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Technical Report for period ending: 03/31/1995

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[Signature]
Contracting Officer Representative

May 12, 1995

bcc:
David Hunter
DE-FC22-93BC14809
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Conversion of High Carbon Refinery By-Products

INTERIM TECHNICAL PROGRESS REPORT

Mechanical Design and Construction
New Transport Reactor System

Second Quarter - Fiscal Year 1995
(Jan-Mar 1995)

Work Performed Under Contract No.: DE-FC22-93BC14809

For
U.S. Department of Energy
Pittsburgh Energy Technology Center
Bartlesville Project Office
Bartlesville, Oklahoma

April, 1995
Job 7519

By
The M.W. Kellogg Company
Houston, Texas
Conversion of High Carbon Refinery By-Products

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DOE/BC/14809 -- 6
1.0 INTRODUCTION

During the last quarter, the detailed mechanical design of the new reactor system was completed and construction of the unit was well underway. The new design includes a mixing zone, riser reactor, cyclone, and downcomer as well as instrumentation, heating elements, insulation, and a structural system for supporting the unit. Design modifications were also made to the hydrocarbon feed system. There were no changes required for the downstream sections which cool and condition the reactor product gas, recover liquid products (if any), and measure product gas make.

Construction of the unit is expected to be completed by early May, with shakedown runs beginning immediately after. Installation of the electrical windings, insulation of the unit, erection, hook-up, and checkout are the main items yet to be completed. It is expected that the unit will be ready for test work in the latter part of May. The initial tests planned are both pyrolysis runs and partial oxidation runs using a simulated aromatic naphtha feed. Later this year, heavier hydrocarbon feeds will be tested.

2.0 DESCRIPTION OF UNIT

Figure 1 is a simplified sketch of the new unit, which consists of a mixing zone, a riser, a cyclone, and a downcomer. The system has been designed to operate at temperatures as high as 1800°F and pressures up to 100 psia.

The hydrocarbon feed is usually injected into the upper part of the mixing zone where it mixes with hot solids, returning to the zone from the standpipe, and oxidant/steam/N₂ fed to the bottom of the reactor. The solids/vapor mixture flows upward through the riser and the hydrocarbon undergoes pyrolysis, with laydown of carbon on the solids. The mixture enters the cyclone, which separates virtually all of the solids and returns them to the standpipe. Product gas is sent to the cooling, conditioning, and recovery system. Solids flow from the standpipe back to the mixing zone is controlled by a plug valve at the bottom of the standpipe.

During pyrolysis runs, only steam is injected into the bottom of the mixing zone. At the higher riser temperatures, this steam will gasify some of the carbon on the solids, but basically the carbon is allowed to accumulate on the circulating solids. During partial oxidation runs, air is injected at the bottom, either with or without steam, to burn off the net carbon make from pyrolysis of the feed in the riser. This produces an "equilibrium" loading of carbon on the solids.

3.0 MECHANICAL DESIGN

3.1 Reactor

The reactor is comprised of two sections, a lower mixing zone and an upper riser. The mixing zone is fabricated from 1½" schedule 160 Incoloy 800HT pipe, and is 10 feet high. The riser is 1" schedule 160 pipe, approximately 30 feet high, and is made from the same material. Details of the reactor are shown in Figure 2.

The mixing section is designed to operate as a dense phase turbulent fluidized bed, with gas velocities typically 1-3 ft/sec. Oxidant (air) and/or steam, or N₂, enters the zone through the bottom flange and flows through a specially designed gas distributor. Solids returning from the standpipe enter this section 1.5 feet above the flange and are thoroughly mixed with the gas in the turbulent bed. During partial oxidation runs, this will ensure that the oxygen is fully consumed before the gas reaches the top of the mixing section.
FIGURE 1
TRANSPORT REACTOR UNIT

- GAS TO FILTER
  - CYCLONE
  - RISER
  - STANDPIPE
  - HYDROCARBON FEED
  - MIXING ZONE
  - OXIDANT AND/OR STEAM
FIGURE 2
REACTOR DETAILS

RISER

1" SCH 160

JUNCTION BLOCK

29 FT

FEED

N2

1.5" SCH 160

FEED

SOLIDS DRAIN

SOLIDS FROM STANDPIPE

MIXING ZONE

29 FT

10 FT
Hydrocarbon feed, either liquid or vapor, is injected well up in the mixing section, at a point 9 feet above the bottom flange, and is injected upward at a 30° angle to the vertical. This arrangement should provide very good dispersion of the feed in the upper portion of the turbulent bed just prior to the vapor/solids mixture entering the riser.

