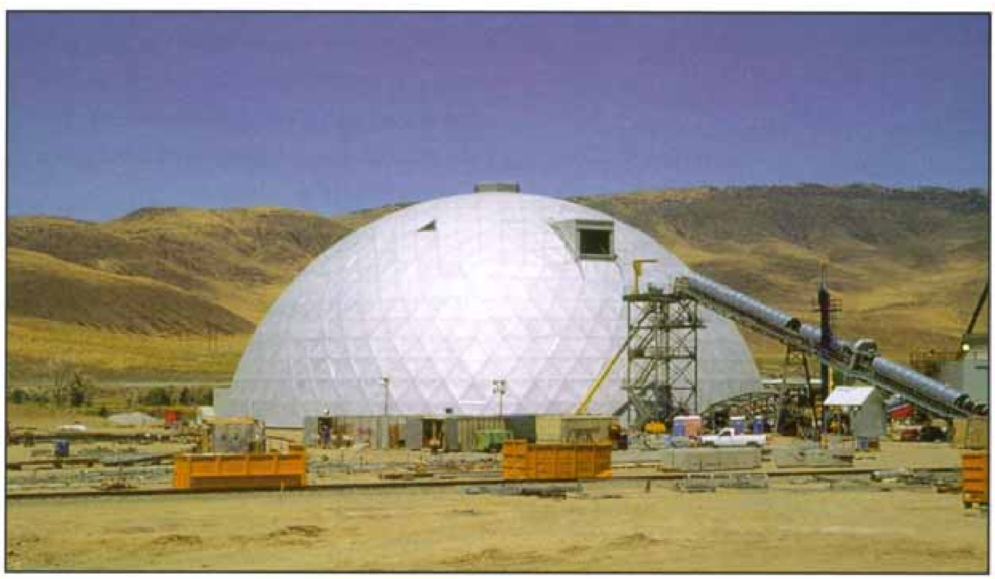
Solid waste produced will either be sold to the agricultural industry or the construction industry, or disposed of in a nearby private landfill.

The 42 month demonstration period is scheduled to begin in February 1997. Data will be obtained with respect to cost, performance, stack emissions, and operability, maintainability and reliability of the system. Improvements in this system are expected to be realized during the course of the demonstration.

Additional improvements are expected to be incorporated in future KRW-based IGCC power plants.

As additional IGCC power plants are built based on KRW technology, and at larger sizes, DOE and SPPCo expect that capital costs will drop eventually to less than $1000-$1350/kW. With large IGCC power plants using both advanced steam conditions and gas turbines, heat rate is projected to be 7000-7500 Btu/kWh (46-49 percent efficiency), higher heating value basis.

View of Piñon Pine Power Project. Part of the power island is in the foreground and the gasifier island structure is at left rear.



Coal Storage Dome. A 20 day supply of coal is kept in this 250 foot diameter structure. The dome is completely closed, thereby eliminating fugitive dust.

The Piñon Pine Power Project

Background

Coal gasification has been used worldwide for many years. Primitive coal gasification provided town gas more than 100 years ago, and a gasification industry produced coal-based transportation fuels for Germany in World War 11.

Today, a major chemical and transportation fuel industry exists in The Republic of South Africa, mostly based upon advancements of World War 11 gasification technologies.

The Dakota Gasification plant in North Dakota produces synthetic natural gas and chemicals based on the same fixed bed gasification technology as is used in the Republic of South Africa. Numerous gasification plants are operational in China.

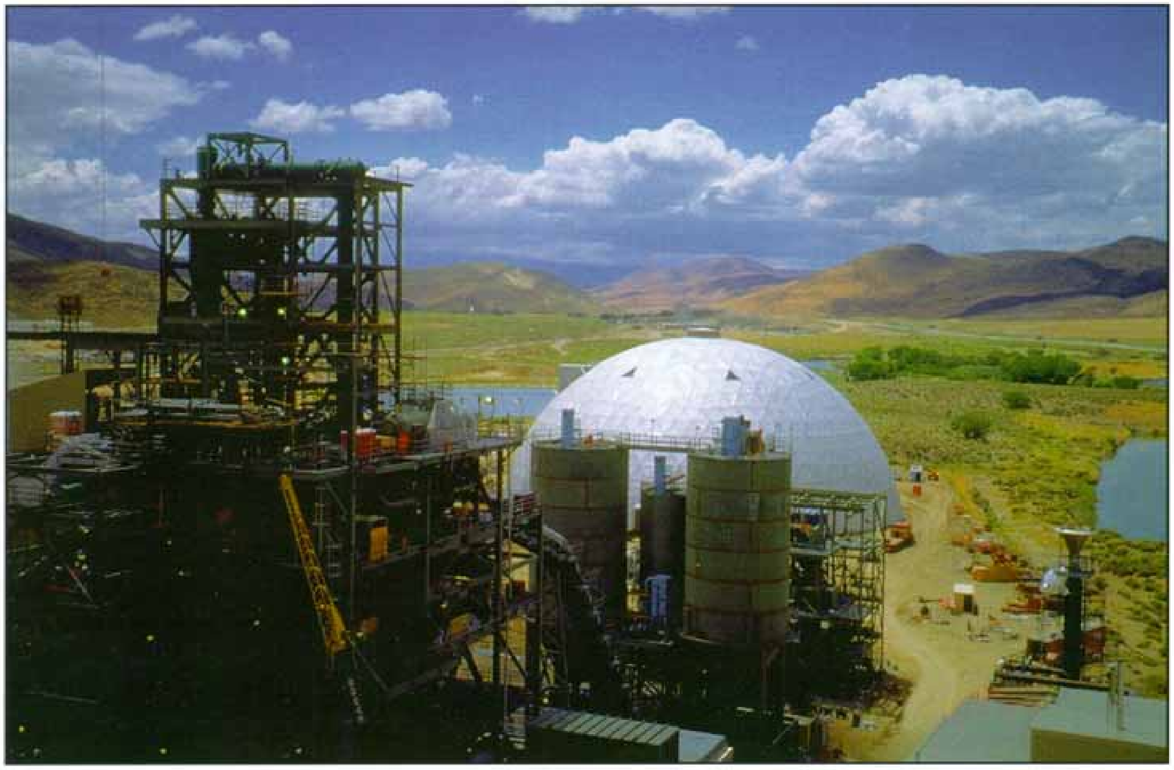
The Eastman Chemical facility in Tennessee produces methanol based on modem U.S. coal gasification technology. And an IGCC power plant is in operation in The Netherlands.

Advanced gasification and IGCC technology development began in the U.S. about 25 years ago, the stimuli being the desire for: (1) development of coal-based replacements for natural gas and oil due to shortages and price increases, and (2) more efficient, clean, coal-based power plants.

Modem IGCC technology is a response of the U.S. government and industry to these needs. Such systems use advanced pressurized coal gasifiers to produce a fuel for gas turbine-based electric power generation; the hot gas turbine exhaust produces steam to generate additional electricity.

The KRW gasifier, currently licensed by The M.W. Kellogg Technology Company, is the product of 13 years of development at the Waltz Mill, Pennsylvania site and earlier bench scale studies at the Westinghouse Research Laboratory. About 13,000 hours of operating experience on a 20 ton per day process development unit (PDU) was accumulated, including about 3000 hours of hotgas cleanup.

