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1899 L Street, N.W., Suite 1000
Washington, D.C. 20036

AM-99-13

Refining Gasification: Petroleum Coke to Fertilizer at Farmland's Coffeyville, KS Refinery

by

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Presented at the

NPRA
1999 Annual Meeting
March 21-23, 1999
Convention Center
San Antonio, Texas

Introduction

As of January 1999, the Farmland Coke to Ammonia Project is nearly 60% complete, and will begin start-up activities in late 1999. When operational, about 1100 tons per day of petroleum coke from Farmland's Coffeyville Refinery will be converted to 1,000 metric tons (tonnes) per day of ammonia. The Texaco Gasification Process will be used to convert the coke to high purity hydrogen for subsequent conversion to ammonia. A portion of the ammonia will be converted to 1,500 STPD of urea-ammonium-nitrate (UAN), a liquid fertilizer product.

The existing refinery will also benefit from the installation of the project. The Air Separation Unit (ASU) will supply low cost oxygen to the refinery's Sulfur Recovery and FCC Units to enhance operations and capacities. The ASU will also provide a reliable supply of very dry nitrogen to the refinery for use in purging and instrumentation. The gasification and ammonia units will provide a portion of the refinery's need for 600 psig-superheated steam. In the future, hydrogen will be available for refinery use when refinery economics exceed the ammonia value. We also expect to use certain low value refinery streams as supplemental feeds to the gasifier.

The project is unique in several respects. It is based on the relocation and refurbishment of the gasification section of the Cool Water Integrated Gasification Combined Cycle Demonstration Program. The relocation and re-use of this equipment required a significant revamp of the existing design with the objective of increasing throughput and increasing sulfur-handling capacity, all with the additional objective of containing the capital cost. New units were added to convert carbon monoxide to hydrogen and to purify the hydrogen product.

The resulting design is cost effective and efficient. The waste value of the low quality petroleum coke led to an innovative tax exempt financing. The project was approved by Farmland, and detailed engineering began in December of 1997.

Driving Forces -1996

Farmland Industries, Inc.:
Farmland is the largest farmer-owned cooperative in North America. It is owned by 1700 member cooperatives representing over 600,000 farmers, with revenues of $8.8 billion dollars in fiscal 1998. Farmland is a diverse organization with many business ventures related to the activities of its farmer-owners. The Coffeyville project links two of their business unit activities. Farmland is one of the largest manufacturers and marketers of ammonia based fertilizers in the United States, with both domestic and international manufacturing facilities. Farmland's Coffeyville, Kansas refinery is rated in excess of 100,000 BPD.

By the middle of 1996, Farmland had instituted an expansion and revamp of the Coffeyville Refinery with the goal of improving refinery profitability. Central to this effort was an expansion of the crude running capacity to 125,000 BPD from 60,000 BPD, including the addition of units to allow the processing of lower cost, higher sulfur crude oils. The revamp included acquisition and relocation of a crude unit from a closed refinery, as well as the

installation of additional sulfur processing capacity. The successful relocation of these units has made Farmland comfortable with the relocation and use of surplus processing units.

However, the degradation of coke quality with the new crude slate was a serious concern. The switch meant the coke would increase markedly in sulfur and metals content, and it would be necessary to market coke in the fuel grade market. Previously, the coke sold in the anode market for a premium price. Based on coke market factors, the new coke would not have a positive value, given the inland location of the refinery - away from the prime Gulf Coast markets. The crude slate and increased capacity also meant the amount of coke would increase substantially.

Historically, Farmland's farmer-owners have consumed substantially more ammonia than Farmland manufactured, the difference being acquired in the world market. In December, Farmland and Mississippi Chemical commissioned the world's largest single train ammonia plant in Trinidad and Tobago to reduce this shortage. Farmland is primarily dependent on natural gas-based ammonia supplies. Ammonia pricing and profitability tend to be cyclic, depending on the supply and demand at any given time. An ammonia project based on low value petroleum coke located in the United States has great appeal to Farmland.

