DOE INDIRECT COAL LIQUEFACTION - HURDLES AND OPPORTUNITIES FOR ITS EARLY COMMERCIALIZATION. **John Shen and Edward Schmetz, U.S. Department of Energy, Germantown, MD 20874, Gary Stiegel and Richard Tischer, U.S. Department of Energy, P.O. Box 10940, Pittsburgh, PA 15236**

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INTRODUCTION

Coal is the most abundant domestic energy resource in the United States. The Fossil Energy organization within the U.S. Department of Energy (DOE) has been supporting a coal liquefaction program to develop improved technologies for converting coal to clean and cost-effective liquid fuels and/or chemicals to complement the dwindling supply of domestic petroleum crude. The goal of this program is to produce coal liquids that are competitive with crude at $25 per barrel. Indirect and direct liquefaction routes are the two technologies being pursued under the DOE coal liquefaction program. In indirect liquefaction, the emphasis is on the development of improved liquid phase reactor technology to convert "lean syngas" (low hydrogen to carbon monoxide ratio) produced from advanced coal gasifiers. In this paper, the terms of "liquid phase reactor" and "slurry phase reactor " are considered interchangeable.

An overview of the DOE indirect liquefaction program, including the development highlights of the Liquid Phase Methanol technology which is undergoing commercial demonstration at the Eastman Chemicals plant in Kingsport, Tennessee within the DOE Clean Coal Program, can be found elsewhere (Shen, et al. 1996). This paper will update the status of DOE indirect liquefaction program, and briefly review the recent development in the commercial liquid phase reactor design. It also will discuss the hurdles and opportunities for the early commercialization of this technology.

UPDATED STATUS OF DOE INDIRECT LIQUEFACTION PROGRAM

Slurry Phase Fischer-Tropsch Three slurry phase Fischer-Tropsch runs have been made at the proof-of-concept (POC) unit at LaPorte, Texas between 1992 and 1996, with costs shared by industrial consortiums headed by Air Products and Chemicals (APCI). The first two runs used iron catalysts and the third one a cobalt catalyst. Highlights of the first two runs have been reported earlier (Shen, et al. 1996). More detailed review of the first run data also has been published (Bhatt, et al. 1995)..These results indicate that, with the system to convert lean syngas over iron catalysts, more work is needed to improve the correlations between the autoclave and POC slurry phase reactor data. