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CONVERSION OF HIGH CARBON
REFINERY BY-PRODUCTS

Quarterly Technical Progress Report
Mechanical Completion and Start-up
New Transport Reactor System

Third Quarter - Fiscal Year 1995
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By

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I. OBJECTIVE

The objective of the study is to demonstrate that a partial oxidation system, which utilizes a transport reactor, is a viable means of converting refinery wastes, by-products, and other low-value materials into valuable products. The primary product would be a high quality fuel gas, which could also be used as a source of hydrogen.

The concept involves subjecting the hydrocarbon feed material to pyrolysis and steam gasification in a circulating bed of solids. Carbon residue formed during pyrolysis, as well as metals in the feed, are captured by the circulating solids, which are returned to the bottom of the transport reactor. Air or oxygen is introduced in this lower zone and sufficient carbon is burned, sub-stoichiometrically, to provide the necessary heat for the endothermic pyrolysis and gasification reactions. The hot solids and gases leaving this zone pass upward to contact the feed material and continue the partial oxidation process.

II. SUMMARY OF TECHNICAL PROGRESS

To date, the project has gone through essentially three phases of testing, with the third phase still in progress. Initial testing was done in a bench-scale reactor unit (BRU), a dense phase fluidized bed semi-batch reactor. These tests were of a scoping nature, to identify system parameters for subsequent tests. The second phase consisted of tests in the Transport Reactor Test Unit (TRTU), a continuous flow pilot plant transport system which can be run either in the pyrolysis mode, or combustion mode, or as a fully integrated partial oxidation system. However, owing to severe operational problems, integrated operation with a highly coking feed could not be achieved, and only a limited number of pyrolysis/gasification runs were completed. As a result, Kellogg decided to build a new transport pilot plant facility specifically designed for handling heavy hydrocarbon feeds.

Construction of this facility, the TRTU-II, was completed in May of this year, and start-up was attempted in June. Problems with the reactor heating system forced a premature shutdown of the unit, and re-design of this system is currently in progress. Details are provided below.

Mechanical Completion of Reactor Unit

Construction of the new reactor was completed in mid-May, with the installation of the electrical heater windings and insulation. The unit was successfully erected and the counterweight support system was adjusted after dry-out of the insulation. The unit was then turned over to operations for checkout.

Commissioning of the system consisted of routine tasks. All rotameters were calibrated or re-calibrated. Gas lines were checked to ensure that connections were properly made. Instruments were checked for proper operation. Minor modifications were made to the data logging system to provide better and more complete output. No significant problems were encountered, and by late May the unit was ready for initial heat-up.

A sketch of the reactor system which shows the major components is shown in Figure 1. The reactor consists of a lower mixing zone, 1½" schedule 160 by 10' tall, and an upper riser, 1" schedule 160 by about 30' tall. The top of the riser bends smoothly into the cyclone, which removes solids from the gas and returns them to the standpipe below. The standpipe, 1½" schedule 160 by 33' tall, serves as the main inventory vessel and also provides the head needed to maintain solids circulation through the unit. Flow of solids is controlled by a plug valve at the base of the standpipe.

Hydrocarbon feed enters near the top of the mixing zone where it mixes with hot gases and solids to begin the pyrolysis process. Transport nitrogen, if needed, is also injected near this point and accelerates the solids/gas mixture upward through the riser. Oxidant and steam enter through a distributor at the bottom of the mixing zone where the oxidant consumes some of the carbon laid down on the solids by the pyrolysis reactions.

Figure 2 is a photograph which shows the unit after erection in the pilot plant. The TRTU is the blue colored unit in the center. The standpipe is on the left, with the reactor on the right. The cyclone is just visible at the top of the unit. Note that the unit extends almost to the top of the pilot plant building.