The process has been shown to operate economically and efficiently in either the



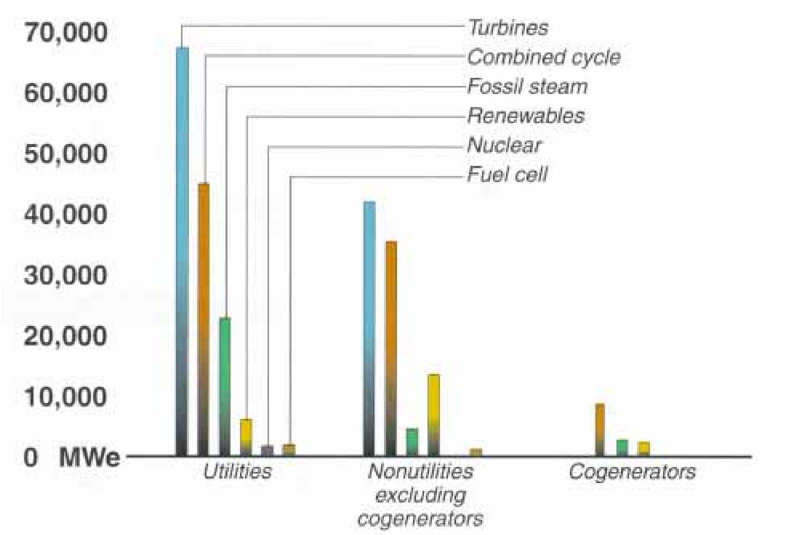
Easterly view of site area during construction. The gasifier structure is to the left and the raw coal storage dome is center. I-80 is in the background.

air- or oxygen-blown modes, and to be applicable to all grades of coal. Development was by Westinghouse Electric Corporation until 1984, when it was succeeded by Kellogg-Rust Inc., and the technology renamed the KRW gasification process. In 1986 ownership was acquired by Kellogg. The PDU was shut down in late 1988, after the development program was completed.

Gas turbines for electric power generation have been one of the consequences of jet aircraft engine development. At the end of 1994, gas turbines contributed about 12 percent (59,600 MWe) to the fossil fuel-based generating capability of U.S. electric utilities. Gas turbine generation capability increased by 23 percent over the period 1990-1994 even though the fossil-based generation capability increased by only one percent during this period.

This increasing use is due to technology advances, relatively low cost per kW and shorter construction time than conventional generation. Advances in design and matrials have led to major increases in the size and performance capability of gas turbine

New Generating Capacity Forecast 1994-2015



DOE Projects that over the period 1994-2015, gas turbine and combined-cycle based generation will be 78 percent (197,000 Me) of the total new capacity additions of utility plus non utility generators (252,000 Me).

Source: U.S. Energy Information Agency, 1996

Major Project Team Members/Subcontractors/Vendors

Sierra Pacific Power Company	Owner/Operator
Foster Wheeler USA Corporation	Architect/Engineer
The M.W. Kellogg Company	Gasifier Architect/Engineer
Foster Wheeler Constructors Inc.	Construction Manager
Bechtel Power Company	Consulting Engineer
General Electric Company	Gas Turbine, Steam Turbine & Erection
Westinghouse Electric Corporation	Hot-Gas Filter System
Mark Steel	Gasifier Vessel
BOC Process Plants	Nitrogen Package
Marley Cooling Tower	Cooling Tower
Moore Products	Distributed Control System
TEMCOR	Coal Storage Dome
EDC Inc.	Coal Handling Equipment
Krupps Robin	Stacker Reclaimer
MEI Contractors, Inc.	Electric/instrumentation Contractor
Granite Construction Company	Underground/Foundation Contractor
Cherne Contracting Corporation	Combined Cycle Piping Contractor

units. Still more efficient models are expected to be available in the near future.

Today's IGCC is efficient because of major improvements that have taken place in coal gasification and gas turbine technologies, and a high degree of system integration that efficiently recovers and uses waste heat.

Atmospheric emissions are low due to the availability of proven technologies for highly effective removal of sulfur and other contaminants from the fuel gas.

Project Benefits

The Piñon Pine Power Project is expected to demonstrate features and benefits of advanced IGCC technology. These benefits include public acceptability, highly efficient operation, low environmental impacts, and low cost power for Northern Nevada. With their need for additional power, and the cost sharing advantages of the CCT program, these features persuaded SPPCo to be the Participant in the Piñon Pine Power Plant Project.

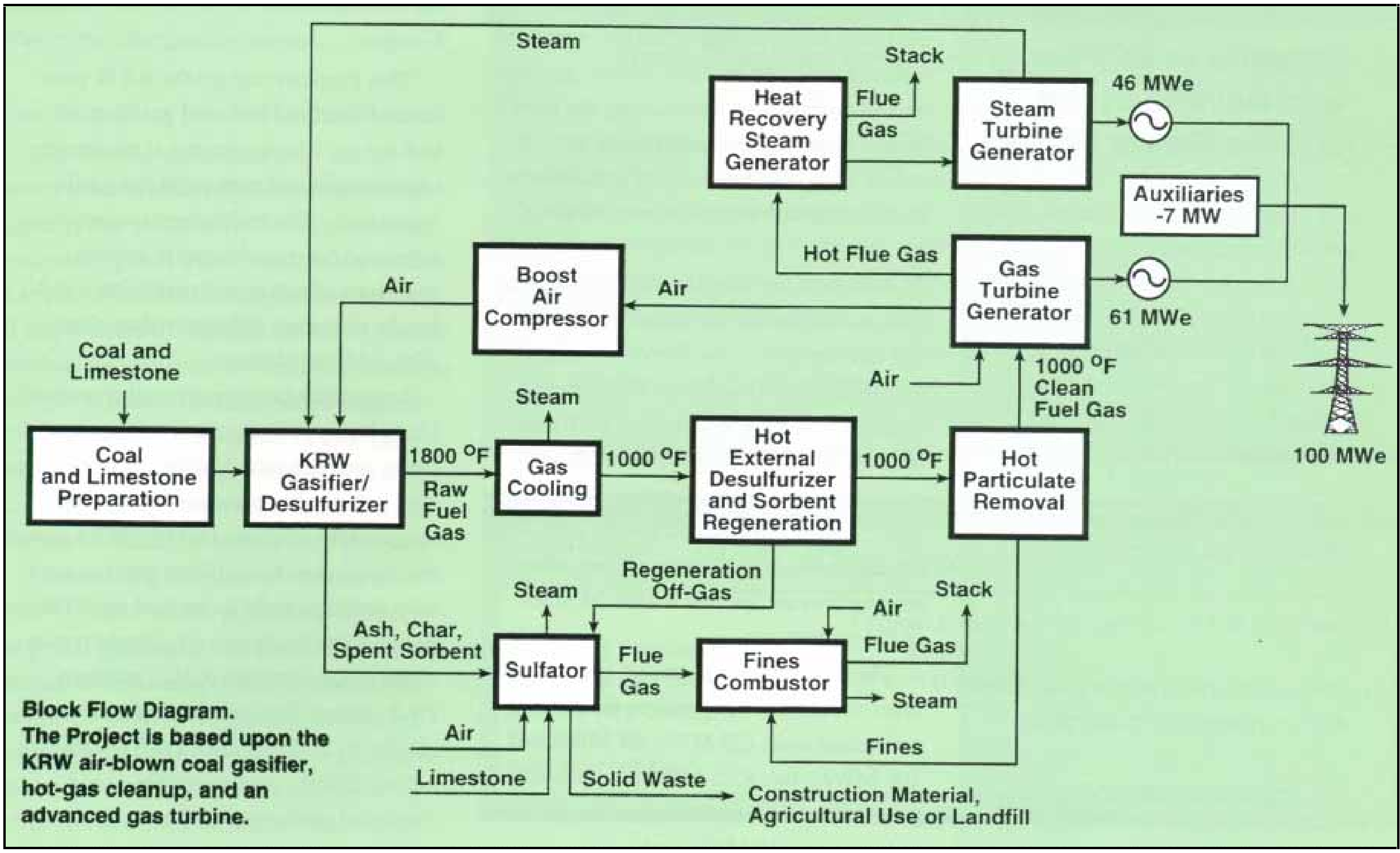
The KRW technology could be placed into use throughout the United States after it achieves the anticipated successful demonstration. The features expected to be demonstrated in the Piñon Pine Power Project plus the applicability of the KRW gasifier to a broad spectrum of coals should create broad geographic appeal for this IGCC technology.

Future users would be expected to realize an even greater level of benefits than those from this demonstration project. Technology improvements and the efficiency improvements accompanying larger size power plants would be expected to yield lower costs and still better environmental performance. Technology owners will benefit from sales and licensing of their respective products.

