The Piñon Pine Integrated Gasification Combined Cycle Project
Project Description and Status

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Abstract
In the fourth round of the Clean Coal Technology Program, the U.S. DOE selected the proposal from Sierra Pacific Power Company (SPPCo) to demonstrate the commercial viability of air-blown, pressurized, fluidized-bed Integrated Gasification Combined Cycle (IGCC) technology for utility power generation. The project will also demonstrate firing a low-Btu gas in an advanced gas turbine as well as showing the long-term reliability, availability, maintainability and environmental performance of this IGCC technology on a commercial scale. The U.S. DOE's share of the project is $168 million, with SPPCo paying the remaining 50% of the $336 million total cost. SPPCo completed construction of the Piñon plant in February of 1997 and began operating the power island portion of the plant. The Piñon plant is located at SPPCo's Tracy Station, 17 miles east of Reno, Nevada. The Piñon IGCC project uses hot-gas cleanup and features a Kellogg-Rust-Westinghouse (KRW) fluidized-bed, ash-agglomerating gasifier operating in an air-blown mode. Since the gasifier was first fired in January 1998, SPPCo has made slow progress toward achieving integrated operation of all systems. SPPCo's progress has been slowed by problems mostly external to the gasifier. The purpose of this paper is to summarize the technology featured in the Piñon IGCC Project, discuss some of the operational problems and present the project status.

The Clean Coal Technology (CCT) Program
The Piñon Pine Project is part of the U.S. DOE's CCT Program. The 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. DOE has implemented the program 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 project costs is about $2.0 billion, or approximately 34 percent of the total. The projects= industrial participants are providing the remainder **C** nearly $4.0 billion.

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.

Integrated Gasification Combined Cycle (IGCC)
Among the technologies being demonstrated in the CCT program is IGCC. IGCC is an innovative electric power generation technology that combines modern coal gasification with gas-turbine and steam-turbine 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 exhaust of the gas turbine 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 (CO_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.

Both greenfield and repowering application of IGCC could provide the flexibility needed for utility compliance planning for SO_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/year of SO_2 allowable under the Clean Air Act Amendments.

Modularity and fuel flexibility are other important attributes of IGCC power plants. Before the gasifier is constructed or when it is not available, the combined cycle unit can be operated on other fuels, such as natural gas or fuel oil, to provide power. The size of gas turbine units can be chosen to meet specific power 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 fuel costs warrant operating only the gas turbine.

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.

Figure 1. ***Sierra Pacific's Tracy Station east of Reno, Nevada.***

The Piñon Pine Power Project
Project Participant
Sierra Pacific Power Company (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 part 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.

Cost

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 equally with DOE.

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, Nevada, about 17 miles east of Reno, on Route 80. The site is on flat terrain abutting the Truckee River in the Truckee River Canyon. Figure 1 shows the plant.

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).

Gasifier

This Piñon gasification island features the Kellogg-Rust-Westinghouse (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.

