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Topical Report
Task 2DETAILED PROJECT PLANDesign, Construction and Operation
of Pilot Scale Charfuel® Process**DISCLAIMER**

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by

Char-Fuels Associates, Ltd.
Englewood, CO

MASTER

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DETAILED PROJECT PLAN
Design, Construction and Operation
of Pilot Scale Charfuel® Process

I. Preparation of Detailed Construction Plan

The detailed design of the Charfuel® pilot scale unit will be performed by Stone & Webster Engineering Co. except for the POX reactor system which will be designed by Ford, Bacon & Davis Technologies, Inc.. The Work Plan for developing the detailed pilot scale design is as follows:

- I.1 Prepare design basis and criteria document.
- I.2 Prepare process flow diagrams, develop mass and energy balances, and establish operating and design conditions.
- I.3 Size and prepare equipment specifications for all equipment.
- I.4 Develop initial piping and instrumentations diagrams, including major piping, valving, and major instrumentation and controls.
- I.5 Start general arrangement drawings.
- I.6 Start piping and mechanical design, including pipe sizes and specifications, expansion requirements, insulation and heat tracing requirements, equipment nozzle orientation, and equipment support requirements and location.
- I.7 Start detailed instrumentation and controls design, instrument list, instrument data sheets, data acquisition requirements, and electrical design requirements.
- I.8 Based on vendor drawings and engineering data, update P&I diagrams and piping and mechanical design.
- I.9 Based on updated P&I diagrams and piping and mechanical design, finalize general arrangement drawings, including equipment and vessel arrangements as well as equipment and vessel nozzle orientation and supports.
- I.10 Design all required foundations and structures.
- I.11 Complete electrical design and finalize instrumentation and controls.
- I.12 Prepare start-up, operating and shut-down procedures and test plan.
- I.13 Develop gas supply systems requirements and negotiate gas supply contract. Gas supply systems and installation will be by gas supply contractor.

- I.14 Develop utility requirements. Interpro to design and install utility supply systems, including water, steam, natural gas and air.
- I.15 Prepare construction bid package including P&I diagrams, piping and mechanical design documents and specifications, foundation and structural design drawings and specifications, instrumentation and electrical documents and specifications, and equipment and vessel vendor drawings and data.

II. Procurement of Materials and Equipment

The Project Plan for procurement of equipment, instrumentation and specialty items is detailed below. Bulk materials, such as concrete, structural steel, piping, etc., will be procured by the construction contractor.

- II.1 Based on the equipment data sheets and specifications developed in detailed design, prepare major equipment bid documents.
- II.2 Prepare equipment vendors list. Issue equipment bid documents to vendors and obtain firm price bids.
- II.3 Evaluate equipment bids, select vendors, and issue purchase orders for major equipment.
- II.4 Obtain, review and approve equipment vendor drawings and data.
- II.5 Based on the instrument data sheets and specifications developed in detailed design, prepare instrument bid documents.
- II.6 Prepare instrument vendors list. Submit bid documents to vendors and obtain firm price bids.
- II.7 Evaluate instrument bids, select vendors and issue purchase orders.
- II.8 Prepare bid documents for misc. short delivery equipment and specialty items such as quench spray nozzles and Venturi mix nozzle.
- II.9 Prepare vendors list for miscellaneous equipment and specialty items. Issue bid documents to vendors and obtain firm price bids.
- II.10 Evaluate miscellaneous equipment and specialty item bids, select vendors and issue purchase orders.

III. Construction, Testing and Start-up

- III.1 Construction of the Charfuel® pilot scale unit will be performed by a qualified contractor based on competitive bid. S&W will prepare the construction package during the detailed engineering phase of the Project. S&W will also perform construction management activities.

- III.1.1 Develop construction bidders list. Submit construction bid package to bidders and obtain firm construction bids.
 - III.1.2 Evaluate construction bids, select construction contractor and negotiate contract.
 - III.1.3 Release contractor to move onto site, order structural steel, and mobilize work force.
 - III.1.4 The construction contractor will prepare site; pour and finish concrete foundations; erect structural steel stairways, gratings, etc.; set equipment; install piping, valves, fittings and supports, including gas supply piping; and install all instruments and controls. Construction manager (Stone & Webster) and CFA personnel will be on site to inspect and approve field routing of piping and location of major controls, instruments and valves.
 - III.1.5 Interpro will complete tie-ins to existing facilities such as the pulverizer/dryer, water supply, and the natural gas, steam and electric power systems. Interpro will also install all required electric wiring and conduits, motor starters, switches, breakers, permanent lighting, etc., as well as the data acquisition system. Interpro will also install required insulation and heat tracing.
 - III.1.6 The gas supply contractor will install gas supply systems, including vessels, pumps, evaporators, instruments and controls, etc. Piping from gas supply systems to the main structure will be installed by the construction contractor.
- III.2 As each subsystem is completed, it will be proof tested and the control system checked out. The proof testing will follow appropriate QA/QC guidelines and code requirements for proper pressure and temperature environments. The control system check-out will include behavior under simulated operating conditions. Electrical continuity tests will be completed on all wiring.