Project Description

Project Participant

SPPCo, the Participant in the Piñon Pine Power Project, is an investor owned utility with headquarters in Reno, Nevada. Its service area is primarily Northern Nevada and a small pan of California in the Lake Tahoe area. SPPCo's total generation capacity is 965 MWe, produced primarily from three steam power plants: Tracy, Fort Churchill and North Valmy. There are also several gas turbine generating units. North Valmy consists of two coal-based 250 MWe units that are jointly owned with Idaho Power Company. There are two interties with other states, a 345 kV line to Idaho and smaller interties to California.



Block Flow Diagram.
The Project is based upon the KRW air-blown coal gasifier, hot-gas cleanup, and an advanced gas turbine.

Other Key Firms

SPPCo contracted with Foster Wheeler USA Corporation (FW USA) for overall project management, engineering, procurement and construction of the project. FW USA in turn has subcontracted with The M.W. Kellogg Company for the complete engineering and procurement of key components of the gasifier island. General Electric Company (GE) is the supplier of the gas turbine and steam turbine units. Westinghouse Electric Corporation provided the hot particulate removal system.

Area/Site Description

The Piñon Pine Power Plant Project is located at the Tracy power plant in Storey County, about 17 miles from Reno, Nevada. The site is on flat terrain abutting the Truckee River in the Truckee River Canyon.

View of Piñon Pine IGCC Power Plant. Silos in foreground are for coke breeze (startup fuel), coal and limestone. Other stacks are with older generating units.

Benefits to SPPCo and Nevada of the Piñon Pine Power Project

- the "least cost option" to provide electricity
- reduced financial risk due to modular construction
- the unit size meets expected load growth
- coal is forecast to remain cheaper than
- flexibility of fuel use
- 20 percent lower water use than conventional generation
- low environmental impacts
- 700 jobs created at peak of construction
- 40 permanent full time operating jobs
- $3 million in annual taxes to be paid by SPPCo
- area goodwill and expenditures from expected worldwide visitors

The area is and high desert typical of the Great Basin region. Nearby vegetation includes desert shrubs and annual grasses. Riparian vegetation exists along the river banks. A few trees shield part of the site from I-80 north of the site. The Southern Pacific Railroad is immediately south of the site.

Area land use includes agriculture, recreation, residential, industrial and commercial development. The canyon is zoned industrial. The Desolation Wilderness Area, Mount Rose Wilderness Area and the Stillwater National Wildlife Management Area are within 62 miles of the plant. The Pyramid Lake Indian Reservation is in adjoining Washoe County. Three other reservations are located within 50 miles of the project site.

The Tracy power plant site is about 724 acres containing three oil/gas fired steam generating units (53 MWe, 83 MWe and 108 MWe), two 83.5 MWe simple cycle gas turbine units, and two smaller gas turbine units (10 MWe each).

SPPCo possesses water rights from the Truckee River and ground water for operation of the IGCC power plant.

Air quality in the Tracy area meets federal and state standards.

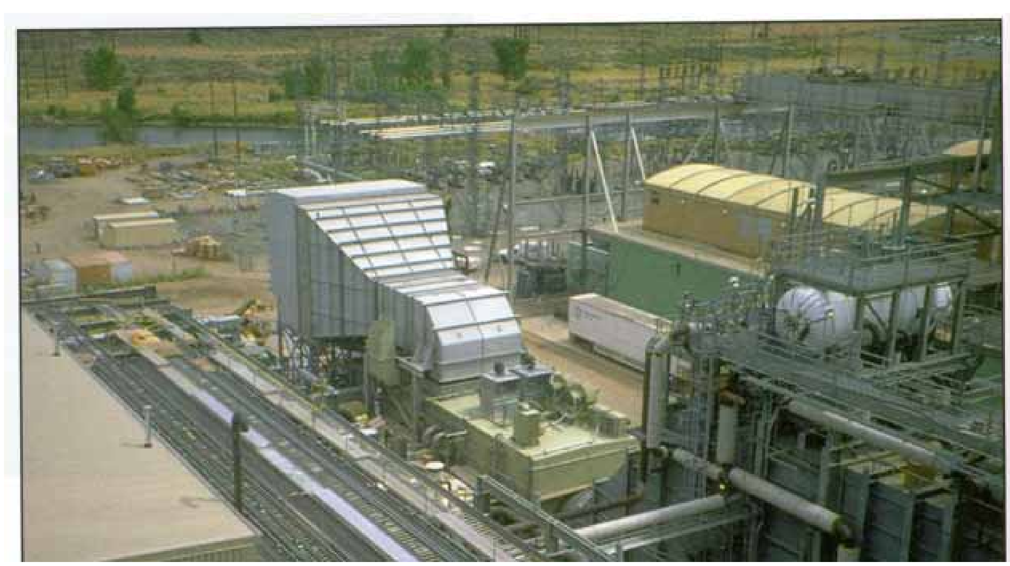
Power Plant

Gasifier

This Project employs the KRW pressurized fluidized bed coal gasification technology which operates at moderate temperatures and uses air in the gasification step. The technology utilizes advanced hot-gas cleanup to control emissions of sulfur and particulates and results in greater efficiency than plants with cold-gas cleanup.

Low sulfur bituminous coal from the Uinta Basin in Utah, air, limestone and steam are fed to the gasifier. Some of the coal is burned to maintain an operating temperature of about 1800°F (982°C), and the remainder devolatilizes and reacts with steam to yield a raw fuel gas. The gas contains hydrogen (H_2), carbon monoxide (CO), methane (CH_4), nitrogen (N_2), carbon dioxide (C02), water vapor (H_20), hydrogen sulfide (H_2S), carbonyl sulfide (COS), ammonia (NH_3), and entrained particulate matter.

The gasifier operating temperature is high enough that the product gas is free of tars and oils. With the low sulfur project coal, about half of the sulfur is removed within the gasifier by the limestone, and a mixture of ash, any unreacted char, spent



Piñon Pine Power Project Power Island. HRSG at right front. The gas turbine air intake structure is left center.

limestone and unreacted limestone is withdrawn from the gasifier bottom.

Gas Cleanup

Gas cleanup equipment in an IGCC power plant is relatively inexpensive compared to flue gas cleanup in a conventional coal-steam power plant. Smaller equipment is required because a much smaller volume of gas is cleaned. The gas volume is smaller because contaminants are removed when the fuel gas is pressurized and before combustion. In contrast, the volume of flue gas from a coal-steam power plant is greater because the fuel has been combusted and the flue gas is cleaned at atmospheric pressure.

After cooling the gasifier effluent to 1000°F (538°C), with production of steam for power generation, the raw fuel gas is cleaned of remaining sulfur to 20 parts per million by a regenerable zinc oxide/nickel oxide sorbent. The hot-gas cleanup system utilizes a transport absorber, and spent sulfur sorbent is regenerated in a transport regenerator that is integrated with the absorber. These transport systems are an outgrowth of proven refinery equipment, and result in considerably lower capital costs and expected operating costs than fixed bed desulfurization technology.

Entrained dust is removed from the fuel gas by means of ceramic filters using a system provided by Westinghouse Electric Corporation. The system has been tested in several installations.

Power Island

The cleaned hot gas is delivered at 1000°F (538°C) to a GE model MS 6001FA gas turbine unit, where it is combusted to produce about 61 MWe of electric power. The advanced firing system (rotor inlet temperature of 2350°F/1288°C) and cooling system of F-class gas turbines provide combined cycle power plants with the highest total-cycle efficiency of any proven type of fossil-fueled electric power generation system.

Heat Recovery Steam Generator (HRSG)

Hot flue gas exhausts the gas turbine and enters a HRSG where two pressure levels of steam are generated. High pressure steam (950°F/950 psia, 510°C/67.17 kg-force/cm^2) is for power generation. Lower pressure steam (90 psia/6.33 kg-force/cm^2) is also generated for use in the steam turbine generator and elsewhere. The steam turbine produces 46.2 MWe of power. Flue gases are released to the atmosphere by a 225 foot stack.

Extraction from the steam turbine provides steam to the gasifier. This extraction also provides steam for NO_X control when the gas turbine is operated on natural gas or propane.