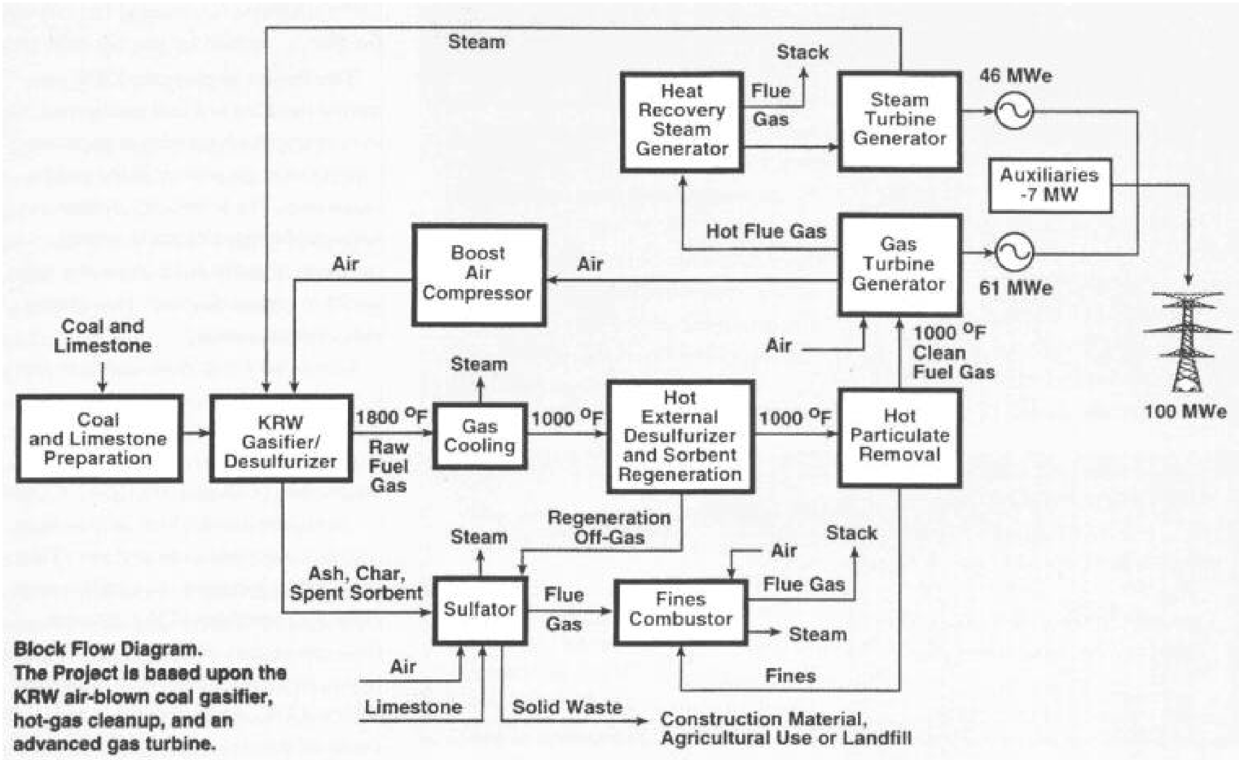


Figure 2. ***Piñon Pine Project block flow diagram.***

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 was accumulated, including about 3000 hours of hot-gas cleanup. The process has been shown to operate economically and efficiently in either the air- or oxygen-blown modes, and to be applicable to all grades of coal.

Low-sulfur bituminous coal (from the Uinta Basin in Utah), air, limestone (from nearby Carson City, Nevada), 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 (CO_2), water vapor (H_2O), hydrogen sulfide (H_2S), carbonyl sulfide (COS), ammonia (NH_3), and entrained particulate matter. Figure 2 illustrates the process.

The gasifier operating temperature is high enough that the product gas is free of tars and oils. With the low-sulfur coal (see Table 1) used in this project, about half of the sulfur is removed in the gasifier by the limestone. Ash, any unreacted char, spent limestone and unreacted limestone is withdrawn from

Table 1. As Received Coal Properties

Btu/lb	11,188
Sulfur, %	0.37
Ash, %	8.80
Moisture, %	10.97

Figure 3. ***Coal unloading and coal storage dome. A 20-day supply of coal is kept in this 250-foot diameter***

the gasifier bottom. Appendix I describes the gasifier and gasification process in more detail. Figure 3 shows the coal storage and unloading facilities. Figure 4 shows the KRW gasifier during installation.

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. An IGCC plant requires smaller equipment 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 the fuel gas is burned. 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 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 operating costs than fixed-bed desulfurization technology. Refer to Appendix II for more information on this process.

Particulate matter in the desulfurized coal gas that exits the transport desulfurizer must be removed before the gas enters the gas turbine. A hot-gas filter, supplied by the Westinghouse Electric Corporation, 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 filter elements are housed in a steel vessel with access for replacement of candles. Figure 5 shows the arrangement of the filtration system.

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.

