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Development of Pressurized Circulating Fluidized Bed Partial Gasification Module (PGM)

DOE Contract No: DE-FC26-00NT40972

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Abstract

Foster Wheeler Power Group, Inc. is working under US Department of Energy contract No. DE-FC26-00NT40972 to develop a partial gasification module (PGM) that represents a critical element of several potential coal-fired Vision 21 plants. When utilized for electrical power generation, these plants will operate with efficiencies greater than 60% and produce near zero emissions of traditional stack gas pollutants.

The new process partially gasifies coal at elevated pressure producing a coal-derived syngas and a char residue. The syngas can be used to fuel the most advanced power producing equipment such as solid oxide fuel cells or gas turbines, or processed to produce clean liquid fuels or chemicals for industrial users. The char residue is not wasted; it can also be used to generate electricity by fueling boilers that drive the most advanced ultra-supercritical pressure steam turbines.

The amount of syngas and char produced by the PGM can be tailored to fit the production objectives of the overall plant, i.e., power generation, clean liquid fuel production, chemicals production, etc. Hence, PGM is a robust building bock that offers all the advantages of coal gasification but in a more user-friendly form; it is also fuel flexible in that it can use alternative fuels such as biomass, sewerage sludge, etc.

This report describes the work performed during the October 1 – December 31, 2002 time period.

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1.0 Introduction

Foster Wheeler Development Corporation is working under DOE contract No. DE-FC26-00NT40972 to develop a partial gasification module (PGM) that represents a critical element of several potential coal-fired Vision 21 plants. When utilized for electrical power generation, these plants will operate with efficiencies greater than 60% while producing near zero emissions of traditional stack gas pollutants.

The new process partially gasifies coal at elevated pressure producing a coal-derived syngas and a char residue. The syngas can be used to fuel the most advanced power producing equipment such as solid oxide fuel cells or gas turbines or processed to produce clean liquid fuels or chemicals for industrial users. The char residue is not wasted; it can also be used to generate electricity by fueling boilers that drive the most advanced ultra-supercritical pressure steam turbines.

The unique aspect of the process is that it utilizes a pressurized circulating fluidized bed partial gasifier and does not attempt to consume the coal in a single step. To convert all the coal to syngas in a single step requires extremely high temperatures (~2500 to 2800F) that melt and vaporize the coal and essentially drive all coal ash contaminants into the syngas. Since these contaminants can be corrosive to power generating equipment, the syngas must be cooled to near room temperature to enable a series of chemical processes to clean the syngas. Foster Wheeler's process operates at much lower temperatures that control/minimize the release of contaminants; this eliminates/ minimizes the need for the expensive, complicated syngas heat exchangers and chemical cleanup systems typical of high temperature gasification. By performing the gasification in a circulating bed, a significant amount of syngas can still be produced despite the reduced temperature and the circulating bed allows easy scale up to large size plants. Rather than air, it can also operate with oxygen to facilitate sequestration of stack gas carbon dioxide gases for a 100% reduction in greenhouse gas emissions.

The amount of syngas and char produced by the PGM can be tailored to fit the production objectives of the overall plant, i.e., power generation, clean liquid fuel production, chemicals production, etc. Hence, PGM is a robust building block that offers all the advantages of coal gasification but in a more user friendly form; it is also fuel flexible in that it can use alternative fuels such as biomass, sewerage sludge, etc.

The PGM consists of a pressurized circulating fluidized bed (PCFB) reactor together with a recycle cyclone and a particulate removing barrier filter. Coal, air, steam, and possibly sand are fed to the bottom of the PCFB reactor and establish a relatively dense bed of coal/char in the bottom section. As these constituents react, a hot syngas is produced which conveys the solids residue vertically up through the reactor and into the recycle cyclone. Solids elutriated from the dense bed and contained in the syngas are collected in the cyclone and drain via a dipleg back to the dense bed at the bottom of the PCFB reactor. This recycle loop of hot solids acts as a thermal flywheel and promotes efficient solid-gas chemical reaction.

Left untreated the syngas will contain tar/oil vapors, alkali vapors, and hydrogen sulfide at levels dependent on PGM operating conditions and fuels. The downstream users of the syngas will dictate a tolerance level for each of these gas constituents. If the users can tolerate both tar vapors and hydrogen sulfide, the syngas can be cooled to a level that condenses the alkali vapors on the particulate being removed by the barrier filter. Although this is a simple solution to an alkali problem, syngas cooling typically lowers the plant efficiency. When efficiency is to be maximized, as in the case of Vision 21 plants, the clean up can be done hot/without syngas cooling. In this case, lime based sorbents can be fed to the PCFB reactor along with the coal to catalytically enhance tar cracking and react with the hydrogen sulfide to capture the sulfur as calcium sulfide. Depending upon sorbent feed rates and gas residence times, the hydrogen sulfide can be reduced to near equilibrium levels which for high sulfur fuels (>3% sulfur) amounts to 95 to 98% sulfur capture. Alkali levels can be brought to gas turbine acceptable levels by injecting finely ground getter material such as emathlite or bauxite into the syngas downstream of the recycle cyclone. The fine particulate that escapes the recycle cyclone together with the injected alkali getter material are carried into the barrier filter by the syngas. As the syngas flows through the porous filter elements, the particulate collects on the outside of the elements and forms a permeable dust cake that ensuing syngas must pass through. The getter absorbs the alkali vapors as the syngas flows to the filter and passes through the filter dust cake. As the dust cake thickness increases, the filter pressure drop increases. Upon reaching a predetermined pressure drop, the dust cake is blown off the element by a back pulse of a clean high-pressure gas such as nitrogen injected into the clean side of the element. The dislodged dust cake falls to the bottom of the filter vessel and drains from the unit. If even higher sulfur capture efficiencies are desired, a second more reactive sorbent can be injected into the syngas for enhanced filter cake sulfur capture. Although the barrier filter is provided to reduce syngas particulate loadings to less than 1 ppm, it can also serve as a reactor in that its filter cake can be used for alkali vapor removal and sulfur capture. The char-sorbent-getter residue generated in the PGM drains continuously from the filter along with an intermittent PCFB reactor bed drain for transfer to the char combustor.

