A TURN IN THE ROAD: EASTMAN CHEMICALS FROM COAL

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In 1980, Eastman announced a bold new venture that made news around the world. Eastman disclosed its plans to take a new and important turn in the road - to produce acetic anhydride and other chemicals from coal. As far as known, Eastman will be the first manufacturer in the United States to produce a modern generation of industrial chemicals from coal. The symbolic groundbreaking ceremony, which was held last year, highlighted a decade of work by Eastman men and women to identify, develop, and assemble the numerous technologies necessary for a viable commercial venture.

Eastman Kodak Company is probably best known for its easy-to-use photographic films and cameras and its high quality photofinishing services. This is the primary business of the Photographic Division based in Rochester, New York. The Eastman Chemicals Division is the other operating division of Kodak and is among the 20 largest domestic chemical companies with 1980 sales revenue of $2.1 billion. The Chemicals Division provides many of the chemicals and resins for Kodak's imaging products and is a major trade supplier of over 300 industrial chemicals, fibers, and plastics. The division employs about 19,000 people and has U.S. manufacturing locations in Tennessee, Texas, South Carolina, New York, and Arkansas. Headquarters for the Chemicals Division are in Kingsport, Tennessee, which is also the site of the new coal gasification plant.

Before reviewing Eastman's gasification project, it is important to know the way Eastman has produced acetic anhydride through the years in order to understand more fully the significance of the decision. Tennessee Eastman began making acetic anhydride when Eastman Kodak transferred the production of cellulose acetate for film base from Rochester to Kingsport about 50 years ago. Acetic anhydride was originally made from by-product acetic acid from a wood distillation process for methanol. By the 1940's it became more economical to purchase alternate raw materials derived from petroleum. In 1951, Eastman built a plant in Texas to provide a reliable supply of more basic raw materials made from natural gas liquids. The current process involves the catalytic decomposition of hot acetic acid vapor into ketene and water. The highly reactive ketene readily combines with additional acetic acid to form acetic anhydride. Today, Eastman has the capacity to produce about one billion pounds per year of acetic anhydride primarily for internal use in the manufacture of photographic film base, ESTRON acetate cigarette filter tow and textile yarns, TENITE cellulosic plastics, and certain coatings chemicals.

In the late 1960's, Eastman stepped up its program of energy conservation and began a search for lower-cost chemical feedstocks even before the growing national concern caused by the ten-fold increase in petroleum prices during the past decade. An early study, conducted by Eastman in 1970, acknowledged the declining domestic petroleum reserves and projected that coal would become a more attractive energy source and an important chemical feedstock in the longer term. Although in 1970 no one really anticipated the actual events which would take place in the Middle East, the run up in the price of foreign oil from $3 per barrel to $12 per barrel following the 1973 Arab oil embargo confirmed the pressing need for alternate supplies of nonpetroleum feedstocks. It was judged that the development of modern conversion methods to transform coal into more usable fuel products and chemical feedstocks would be the domain of the large energy companies. However, Eastman had the ability to develop the downstream processes to utilize coalbased feedstocks to produce chemicals now made from petroleum. Estimates were prepared which indicated that medium-BTU or synthesis gas could eventually be produced from coal gasification processes at costs substantially below the equivalent amount of ethylene. Coal gasification was found to be less costly, more flexible for chemical manufacture, and operable on lower quality coals than liquefaction techniques involving the direct, high-temperature hydrogenation of coal to form complex chemical mixtures or synthetic oils suitable for processing in conventional petroleum refineries. Further analysis identified acetic anhydride and other target molecules of interest to Eastman which might be produced from the mixture of carbon monoxide and hydrogen called synthesis gas.

As a result, a research program was begun to synthesize acetic anhydride on a bench-scale . The main emphasis was the development of suitable catalysts to produce acetic anhydride from the lowest-cost starting materials, with a minimum of by-products, and under conditions easily achievable in commercial production. Although initial yields were relatively low, it was determined that acetic anhydride could be made from methyl acetate and carbon monoxide, a component of synthesis gas. Continuous pilot plants of modest size were built in 1977 to test various materials of construction and to demonstrate that the rather expensive catalyst system which had been developed could be reused indefinitely. The data from the pilot operations were used to formulate mathematical models for the conceptual flowsheet design. The process was scaled up to the full-sized commercial plant, and the math models aided in optimizing the final engineering design. Eastman scientists and engineers spent many years in the discovery and development of this revolutionary approach to the manufacture of acetic anhydride which serves as the foundation for the entire commercial venture for Eastman to produce chemicals from coal.

Next, Eastman's gasification plans and the important considerations which led to the processes selected will be reviewed. The gasification complex will include a Texaco coal gasification plant for synthesis gas manufacture, raw gas clean-up and separation facilities, a sulfur recovery unit, a coal-fired steam plant with electric power cogeneration, and chemical plants to produce methanol, methyl acetate, and acetic anhydride. The plant will gasify approximately 900 tons/day of high sulfur coal from nearby mines. The new facilities are under construction on a 55-acre site across the Holston River from the main plant with completion scheduled for 1983. Bechtel Petroleum, Incorporated, is handling the engineering design, equipment procurement, and project management. The Daniel Construction Company has a long history of successful projects for Eastman and serves as the general construction contractor. The venture is financed entirely from company earnings; no federal assistance has been or will be sought.

Although the principal emphasis was always on coal, many factors had to be considered before selecting the most economic feedstock for the synthesis gas plant. All types of synthesis gas plants should be located close to their raw material source to minimize transportation charges. Location on the Gulf Coast, on a natural gas pipeline, or near an inland refinery will generally favor natural gas or residual oil. A coal gas plant should be near the mine mouth to minimize freight charges.

The major portion of the unit cost of synthesis gas from a natural gas-based plant is the feedstock gas itself which is included in the operating cost. Since natural gas contains very little sulfur, the product gas does not have to be scrubbed to meet environmental requirements or to protect sensitive downstream catalysts. A more expensive plant is needed for coal operation due to the increased complexity of gasifying a solid material, product gas clean-up, and sulfur recovery. As a result, the minimum economical plant size for coal operation is about ten times larger than a natural gas reformer. Once committed, capital costs are not subject to further escalation. Most experts agree that the price of petroleum and natural gas will rise much faster than coal prices which will be closely related to its mining and delivery costs. Therefore, the relatively low annual operating cost of a coal-based plant offsets the higher initial capital cost and provides an increasing economic advantage during periods of high inflation which results in a lower overall cost for synthesis gas by 1985. A residual oil-based plant is intermediate in overall unit cost. This analysis assumes that each synthesis gas plant is located near its raw material source.

The maximum incorporation of the total weight of the synthesis gas into the product chemical is also important to the cost efficiency of the overall process. In general, synthesis gas will reach its maximum advantage in the production of oxygenated materials where a larger portion of the synthesis gas is converted into a saleable product. The primary feedstocks and their associated processes produce widely different synthesis gas compositions, which may be expressed as the volumetric ratio between hydrogen and carbon monoxide. Natural gas reforming produces the highest ratio of hydrogen in a synthesis gas and is particularly suited to ammonia production where no carbon monoxide is required. At the other extreme, coal gasification provides the maximum concentration of carbon monoxide in a synthesis gas and is favored for carbonylation reactions, such as with methyl acetate to produce acetic anhydride. The maximum material efficiency will be realized for various organic chemicals by using the feedstock and its associated process which most nearly corresponds with the hydrogen to carbon monoxide ratio of the desired chemical. Although relatively costly, the synthesis gas composition from each process may be adjusted by employing a water-gas shift reactor as required.

As noted, choosing an economical synthesis gas feedstock is a complex process which is influenced by longterm raw material price projections, plant size and location, associated conversion processes, and the desired chemical product. When all factors were considered for Eastman's project to produce acetic anhydride, the best alternative was to locate a gasification complex in Kingsport and to provide coal for synthesis gas manufacture from the nearby Appalachian coal fields, which have proven through the years to be a reliable supply of boiler fuel.

In the mid-1970's, the prospect of natural gas curtailments in Kingsport prompted Eastman to investigate alternate fuel sources. Thus, Eastman became familiar with modern coal gasification technologies and the modifications necessary to produce chemical feedstocks. Eastman evaluated three basic types of commercial coal gasifiers including the fixed or slowly-moving bed, fluidized bed, and entrained bed units. Each type of gasifier has relative advantages and disadvantages, and no single design will be suitable for every intended use of the product gas. When all factors were considered for Eastman's project, the Texaco Coal Gasification Process, involving an entrained bed gasifier, provided the most economical source of synthesis gas from local coals. This conclusion was reached after several internal studies and confirmed by two outside evaluations performed independently by both Bechtel and Fluor. Finally, a successful test run was made with the selected coal at the Texaco pilot gasifier in Montebello, California.

In an entrained bed gasifier, oxygen and either water or steam, along with finely-ground coal are introduced into the reaction vessel through a common feed nozzle and pass downward through the reactor in a concurrent manner. The operating temperature is maintained above the melting point of the coal ash so that the unreactive slag will drain from the unit. As a result of the relatively high operating temperature and the unique flow pattern, the gasification reaction rates are much faster, by-product tars are destroyed within the unit, and the production of methane is minimized. The product gas is mainly carbon monoxide and hydrogen which makes this unit particularly suitable for chemical synthesis.

The Texaco Coal Gasification Process is moving rapidly toward commercialization. This coal-based process is a variation of the widely licensed, proprietary partial oxidation process producing synthesis gas from a number of hydrocarbon feedstocks, principally low-valued, high-sulfur crude and residual oils. The Texaco gasifier may be operated on a wide variety of low-quality coals at pressures up to 1200 psi which results in high throughput and single pass conversion. Since the raw gas is generated at elevated pressures, the size of the gas clean-up equipment is reduced and the need to compress the product gas prior to its use as a chemical feedstock is minimized. The Texaco Coal Gasification Process due to its inherent cleanliness is an environmentally acceptable means of providing gaseous products from coal. Since the coal is handled as a water slurry, wet-grinding eliminates the dust problems ordinarily associated with dry-grinding operations. The relatively high operating temperature within the gasifier leaves only trace amounts of hydrocarbon by-products in the coal gas. The majority of the water needed for slurrying, cooling, and scrubbing operations is reused within the process except for a small blow-down stream to prevent the accumulation of water-solubles. The coal ash is drained from the reaction area as a molten slag and quenched in a water bath in the bottom of the gasifier. The coarse ash is removed as glassy pellets through a lock hopper system. The inert ash pellets have shown very low levels of leachability and will qualify for nonhazardous waste landfilling. Ruhrkohle A.G. and Ruhrchemie A.G. have licensed Eastman their own developments in the areas of coal grinding and waste heat recovery made during their three-year operation of a Texaco gasifier in West Germany.

The gasification section in Eastman's plant will contain two gasifiers, each of which is capable of producing the required volume of synthesis gas for chemical manufacture. This equipment duplication will permit a reliable on-stream operation as experience is gained with this new process and will allow for planned maintenance, including refractory replacement. Air Products and Chemicals will build a three-train industrial gas facility to supply oxygen to Eastman's gasification complex and nitrogen to other parts of the main plant. The oxygen will be transported at high pressure via pipeline to Eastman's coal gasifier where it will react with a coal-water slurry to form primarily carbon oxides and hydrogen with trace amounts of methane. The sulfur in the coal will be converted mainly to hydrogen sulfide. The hot product gas will first be scrubbed with water to cool the gas and remove any ash particles. A portion of this stream will then be sent to a water gas shift reactor to increase the hydrogen content by the cobalt-molybdenum catalyzed reaction of carbon monoxide and water. Finally, low pressure steam will be recovered as the product gas is cooled further before additional purification. The full recovery of this heat can increase the thermal efficiency of the process by almost 20% and is essential for economical operation.

The raw product gas will then be treated to remove the so-called "acid gases." The carbon dioxide and hydrogen sulfide are absorbed by a cold methanol wash in a Rectisol unit. Now purified, the remaining synthesis gas will be cryogenically separated into a relatively pure carbon monoxide stream for the acetic anhydride plant and a hydrogen stream suitable for methanol production. The Rectisol unit and the gas separation plant are highly integrated and both will be provided by Lotepro, a U.S. subsidiary of Linde A.G. which is performing the engineering in West Germany. The by-product carbon dioxide from the Rectisol process will be vented after water-scrubbing to remove any residual methanol. Elemental sulfur will be recovered from the hydrogen sulfide in a Claus unit designed by Ford, Bacon, and Davis. A Shell Claus Off-Gas Treating (SCOT) unit will remove the last traces of sulfur from the Claus vent gas. Overall, 99.7% of the sulfur originally contained in the coal will be recovered in molten form and sold. In all areas of the new complex, discharges will be kept within state and federal regulatory standards by the installation of advanced environmental control technologies.

Methanol will be produced from carbon monoxide, carbon dioxide, and hydrogen using a highly efficient low-pressure process licensed from Lurgi. The proper gas feed composition for methanol production is formed by combining the hydrogenenriched synthesis gas from the shift reactor and the hydrogen stream from the gas separation unit. The methanol will be reacted with by-product acetic acid from our cellulose esters manufacturing operations to form methyl acetate. This esterification process is also an

Eastman innovation which resulted from a successful pilot operation of a novel system to produce refined methyl acetate in a very energy-efficient manner. Finally, the purified carbon monoxide from the gas separation plant will be reacted with methyl acetate to form acetic anhydride using the proprietary catalyst system and process developed by Eastman and described earlier. Without this key breakthrough in acetic anhydride technology, the entire commercial venture would not be possible. Eastman and Halcon International have an agreement which combines their carbonylation process technologies to produce acetic anhydride and assigns Halcon the worldwide licensing rights.

Eastman's project is a small but important step in the nation's interest to reduce dependence on foreign oil. The chemicals produced in this complex would require the equivalent of one million barrels of oil a year using conventional technology. Coal-based synthesis gas has been identified as an economical feedstock for chemicals manufacture and will become more attractive as the differential between coal and petroleum prices increases. Eastman is committed to a program of finding new ways to broaden the use of synthesis gas as a means of producing other chemicals from coal.

Meanwhile, the coal conversion segment of the synthetic fuels industry will gradually develop in other areas. The fully integrated domestic oil companies also recognized the declining reserves of petroleum many years ago and obtained extensive rights to lands bearing oil shale, uranium, lignite, and coal. These oil companies and others have invested hundreds of millions of dollars in pilot plants and demonstration plants to convert coal into more usable fuels and chemical feedstocks. The first and most promising ventures are likely to be coal gasification plants producing medium-BTU fuels and synthesis gas. By 1985, it will be more economical to produce synthesis gas for chemical manufacture from coal at certain locations, including Kingsport, than from natural gas or residual oil on the Gulf Coast. Large scale commercialization based on the methanation of coal gas to form a truly synthetic natural gas equivalent will follow later in the 1990's. New generations of gasifiers employing pressurized operation, catalytic gasification, advanced fluidized beds, and improved sulfur removal will be developed. A relatively small portion of the total capital of a coal gasification plant is committed to the reactor area alone. Therefore, it is economically conceivable that gasification complexes already in place would be modified to take advantage of new, more efficient gasification techniques as they are developed.

The petrochemicals industry currently utilizes petroleum and natural gas as starting materials to manufacture products valued at $56 billion annually. The industry faces a tremendous challenge in the 1980's to keep plants running both reliably and profitably while adjusting to the changing social and political environments and contending with international unrest. Fortunately, the financial rewards for good performance are equally great. Indeed, the chemical industry is at a turn in the road and the most successful companies of the 1980's may well be those which develop new advanced technologies to move their operations toward lower cost feedstocks and fuels. With acetic anhydride, Eastman began with wood, converted to petroleum, and now is taking a new and important turn in the road by moving to coal.