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United States Department of Energy

PILOT PLANT TEST PLAN

SYNTHESIS GAS DEMONSTRATION PLANT PROGRAM PHASE I

JANUARY 1979

PREPARED UNDER CONTRACT No. ET-77-C-01-2577

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TEST PLAN

For Work To Be Performed Under The Terms
Of Subcontract No. 3 Between

Ebasco Services Incorporated

and

Texaco Incorporated

For

The Synthesis Gas Demonstration Plant Program

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Ebasco Services Inc

December 1978

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Prepared for the

U.S. DEPARTMENT OF ENERGY

Assistant Secretary for Energy Technology
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Introduction

Section I in Appendix A to Subcontract No. 3 between Ebasco Services Inc. and Texaco Inc. for the Synthesis Gas Demonstration Plant Program provides for pilot plant testing to be performed at Texaco's Montebello Research Laboratory.

The Type Ia test consists of laboratory scale screening analyses which are detailed in Appendix A of Subcontract 3 and, therefore, will not be considered further here.

The Type Ib and Type Ic tests are pilot plant evaluations which will be outlined in detail in this document.

Each Type Ib test consists of one or two short pilot plant runs during which approximately 6 tons of coal will be gasified at 1200 psig. The object of this test is to confirm the operability of the process with the selected coal, refine the estimates of preferred operating conditions, product gas yield and composition, obtain slag and char properties and establish the basis for a sustained run with the selected coal. Unexpected operating problems will be identified.

The Type Ic test will consist of a sustained 14-30 day gasification of the design coal at 1200 psig. The object of this test is to establish equilibrium conditions in all streams, obtain analytical data from all streams, obtain slag and char physical properties, demonstrate sustained operation with the design coal and confirm the design basis.

SECTION 1

PILOT PLANT PROCESS FLOW

The Texaco Coal Gasification Process is a noncatalytic partial oxidation process that is based on certain reactions between oxygen and hydrocarbons that take place at high temperatures to produce synthesis gas composed primarily of hydrogen and carbon monoxide. The high temperature reactions occur when the hydrocarbon and a deficiency of oxygen are introduced under pressure into a refractory lined vessel.

The pilot plant consists of seven sections, the coal grinding and storage system, the slurry preparation and feed system, the oxygen feed system, the gasifier, the slag removal system, the char recovery and water recycle system and the syngas treatment system. The flow rate of each gaseous and liquid stream is recorded during every run.

Coal Grinding and Storage System

This system consists of a primary crusher and a fine grinder, a screen classifier and associated charging hoppers, conveyors and storage bins. Coals handled in the system must be relatively dry and free flowing with a maximum top size of two inches. The system is capable of fine grinding a maximum of one ton per hour of a good grade of bituminous or subbituminous coal. Only limited outside storage of raw coal is available on site at the present time. Additional outside storage for large quantities of coal can be arranged for at a nearby facility (Black Products Co. in Fontana, Calif.)

Slurry Preparation and Feed System

Two agitated mix tanks are available, each of which can hold approximately 10 tons of coal-water slurry. Ground coal from the screen classifier is conveyed directly to either mix tank. Water is added batchwise in the proper ratio.

Slurry from the mix tanks is transferred in batches to a scale mounted run tank prior to charging to the gasifier.

Two auxiliary storage tanks for coal-water slurry are available. Each tank holds approximately 25 tons of slurry.

Oxygen Feed System

Liquid oxygen of 99.5 % purity is stored on site. The oxygen is pumped up to the desired pressure and vaporized before feeding to the gasifier. The flow rate of gaseous oxygen is measured with a conventional orifice, recorded, and controlled at the desired flow rate during each run. A section of steam traced line is used to preheat the oxygen to 300-325°F prior to metering, to insure a steady temperature at the orifice.

Oxygen and slurry are fed to a proprietary Texaco burner from which the streams enter the gasifier at the desired pressure and mass ratio.

High Pressure Solids Gasifier

The pilot plant gasifier is designed to operate at a maximum pressure of 81 atmospheres.

The top section is lined with a special refractory material specifically designed to withstand the severe operating environment expected. In this section, the partial oxidation reactions take place.

The lower section is a quench chamber. A reservoir of water is maintained in the bottom of this chamber at all times.

Slag Removal System

Molten slag, which forms during the gasification of the coal, is carried into the quench chamber with the syngas. Upon contacting the reservoir of water in the quench chamber, the molten slag solidifies.

The slag is removed from the bottom of the quench chamber during each run with a lockhopper system.

Char Recovery and Water Recycle System

During the gasification process, a small amount of char is formed which must be removed and recycled when practical.