The proposed partial gasifier module (PGM) represents a building block of the Vision 21 program, which can be connected with a variety of additional modules to form complete Vision 21 plants (Figure 1). The PGM represents an “enabling” technology within the Vision 21 framework in that it can serve as a central processing unit for converting the raw fuel (coal, coke, biomass, or other opportunity fuels) into useful by-products (electricity, steam, chemicals, or transportation fuels).

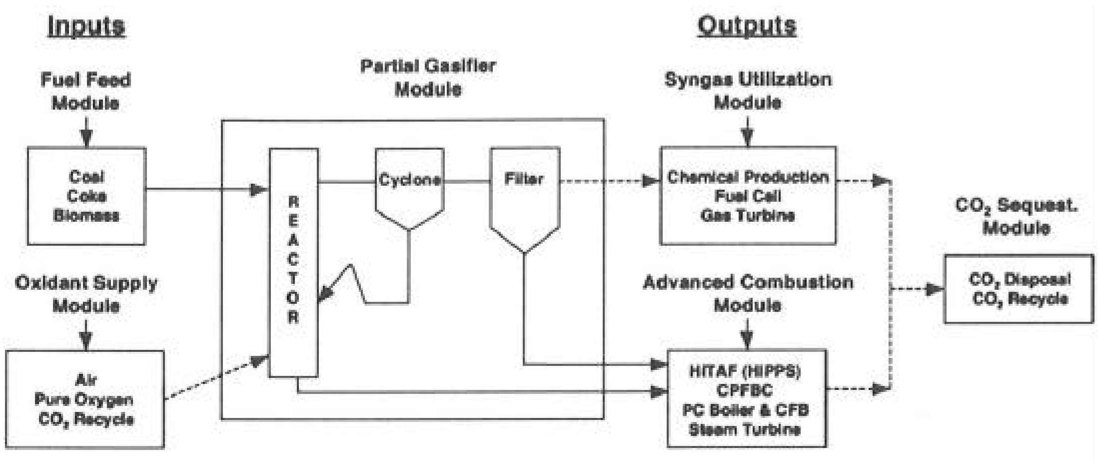

Fig. 1 Vision 21 Modules – Enabling Technologies

2.0 Executive Summary

FW's partial gasification tests in an air blown pressurized circulating fluidized bed gasifier pilot plant have been successfully completed. Under this test program, five different coals, petroleum coke, and sawdust were gasified and the effects of oxygen and CO_2 enrichment of the fluidizing air studied via 22 test points. Although detailed data analysis results will not be available until the end of the next quarter (6 points have been completed to date), testing has shown that the PCFB gasifier:

a. can gasify a wide variety of fuels;
b. can handle highly caking coals without agglomeration problems;
c. can operate in a co-firing biomass-coal mode;
d. can operate with oxygen and carbon dioxide enriched air;
e. can use porous metal filters to filter particulate without tar/oil blinding;
f. char residue can be easily handled.

3.0 Proposed Program

FW possess a coal-fired PCFB pilot plant at its John Blizard Research Center in Livingston, NJ. The facility can be operated in either a combustion or gasification mode with a gross heat input of up to 12 million Btu/hr. To support the Vision 21 program, the facility will be operated in the gasification mode with the focal point being the PCFB reactor with its recycle cyclone dipleg and loop seal and a barrier filter. These three components form the PGM shown in Fig. 2 and a syngas cooler can be installed to control the filter inlet temperature.