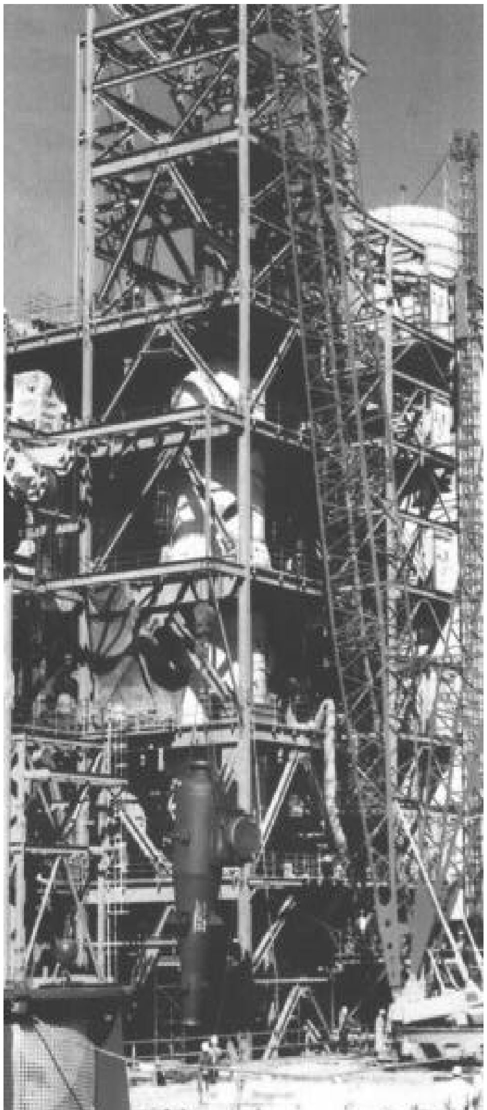


Figure 4. ***Cyclone for KRW gasifier being lifted for installation. Gasifier is in support structure.***

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 burned 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.

This will be the first Model MS 6001FA gas turbine to operate on low-Btu fuel gas. Combustion testing of low-Btu fuels at GE confirmed that the unit will operate satisfactorily on fuel gas from the KRW gasifier.

As a result of the air-blown gasification process, the fuel gas is about 49 percent nitrogen. This 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.

Hot flue gas leaves the gas turbine and enters a Heat Recovery Steam Generator (HRSG), which generates steam at two pressure levels. The high-pressure steam (950°F/950 psia, 510°C/67.17 kg-force/cm^2) is for power generation. The low-pressure steam (90 psia/6.33 kg-force/cm^2) is used in the steam turbine generator and elsewhere. The steam turbine produces 46.2 MWe of power. Flue gases are released to the atmosphere through a 225-foot stack. Figure 6 shows the gas turbine and HRSG.

Auxiliaries consume about 7 MWe, resulting in a net output of about 100 MWe. Parasitic power consumption is low (compared to that required for an oxygen-blown gasifier) because the Piñon plant only needs a small air separation plant to supply nitrogen to purge the system.

Waste Treatment

Solids leaving the gasifier are treated in the Sulfator, located in the gasifier structure. The Sulfator is a fluidized-bed combustor, which uses limestone for sulfur capture. Here, spent gasifier sorbent is converted to calcium sulfate and the remaining char is burned, producing steam.

Also, regeneration gas leaving the transport system is routed to the Sulfator for SO_2 capture by the limestone. Appendix II describes the Sulfator in more detail. The Sulfator product solid waste may be sold to the agricultural and construction industries, or placed in a landfill. Fines captured by the ceramic filter are routed to the fines combustor, the exhaust from which produces steam for power production in the steam turbine.

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

Efficiency

The Piñon 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 higher efficiency than a conventional coal-fired power plant of similar output. The superior efficiency is a consequence of the system's technology and its design, which includes a high level of system integration.