Coal Properties

	Typical Expected Range	Most Probable
Btu/lb (as received)	11,250-11,750	11,400
Sulfur, % (dry basis)	0.35-0.55	0.45
Ash, % (dry basis)	7-11	10
Moisture, %	7-14	10
lb Sulfur/10^6 Btu	–-	0.39

This will be the first Model MS 6001FA gas turbine to operate on low-Btu fuel gas. Combustion testing of low-Btu fuels at General Electric and acceptance testing of the specific Project gas turbine confirm that the unit will operate satisfactorily on fuel gas from the KRW gasifier.

As a result of the air-blown gasification process, the KRW fuel gas contains about 49 percent nitrogen. This constituent significantly contributes to the moderation of peak temperatures reached within the gas turbine combustors, and thereby causes the formation of NO_X to be less than it would be otherwise.

NH_3 in the fuel gas, at a concentration of about 200 ppmv, is partially combusted in the gas turbine to produce NO_X. Although there are unpublished data to show that less than half of the NH_3 is converted to NO_X the emission calculations are conservative and assume that all is converted.

Bottom of KRW gasifier during erection. The nozzles are for introduction of steam and recycled product gas.

Expected IGCC Power Plant Performance

(At average plant ambient conditions: 50°F, 20% relative humidity)

Coal Feed, tons per day	881
Gas Turbine Power Output, MWe	61.0
Steam Turbine Power Output, MWe	46.2
Gross Power Output, MWe	107.2
Auxiliary Power Consumption, MWe	7.5
Net Power Output, MWe	99.7
Net Heat Rate, Btu/kWh (HHV basis)	8390
Thermal Efficiency, % (HHV basis)	40.7

Hot turbine exhaust produces steam in a heat recovery steam generator (HRSG) that produces another 46 MWe by means of a steam turbine generator. Facility auxiliaries consume about 7 MWe, resulting in a net output of about 100 MWe. Parasitic power consumption is low due to the absence of an air separation plant for oxygen production.

Waste Treatment

Solids exiting the gasifier are treated in the Sulfator, which is a fluidized bed combustor, located in the gasifier structure, where limestone is added for sulfur capture. Here, spent gasifier sorbent is converted to calcium sulfate, and the remaining char is burned and steam is produced.

Exit gas from the transport regenerator is routed to the Sulfator for $S0_2$ capture by limestone. The Sulfator product solid waste may be sold to the agricultural and construction industries, or landfilled. Fines captured by the ceramic filter are routed to the fines combustor.

Since water is not condensed in the gasifier island, there is no waste water effluent or cost associated with waste water treatment. Boiler feedwater treatment effluent and cooling tower blowdown flow to the evaporation pond.

Efficiency

The Project IGCC power plant is designed to have a net heat rate of 8390 Btu/kWh (efficiency of 40.7 percent), higher heating value basis, which is 20 percent greater than a conventional coal steam power plant of similar output. The superior efficiency is a consequence of the system's technology and its design, including a high level of system integration.

Examples of system integration include the following. Gasification air is extracted from the air compressor of the gas turbine, thereby utilizing its large and efficient air compressor. For optimum efficiency, the gasifier operating pressure was selected to match the inlet pressure requirement of the gas turbine. Steam produced from various gas and solid cooling stages is integrated into appropriate elements of the process and power generation system.

Simplified KRW Gasifier Chemistry

Coal gasification and desulfurization chemical reactions occur within the KRW gasifer (295 psia, 1800°F):

Coal Gasification

C (coal) + O_2	---->	CO_2 + Heat
C + H_2O(steam)	---->	CO_2 + H_2
C + CO_2	---->	2CO
CO + H_2O	---->	CO_2 + H2
S (coal) + H_2 + CO	---->	H_2S + COS

Desulfurization

$CaCO_3$ (limestone) + Heat	---->	CaO + CO_2
CaO + H_2S	---->	CaS + H_20

External Desulfurization (Absorber)

Sulfur compounds are removed from the fuel gas by a zinc oxide based sorbent, which contains nickel oxide, to reduce total sulfur in the fuel gas to a concentration less than 20 parts per million.

Sulfur Absorption

ZnO + H_2S	---->	ZnS + H_2O
ZnO + COS	---->	ZnS + CO_2
NiO + H2S	---->	NiS + H_2O
NiO + COS	---->	NiS + CO_2

Sorbent Recovery (Regeneration)

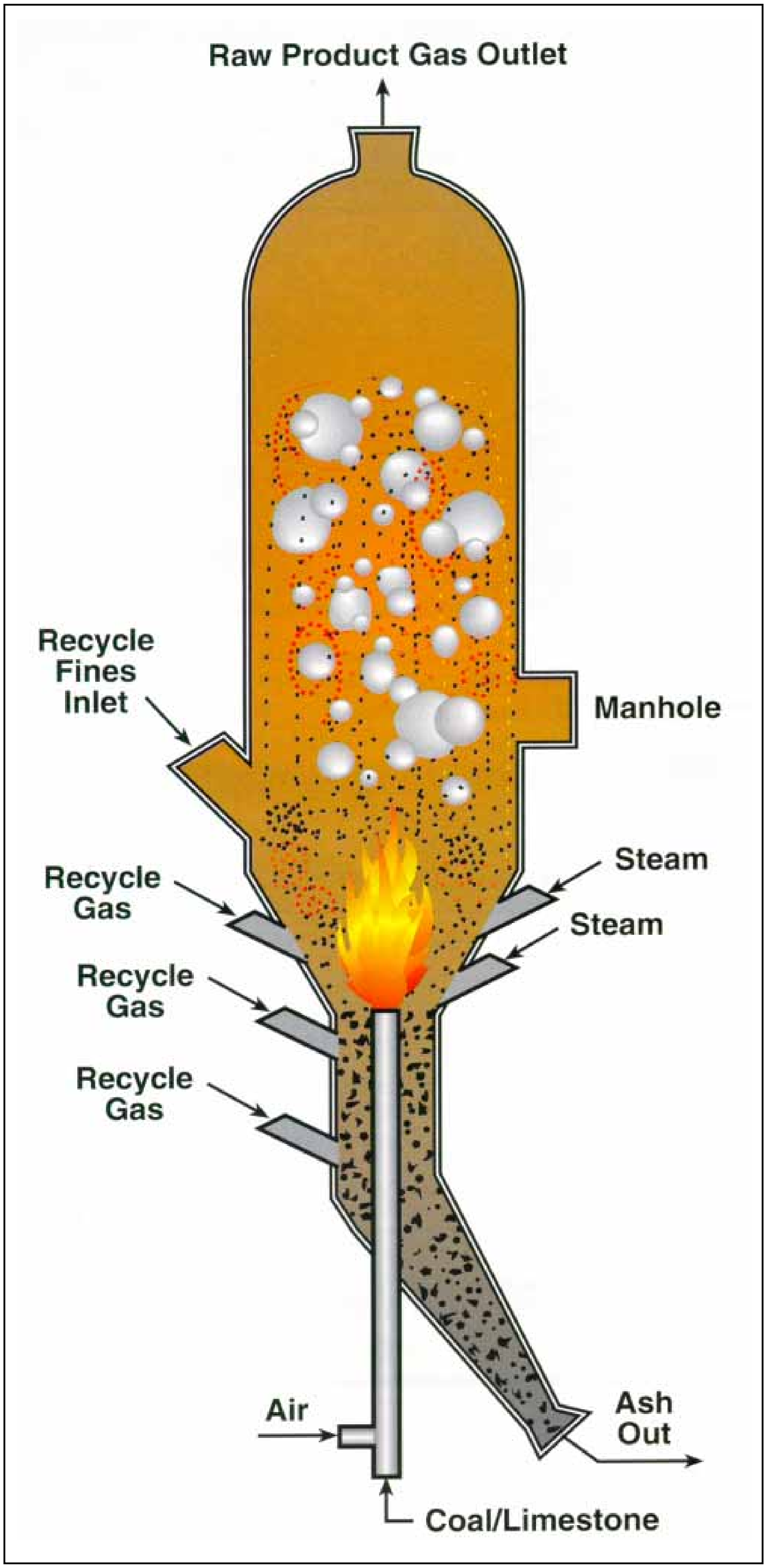
2ZnS + $3O_2$ (air)	---->	2ZnO + $2SO_2$
2NiS + $3O_2$ (air)	---->	2NiO + $2SO_2$