Specification compliance will be checked by examination of all vessel stamps and vessel test documents. A visual inspection will be performed to assure code compliance. Low and high pressure gas and leak detection proof testing will be done. All piping and connections will be tested visually, by X-ray or by other means.

- III.3 The Construction Manager will coordinate testing and start-up activities. His function would be to coordinate the test program, oversee equipment shakedown and performance acceptance tests, review acceptance tests, and make recommendations to the Project Manager concerning equipment acceptance or any required contract adjustments that may be required.

Operating instruction documentation will be required of all contractor/vendors. The operating test plan will be used to simulate operation. Operators will be

drilled in the proper methods and safe procedures of operating and purging the entire system with nitrogen and of starting the POX unit at low output. Full documentation of all methods and procedures will be created. Tests of normal and emergency shutdown procedures will be conducted by Interpro and supervised by S&W and CFA.

The subsystems operability will be verified by running all motors, operating controls and equipment and checking the relevant instrument response. This activity will include the data acquisition subsystem.

The existing coal pulverizer/dryer system will be tested and samples of coal will be collected and analyzed for particle size distribution and moisture content.

Following subsystem testing, all mechanical equipment and electrical equipment will be operated to verify its operability. The POX unit will be operated to verify its heat generating specification. The hydrocracker and its components will be tested to verify that specifications for coal and char flow, coal feed, gas supply, POX gas, storage, reactor operation, char separation, char cooling, etc. are met. System shutdown procedures and system emergency dump procedures will be verified. Upon successful completion of all shakedown and start-up routines, the system will be declared ready for operability testing.

The hydrocracker system will be tested by starting the POX unit at its operational level, introducing coal to the hydrocracker, and practicing normal start-up and shutdown procedures. Operation of the system will continue for a period sufficient to produce a representative quantity of char and process oil for analysis.

- III.4 The Project Manager will review contractor deficiency lists, if any; he will review all contractor facility documentation; he will have all deficiencies corrected; and he will sign off on the appropriate acceptance documents.

Potential Problems and Solutions During Construction

All of the equipment required in the Charfuel® pilot scale unit is relatively small and fabricated from readily available materials of construction. No problems relating to procurement of equipment are expected. S&W and CFA will monitor the status of all major equipment from procurement through fabrication, shop inspection, and shop testing.

No unusual problems are expected for constructing the pilot scale unit. The Project site is located at an active research and development facility and, therefore, infrastructures such as roads, utilities required for construction, etc., are in place. Adequate space is available for storing all equipment and materials required for construction of the pilot scale unit until the stored items are needed by the construction contractor.

Bulk materials for construction, such as structural steel, piping, valves, flanges, etc., are readily available in the sizes and ratings required. All required utilities such as steam, cooling water, electric power, and natural gas are in place.

Shakedown and start-up problems are normally hard to predict for a facility such as this. The most likely problem area during start-up will be the refractory lined hydrocracker which must be carefully started up to prevent damage or severe cracking and spalling. Refractory material must be cured and heated in strict adherence with manufacturers recommendations. The hydrocracker will be subjected to thermal stresses and thermal cycling due to several expected start-ups and shutdowns and potential refractory spalling may occur due to injection of recycle quench oil.

IV. Test Program and Operations

The proposed test program will provide data to verify that the facility and process designs are performing as expected, or will provide data which will facilitate the design and implementation of appropriate modifications. Table I sets out those components to be considered for inclusion in the overall operation plan. This list will be reviewed periodically by Project participants to ensure that it contains the appropriate components for successful demonstration, operation, and recording of all pertinent information, including data and results from each run.

TABLE I
OPERATION PLAN COMPONENTS

1. Identify Project objectives
2. Specify criteria to determine if objectives are being met or if they have altered.
3. Define operating parameters and conditions for each test run.
4. Establish anticipated schedule based on objectives and either a past or projected schedule completion success factor.
5. Identify maintenance or repairs to be performed prior to, during, or after the operation/ demonstration that will impact schedule, operations or personnel.
6. Identify special precautions for working during operations; concerns for repairs during hot operations; and precautions for personnel when collecting process samples at high temperature or pressure.
7. Specify data requirements such as:
 - (a) Continuous measurements to be routinely made and recorded on the system data logger, including specific calibrations or maintenance required for the monitors or data logger.
 - (b) Sample collection frequency and location from which stream samples must be collected to ensure a representative stream sample is collected.