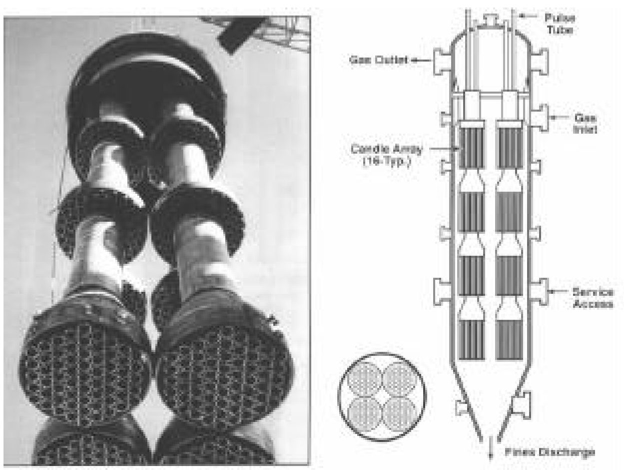


Figure 5. ***Hot Particulate Removal System.***

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.

Environmental Considerations

The Piñon Pine Power Plant Project is designed to have a low environmental impact. Because of the plant's inherent high efficiency, the Piñon plant will use less natural resources (coal, limestone and water) than a conventional coal-fired power plant. Water use, especially important in desert regions, is 20 percent less than that of conventional coal-based generation. Table 2 shows expected inputs and output of the plant.

Table 2. Expected Inputs and Outputs at Full Load, 100 % Capacity Factor

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, cu ft/sec	
Cooling Tower (surface water)	1.522
Demineralizer (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, cu ft/sec	
Cooling Tower Blowdown	0.117
Evaporation & Drift	1.412
Demineralizer Waste	0.0082
Gasifier Stream Waste	0.0732
Solid Waste	
Sulfator, tons/yr	43,635

Solid waste produced will be less than from a conventional coal-fired power plant with a wet scrubber. The wastewater evaporation pond will be double lined and provided with monitor wells.

Atmospheric emissions are expected to be lower than permit 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 low-sulfur coal. Resultant ambient air quality will meet all requirements, including those for Prevention of Significant Deterioration of air quality.

Figure 6. ***General Electric MS6001FA gas turbine (right) connected to HRSG (left).***

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. Based on unreported data, engineers expect that less than half of the ammonia will 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.

Project Milestones

To achieve smooth operation of the IGCC system, the operation of the combined cycle system must be reliable and smooth. Startup, performance testing of the combined cycle system and synchronization with the grid were achieved with a minimum of issues.

SPPCo first fired the gas turbine on August 15, 1996. On September 18, 1996, the steam turbine and gas turbine operations were synchronized to form the combined cycle. Subsequent performance testing of the combined cycle unit demonstrated that the unit met 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 was formally available for dispatch purposes on the SPPCo system.

SPPCo and DOE developed a 54-month schedule to complete the design, engineering, and construction work. After all environmental and construction permits were received, civil work started in February 1995 and was completed in February 1997.

The demonstration period began in February 1, 1997 and will continue for 42 months, ending July 31, 2000. Operation will be primarily on low-sulfur Uinta Basin bituminous coal from Utah.

Results of Operations

SPPCo continues to make progress toward achieving integrated operation of all systems. Some earlier problems (related to measuring solids levels) in the fines handling system have been resolved; however, other non-gasifier problems such as fines bridging in vessels have prevented feeding coal for more than 6-8 hours continuously. The gasifier has operated through numerous startup-shutdown cycles with reproducible specification-quality syngas.

In May, 1999, SPPCo experienced significant, although repairable, problems inside the gasifier. These problems involved damage to the air and coal feed tubes as well as loose refractory that lines the inside of the gasifier.

Refractory repairs were completed on Wednesday, June 23, 1999. After assembly of the coal feed tube and air tube into the bottom gasifier section, SPPCo re-install the assembly into the gasifier. SPPCo continues to operate the plant normally in the natural-gas-fired, combined cycle mode.

Through July 23, 1999, the gasifier has produced syngas for a total of 33.25 hours since the first syngas was produced in January 1998. The graph shows how the hours were accumulated.