Expected Inputs and Outputs at Full Load, 100% Capacity Factor

Piñon Pine Power Project

Capacity, MWe	107 Gross 100 Net
Power Production, MWh/yr	832,200
Inputs	
Fuel Consumption, tons/yr	321,420
Limestone, tons/yr	20,120
Water Consumption, cfs	
Cooling Tower (surface water)	1.522
emineralizer (groundwater)	0.145
Utility Stations (groundwater)	0.001
Outputs	
Air Emissions, tons/yr	
Sulfur Dioxide	225
Oxides of Nitrogen	575
Particulate Matter	123
Carbon Monoxide	304
Carbon Dioxide	790,000
Aqueous Effluents, cfs	
Cooling Tower Blowdown	0.117
Evaporation & Drift	1.412
emineralizer Waste	0.0082
Gasifier Steam Waste	0.0732
Solid Waste	
Sulfator, tons/yr	43,635

[1]Assuming annual average ambient temperature of 10°C (50°F) and maximum design coal capacity of 881 tons/day.



KRW Gasifier

Environmental Considerations

The Piñon Pine Power Plant Project is designed to have low environmental impacts. Use of natural resources (coal, limestone and water) will be less than for a conventional coal fired power plant. Water use, which is especially important in desert regions, is 20 percent less than conventional coal-based generation.

Solid waste produced will be less than from a conventional coal fired power plant with a wet scrubber. The waste water evaporation pond will be double lined and monitored.

Atmospheric emissions are expected to be lower than requirements. Conservatively about 91 percent of the sulfur fed to the plant will be captured by the hot-gas cleanup system. The total level of sulfur capture would be about 98 percent if a high-sulfur coal were used instead of the Project's low-sulfur coal. Resultant ambient air quality will meet all requirements, including those for prevention of significant deterioration (PSD) of air quality.

NO_X emissions are expected to be lower than values used for permitting. These values conservatively assume that all of the ammonia produced in the gasifier is converted in the gas turbine to NO_X. Unreported data indicates that less than half would be expected to be converted to NO_X.

NO_X emissions are inherently low because the high nitrogen content of the low-Btu fuel gas has a tempering effect on the combustion temperature. The hot ceramic filter system is expected to be more effective than an electrostatic precipitator or baghouse in controlling particulate emissions.

In accordance with requirements, DOE conducted a comprehensive environmental study of the Project, and prepared an Environmental Impact Statement. As a result of conclusions reached, DOE issued a favorable *Record of Decision.* All permits to construct the plant have been obtained.

Cost/Schedule Milestones

The estimated construction cost of the first-of-a kind Piñon Pine Power Plant is approximately $232 million and the 42 month demonstration is estimated to cost $104 million; the total cost of $336 million is being shared 50/50 with DOE.

A 54 month schedule was developed to complete the design, engineering, and construction work. After all environmental and construction permits were received, civil work started in February 1995 and construction is essentially complete. Shakedown of the individual subsystems began in June 1996, and combined cycle unit startup was initiated in August 1996.

The demonstration period will begin in February 1997 and proceed for 42 months. The demonstration will consist of performance evaluations of plant subsystems, with adjustments when necessary and feasible to achieve the design performance. Operation will be primarily on low-sulfur Uinta Basin bituminous coal from Utah. An objective is to achieve 70 percent capacity factor in 24 months.

Operation is also planned on a high-sulfur eastern or midwestern bituminous coal to demonstrate performance on this plentiful fuel. These tests are scheduled for completion during the demonstration period.

Performance mapping will take place at a variety of operating conditions, including startup, part power, full power, and at various ambient temperatures. Operating and performance details will be carefully monitored, including emissions. Detailed records will be kept regarding operating and maintenance costs. When the demonstration is complete, a large body of operating data will be available for the benefit of DOE, project participants, and others.

An objective of the demonstration is to identify future modifications in equipment and operation that can be made to IGCC systems to improve performance and decrease costs. Some of these changes will be possible during the Piñon Pine Power Plant project demonstration and will be implemented if practical.

Results

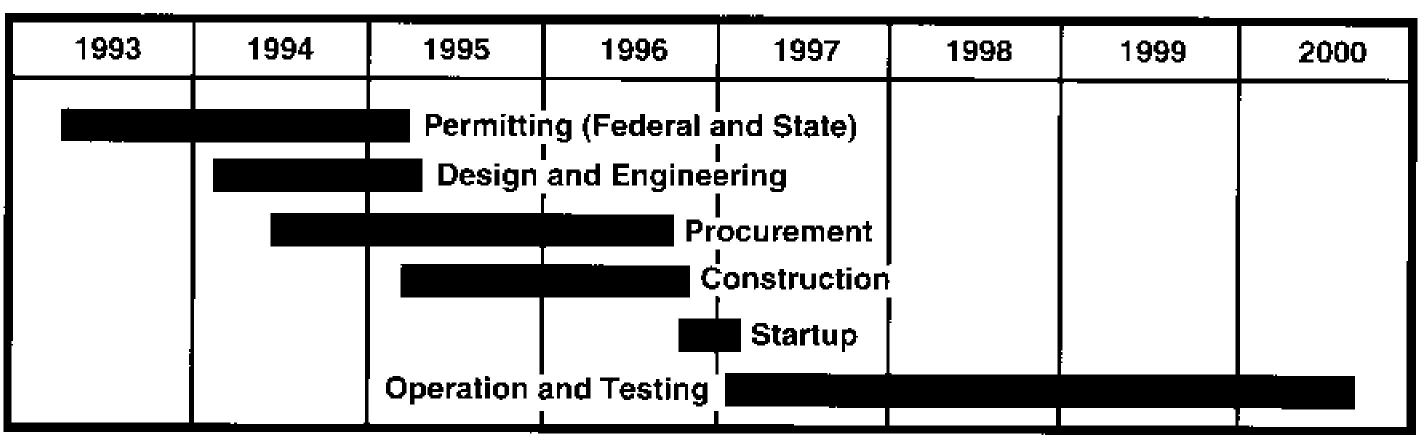
Construction activities at the Piñon Pine Power Project have been completed, and commissioning of both power island and gasifier island has been on-going with the former being essentially complete. Startup activities are proceeding on schedule and the demonstration period is expected to begin in February 1997 according to plan.

Twelve of the forty-seven gasifier subsystems have been turned over by the construction team to the startup team and commissioned, signifying that these subsystems are ready to use. It is expected that the remainder of the packages will be turned over by mid January 1997 to support an orderly overall system startup.

Operator training, especially with respect to the new technologies and systems, is important for the smooth integration of the IGCC power plant with overall current Tracy operations. Consequently training

text continues on p. 17

Piñon Pine IGCC Power Project Schedule



Process Description

KRW Gasifier Island

The KRW gasifier is based upon the fluidized bed principle in which particles (coal and limestone) are suspended in a stream of flowing gases. Because their size and weight prevent them from blowing out, most of the particles remain within the bed until most or all of their carbon is gasified. These devices are called fluidized beds because the bed of suspended particles has a definite surface that looks like a liquid. The coal particles undergo gasification chemical reactions within the bed. Smaller ash and char particles entrained in the raw gas leaving the gasifier are captured by a cyclone and returned by a dipleg.

The gasifier operates at approximately 1800°F (982°C), which is low enough to avoid most inefficiencies and costs associated with cooling the gas prior to gas cleanup, while being high enough that gasification reactions proceed relatively rapidly and formation of tars and oils is avoided.