Problems During Start-up

Plans were developed, reviewed, and finalized for using a simulated naphtha feed during the initial start-up. This feed can be fully vaporized before being injected into the reactor and has a low coking tendency. Not only does this facilitate the start-up, but it also permits the acquisition of some basic information under relatively mild conditions. It was planned to evaluate the effects of steam, temperature, and alkali addition (to the solids) on the gasification and combustion reactions taking place during partial oxidation. A reactor temperature of 1800°F was selected for the test.

The initial heat-up was done slowly and carefully to make sure that all heating elements and controllers were functioning normally. During this period, the reactor temperatures were limited to approximately 1000°F. With solids (FCC catalyst) circulation established, temperature control was excellent. Temperatures throughout the entire reactor/standpipe system were typically within a range of 20-30°F.

System temperatures were gradually raised to 1800°F without incident, and the heaters appeared to be easily capable of maintaining the system at this temperature. Some problems were experienced in maintaining stable solids circulation and there appeared to be bridging occurring in the standpipe. Solids circulation rates were well below the maximum design rate of 1600 lb/hr, and solids losses from the system were, at times, high.

Before naphtha feed could be started, several of the windings burned out. Some of the heating elements experienced large temperature excursions, with temperatures well in excess of 2000°F being recorded. These excursions may have been related to the solids circulation problems. As a result, the unit was shut down and cooled to ambient temperature. Inspection of the burned out windings revealed that there were problems with the ceramic tape and beads as well as the heating element wire.

FIGURE 1
SIMPLIFIED SKETCH OF REACTOR SYSTEM

FIGURE 2
PHOTOTGFAPH OF REACTOR SYSTEM AS ERECTED

The ceramic tape is used as a pipe wrap between the metal surfaces and the heating elements. The tape was torn in numerous places, exposing the metal surface underneath, and had lost most of its structural integrity. Sections around the reactor mixing zone were brittle and easily crumbled to dust.

The ceramic beads are used as insulators around the heating element wire. In numerous places the beads, which are silica base, were partially melted. The vendor recommends that the beads not be used where temperatures of 2000°F or higher can be expected.

The heating element wire, Kanthal AF, also failed in several places. Failures were of two types: tensile failure and shorting out of the wire due to contact with exposed metal surfaces.

Almost half of the windings experienced a failure, all due to limitations on materials of construction. An investigation has begun to identify better materials for all components of the heating system.

III. PLANS FOR NEXT QUARTER

The major effort during the fourth quarter will be directed towards re-design of the reactor heating system. Investigation of materials of construction will continue. This investigation has already identified potentially superior materials for the ceramic tape and beads.

The entire design of the heating system will be reviewed to determine whether other changes may be needed. A prime objective of this review is to see if a new design could reduce the potential for tensile failure of the components.

The heater control system will also be reviewed to determine whether any refinements are needed. Although the reactor system is designed to operate at temperatures of 1800°F or less, the control system will have to accommodate upsets, such as loss of solids circulation, which can lead to short-term temperature excursions.

After new materials have been selected and a new design developed, it is planned to build a test piece which will incorporate both the old and new designs. This piece will be thoroughly tested over the complete range of temperatures expected in the reactor system to confirm the validity of the new design and materials. Modifications will be made, if necessary, until we are confident that the design will work satisfactorily.

Assuming the successful testing of the new heating system design, the entire reactor assembly will be taken down, repaired, and re-erected. It is expected that most, if not all, of this work will be done in September, and the unit should be available about October 1. Consequently, no experimental work is anticipated this quarter.

While the work on the heating system proceeds, the unit will be available for cold flow tests. These test will evaluate the effect of the plug valve on solids circulation, which seemed to be a problem during start-up. The valve was in the side entry position during start-up, but can also be positioned for bottom entry into the standpipe. Both positions will be fully evaluated for effective and stable control of solids flow over the desired

range of solids circulation rates. Changes to the valve design may be desirable as well, and these will also be evaluated during cold flow testing. It is expected that these tests will be completed by mid-August and will not affect the 1 October target date for starting the experimental work.