Table 3. Gas Composition at Partial Load

Constituent	Volume Percent
CO	21.1
CO_2	8.0
CH_4	0.4
H_2	11.9
N_2	53.1
H_2O	5.5
Total	100.0
H_2S	12 ppmv
COS	40 ppmv
LHV*	104 Btu/scf

*Lower Heating Value

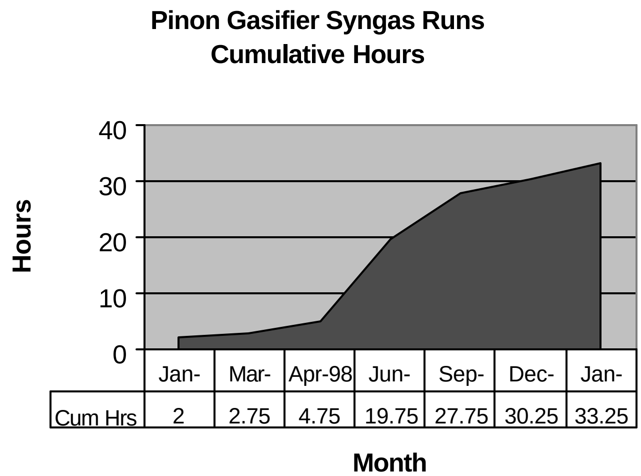


Table 3 shows the syngas composition for a typical gasifier run in the past year. For this run, the gasifier was operating at 120 psig (compared to a design pressure of 280 psig) and an average gas temperature of 1750 °F (compared to a design value of 1800 °F). For this run the gasifier was not at steady-state conditions. The LHV is somewhat lower than the design value of 129 Btu/scf because of the methane component not reaching the design content of 1.4%. Methane content of the gas will increase – approaching the specification value – as the gasifier operates closer to design pressure. Also, the presence of coke breeze in the gasifier to facilitate start up does not yield as much methane as the coal, which will be fed as the operation of the gasifier approaches the design conditions.

Status and Future Testing

SPPCo continues to address problems that limit the operation of the gasifier to only a few hours at a time. When the gasifier can be operated at steady state conditions for about 12 hours, SPPCo will begin removing the limestone and ash from the bottom of the gasifier and transporting it to the Sulfator. When SPPCo is confident that the gasifier and its auxiliary systems will operate reliably, SPPCo, with the assistance of GE, will transition the gas turbine fuel from natural gas to syngas. Operation of the power island on syngas will continue throughout the remainder of the operations phase.

Summary

Since the gasifier was first fired in January 1998, SPPCo has made progress toward achieving integrated operation of all systems. SPPCo's progress has been slowed by problems mostly external to the gasifier. SPPCo and DOE are confident that they will be able to operate the power island on syngas and that the Piñon Pine plant will produce valuable data for developers of power plants featuring the KRW gasification technology.

The results of the demonstration program will undoubtedly lead to improved design and reduced operating and maintenance costs. Future applications and ongoing R&D will yield more improvements.

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. Where Piñon technology can be used to repower a facility, use of existing steam turbine(s) and the plant infrastructure, will further reduce costs.