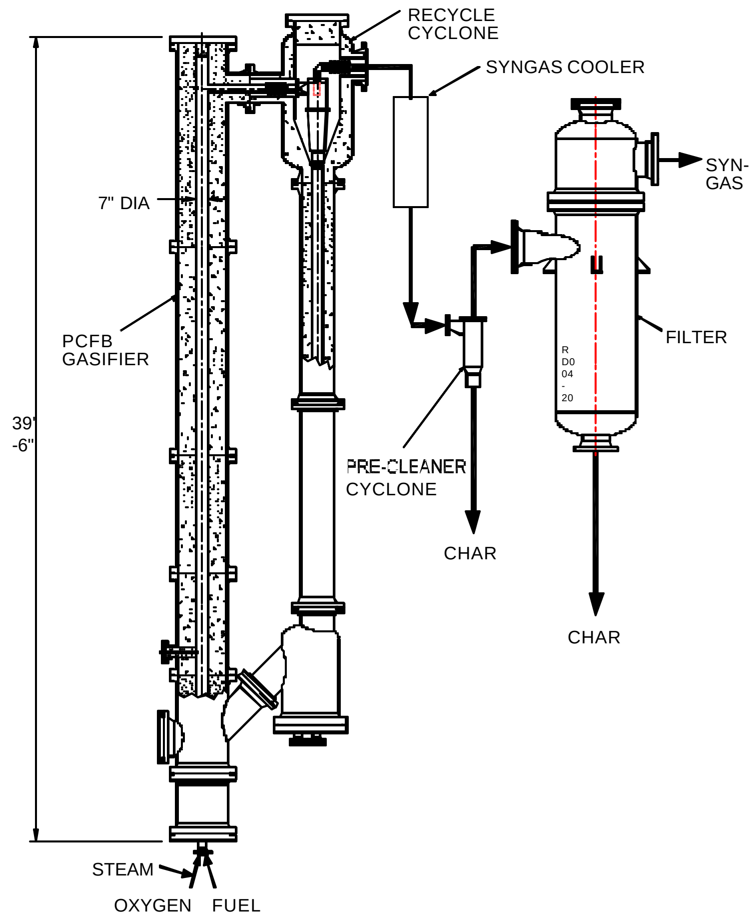

Fig. 2 Partial Gasifier Module Experimental Test Unit

The PCFB reactor is a 30” OD x 39’-6” tall vessel that is refractory lined to a 7” ID. Two lock hopper feed trains operating in parallel bring coal and sorbent to process pressure and feed the materials into a common line that injects the material into the reactor. The coal and sorbent are blown into the unit by air via a vertical 1” Sch 80 pipe located on the centerline and at the base of the unit. A 1½” pipe concentric with the feed pipe admits the balance of the process air together with steam. A relatively dense bed of coal, char, and sorbent form at the base of the unit. Syngas, together with entrained bed particulate matter, flow vertically up the unit at velocities ranging from 12 to 15 ft/sec and exit via a 4” ID radial nozzle 34’-10” above the top of the feed pipe. A recycle cyclone removes larger size particles from the syngas and returns them to the base of the unit via a dipleg and loop seal. The partially cleaned syngas passes through a cooler, a second stage cyclone, and enters a barrier filter vessel for removal of the remaining particulate. The filter can contain up to twenty-two 2 3/8” OD x 60” long candles all hung at one elevation from a metallic horizontal tube sheet. The syngas cooler is designed to yield filter inlet temperatures ranging from 650 to 800EF to allow operation with porous metal iron aluminide candles. The char-sorbent residue generated in the PGM is drained from the bottom of the PCFB reactor via a

2½" wide annulus around the 1½" air supply pipe. The draining material enters a holding section where counter flowing nitrogen cools the material as a packed bed to approximately 500EF. A lock hopper provided under the PCFB reactor and under the filter collects and depressures the material in batches for disposal.

Under the Vision 21 program, the PGM will be operated at varying conditions to determine syngas and char yields, heating values, and compositions when operating with:

1. alternative fuels, e.g., coke and coal-biomass cofiring
2. oxygen-enriched air

The Vision 21 effort is divided into the following five tasks:

Task 1 – Research and Development – Included in this effort are characterization of feedstocks to be tested, material evaluations to determine process induced corrosion rates, computer modeling of the PGM, and updates of possible Vision 21 plant configurations.

Task 2 – Engineering Design – Included in this task is the design of all modifications that must be made to and the procurement of materials that must be incorporated in the existing pilot plant to facilitate the Vision 21 test program.

Task 3 – Construction – This task covers the construction of all Task 2 changes/ modifications.

Task 4 – Testing – Included in this effort are parametric tests and data analyses dealing with alternate feedstocks and oxygen-enriched air plus evaluations of Stamet feed pump and filter performance.

Task 5 – Project Management – Conduct all activities needed to insure that project objectives are met on time and within budget; issue all cost and progress reports and a final report documenting the results of all test activities.

4.0 Progress for October – December, 2002, Time Period

Task1 – Research and Development

Vision 21 commercial plant performance predictions completed in the 2nd quarter year 2002 reporting period, showed that a PGM based plant incorporating a SOFC and a char burning atmospheric pressure CFB boiler in the Figure 3 configuration would exceed the 60% efficiency goal. As a follow up to that effort, FW is preparing a conceptual design and budgetary cost estimate for a near term demonstration of that plant. Rather than attempt to maximize plant efficiency, the objective of the demonstration is to operate the plant's key components for the first time as an integrated system. The plant will incorporate components with those technologies/

capabilities/sizes expected to be available in 5 to 10 years and, as such, the plant will be a first, lower efficiency step toward the extensive R&D needed to reach the Vision 21 60% efficiency goal.

In the previous reporting period FW sent an inquiry to a leading solid oxide fuel cell (SOFC) developer and asked if they would support FW's effort by:

1.) indicating what size unit they would anticipate being available in 5 to 10 years based on current development/R&D plans
2.) recommending operating conditions and allowable syngas contaminant levels
3.) indicating the expected performance and
4.) providing a budgetary cost estimate for the fuel cell

Despite several attempts to expedite an answer, no response was received from the SOFC developer. A similar inquiry was made to a leading molten carbonate fuel cell developer, but they required that their fuel cell be integrated with a small microturbine as a package – an arrangement that does not fit the Vision 21 plant concept. As a result, FW is basing its demonstration plant conceptual design on a 20 MWe SOFC operating at a nominal 1275F with the below assumed performance and will use published SOFC costs projections to estimate plant economics.