Texaco:

Texaco is the leading licensor of gasification technology in the world, with over 50 years experience. Currently, there are 68 gasification plants operating or in various stages of engineering and construction, with a combined syngas production capacity of 5.1 billion standard cubic feet per day. Many of these facilities have, as the ultimate product, ammonia, or produce an intermediate stream of high purity hydrogen, the basic feedstock for ammonia manufacture. In particular, one facility has operated very reliably since the mid-1980's on coal and petroleum coke feeds, producing at a design rate of 1,000 tonnes of ammonia per day. That facility has gasified between 2,000,000 and 3,000,000 tonnes of pet coke and currently operates with coke as the only feed.

Texaco also had an opportunity to obtain the gasification section of the Cool Water Integrated Gasification Combined Cycle (IGCC) Demonstration Program. This was a government-backed demonstration of the integration of gasification with combined cycle power production that operated from 1984 to 1989. The Cool Water facility had become part of Southern California Edison (SCE) at the conclusion of the program. A commercial venture at the Daggitt site had proven very difficult and Texaco decided to offer the equipment as a relocation opportunity.

At this same time Texaco was also involved in the start-up of a small coke gasification-cogeneration unit at the El Dorado Refinery. This 180-ton per day unit had been financed as an operating lease through the issue of tax exempt bonds, which were available due to the low value of the petroleum coke. The attractiveness of this financing method is the low lease payment based on the tax-free interest rate and the small amount of equity required. With the equity being contributed by financial institutions and the lease payments guaranteed by Texaco, there was no capital input required by Texaco to go forward with the project. The Delaware City Cogeneration Project at the Delaware City Refinery has also been financed in this

manner. That is also a coke gasification-cogeneration unit but the scale, at about 2,000 tons per day, is much larger than the El Dorado project.

Texaco also has experience in project financing for other gasification projects. Several of the power projects in Italy that use Texaco gasification technology have been successfully project financed. To our knowledge, projects using Texaco technology are the only gasification projects to ever have been successfully project financed.

Project Concept and Objectives: Driving forces came together in mid and late 1996 to conceptualize the Coffeyville Project as a 1,000 tonne per day ammonia project based on maximum use of the Cool Water equipment. The feed would be the low value Farmland coke, with outside coke purchases as necessary to make up any deficit. The project objectives for Farmland would be to turn the low value coke problem into an advantage while at the same time creating a new USA based ammonia supply independent of natural gas supply and demand issues. A secondary objective would be to finance the project using the tax-exempt financing method used by Texaco at the El Dorado and Delaware City projects. The ability to finance the project with the minimum of equity was very attractive to Farmland. Farmland's prior, successful experience with relocation and use of surplus process units allowed them to be comfortable with the idea of re-using the Cool Water units.

1997- Feasibility Effort/Financing

Division of Work: At the end of 1996, enough preliminary work had been accomplished for Farmland to justify contracting with Texaco Development Corporation (the licensing arm of Texaco) for a Texaco Hydrogen Generation Process (THGP) design specific to the Coffeyville site and the Cool Water equipment. An engineering contractor was also employed for the overall design of the facility, including the Ammonia Unit, the offsites, utilities, and the refinery integration. This included preparing a detailed cost estimate with sufficient accuracy to finance the project. The release to start this effort was given in February of 1997.

Texaco's work scope called for the preparation of a Process Information Package (PIP), which included the basic process design, process flow diagrams (PFD's), heat and material balances. preliminary piping and instrument diagrams (P&ID's), as well as other information in sufficient detail to allow a qualified engineering contractor to perform detailed engineering. As part of this work scope, Texaco updated the as-built P&ID's of the existing Cool Water gasification units to provide a good starting point in preparing the preliminary P&ID’s and to assist the engineering contractor with its work scope.

Farmland was responsible for overall coordination of the work of all parties, and was directly responsible for obtaining government permitting for the ammonia project, contracting for the oxygen and power requirements of the project, and contracting for the design and procurement of the ammonia production unit. Towards the middle of 1997, it was decided to add the UAN Unit to the design. Farmland was directly responsible for contracting for the design and procurement of that unit.

Process Description: Coke is first ground with water and a fluxant to form a high concentration slurry which is then pumped into the THGP gasifier through a specially designed injector where the slurry is contacted with pure gaseous oxygen from an Air Separation Unit (ASU). The partial oxidation reactions take place upon contact of the two streams and the synthesis gas (syngas) is formed. The raw syngas consists primarily of hydrogen, carbon monoxide, carbon dioxide and hydrogen sulfide, with minor amounts of other compounds. The water in the slurry also serves to moderate the reaction. Temperatures inside the refractory-lined gasifier are in the 2,400"F to 27000F temperature range. At these temperatures, the mineral residue from slurry is a molten slag and flows along with the syngas out the bottom of the gasifier and into a quench chamber. The syngas and slag are rapidly cooled in the water bath contained in the quench chamber and the syngas is separated from the slag.

The slag exits the quench chamber through a lockhopper and becomes a by-product of the process. The syngas flows through additional stages of water scrubbing to remove any remaining particulate from the gas. At this point the syngas is saturated with moisture. The syngas next flows through a Shift Unit where the carbon monoxide in the syngas is reacted, using a catalyst, with the moisture to form hydrogen and carbon dioxide. At the exit of the Shift Unit, the syngas has over 40 mole-% $C0_2$. The shift reaction is exothermic and this heat is used to generate 600 psig saturated steam. This steam is combined with 600 psig steam produced in the Ammonia Unit and sent to the refinery.

After additional heat recovery, the syngas is cooled and processed in the Acid Gas Removal (AGR) unit. The AGR is based on the Selexol Process from UOP. Sulfur containing acid gases are segregated and concentrated to about 44% H_2S prior to being sent to the refinery Claus Unit for further processing. The bulk of the $C0_2$ is removed from the syngas and a portion is sent to the UAN Unit for use as feed to the urea reaction. The ASU owner may eventually take $C0_2$ for purification and sale. Syngas exiting the AGR is about 96 mole-% hydrogen. The syngas is then fed to a PSA Unit supplied by UOP, where the remaining impurities are extracted, resulting in a hydrogen purity of 99.3%. The remaining impurities consist mainly of nitrogen. The hydrogen then flows to the Ammonia Unit. The tail gas from the PSA is about 75% hydrogen and carbon monoxide. This gas is compressed and recycled back to the Shift Unit.

The hydrogen is reacted over a catalyst with nitrogen from the ASU in the Ammonia Unit to form the ammonia product using a process supplied by Casale. A portion of the ammonia is converted to Urea Ammonium Nitrate, a water based fertilizer. This unit is supplied by Weatherly Engineering and is designed to produce 1500 STPD (wet) of UAN.

Design Process: The design process for this project was unusual. The Cool Water equipment could not simply be relocated, refurbished and placed in service. Significant upgrades and modifications were necessary. Syngas capacity needed to be increased about 30%. Major revamps were required to convert the main gasification train from full heat recovery to quench gasification. The acid gas removal, Claus Unit and tail gas treating designs needed significant revision to deal with substantially more sulfur from the coke as well as the large CO_2 content of the syngas at the exit of the Shift Unit. New units also needed to be added - such as the Shift

Unit and a PSA Unit to produce a high purity hydrogen product. After several iterations and the cooperative effort of all the parties involved a design was arrived at that is cost effective, efficient and made the best use possible of the existing equipment. The following is a discussion of just the major design issues:

Svngas Capacity: Cool Water was designed to process 1000 tons per day of coal and had been operated at up to 1200 tons per day. The final coke design calls for about 1100 tons per day of coke. Coke has about 25% more Btu's per pound than does coal so the syngas production is proportionately greater. Fortunately, the existing gasifies were of sufficient size and there was sufficient margin within the design and corrosion allowances to be able to increase the operating pressure slightly to achieve the desired capacity. The decision to recycle the PSA tailgas and the AGR design that made that recycling feasible reduced coke consumption by 15%.

Gasifier Design: Cool Water was designed to be a power plant. The main gasifier did not have a quench chamber. Instead the syngas was cooled in two enormous steam generators prior to having entrained particulate scrubbed out. These exchangers were fourteen feet in diameter, over 100 feet long, and weighed in excess of 600 tons each. A quench chamber needed to be added, since moisture from quenching the syngas is needed in the Shift Unit. Eliminating the steam generators would also reduce structure height. That represented very desirable cost savings.

It was decided to fabricate the new quench chamber as well as the vessels for the Shift Unit from the shells and heads of the steam generators. The new quench chamber will be installed in the existing gasification structure below the gasification reactor while the shift vessels will also be installed in the structure in the space previously occupied by the steam generator. A new solids settler in the gasification water handling system was also fabricated from the shell material. This allowed maximum use of the existing structure and the material available. The steam generator internal piping and excess shell material were junked.

Acid Gas Removal Design: The design of this unit proved a challenge both from the standpoint of cost control and re-use of the existing equipment. It proved impossible to reuse the existing Cool Water Selexol Unit and Tail Gas Treating Unit (TGTU) due to the large increase in acid gas content (mainly C02 but also H2S) of the shifted syngas versus that in the Cool Water design. It also proved impossible to control the cost of this unit using a conventional Selexol design. The conventional approach would have resulted in a capital cost that endangered the feasibility of the project.

After a cooperative effort by all the parties involved, a cost-effective design was achieved that made good use of the existing exchangers, towers and pumps. The primary change was the addition of a secondary column to strip CO_2 out of the rich Selexol solvent using a small quantity of the clean syngas as the stripping medium. The design is a significant departure from the traditional $H_2S/C0_2$ absorber stripper approach. There were three primary benefits:

1. A concentrated sour gas (about 44% H2S) was produced directly from the Selexol stripper, greatly reducing the CO_2 loading on the downstream Claus Unit.

2. No further tail gas treating was necessary to concentrate the sour gas, the TGTU was eliminated, and the equipment cannibalized for use in the new Selexol Unit.

3. The C02 content of the clean syngas was reduced to about 3%. This radically changed the PSA design. The PSA tailgas composition improved dramatically. Instead of being diluted with substantial amounts of CO_2 the tail gas was rich in hydrogen and carbon monoxide. It was now worthwhile to compress and recycle the tail gas back to the Shift Unit. That eliminated the need for a boiler to consume the tail gas and reduced the amount of coke required to make the design ammonia production by about 15%.

When Farmland decided to add the UAN Unit to the design, it was a relatively simple matter to rearrange the Selexol C02 flash tanks to segregate a high purity CO2 stream for use in manufacture of the urea. The UAN Unit is a duplicate of a unit that was recently added to Farmland' s Fort Dodge, Iowa facility.

As a result of this effort, the final cost estimates were ready in October 1997. The economics were analyzed and found acceptable, the release to begin detailed engineering under a limited scope was given in November of 1997, and the project reached financial close on December 11, 1997. In Farmland's analysis of the economics, the project success was measured against the expected swings in ammonia pricing. The project had to tolerate the downturns in the ammonia market as well as be successful during the upturns. The low value feedstock, the savings in time as well as money from re-use of the Cool Water equipment, and the premium UAN product provided the assurance that Farmland needed that the project would be viable across the range of expected ammonia prices.

Other Activities: In parallel with the design effort Farmland proceeded with permitting and the completion of the major contracts that needed to be finalized before the Farmland financing could proceed.

Major Contracts:

- ✓ An over the fence supply contract was executed with BOC Gases for 1600 tons per day of gaseous oxygen for the gasification and refinery requirements and gaseous nitrogen for the Ammonia Unit feedstock.

- ✓ Lump sum contracts were executed with Black & Veatch Pritchard for the detailed engineering and construction of the Gasification Unit, the off site facilities and the Ammonia Unit. This included relocation and re-assembly of the Cool Water equipment.

- ✓ A license was finalized with Casale Inc. for the ammonia technology.

- ✓ A license was finalized with UOP for the Selexol Process.

- ✓ The Texaco Development Corporation Hydrogen Generation Process license was amended and a Guarantee Agreement executed.