A nitrogen feed nozzle is also located at the top of the mixing zone, at a level 6" above the hydrocarbon feed nozzle. This nozzle provides the flexibility to independently adjust the riser gas velocity, if desired, in order to limit the contact time in the riser.

Solids can be drained from the reactor through a connection provided 3 feet above the bottom flange leaving a dead zone equivalent to slightly less than 2 lbs of solids. If necessary, this heel can be removed by removing the bottom flange assembly.

The riser has been designed as a high velocity transport reactor. Typical gas velocities will be 20-30 ft/sec. For flexibility, two additional feed nozzles are located in the riser section. One is located at the very bottom of the riser and is basically an alternate feed point to the feed nozzle in the mixing zone. The other feed nozzle is located halfway up the riser. This nozzle will permit testing to be done under very short contact time conditions (~0.5 sec).

As shown in Figure 2, junction blocks have been used at the three hydrocarbon injection points as well as the solids drain and the point of solids return to the reactor from the standpipe. These blocks are bored out solid blocks of Incoloy 800HT and are generally used where it is impractical to weld the branch line (nozzle) to the header (reactor body). They add structural stability and strength to the design.

### 3.2 Cyclone

The cyclone has a 3.0" ID and is also made from Incoloy 800HT. It has been designed for a very high collection efficiency, greater than 99.99%. The normal inlet gas velocity will be about 40 ft/sec.

Since the system has been designed for minimum solids inventory, to permit faster solids turnover and more rapid equilibration, a very high efficiency is an absolute requirement, in order to conserve solids. For example, with the normal expected solids circulation rate of 1600 lb/hr, a cyclone efficiency of 99.99% corresponds to a solids inventory loss of almost 1%/hr.

The inlet pipe from the riser to the cyclone consists of a long-radius elbow. This design serves two functions. First, it provides a smooth flow entry into the cyclone, which should facilitate good cyclone performance. Second, it accommodates differential thermal expansion between the riser and the standpipe. As designed, the system is capable of withstanding a 200°F difference in average temperatures between the reactor section and the standpipe section.

### 3.3 Standpipe

The standpipe contains the bulk of the solids inventory in the system and provides the head needed to circulate solids back to the mixing zone of the reactor. It is fabricated from 1½" schedule 160 Incoloy 800HT pipe. Figure 3 shows some of the standpipe details.
FIGURE 3
STANDPIPE DETAILS

SOLIDS CHARGING

1.5" SCH 160

JUNCTION BLOCK

SOLIDS SAMPLING

PLUG VALVE

SOLIDS TO REACTOR

33.3 FT
The normal solids level in the standpipe is about 23 feet above the solids entry point into the mixing zone. This level corresponds to the solids circulation rate of 1600 lb/hr. To provide positive control of solids flow, a plug valve, located at the base of the standpipe, will be used. Note that there are two positions shown in the figure, a bottom entry and a side entry. These are alternate positions, and both will be tried to see which gives the best flow control and is easiest to keep free of solids. An aeration port is provided at each valve location to aid in keeping the valve clear and freely moving.

Additional aeration ports are also provided in the standpipe assembly, three along the standpipe itself, and one in the lateral which connects the standpipe to the mixing zone. These keep the solids fluidized and assist in maintaining solids flow.

As shown in the figure, several junction blocks are included in the standpipe assembly. One is used at the solids charging point, another at the solids sampling point, and the third at the plug valve location.

### 3.4 Heating and Insulation

Rather than use clamshell furnaces, as on the old reactor system, it was decided to use Kanthall windings for heating the new unit. This results in a much simpler, cleaner design and permits much easier installation of thermocouples, dP connections, etc.

There are seven independent heating zones, with two on the riser, three on the standpipe, and one each on the cyclone and the reactor mixing section. Most zones have multiple windings in parallel, with a total of 25 windings on the unit. Maximum total heat input to the unit is 83,000 BTU/hr.

The entire system is insulated with 6" of ceramic fiber and 2" of rigid calcium silicate, covered with banded aluminum sheeting. The aluminum is painted (blue) to reduce emissivity. Insulation supports have been included for the upper section(s) of both the riser and standpipe.