- (c) Intermittent measurements to be made visually and recorded in a control room log or individually keyed into the plant computer. This would include measurements made by collecting a sample and performing immediate analysis.
 - (d) Mechanical design performance measurements to be made visually or with instruments on an intermittent basis to determine materials utility and viability for a particular function, as well as reliability of designs under specific conditions of service.
 - (e) Definition of any new monitors or instruments that will be installed or operational for either continuous or intermittent measurements.
 - (f) Data Reduction -- procedures to reduce the instrument data to define demonstration, set point or run averages with required and appropriate statistical information.
8. Specify chemical analysis methods and requirements, including:
- (a) Specifying preparation requirements and procedures for compositing materials to obtain representative stream samples.
 - (b) Identifying those evaluations which will be performed on specific samples during normal operation.
 - (c) Identifying additional operations or new evaluations to be performed to meet the objectives of the operating plan.
9. Specify criteria for equipment performance evaluation
10. Establish QA/QC Requirements. Specific QA/QC requirements will be placed on the primary variables and unit conditions and flows to define the periods of steady state operation. Data from operations not meeting the criteria for steady state operation will not be used for evaluation purposes but rejected as unreliable due to transient operations.
- Data from the laboratory analysis will also be subject to review of the analytical instrument operation, success for meeting standard operating criteria and the reproducibility of results. Where available, reference standards will be used to validate procedures and results. Reference will be made in the operation plan to the specific document(s) where QA/QC requirements are found. Corrective action notices should be issued should analytical results exceed standard statistical limits placed on precision and accuracy.
11. Establish schedule and outline for summary data package to be prepared after completion of designated runs which will report

the chronology of significant events and the nominal data during periods of stable (set point) operation.

12. Prepare a final data package summarizing the conduct of the operation/demonstration and operational problems observed; all data results for defined steady state operating periods; success in meeting objectives; and recommendations for future demonstration. The final report will be as brief as possible yet contain appended all appropriate support information.

- IV.1 A detailed test plan will be developed by CFA, S&W and Interpro prior to the start-up of the pilot unit. The test plan objectives are to (1) verify process operability, (2) optimize operating conditions in the hydrocracker 1st stage (volatilization) to maximize oil yield, and (3) optimize operating conditions in the 2nd stage of the hydrocracker (oil up-grading).
- IV.2 The POX unit will be operated initially using natural gas and oxygen in order to obtain baseline data and to determine if the POX gas is at equilibrium or near-equilibrium composition. Natural gas, CO, steam and oxygen will then be fed to the POX unit and data collected to determine POX outlet gas composition and approach to equilibrium.
- IV.3 The hydrocracker system will be maintained, to the maximum extent possible, at hot conditions for the duration of the test series. Maintaining hot conditions will minimize heat-up and cool-down thermal cycling, assure stable thermal test operation, and minimize test run duration. After each test run, char will be collected from the char lockhopper system and oil will be collected from the product oil collection system. Operating conditions for the next test run (POX gas rate, coal feed rate, intermediate and final quench rates, etc.) will be set and the next test runs made. It is expected that about four hours total time (one to two hours actual test run duration) will be required for each test.
- IV.4 The pilot unit will be shaken down and "calibrated" using W. Kentucky No. 9 coal. Considerable yield data has been developed by others using W. Kentucky No. 9 coal in hydropyrolysis and liquefaction projects. The initial runs will be designed to demonstrate integrated operation of all components and to establish stable operation, i.e., no plugging, temperature excursions, etc. After stable operation is achieved, a test series will be run at 1st stage hydrocracker temperatures of from about 1500° F. to 1750° F. at 30 milliseconds and 300 milliseconds and at a pressure of 500 psig (similar conditions as run by Rockwell). Test duration at a specific set of operating conditions is expected to be one to two hours during the calibration stage. Yield data obtained from calibration runs will be compared with Rockwell yield data. If the yields are not as expected, an evaluation will be made to determine the most likely problem. Modifications will be made and tests re-run until the expected yields are obtained.

- IV.5 After the pilot plant has been successfully operating using W. Kentucky No. 9 coal, Glenrock subbituminous coal will be utilized for operations. A test matrix will be developed including 1st stage hydrocracker temperature range and residence times and 2nd stage temperatures range, residence times and hydrogen partial pressures.