- ✓ An Operating and Maintenance Contract for the Hydrogen Generation Unit was finalized with Texaco Syngas Inc.

- ✓ An agreement was finalized with Texaco Syngas detailing the terms under which technical support would be provided to the project.

- ✓ Texaco finalized a Transfer Agreement and Temporary Entry Permit with Southern California Edison to take ownership of the Cool Water equipment and gain access to the Cool Water site to remove the equipment.

- ✓ Texaco and Farmland executed Transfer Agreements providing for the transfer of ownership of the Cool Water equipment to Farmland.

- ✓ An agreement was finalized with Weatherly providing for the procurement, engineering and construction of the UAN unit.

- ✓ The refinery's over the fence acid gas-processing contract with Tersanderlo Kerley was amended to include the new volumes from the Selexol Unit.

- ✓ An agreement was finalized with CB&~ for the ammonia storage tank, loading terminal and rail extensions.

- ✓ Three contracts were executed with the City of Coffeyville, Kansas' municipal electric company, and a generation source for the construction of two major substations and the construction of 30 miles of power lines. This provided for the infrastructure development needed to deliver the 52 MW of power (plus start-up power) required for the operation of the project.

These are the primary contracts that formed the basis for the financing. Mountains of documents were required to deal with all aspects of the financing. Chase Manhattan was the lead banker in the financing, and Texaco agreed to provide a portion of the equity required. All in all, 1997 was an extremely busy and productive year for all the companies involved in the project.

The City of Coffeyville, Kansas and Southern California Edison (SCE) are deserving of special thanks. The project would not have happened without their cooperation. The City has been a very helpful participant in the project development, both from the standpoint of the financing (they are the lessor under this financing) and also in the development of the infrastructure needed to make the project a reality. The City played an active role in the power development, as well as the siting issues dealing with permitting and access to sufficient lay down space to

deal with all the equipment shipped from Cool Water, as well as the equipment for the new units. SCE was very patient with the fits and starts we went through during the design process, and was very helpful in obtaining all the approvals necessary to remove the equipment from the SCE power site. In that regard, the California Energy Commission was also very helpful in processing the permit requests in an expeditious manner.

1998 - Detailed Engineering/Construction

At year-end, construction at Coffeyville was about 60% complete. All the equipment from Cool Water that will be used at the new site had been removed from Cool Water, and was either at Coffeyville or in refurbishment shops prior to shipment to Coffeyville. The Cool Water site was closed down during August of 1998 except for the activities of a scrap contractor. The scrapper is cutting up and disposing of equipment and piping that will not be re-used. All gasification related equipment at Cool Water - coal handling, slurry preparation, gasification, Selexol, Claus, TGTU and water handling has been removed down to the top of foundations as called for in the agreements with SCE.

1999 - Mechanical Completion/Commissioning Activities

At the end of 1998, we began the planning activities required to coordinate the precommissioning and commissioning of the facility prior to and after the mechanical completion of the project which is scheduled for mid-October 1999. The objective of that effort is to start-up the project as soon as possible after mechanical completion

Operations

A team provided by Farmland Industries and Texaco will operate the Ammonia Project. Farmland as the lessee and ammonia marketer will have overall responsibility for the operation, and will provide the personnel responsible for operation and maintenance of the Ammonia and UAN Units. Farmland has contracted with Texaco Syngas Inc. to operate the Hydrogen Generation Unit. This primarily includes the Gasification Unit, the Selexol Unit, and the PSA Unit, as well as other related equipment. The Texaco management team has been on-site since early in 1998, and is proceeding with the staffing of the operating and maintenance personnel. Operator training should start about March of this year.

Conclusion

This project was made possible through the cooperation and teamwork of the many companies involved, and there were many of parties to this transaction. Some but not all are mentioned in the discussion above, and the complexity of the deal is only briefly outlined in the list of major contracts required for the financing. The fact that they could cooperate to make the project a reality is indicative of the common goals of all the parties and the dedication of the individuals involved. We are all looking forward to a successful start-up at the end of the year.