Most of this material is removed from the syngas in the water reservoir at the bottom of the quench chamber. The char is less dense than slag and tends to remain dispersed in the water.

Syngas Treatment System

The syngas is cooled to condense and remove most of its water content, reduced in pressure, metered with a conventional orifice, sampled and flared. A back-pressure controller on this line maintains a steady gasifier pressure at the desired level.

A sample of the cooled, dry syngas is fed continuously to a gas chromatograph and an infrared analyzer. The gas chromatograph records the volume percent CO, CO₂ and CH₄ in the syngas on a ten minute cycle, while the infrared analysis indicates the volume percent CO and CO₂ in the syngas on a continuous basis. The primary analytical data from the syngas is determined by gas chromatograph or mass spectrometer in the laboratory on samples obtained periodically during each run. Water recovered from the syngas is recycled to the quench surge drum.

SECTION 2

TYPE Ib

PRELIMINARY PILOT PLANT TESTS

Objective

The object of the short test series is to confirm the operability of the process with the selected coal, refine the estimates of preferred operating conditions, product gas yield and composition, obtain slag and char properties, establish the basis for a sustained run with selected coal and identify unexpected operating problems. It is anticipated that operation of the gasifier will be in equilibrium with respect to temperature and syngas, slag and char production. It is recognized, however, that equilibrium of trace components and dissolved solids in the circulating water streams will not be achieved during this test. In addition, the recovered char will not be recycled.

Up to a maximum of three Type Ib tests may be made.

Each Type Ib test will consist of one or two short pilot plant runs at 1200 psig. Due to process parameters employed in the first run of each test series, failure of the first run indicates that process parameters cannot be modified to such an extent that a successful gasification run can be made. Therefore, in such cases no second run will be attempted.

Coal Required

During each two run series, a maximum of 12 tons of dry coal will be gasified. To allow for shipping and handling losses during grinding and slurry preparation, and for the moisture in the coal, it is suggested that a minimum of 18 tons and preferably 20 tons of coal be shipped to the Montebello Research Laboratory for each test. The coal should be relatively dry and free flowing with a maximum top size of two inches. Only coals that have been judged by Texaco to be suitable feedstocks on the basis of Type Ia evaluation will be accepted.

Each coal should be shipped prepaid via covered end dump truck to Texaco Inc., Montebello Research Laboratory, 329 North Durfee Rd., South El Monte, California 91733.

Run Conditions

The following run conditions will be utilized:

Slurry Charge	2000 gallons per run
Slurry Temperature	Ambient
Coal Slurry Concentration	Maximum pumpable concentration (55-65 wt%)
Slurry Charge Rate	2300-2500 lbs per hour
Run Duration	8-9 hours

The total laboratory time required including preparation and cleanup will be about one week.

The oxygen rate to the gasifier during the first run will be set to achieve a maximum gasifier temperature of approximately 2600°F.

The oxygen rate to the gasifier during the second run will normally be set to achieve a minimum gasifier temperature of approximately 100°F above the ash fusion temperature (reducing atmosphere). An intermediate temperature may be selected if warranted from an analysis of the data from the first run.

Slurry and oxygen flow rates will be held substantially constant during each run.

All slag recovered from the lockhopper will be dried and retained for a reasonable period at the conclusion of each run.

Sample Schedule and Analytical Data

Table 1 lists the samples that will be obtained during each run and the sampling frequency. Since all of the slag will be retained at the conclusion of each run, larger samples can be supplied to Ebasco at their request under the terms of the secrecy agreement between Ebasco and Texaco Development Corporation.

Table 2 lists the analyses that will be completed on each sample.

Technical Report

A technical report will be prepared within 60 working days after the completion of each test. The report will include a complete material balance around the unit. All major elements plus the ash will be adjusted by computer to produce 100 percent recoveries. The algorithm used varies the flow rate and analysis of each major stream in relation to its standard error until closure of all material balances are obtained with a minimum total deviation. Although this usually results in very minor changes to the measured variables, the raw, unprocessed pilot plant data will also be reported.

Table 3 lists the items to be included in the material balance.

In addition, each report will include a brief description of the pilot plant, all analytical data obtained during the run, a description of the run and an assessment of the operability and efficiency of the process with the feed coal.

SECTION 3

TYPE Ic

EXTENDED PILOT PLANT TEST

Objective

The Type Ic test will consist of a 14-30 day sustained gasification run at 1200 psig feeding the design coal. The object of this test is to establish equilibrium conditions in all streams, obtain analytical data from all streams, obtain slag and char physical properties, demonstrate sustained operation with the design coal and confirm the design basis. A run that is interrupted in an insubstantial way shall be deemed a sustained run. The run shall be considered completed when after at least 14 days, 24 hours per day of operation, laboratory analyses and pilot plant data indicate that equilibrium conditions have been substantially reached in all streams.