The initial operating runs will be to verify stable operation using Glenrock coal. Data collection runs will be made for the 1st stage of the hydrocracker at the temperature and residence times specified in the test plan. The second stage will not be used for these tests. Vapor from the 1st stage will be quenched to less than 900° F. to essentially terminate reactions. Char and oil will be collected and product gas measured and analyzed for each test run. The data will be evaluated to determine the operating conditions producing the maximum oil yield. After the maximum oil yield and operating conditions have been determined, a series of tests will be run with both the 1st and 2nd stages in operation. The 1st stage will be operated at the conditions that produce the maximum oil yield. The 2nd stage will be operated over the range of temperatures, residence times and hydrogen partial pressures specified in the test plan. Hydrogen will be used to partially quench the reaction products to desired 2nd stage temperature. Recycle heavy oil will not be used during these tests. Baseline data will therefore be obtained without recycle heavy oil. Once the optimum or near optimum conditions are determined for the 2nd stage, tests using recycle heavy oil and hydrogen as the intermediate quench will be run at optimum 1st stage conditions to determine effects on oil quality by subjected the heavy oil to additional cracking and hydrogenation exposure time. The data from all of the 2nd stage test runs will be evaluated to determine the effects on oil quality, including hydrogen, sulfur, nitrogen, and oxygen content, boiling point range, viscosity, gravity, BTX content, etc.

After the optimum conditions have been determined, a continuous test run (two to four days) will be made to verify stable continuous operation, verify consistent yield data, and to produce sufficient char and oil for off-site tests (Charfuel® slurry formulation, rheology, and combustion tests).

Potential Problems and Solutions During Operations

Potential problem areas during operation include:

- (i) non-uniform solids flow to the hydrocracker through small lines;
- (ii) bridging, plugging and fouling due to handling solids and heavy oil in relatively small equipment and small piping; and,
- (iii) refractory spalling, cracking erosion, etc.

Steady, uniform flow of coal to the hydrocracker and high mixing efficiency of POX gas and coal particles are critical to the successful operation of the pilot scale plant. Gas spargers, and gas injection connections are strategically located to minimize solids bridging and plugging and to aid in obtaining steady, uniform solids flow. Heavy oil is maintained at temperatures sufficiently high to minimize fouling and plugging problems.

Maintaining the hydrocracker system at hot conditions during the operating phase should minimize thermal stresses which typically cause damage to refractory materials. Outer

metallic vessel and piping walls that are lined with refractory materials will be continuously monitored for "hot spots".

V. Data Collection and Analysis

V.1 Technical Evaluation

Data will be collected, analyzed and reported for each test run. During the design phase, all data collection system requirements will be specified and each subsystem will be designed to accomplish its task. The system requirements will include the following:

- Automated process measurements (flows, temperatures, and pressures)
- Manual data input
- Data sampling frequency
- Type and number of measurement transducers
- Other analytical instruments needed.

Software will be provided to calculate mass and elemental balances which will be developed for each test run. The collected data will be evaluated for consistency with other test run data and material and elemental balances will be reviewed for adequacy. Material and elemental balances for any given test run that are not within predetermined accuracy limits will be re-run such that the entire collected data base is consistent and reliable. Data to be collected for making material and elemental balance calculations will include:

- Total coal fed to the hydrocracker system, a coal analysis, and coal feed temperature
- All feed gas rates, temperatures, and pressures
- POX outlet gas temperature and analysis
- Hydrocracker first stage temperature and pressure
- Hydrocracker second stage temperature and pressure
- Recycle quench oil rate, temperature, and analysis
- Hydrogen quench gas rate and temperature
- Final quench liquid rate, temperature, and analysis
- Hydrocracker outlet temperature and pressure
- Heavy oil condenser inlet and outlet temperatures
- Oil/water condenser inlet and outlet temperatures
- Light oil condenser inlet and outlet temperatures
- Product gas rate, temperature, pressure, and analysis
- Vent gas rates, temperatures, pressures, and analysis
- Total char collected and analysis
- Total oil collected and analysis
- Total process water collected and analysis
- Test duration time

Prior to each coal run, a coal sample will be pulled to determine ultimate analysis. This baseline data will be used in making elemental balances. The mass and energy balance calculations will also consider the input streams into the POX unit; and

the gaseous, liquid, and char streams following product separation. The mass and energy balance software will calculate (over a specified time range) the total mass of material in each process stream, elemental constituents (C, H, N, O, S) of each process stream, sensible heat of each process stream, heats of reaction for pertinent processes, and thermal efficiencies of the entire demonstration plant operation.

Process data will be monitored with the data acquisition system. Process streams will be sampled and analyzed on a periodic basis as defined by the operation/test plan. The product gas stream will be monitored with on-line gas chromatographs to measure the gas composition. Cooled POX outlet gas samples will be analyzed in the laboratory.