With air as the transport gas, a continuous stream of coal and limestone is introduced to the KRW gasifier from lock-hoppers to the gasifier coaxial central feed tube that protrudes into the fluidized bed. Additional air is also fed through the feed tube and the streams merge to form a central jet. Partial combustion of the coal occurs in the jet, the heat release causing the coal to be quickly devolatilized to produce a char. The temperature of the central jet is sufficiently high to crack any tars or oils that might be produced.

The heat release and high velocity of the central jet cause the char particles to be circulated within the fluidized bed where they react chemically with steam. The gasification reactions produce a low heating value coal gas consisting primarily of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), nitrogen (NO_2), water (H_20), hydrogen sulfide (H_2S), carbonyl sulfide (COS) and ammonia (NH_3).

At gasifier operating conditions, the limestone fed with coal quickly calcines to produce lime that reacts with the hydrogen sulfide, produced by the gasification reactions, to give solid calcium sulfide (CaS).

With the low-sulfur Project coal, approximately 50 percent of the sulfur released is expected to be captured within the fluidized bed. The preponderance of the remainder of the sulfur is removed in the external transport absorber desulfurizer. With high-sulfur eastern coals to be tested, more than 90 percent of the sulfur could be removed within the gasifier by the limestone. The exact amount will depend on the specific sulfur level of the coal.

After gasification of coal particles occurs, ash particles remaining within the bed stick to each other and also to reacted and unreacted limestone. The ash agglomerates formed defluidize and fall to the bottom of the gasifier where they are cooled by recycled product gas, while being continuously removed from the vessel. This solid waste is pneumatically transported to the Sulfator for further processing.

Coal gas leaving the top of the gasifier contains entrained particles of char, ash and sorbent. Most of these particles (fines) are captured by a cyclone and returned to the gasifier by a dipleg. The coal gas leaving the cyclone is cooled to 1,000°F (538°C), the operating tempera-ture of the external transport desulfurizer. Steam produced from cooling the raw gas is integrated with the remainder of the steam system of the Piñon Pine Power Project.

KRW Fuel Gas Composition After Hot-Gas Desulfurization and Particulate Removal

Constituent	Volume Percent
CO	23.9
H_2	14.5
CO_2	5.5
H_2O	5.5
CH_4	1.4
N_2	48.6
Ar	0.6
Total:	100.0
NH_3	200 ppmv
H_2S	20 ppmv
COS	0 ppmv
Heating Value (Btu/SCF),	
Higher heating value basis	138
Lower heating value basis	129

External Hot-Gas Desulfurization

Desulfurizer

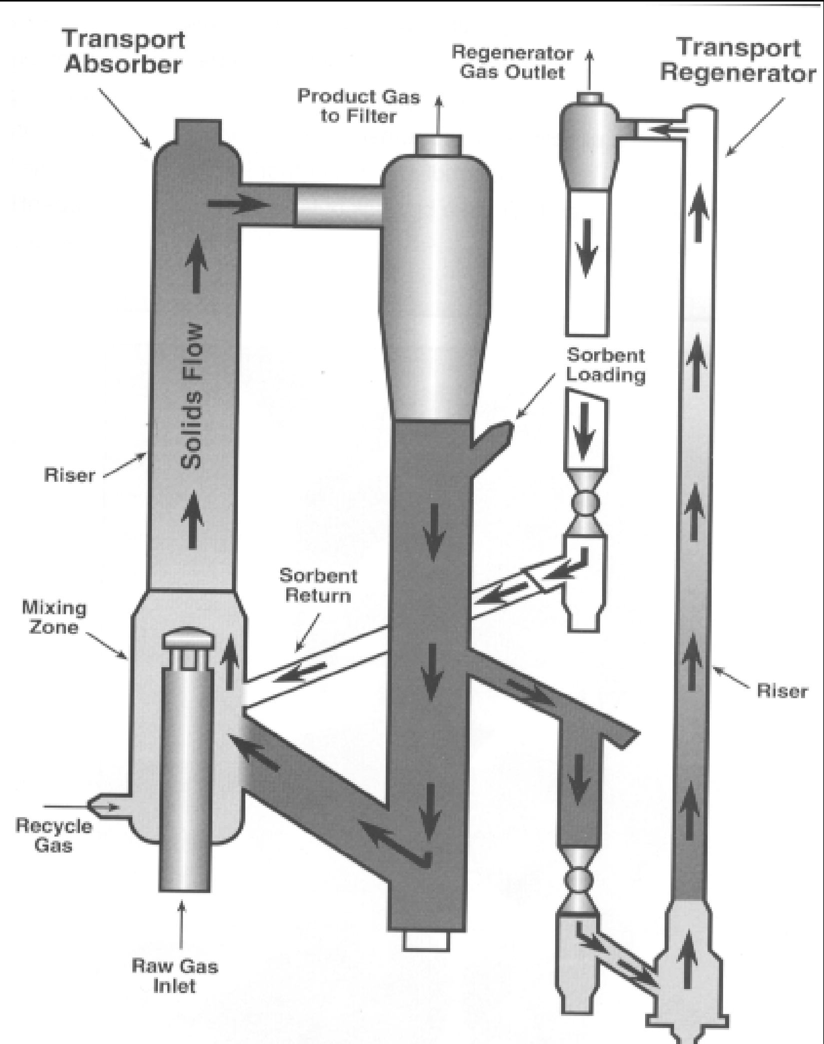
In the transport desulfurizer, developed and licensed by The M.W. Kellogg Technology Company, the total sulfur in the coal gas is reduced to less than 20 parts per million (ppmv) by a zinc oxide based sorbent, which contains nickel oxide. The hardware system consists of a transport absorber and a transport regenerator.

Fuel gas enters the mixing zone at the bottom of the transport absorber riser where it mixes with the sorbent. Absorption of sulfur compounds takes place in the riser section as the fuel gas and sorbent flow upward. A cyclone captures sorbent particles that are directed to a standpipe for recycle to the transport clesulfurizer.

Regenerator

A slipstream of sulfurized sorbent is withdrawn from the absorber standpipe and enters the bottom of the transport regenerator along with preheated air. The sorbent regeneration reactions occurring between the upward flowing particles and air convert zinc sulfide back to the original oxide with the formation of sulfur dioxide (SO_2). Regenerated sorbent is returned to the transport absorber by controlled gravity flow.

The regenerator effluent gas consists of nitrogen, a small amount of particulate matter and SO_2. The effluent exits at about 1370°F (7431°C) and flows to the Sulfator for final treatment.



Transport Absorber/Regenerator System. Product gas is cleaned at 1000°F to less than 20 ppmv.

Sulfator

With the exception of the small quantity of sulfur remaining in the gas turbine fuel (20 ppmv), the sulfur originating in the feed coal is ultimately treated in the Sulfator. The Sulfator is an atmospheric air-fluidized bubbling bed reactor that :

- captures SO_2 released from regeneration of sufidized zinc oxide/nickel oxide sorbent
- converts calcium sulfide produced in the gasifier to calcium sulfate
- combusts residual carbon in the ash agglomerates

Capture of released SO_2 is by unreacted limestone from the gasifier plus added limestone. To minimize emissions of SO_2, the nominal operating temperature of the Sulfator is 1600°F (871°C). Solids removed from the Sulfator, ash plus calcium sulfate and unreacted limestone, are suitable for landfill.