### 3.5 Structural Support System

The reactor/cyclone/standpipe system is supported (anchored) at the bottom and allowed to "grow" upward as it heats up to the normal operating temperature of about 1800°F. A counterweight system is used at the top and in the middle of the unit to maintain directional stability during heatup. Four-way guides are also provided near the middle and top of both the riser and standpipe to limit lateral movement.

This type of design for the support system minimizes vertical movement of the bottom sections of the unit (mixing zone, lateral, plug valve assembly), where most of the process connections are. It has been successfully used in several other pilot plants built at the Kellogg Technology Development Center.
3.6 Instrumentation and Analytical

A process and instrumentation drawing, which shows all of the instrumentation on the mixing zone, riser, cyclone, and standpipe, is attached (DWG No. 1500C). The unit is not as heavily instrumented as the previous unit, but there are sufficient thermocouples, pressure and dP measurements, and flow meters to adequately monitor the unit and determine densities, solids levels, solids flows, etc. All of the thermocouple readings and dP measurements are continuously recorded by a computer data logging system or on chart recorders.

Much of the instrumentation for the upstream (feeds) and downstream (gas processing) sections of the pilot plant remain from the previous unit. These sections are shown on the attached drawings (DWG No. 1500A, 1500B). Important temperature, pressure, and dP measurements for these systems are also continuously recorded by the data logger.

The unit has several gas analyzers, and measurements of CO, CO2, SO2, and O2 can be continuously recorded by the data logger. There is also a gas chromatograph which can be periodically used for determining gas compositions. Additionally, gas sampling stations are provided for obtaining grab samples for complete gas analysis.

3.7 Feed System

Most of the feed systems (steam, air, N2, etc.) are already in place, remaining from the prior unit. The major change is the modification of the hydrocarbon feed system. A new metering pump, capable of pumping feeds at up to 300°F, will be installed. This will be very useful for feeding some of the heavier hydrocarbons planned for future runs.

Hydrocarbon feed rate is simply measured by change in weight of the feed tank. This measurement will now be continuously recorded by the data logger.

4.0 CONSTRUCTION PROGRESS

As mentioned earlier, the main items to be done are installation of the windings, insulation, erection, hook-up, and checkout. In addition, the hydrocarbon feed system has to be installed and some fabrication work remains on the plug for the plug valve assembly.

Fabrication of all reactor, cyclone, and standpipe components, including structural and insulation supports, has been completed. All thermocouples and dP connections have been finished, with all welds requiring an X-ray inspection passing. The entire loop was successfully pressure tested at 5000 psig before heat treatment for stress relieving.

It is anticipated that commissioning of the unit can begin about mid-May. A critical part of the commissioning procedure will be the initial heatup of the unit to its normal operating temperature of 1800°F. Assuming that the commissioning proceeds on schedule, the unit will be ready for testing during the latter part of May.
NOTES:

- RISER IS 1 INCH SCH 160 BRIGHT PIPE.
- STANDPIPE IS 1.5 INCH SCH 160 BRIGHT PIPE.
- MIXING SECTION IS 1.5 INCH SCH 160 BRIGHT PIPE.
- CYCLONE IS 4.5 INCH O.D. BRIGHT B-564 PIPE.
- JUNCTION BLOCKS WILL BE CONSTRUCTED OF BRIGHT B-564.
- FEED NOZZLES WILL BE DESIGNED TO BE REMOVABLE.

PRESSURE & DP TRANSMITTER TAPS ARE TO BE INSTALLED DOWNFLOW AT A 45 DEGREE ANGLE FROM HORIZONTAL.

AERATION/FLUIDIZATION TAPS ARE TO BE INSTALLED DOWNFLOW AT A 45 DEGREE ANGLE FROM HORIZONTAL.

THE SOLIDS SAMPLING DEVICE WILL SERVE AS A DRAIN DURING COMBUSTION/OXYGENATION/OXYGEN FLUIDIZATION OPERATIONS.

THE SOLIDS DRAIN ON D-208 WILL SERVE AS A FEED NOZZLE DURING COMBUSTION/HYDROGENATION OPERATIONS.

PRESSURE, DP TRANSMITTER & FLUIDIZATION TAPS WILL BE SCH 80 BRIGHT PIPE NIPPLES.

- 40.50' 40.53' 39.83' 39.00' 38.00' 37.10' 36.00' 35.20' 34.20' 33.20' 32.00' 30.53' 30.00' 28.00' 26.50' 24.50' 23.40' 21.50' 19.10' 19.00' 19.50'