Nominal 1275F SOFC Performance Assumptions:

- hydrogen conversion: 85%
- converted hydrogen energy to electricity: 53%
- converted hydrogen energy to steam cycle: 44%
- converted hydrogen energy lost; 3%

The demonstration plant incorporates a PGM with a SOFC and an atmospheric pressure circulating fluidized bed boiler that burns the char residue along with fresh coal. Figure 4 is a simplified schematic of the plant. After cooling and removal of particulate matter, the syngas produced by the PGM is divided into three streams. One stream conveys PGM char to the CFB boiler, a second fuels the SOFC after undergoing water gas shift and membrane separation of non-hydrogen components, and the third fuels the gas turbine combustor.

FW modified its ASPEN model of a Gasification Fluidized Bed Combined Cycle Plant to reflect the Figure 4 arrangement. The plant has a gross output of 367.4 MWe; it incorporates a General Electric 6 F gas turbine producing 87.4 MWe of power together with a 20 MWe SOFC and a 3600 psig/1050F/1050F/2 in Hg supercritical pressure steam turbine producing 260.0 MWe.

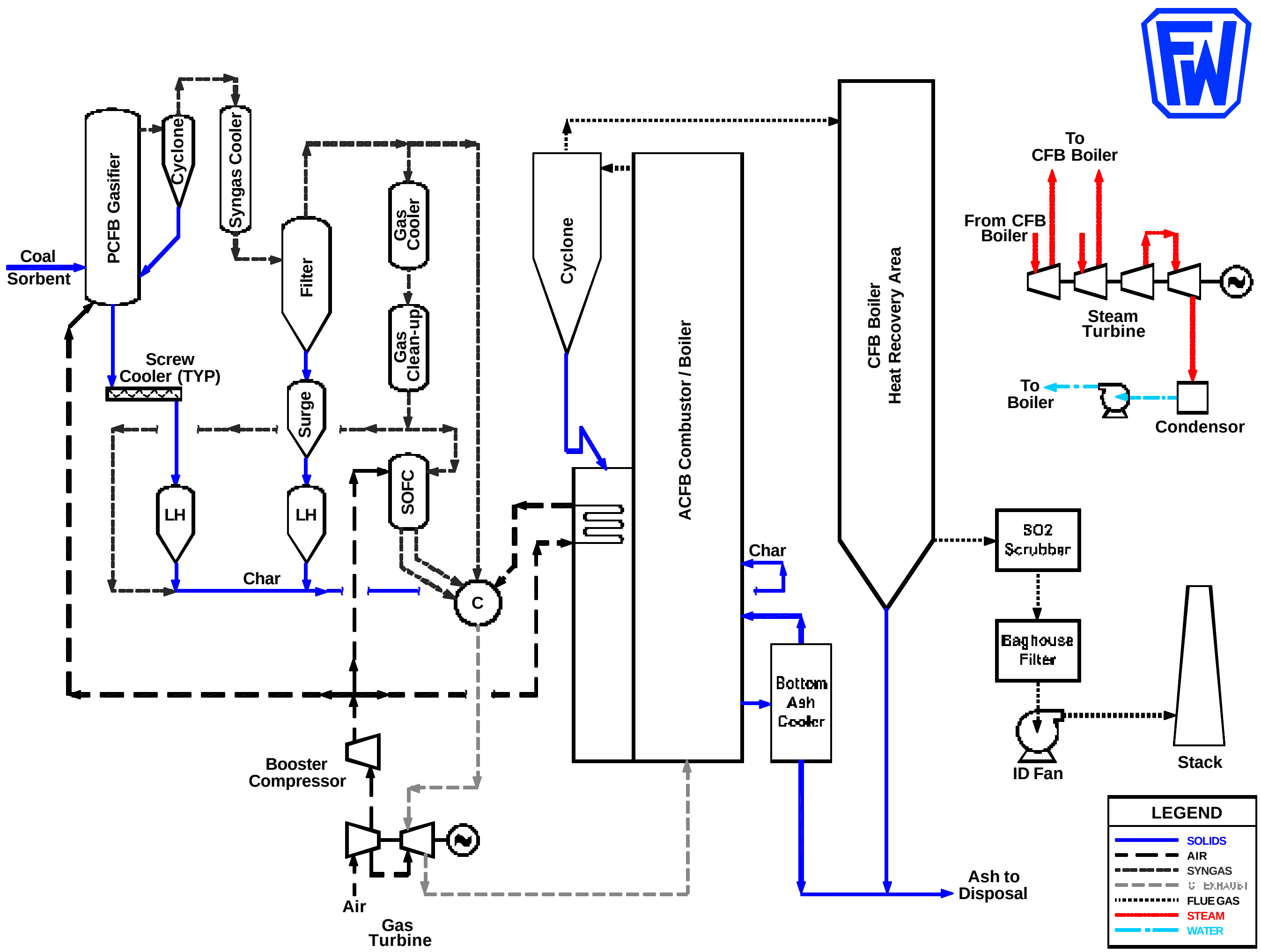

Fig. 3 Simplified Schematic of PGM with ACFB Boiler

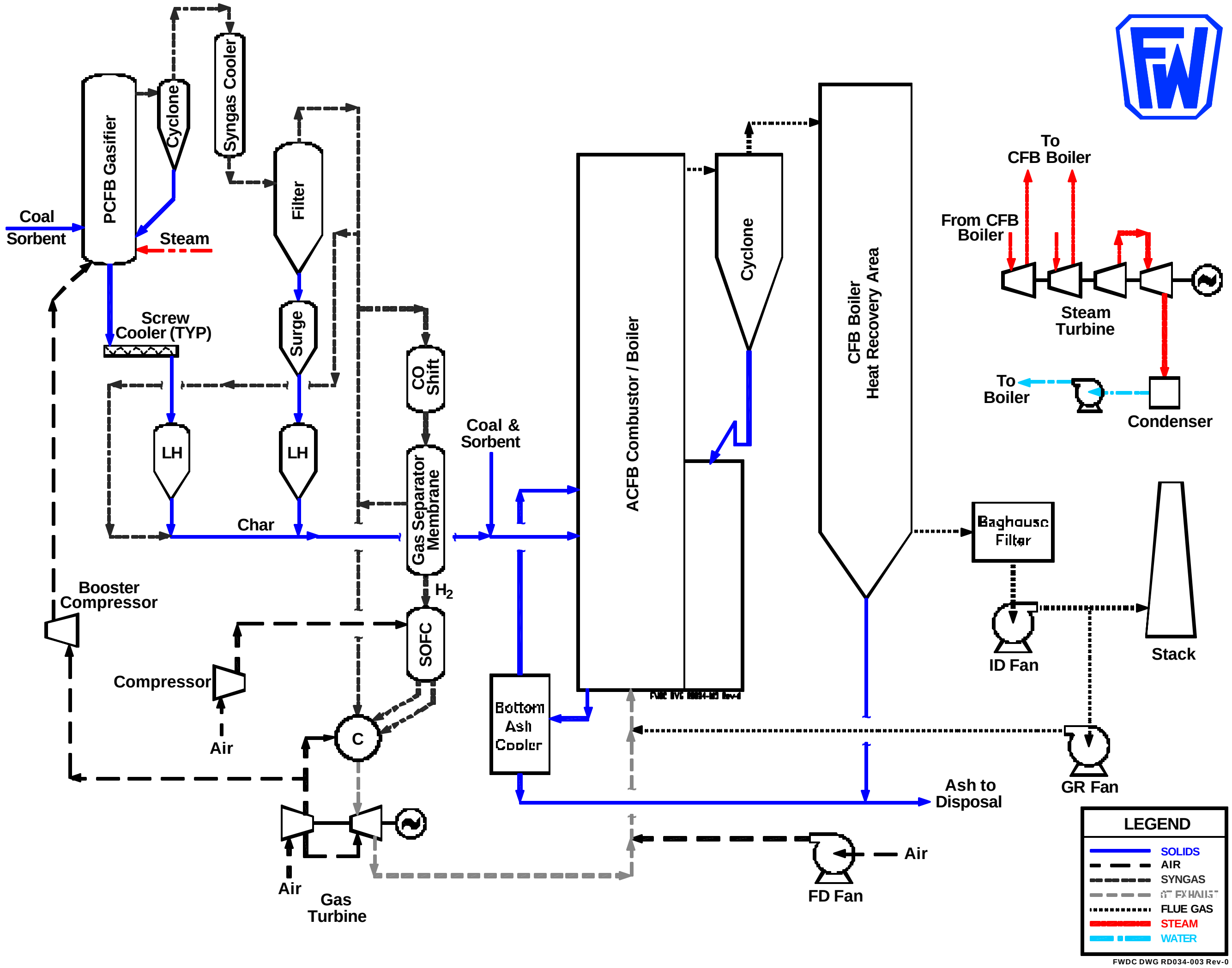

Fig. 4 Vision 21 Early Implementation PGM Demonstration Plant

In the plant configuration shown in Figure 3 the gas turbine compressor supplies the air required by the PGM, the SOFC, and the gas turbine combustor. Most present day gas turbines can export about 20 to 25% of their compressor discharge air without requiring a development effort. If this approach were to be used in the demonstration plant more than 25% of the compressor air would have to be exported. To eliminate the need for gas turbine development work and to ease integration/ operating complexity in this first of a kind plant, the SOFC has been provided with its own dedicated air compressor. As a result, only about 19% of the gas turbine compressor discharge needs to be exported and the additional air provided by the SOFC compressor increases the plant gross power output by about 5 MWe.

Even though Figure 4 is a demonstration plant, economics dictate that it have high availability and its complexity should not be daunting to electric utility operators. Providing the SOFC with a separate compressor simplifies control and operation and, should the SOFC portion of the plant be out of service, the gas turbine and CFB boiler can continue to generate electricity at essentially their respective full load values. Similarly, the CFB boiler is provided with forced draft and gas recirculation fans that allow it to operate even if the gas turbine and SOFC are out of service.