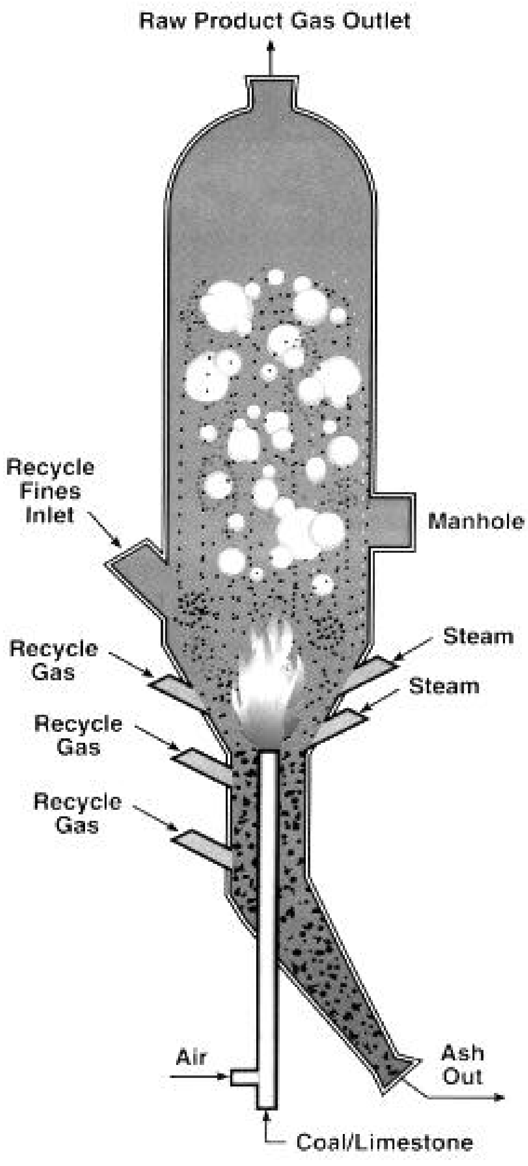
References

US. Department of Energy, “The Piñon Pine Power Project” Clean Coal Topical Report Number 8, December 1996.

Sierra Pacific Power Company for U.S. Department of Energy, “Tracy Power Station – Unit No. 4 Piñon Pine Power Project Public Design Report,” December 1994. DOE/MC/29309 – 4056.

Appendix I
Process Description
Kellogg-Rust-Westinghouse (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 formation of slag and most inefficiencies and costs associated with cooling the gas prior to gas cleanup. The operating temperature is 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 lockhoppers 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 resulting 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 dioxide (NO_2), water (H_2O), 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 yield solid calcium sulfide (CaS).

With the low-sulfur coal burned at the Piñon Plant, 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 forming ash agglomerates. These agglomerates 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 through a dipleg. The coal gas leaving the cyclone is cooled to 1,000°F (538°C), the operating temperature of the external transport desulfurizer. Steam produced by cooling the raw gas is integrated with the remainder of the steam system of the Piñon Pine Power Project.

Appendix II
External Hot-Gas Desulfurization

Desulfurizer

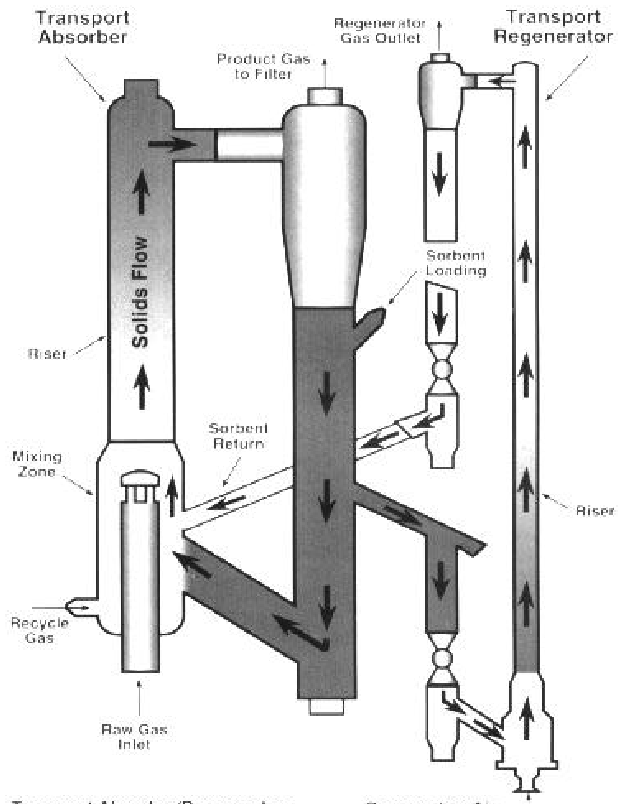
In the transport desulfurizer, developed and licensed by The M.W. Kellogg Technology Company, the total sulfur in the coal gas is reduced to less than 20 parts per million (ppmv) by contact with a zinc-oxide-based sorbent. The hardware system consists of a transport absorber and a transport regenerator.

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 desulfurizer.

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 the air convert zinc sulfide back to zinc oxide with the liberation of sulfur as 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 (743°C) and, after passing through a cooler, 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 amount 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 sulfidized 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 fresh 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.