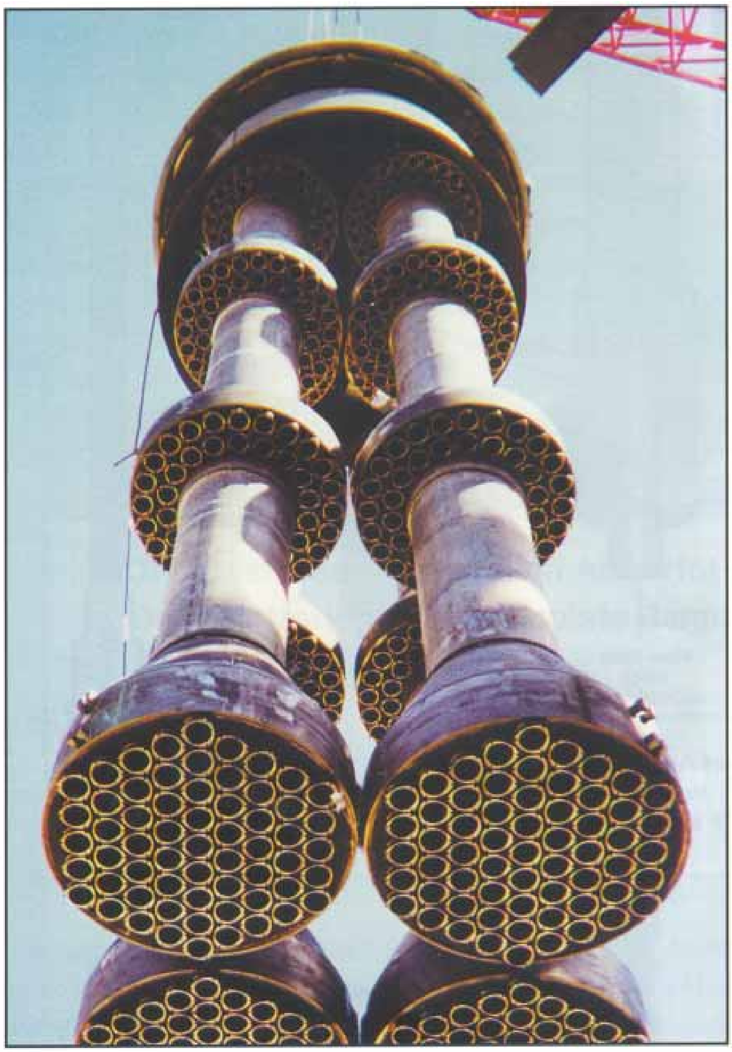
Flue gases exiting the Sulfator flow to a fines combustor that burns fines captured by the ceramic filter (with support from a small quantity of natural gas). The fines combustor HRSG produces steam and cools the gas. Entrained solids in the flue gas are removed by a baghouse and clean flue gas is exhausted through a second liner in the stack of the power island.

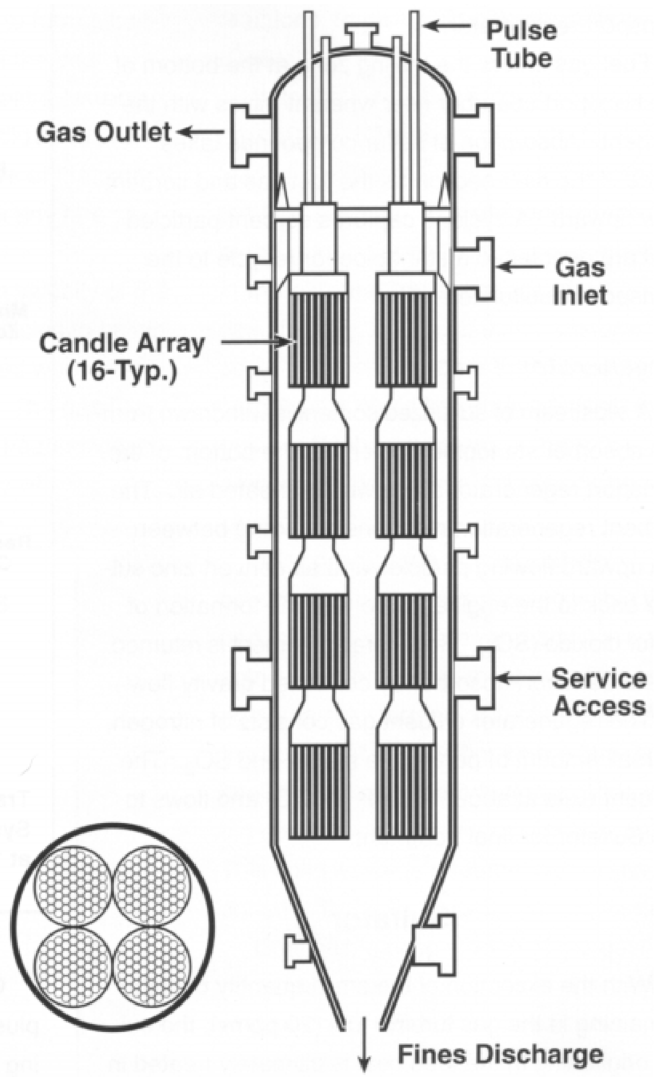
Hot Particulate Removal

Particulate matter in the desulfurized coal gas that exits the transport desulfurizer must be removed before the gas enters the gas turbine. Removal is by a hot-gas filter, which removes essentially all of the remaining particulates. The hot-gas filter is a ceramic candle type filter that is cleaned of accumulated filter cake by back pulsing with recycle product gas.

The system operates at 1000°F (538°C), the gas turbine fuel inlet temperature. This temperature is low enough to condense any volatile alkali metal compounds in the fuel gas on the filter cake, thereby preventing damage to the gas turbine.

The filter elements are housed in a steel vessel with access capability for replacement of candles. The system selected was provided by Westinghouse Electric Corporation.





HOT PARTICULATE REMOVAL SYSTEM

The system consists of a vessel 10 feet in diameter, containing 748 silicon carbide candle filter elements that are 1.5 meters long. The candles are arrayed on sixteen plenum assemblies. The photograph shows the plenum assembly being lowered into the vessel. Filter elements were installed after the assembly was in place.

has been an ongoing priority program at the Tracy Station.

Another important factor in the transition of Tracy to include the IGCC generating unit is smooth startup of the gasifier and the IGCC system. For this to be accomplished, reliable and stable operation of the combined cycle system must be achieved. Thus, initial efforts have focused upon making the combined cycle system operational, and several important milestones have been achieved.

Startup, performance testing of the combined cycle system and synchronization with the grid was achieved with a minimum of issues:

- First-fire on the gas turbine occurred on August 15, 1996.
- Synchronization of the steam turbine with gas turbine operations occurred on September 18, 1996.
- Subsequent performance testing of the gas turbine and steam turbine demonstrated that the combined cycle unit meets both output and emission requirements on natural gas.
- In a combined cycle mode, the power island has been operational on natural gas since late October 1996.

In December 1996, the combined cycle unit was designated as being available for commercial operations, and is formally available for dispatch purposes on the SPPCo system.

Other preparations for start of the demonstration continue. Sorbent for the hot-gas cleanup system was loaded into the transport absorber system in November 1996. Coke, required for gasifier startup, and limestone have been purchased and delivered to the site; a local source of limestone was identified. First coal delivery for gasifier operations will be in January 1997.

Gas Turbine/HRSG Emissions

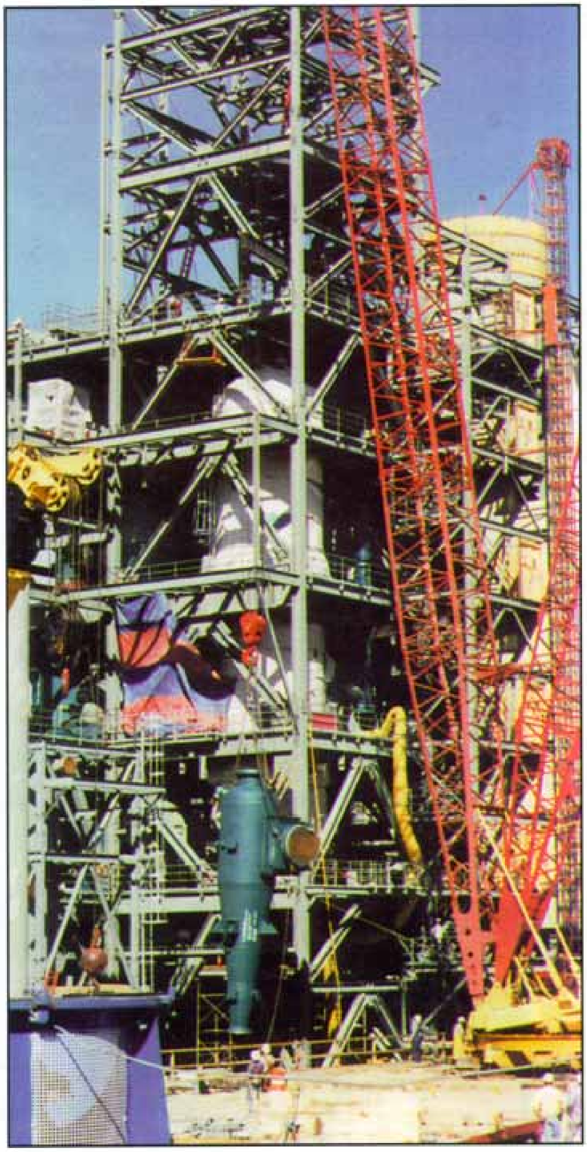
Pollutant	Emission Rate	Emission Limit	Regulation
Federal			
NO_X ppm	42(1)	125	40 CFR Part 60 Subpart GG
SO_2% Volume	0.0005	0.015	40 CFR Part 60 Subpart GG
Nevada			
Sulfur, lb/hour	7.7(2)	426	NAC 445B.373
PM-10, lb/hour	20(3)	158.9	NAC 44513.362