A preliminary/first cut heat and material balance was prepared for the Figure 4 demonstration plant. The plant operates with bituminous coal from the West Elk Mine in Colorado (see Table 1 for a typical coal analysis). The 1900F syngas produced by the partial gasifier is cooled to 650F and stripped of entrained particulate matter in a porous metal filter. The particulate free syngas divides into three streams. About 1% is used to convey PGM char to the CFB boiler, 72% proceeds to the gas turbine combustor, and the 27% balance undergoes water gas shifting and hydrogen membrane separation. The hydrogen permeate at 450F and 20 psia is compressed to 350 psia, undergoes a final stage of cleanup at 972F (sulfur and chlorides removal via a zinc oxide bed), and is delivered to the SOFC at 972F. Air at 270F is supplied to the SOFC which operates at 1277F. The unused hydrogen exiting the SOFC is quenched by mixing with the membrane retentate, whereas the exiting air is cooled to 1123F via heat exchange with the air entering the SOFC. The two exiting streams are then burned with the balance of the PGM syngas in the gas turbine combustor yielding a 2084F firing temperature. Based on the pressures, temperatures, and flow rates calculated for the plant, discussions were opened with manufacturers of commercially available catalysts and hydrogen separating membranes to confirm assumed performance levels and obtain sizing and pricing data.

Task 2 – Engineering Design

This task was completed in a prior reporting period

Task3 – Construction

This task was completed in a prior reporting period

Task 4 – Testing

PGM pilot plant testing was completed in January 2002, and laboratory analyses of solids and gas samples collected during the program continued through June. The 22 test points completed during the program involve a total of 116 syngas bag samples and 95 solid samples, all of which have been analyzed. A total of four coals, petroleum coke, and sawdust were tested. Table 1 presents their typical compositions, and it is to be noted that the particular Pennsylvania coals shown were specifically chosen because of their high free swelling index; the latter are highly caking coals and were selected to demonstrate the PCFB gasifier's ability to accommodate agglomerating fuels. One test point was completed with the sawdust cofired with the highly caking Dilworth bituminous coal, 7 points with petroleum coke, 3 points with subbituminous and 11 points with bituminous coals. Of the 7 petroleum coke test points, two used oxygen enriched air and one used carbon dioxide enriched air.

A major data analysis preparation effort was performed in the previous reporting period involving preparation of:

1.) a spreadsheet template for each of the 22 test points for retrieving operating data from the pilot plant on-line data historian
2.) interface macros for retrieving sample data (the analysis of the many samples of the coals, sorbents, chars, syngas, etc., collected in the program are logged in the laboratory's database and must be retrieved for use by our data reduction programs)
3.) spreadsheets for performing mass, energy, and elemental balances and determining carbon conversions and syngas heating values
4.) a spreadsheet template for presenting data analysis test results

Table 2 lists the operating conditions together with start and stop times for each of the 22 test points. Mass and energy balances are being prepared for each of the test points and carbon conversions and syngas heating values are being added as they are completed.

Analyses of the three subbituminous coal test points and three western bituminous coal test points have been completed and results entered in Table 2. As expected, carbon conversions increase with increasing temperature; with subbituminous coal being very reactive, its carbon conversions ranged from 80.6 to 90.6%, whereas the bituminous West Elk coal ranged from 72.4 to 76.8%. Syngas heating values on a dry and purge nitrogen free basis ranged from 105 to 114 Btu/SCF for subbituminous to 116 to 119 Btu/SCF for the bituminous coal.

Analyses of the test data will continue and should be completed in the next quarter. As previously reported, general observations are that the test program was very successful in that:

a. it has confirmed commercial plant predictions;
b. it has demonstrated that a PCFB can gasify a wide variety of fuels ;
c. it can handle highly caking coals without agglomeration problems;
d. it can operate in a co-firing biomass-coal mode;
e. it can operate with oxygen and carbon dioxide enriched air;
f. porous metal filters can be used to filter particulate without tar/oil blinding;
g. the char residue produced by the PCFB can be easily handled.

Table 1 Typical Composition of Fuels Tested

Mine Location	Eagle Butte WY	West Elk CO	Jones Fork KY	Dilworth PA	Buchanan PA	---	---
Fuel	**Subbitum.**	**Bitum.**	**Bitum.**	**Bitum.**	**Bitum.**	**Pet Coke**	**Sawdust**
Proximate, Wt % AR							
Moisture	23.57	3.55	6.83	7.50	7.12	1.84	4.28
Volatiles	31.50	37.11	35.74	33.41	19.05	11.14	76.79
Fixed Carbon	39.23	51.53	49.77	51.63	67.93	84.12	16.55
Ash	5.70	7.81	7.66	7.46	5.90	2.90	2.38
Ultimate, Wt % AR							
Carbon	54.09	73.22	70.93	72.96	79.44	88.03	47.64
Hydrogen	3.45	5.16	4.65	4.67	3.85	3.73	5.42
Nitrogen	0.72	1.51	1.44	1.45	1.08	1.28	0.44
Chlorine	0.00	0.05	0.14	0.12	0.17	0.00	0.00
Sulfur	0.29	0.64	1.06	1.41	0.74	2.16	0.03
Ash	5.70	7.81	7.66	7.46	5.90	2.90	2.38
Moisture	23.57	3.55	6.83	7.50	7.13	1.84	4.28
Oxygen	12.18	8.06	7.29	4.43	1.69	0.06	39.81
HHV, Btu/lb	9070	12899	12798	12977	13760	14793	8238
FSI	---	1 1/2	3 1/2	8	8	---	---

Task 5 – Project Management

The project is proceeding in accordance with the Figure 5 schedule and, as such, will be completed on time and within budget.