Samples of the major process streams will be collected during each test run. The streams that will be sampled and analyzed include (1) dry coal feed, (2) char product, (3) product oil, (4) POX outlet gas, (5) all quench streams, (6) process water, and (7) product gas. The sampling frequency will depend on the length of the run and variation in process conditions.

Sampling systems will be designed to ensure that a representative sample will be collected. The samples will be collected in appropriate-size amber bottles, blanketed with nitrogen, sealed, and refrigerated. Analyses to be performed are summarized in Table II. The analytical procedures used for these analyses are standard ASTM procedures. All required quality assurance procedures will be followed to ensure high quality of the data.

TABLE II

Analyses to be Performed on Composite Samples**A. Elemental Analysis**

Stream	Analysis	Technique
Product Gas	Composition C1 to C10 hydrocarbons H ₂ , CO, CO ₂ Sulfur species Water Content	Gas Chromatography
Untreated Process Oil, Recycle Oil, and Hydrotreated Oil	Elemental Composition C,H,N S O Particulate loading Water determination	Elemental analyzer Sulfur analyzer Oxygen analyzer Gravimetric Distillation
Char**	Ultimate analysis Proximate analysis Water determination	Elemental analyzer Proximate analyzer/oven Gravimetric/oven
Water**	Oil wetting Total organic carbon	Gravimetric/extraction Elemental analyzer

B. Chemical Characterization Analysis

Stream	Analysis	Technique
Process Oil	Viscosity	Viscometers, bath
Recycle Oil	Average molecular weight Distillation profile	VPO Gas chromatography
Char	Ash fusion Elemental ash analysis	Furnace Elemental analysis
Water	Organic types TDS	

* Includes analyses for trace elements (toxics) for selected samples

V.2 Economic Evaluation

CFA, with assistance from Morrison Knudsen Engineers; Ford Bacon & Davis Engineers; Kidder, Peabody & Co., Inc.; Arthur Andersen & Co.; and, W.R. Grace & Co., has generated a comprehensive financial model to evaluate the economic viability of the Charfuel® coal refinery. Also, several conceptual level design and economic evaluations of the Charfuel® coal refining process have been performed by Morrison Knudsen Engineers; Ford, Bacon & Davis; and Stone & Webster. These designs include process flow diagrams, heat and material balances, utility balances, equipment sizing and design conditions, equipment cost estimates,

factored cost estimates, and operating cost estimates. The design, operating and yield data obtained from the pilot scale unit will be used to update these previous designs. The previous design basis will be adjusted based on information and data obtained in the pilot scale operation. Critical components, such as the coal feed injection nozzle and hydrocracker, will be scaled-up to the maximum practical size based on pilot scale performance. POX unit, char separator and recycle quench oil operating performances will also be evaluated and any required design changes made in scale-up application. Materials of construction used in the pilot scale unit will be evaluated to determine suitability for a large scale, continuously operating unit. Data (yield and composition of char, oil, and gas) obtained in the pilot scale unit will be used to develop new heat and material balances as well as product and by-product rates, and to confirm (or modify) overall process configuration. Individual process units, such as gas purification, will be scaled from the previous design to obtain new utility requirements and capital cost. Revised overall plant utility balances and revised plant capital cost estimates will be prepared. Operating costs (operating, labor, maintenance, etc.) will be estimated. The new product and by-product rates and capital and operating costs will be used in CFA's financial model to determine economic viability of the Charfuel® coal refinery.

Potential Problems and Solutions During Data Collection

No problems are foreseen for the Data Collection and Analysis Task.

VI. Feasibility Analysis

A feasibility analysis will be performed to determine the suitability of system performance for large scale operation. A prime objective of the pilot scale unit is the integrated operation of the hydrocracker with the POX unit, coal feed system, coal injection nozzle, char separator, and heavy oil collection and recycle system. Successful operation of these components is critical to scale-up. Pilot scale system performance will be closely monitored for stable operation, controllability, temperature and pressure excursions, etc., as well as individual component performance in meeting its operating specifications, i.e., char separator efficiency, POX outlet gas temperature and composition, etc. Large scale performance will be evaluated to determine if direct scale-up is suitable or if equipment and/or control system design changes or additional equipment is required.

VII. Project Milestones and Decision Points

A Project schedule showing milestones and decision points is included herewith. The tasks identified on the schedule correspond with those described in the Statement of Work in CFA's proposal to DOE submitted September 15, 1992

MILESTONE SCHEDULE
Pilot Scale Charfuel® Process Unit

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