Coal Required

To allow for shipping and handling losses and for the possibility that more than 14 days of operation will be required to reach equilibrium, arrangements should be made to ship approximately 450 tons of the design coal via rail to Black Products Co. at the Santa Fe terminal, Kaiser Station, Fontana, California, attention Frank Klimaitis. Prior arrangements for off-loading, storage and shipping via end dump trucks to the Montebello Research Laboratory must be made with Mr. Fred Belz at Black Products Co., 13513 Calumet Ave., Chicago, Illinois 60627. The coal shipped should be relatively dry and have a maximum top size of two inches.

Run Conditions

The following run conditions will be utilized:

Slurry Charge Rate	2200-2500 lb/hr
Slurry Temperature	Ambient
Coal Slurry Concentration	Maximum pumpable concentration (55-65 wt%)
Oxygen Charge Rate	Optimum, based on previous Type Ib evaluation
Gasifier Pressure	1200 psig
Run Duration	14-30 days
Total Gasified	200 tons minimum
Total Laboratory time required including preparation and cleanup	4-5 weeks

All feed rates will be held substantially constant during the run and char and water will be recycled. Water will be recycled on a continuous bases. The char will be recycled by batch transfer from the char settler to the slurry mix tank each time a new batch of slurry is prepared. Fine slag will be collected once per shift in an open-top hopper for sampling, weighing and drying.

Sample Schedule & Analytical Data

Table 4 lists the samples that will be obtained during the run and the sampling frequency.

Table 2 lists the analyses to be completed on each sample. Because char will be recycled during this test, an ultimate analysis including chloride will be completed on each sample of charge slurry. In addition, one sample of charge slurry every four days of operation will be analyzed for ash fusion temperature, gross heating value, and semiquantitative analysis of the ash.

Technical Report

A technical report will be prepared within 60 working days after completion of the run. The report will include a complete material balance around the unit for each day of operation. Both raw data and computer adjusted data will be reported. The data will be substantially as shown on Table 3 except that the Dry Coal in Slurry will include recycle char.

In addition, the report will include a brief description of the pilot plant, all analytical data obtained, a description of the run and an assessment of the operability and efficiency of the process with the feed coal. Trace component concentrations in the clarified water will be plotted as a function of time to show the approach and attainment of equilibrium.

SECTION 4

SCHEDULE & COSTS

Type Ib Tests

Texaco has agreed to complete a maximum of three Type Ib tests, the first of which is scheduled to take place during the last quarter of 1978. It is assumed that the other two Type Ib tests will be completed during the first quarter of 1979 if Ebasco desires that these tests be made and can arrange to ship the coals to the Montebello Research Laboratory in time.

A more definite time schedule cannot be made until the high pressure pilot plant gasifier has been fully commissioned and operated, and Ebasco notifies Texaco the number of runs desired and the final arrangements for shipping the desired coals to the Montebello Research Laboratory.

The Ebasco project manager will be notified one week before each run begins so that he may send observers if he so desires.

Each run will require one week of Laboratory effort at a fixed price of \$67,500 during 1978 and \$74,250 in 1979.

Type Ic Test

The Type Ic Extended Pilot Plant Test is scheduled for completion before July 31, 1979 pending successful operation of the high pressure pilot plant gasifier, completion of sulfur recovery facilities and availability of the desired feed coal. It is anticipated that four to five weeks of laboratory effort will be required. The cost of the test is a fixed price of \$371,250.

The Ebasco project manager will be notified approximately two weeks before the run will begin so that he may send observers if he so desires.

SECTION 5

TABLES 1-4

<u>TABLE</u>	<u>TITLES</u>
1	Samples & Sampling Frequency - Type Ib Test
2	Analytical Data to be Supplied by Texaco
3	Material Balance
4	Samples & Sampling Frequency - Type Ic Test

Table 1

SAMPLES & SAMPLING FREQUENCY
Type Ib Test

<u>SAMPLE DESCRIPTION</u>	<u>SAMPLE SIZE</u>	<u>SAMPLING FREQUENCY</u>
Charge Coal	1 qt.	initial sample
Charge Slurry	1 qt.	initial, intermediate & final
Quench Blowdown Water	1 qt.	every 2 hours
Scrubber Blowdown Water	1 qt.	every 2 hours
Clarified Water	1 qt.	initial, and final
Dry Syngas	std. sample bomb	every 2 hours
Flash Gas	std. sample bomb	every 2 hours
Recovered Char- Water Slurry	2 qt.	at conclusion of run
Coarse Slag*	1 qt.	at conclusion of run
Fine Slag-Water Slurry*	2 qt.	at conclusion of run

*All of the coarse and fine slag will be dried and retained for a reasonable period following the conclusion of each run.