Table 2 Vision 21 Test Conditions and Results

Test Run		**VTR-01-01**	**VTR-01-02**	**VTR-01-03**	**VTR-02-01**	**VTR-03-01**	**VTR-03-02**	**VTR-04-01**	**VTR-04-02**	**VTR-04-03**	**VTR-04-04**
Begin Date		10/02/01	10/03/01	10/03/01	10/23/01	11/13/01	11/13/01	12/04/01	12/05/01	12/05/01	12/06/01
Begin Time		23:00	2:00	12:15	5:00	6:00	18:00	17:00	0:30	10:00	2:30
End Date		10/03/01	10/03/01	10/03/01	10/23/01	11/13/01	11/13/01	12/04/01	12/05/01	12/05/01	12/06/01
End Time		1:00	4:00	14:15	7:00	8:00	20:00	20:00	4:30	13:00	6:30
Operation Condition											
Fuel	-	West Elk	West Elk	West Elk	JF Coal	JF Coal	JF Coal	EB Coal	EB Coal	EB Coal	BU Coal
Carbon content	%	73.6	73.6	73.6	77.8	79.9	79.9	60.1	60.1	59.1	85.0
Pbed (PI-3007)	psig	117	117	123	93	90	117	116	120	103	122
Tbed (TI-3016)	F	1925	1931	1909	1941	1955	1961	1804	1808	1744	1851
Tbed (TI-3012)	F	1936	1940	1915	1946	1959	1963	1816	1818	1756	1855
Carbon conversion	%	72.4	76.8	72.6	TBD	TBD	TBD	88.3	90.6	80.6	TBD
Feed											
Coal Feed Rate	lb/h	325	311	328	218	228	308	362	347	342	362
Limestone Feed Rate	lb/h	3	3	4	14	29	17	0	0	0	0
Sand Feed Rate	lb/h	0	0	0	0	0	0	9	8	11	5
Air Flow Rate	lb/h	1200	1189	1200	1000	999	1209	1200	1200	1050	1200
Steam Feed Rate	lb/h	107	114	159	175	164	216	35	97	31	157
Output											
Filter Char Drain (FD)											
Drain Rate	lb/h	116	56	66	125	68	89	80	82	113	248
Carbon content	%	68	84	71	4	40	70	18	12	27	87
d50	micr	45	31	30	161	145	81	133	134	99	49
Bed Drain (PD)											
Drain Rate	lb/h	0	0	0	0	0	0	0	0	0	15
Carbon content	%	5	5	5	4	27	22	5	0	0	0
d50	micr	249	249	249	225	244	243	249	311	311	318
Process gas											
flow rate*	lb/h	1472	1502	1507	TBD	TBD	TBD	1544	1605	1351	TBD
heating value LHV*	Btu/lb	116	116	119	TBD	TBD	TBD	113	105	114	TBD
composition* (by v)											
Ar	%	0.82	0.85	0.86	TBD	TBD	TBD	0.73	0.74	0.75	TBD
N2	%	59.7	60.1	58.1	TBD	TBD	TBD	60.2	60.5	59.9	TBD
CO	%	12.3	13.2	11.5	TBD	TBD	TBD	14.7	11.9	14.0	TBD
CO2	%	13.1	12.0	13.9	TBD	TBD	TBD	11.5	13.3	11.7	TBD
H2	%	12.5	12.3	13.7	TBD	TBD	TBD	11.5	12.2	11.9	TBD
CH4	%	1.3	1.1	1.4	TBD	TBD	TBD	1.3	1.3	1.3	TBD
C6+	%	0.35	0.34	0.36	TBD	TBD	TBD	0.30	0.29	0.30	TBD
NH3	ppm	600	600	300	TBD	TBD	TBD	1000	1600	1500	TBD

Table 2 Vision 21 Test Conditions and Results (continued)