(1) Corresponds to 0. 16 lb NO_X per million Btu input.
(2) Corresponds to 0.018 lb $S0_2$ per million Btu input.
(3) Corresponds to 0.02 lb PM-10 per million Btu input.

Predicted Air Quality Impacts of the Piñon Pine Power Project

Pollutant	Averaging Period	Maximum Ground Level Concentration, mg/m^3	Ambient Standard, mg/m^3
SO_2	3 hour	65.8	1300
	24 hour	12.9	365
	Annual	2.0	80
NO_X	Annual	0.9	100
PM-10	24 hour	15.4	150
	Annual	1.1	50
CO	1 hour	125.9	40,000
	8 hour	44.7	10,000

Emissions from the Piñon Pine Power Project result in predicted worst case ground level concentrations of pollutants that are much below air quality standards. When these concentrations are added to background levels of pollutants, the totals are still well below standards.



KRW gasifier in the structure during construction.

Power Island Performance (Natural Gas Fuel)

	Actual Output MWe	Design Output MWe
Gas Turbine	68.2	66.9*
Steam Turbine	24.2	24.0**
Total	92.4	90.9

* Ambient temperature, 50°F; pressure, 12.59 psia; relative humidity, 20%.

** Throttle temperature, 950°F; throttle pressure, 950 psia; throttle flow, 159,500 lb/hr.

Future

IGCC power plants based on the technology used in the Piñon Pine Power Project would be expected to benefit from data, experience and other information gained in the demonstration program. These will undoubtedly lead to improved design and reduced operating and maintenance costs. Additional improvements would be expected from future applications and ongoing R&D efforts.

Lower capital costs (on a per kW basis) will result from reduced engineering requirements and economies of scale associated with larger size IGCC power plants.

There will also be improvements in efficiency, as the technology is fine tuned and as larger units are constructed. In addition, larger size power plants will use reheat steam turbines that will produce significant heat rate improvements. It is anticipated that advances in gasifier island and gas turbine technology will continue, with consequential further improvements in system efficiency and reductions in cost. This will be further enhanced by improved overall steam conditions and thermal integration.

SPPCo and DOE believe that future IGCC greenfield power plants, based upon mature and improved technology, will cost in the range of $1000-1350/kW (1995 basis). Heat rate is expected to be in the range of 7000-7500 Btu/kWh (46-49 percent efficiency), higher heating value basis. Costs will be further reduced if an existing steam turbine is repowered and existing site infrastructure is utilized.

The Clean Coal Technology Program

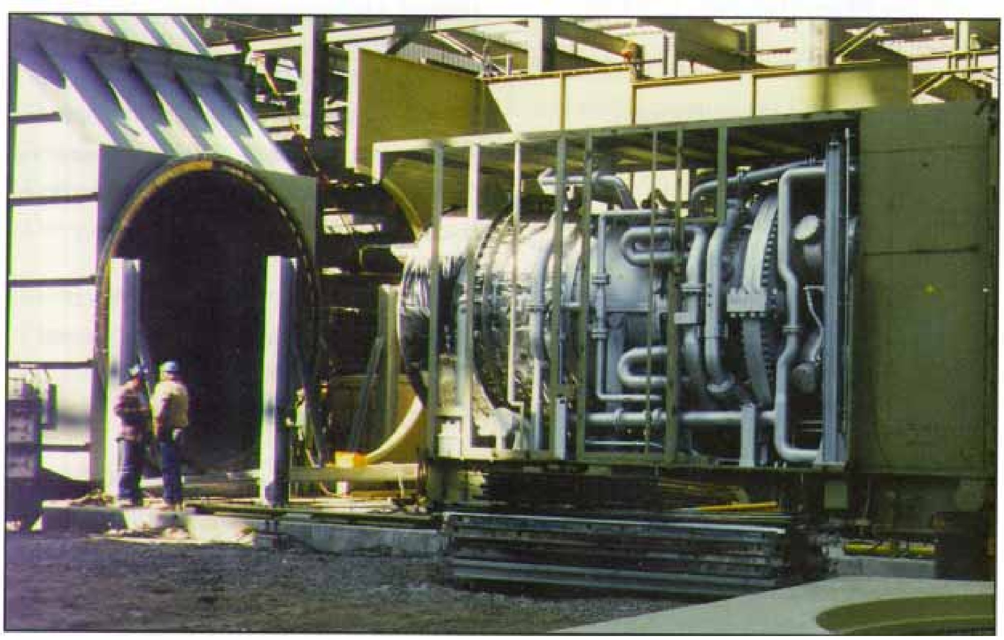
The Clean Coal Technology (CCT) Program is a unique partnership between the federal government and industry that has as its primary goal the successful introduction of new clean coal utilization technologies into the energy marketplace. With its roots in the acid rain debate of the 1980s, the program is on the verge of meeting its early objective of broadening the range of technological solutions available to eliminate acid rain concerns associated with coal use. Moreover, the program has evolved and has been expanded to address the need for new, high-efficiency power-generating technologies that will allow coal to continue to be a fuel option well into the 21st century.

Begun in 1985 and expanded in 1987 consistent with the recommendation of the U.S. and Canadian Special Envoys on Acid Rain, the program has been implemented through a series of five nationwide competitive solicitations. Each solicitation has been associated with specific government funding and program objectives. After five solicitations, the CCT Program comprises a total of 40 projects located in 18 states with a capital investment value of nearly $6.0 billion. DOE's share of the total project costs is about $2.0 billion, or approximately 34 percent of the total. The projects' industrial participants (i.e., the non-DOE participants) are providing the remainder—nearly $4.0 billion.

Clean coal technologies being demonstrated under the CCT Program are establishing a technology base that will enable the nation to meet more stringent energy and environmental goals. Most of the demonstrations are being conducted at commercial scale, in actual user environments, and under circumstances typical of commercial operations. These features allow the potential of the technologies to be evaluated in their intended commercial applications. Each application addresses one of the following four market sectors:

- Advanced electric power generation
- Environmental control devices
- Coal processing for clean fuels
- Industrial applications

Given its programmatic success, the CCT Program serves as a model for other cooperative government/industry programs aimed at introducing new technologies into the commercial marketplace.



General Electric Gas Turbine model MS 6001FA (right) prior to connection to HRSG (left).

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List of Acronyms and Abbreviations

Btu	British thermal unit
CAAA	Clean Air Act Amendments of 1990
CCT	Clean Coal Technology
cfs	cubic feet per second
DOE	U.S. Department of Energy
IGCC	integrated gasification combined cycle
HRSG	heat recovery steam generator
lb	pound (mass)
kW	kilowatt
mg	milligram
M^3	cubic meters
kWe	kilowatt electric
MWe	megawatt electric
PDU	process development unit
PM-10	particulate matter less than 10 micrometers in diameter
ppmv	parts per million by volume
PSD	Prevention of Significant Deterioration
psia	pounds per square inch, absolute
R&D	research and development
SCF	standard cubic foot
SPPCO	Sierra Pacific Power Company