Table 2

ANALYTICAL DATA TO BE SUPPLIED BY TEXACO

Charge Coal

Ultimate analysis, including Cl^- , % moisture, ash fusion temperatures (ASTMD-1857, reducing atmosphere), gross heating value, semiquantitative analysis of ash (see coarse slag below)

Charge Slurry

% Coal (wt), pH, density, viscosity

Quench Blowdown Water

TSS, TDS, pH

Scrubber Blowdown Water

TSS, TDS, pH

Clarified Water

TSS, TDS, pH, $\text{S}^{=}$, Cl^- , $\text{SO}_4^{=}$, OOCH^- , F^- , NO_3^- , BR^- , $\text{PO}_4^{=}$, CN^- , SCN^- , NH_3 , TOC, TIC, COD, Ca, Fe, Na, K

Dry Syngas

Vol (%) A, H_2 , CO, CO_2 , N_2 , CH_4 , H_2S , COS, NH_3

Flash Gas

Vol (%) A, H_2 , CO, CO_2 , N_2 , CH_4 , H_2S , COS, NH_3 , H_2O

Char-Water Slurry

% Solids, pH

Char

Specific Gravity, Ultimate Analysis, including Cl^- , wet sieve analysis including Nos. 6, 14, 20, 40, 100, 200 and 325 mesh, settling rate curve at ambient temperature

Table 2 (Cont'd)

ANALYTICAL DATA TO BE SUPPLIED BY TEXACO

Coarse Slag

Specific Gravity, Bulk Density, Ultimate Analysis, incl Cl^- , dry sieve analysis including Nos. 6, 14, 20, 40, 100, 200, and 325 mesh, semiquantitative analysis including Si, Fe, Al, Ca, Mg, Ti, Cr, Be, K, B, Mn, Pb, Ga, Ni, Mo, V, Cu, Na, Zn, Zr, Co and Sr

Fine Slag-Water Slurry

TSS, TDS, pH, Cl^- , $\text{S}^{=}$, NH_3

Fine Slag

Specific Gravity, bulk density, ultimate analysis including Cl^- , dry sieve analysis including Nos. 6, 14, 20, 40, 100, 200 and 325 mesh, settling rate curve at ambient temperature, semiquantitative analysis including same elements as listed above for coarse slag.

TSS = total suspended solids

TDS = total dissolved solids

TOC = total organic carbon

TIC = total inorganic carbon

COD = chemical oxygen demand

All trace component analyses will be reported in parts per million (PPM)

Table 3

MATERIAL BALANCE

INPUT TO GASIFIER

Slurry Feed Rate, Lb/hr
Wt% Dry Coal in Slurry
Oxygen Feed Rate, Lb/hr

TOTAL INPUT, Lb/Hr

OUTPUT FROM GASIFIER

Dry Syngas, Lb/Hr
Flash Gas, Lb/Hr
Dry Char, Lb/Hr
Dry Coarse Slag, Lb/Hr
Calculated Water, Lb/Hr

TOTAL OUTPUT, Lb/Hr

ANALYTICAL

Dry Coal in Slurry, Ultimate Analysis Wt. Pct.

C
H
N
Cl
S
Ash
O (By Diff)

Table 3 (Cont'd)

Dry Syngas Analysis, Vol. Pct.

H₂

CO

CO₂

N₂

H₂S

COS

CH₄

A

NH₃

Dry Flash Gas Analysis, Vol. Pct.

H₂

CO

CO₂

N₂

H₂S

COS

CH₄

A

NH₃

Carbon on Coarse Slag, Wt. Pct.

Carbon on Fine Slag, Wt. Pct.

Carbon on Char, Wt. Pct.

OPERATING CONDITIONS AND CONVERSION

Percent Carbon Conversion

Gasifier Pressure

Gasifier Temperature

Run Length, Hrs.