VTR-04-05	VTR-04-06	VTR-04-07	VTR-05-01	VTR-05-02	VTR-01-01	VTR-01-01	VTR-01-01	VTR-01-01	VTR-01-01	VTR-01-01	VTR-01-01
12/06/01	12/07/01	12/07/01	01/15/02	01/16/02	TBD	TBD	TBD	TBD	TBD	TBD	TBD
13:00	2:00	11:00	22:30	6:00	TBD	TBD	TBD	TBD	TBD	TBD	TBD
12/06/01	12/07/01	12/07/01	01/16/02	01/16/02	TBD	TBD	TBD	TBD	TBD	TBD	TBD
15:00	5:00	13:00	0:30	8:00	TBD	TBD	TBD	TBD	TBD	TBD	TBD
BU Coal	DW Coal	DW Coal	Coke	Coke	TBD	TBD	TBD	TBD	TBD	TBD	TBD
85.0	80.0	80.0	88.0	88.0	TBD	TBD	TBD	TBD	TBD	TBD	TBD
107	117	109	101	106	TBD	TBD	TBD	TBD	TBD	TBD	TBD
1909	1896	1844	1902	1834	TBD	TBD	TBD	TBD	TBD	TBD	TBD
1903	1891	1838	1912	1845	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
239	269	276	219	251	TBD	TBD	TBD	TBD	TBD	TBD	TBD
0	0	0	3	0	TBD	TBD	TBD	TBD	TBD	TBD	TBD
45	0	0	51	46	TBD	TBD	TBD	TBD	TBD	TBD	TBD
1050	1154	1050	1100	1100	TBD	TBD	TBD	TBD	TBD	TBD	TBD
141	134	140	128	152	TBD	TBD	TBD	TBD	TBD	TBD	TBD
158	138	111	166	112	TBD	TBD	TBD	TBD	TBD	TBD	TBD
62	57	70	60	77	TBD	TBD	TBD	TBD	TBD	TBD	TBD
65	72	56	74	49	TBD	TBD	TBD	TBD	TBD	TBD	TBD
0	0	0	0	0	TBD	TBD	TBD	TBD	TBD	TBD	TBD
0	0	0	28	17	TBD	TBD	TBD	TBD	TBD	TBD	TBD
318	318	318	234	264	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
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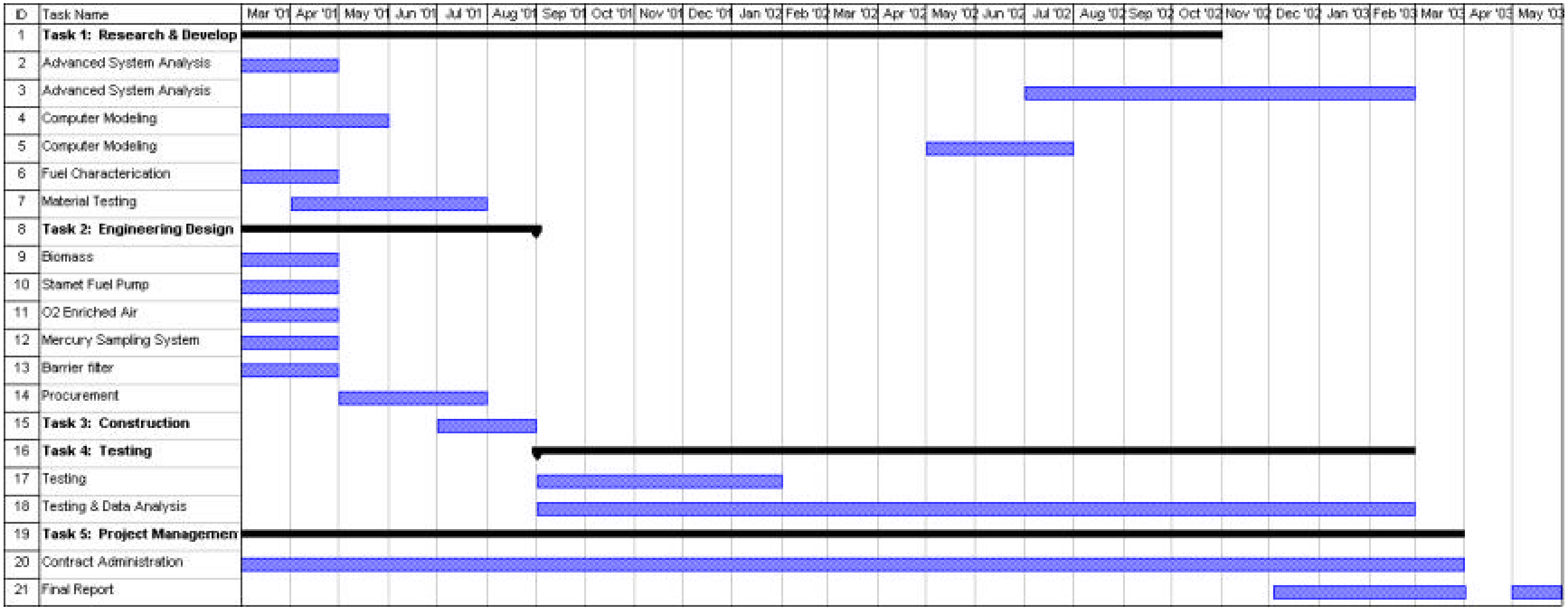

Fig. 5 Vision 21 Partial Gasification Module Project Schedule

5.0 Conclusions

A preliminary heat and material balance was prepared for a first step, 367 MWe (gross) Vision 21 demonstration plant; the plant incorporates an 87 MWe General Electric 6 F gas turbine together with a 20 MWe SOFC and a nominal 260 MWe supercritical pressure steam turbine. Conceptual design of the plant is underway.

Analyses of six of the 22 test points collected in FW's pilot plant PCFB partial gasifier have been completed. As expected, the Eagle Butte subbituminous coal yielded higher carbon conversion but with slightly lower syngas heating values than the West Elk bituminous coal.

6.0 Acronyms and Abbreviations

ACFM	Atmospheric Pressure Circulating Fluidized Bed
ATS	Advanced Turbine System
D50	Mass Mean Particle Size in Microns
DOE	U.S. Department of Energy
FW	Foster Wheeler Power Group, Inc.
HITAF	High-Temperature Air Heater
PCFB	Pressurized Circulating Fluidized Bed
PGM	Partial Gasification Module
SOFC	Solid Oxide Fuel Cell