TABLE 4
Samples & Sampling Frequency
Type Ic Test

Description	No. of Samples Analyzed Per Day	Sample Size	Sampling Frequency
Charge Coal	1	1 qt.	1 per day
Charge Slurry	3	1 qt.	1 per 8 hr shift
Quench Blowdown Water	3	1 qt.	1 per 8 hr shift
Scrubber Blowdown Water	3	1 qt.	1 per 8 hr shift
Clarified Water	2	1 qt.	1 per 8 hr shift
Dry Syngas	3	std. sample bomb	1 per 8 hr shift
Flash Gas	3	std. sample bomb	1 per 8 hr shift
Recovered Char- Water Slurry	All	2 qt.	1 per recycle load
Coarse Slag*	All	1 qt.	1 per hopper load
Fine Slag-Water Slurry*	All	2 qt.	1 per hopper load

*All of the coarse and fine slag will be dried and retained for a reasonable period following the conclusion of the run.

APPENDIX

Appendix A of Subcontract No. 3 between Ebasco and Texaco Inc -
Statement of Work

SUBCONTRACT NO. 3

APPENDIX A

STATEMENT OF WORK

Texaco Inc. - Research & Technical Department ("Texaco") shall provide plant facility and consulting services to Ebasco to support the design and confirmatory studies of the Texaco Coal Gasification Process ("TCGP") for the Synthesis Gas Demonstration Plant Program.

I. PILOT PLANT OPERATION - TEXACO'S MONTEBELLO, CALIFORNIA FACILITIES

Texaco shall provide Technical Support services in the form of Pilot Plant Confirmation Studies.

The integrated gasifier pilot system shall be operated in a safe manner while meeting pertinent governmental environmental statutes and regulations. Operation is to be varied to test the Design Coal.

Texaco shall prepare a detailed test plan within sixty days after the date of signing this Subcontract. The plan shall show: 1) what tests are planned, 2) schedule of tests, 3) data to be obtained and frequency, 4) support services needed, and 5) other pertinent information such as cost estimates.

The major elements of the confirmation studies are as follows:

- (a) Make laboratory analysis and slurry tests of a sample of the coal to determine initial pilot plant operating conditions;
- (b) Make a series of runs varying operating conditions to establish the basis for the sustained run; Demonstrate turndown, emergency shutdown, and startup operations of the pilot unit;
- (c) Demonstrate the sustained 14-30 days gasification of the Design Coal under pressure of 1200 psi;
- (d) Provide necessary design criteria and data base for the Demonstration Plant;

(e) Develop necessary confirmation data, if needed, to improve gasifier operation in the Demonstration Plant; and

(f) Provide mechanical configuration of gasifier.

The Design Coal presently contemplated to be used is classified as an agglomerating coal with a Free Swelling Index of 5 or greater with no less than 2.5% sulfur on a moisture and ash-free basis. The decision as to ability to gasify a coal shall rest exclusively with Texaco, and Texaco's decision shall be final. Texaco shall advise Ebasco as to the reasons for its decision.

The coal to be tested by Texaco shall be supplied by Ebasco and delivered to the Montebello, California facilities of Texaco at Ebasco's expense and as required by Texaco to meet its commitments hereunder.

II. PACKAGE STUDY - TEXACO'S MONTEBELLO, CALIFORNIA FACILITIES

In implementation of the work referred to in Part I(a) above, Texaco shall make an ultimate analysis, ash fusion (reducing) and slurry tests on up to thirteen (as requested by Ebasco) 10-pound samples of coal. In addition, Texaco shall make an Estimate of Operation (one package printout) containing:

- (a) Coal feedrate;
- (b) Oxygen feedrate;
- (c) Water feedrate;
- (d) Quantity of synthesis gas produced;
- (e) Composition of synthesis gas produced; and
- (f) Output of rejected slag.

Texaco will consider making additional tests in excess of the thirteen indicated above.

III. TECHNICAL CONSULTATION

Texaco shall also provide technical consultation on the design of TCGP facilities.

In addition, Texaco shall provide to Ebasco:

- (a) monthly status report indicating (1) progress on the work under this Subcontract, and (2) monthly financial information of estimated actual expenditures, by type of costing, for work performed under this Subcontract (by 25th of month, covering that month);

- (b) a Technical Report in six copies within sixty (60) working days after the completion of each test under Part I(b) and (c) above, with an addendum attached thereto containing a computer printout of the data pertaining to the test concerned. Such information, in conjunction with necessary Subcontractor proprietary background information, will be sufficient to enable Ebasco to make meaningful evaluations of the process.
- (c) a Final Report regarding the work under Part I above, which shall include complete descriptive information regarding the entire program and shall include recommendations but exclude detail data except where necessary to substantiate the narrative.
- (d) assistance in the preparation of technical and management reports (as requested).
- (e) assistance to enable Ebasco to provide, 140 days prior to the scheduled conclusion of Phase I, and in detail satisfactory to Grace, revised estimates of cost for work to be performed for Phases II and III by the Texaco Research and Technical Department.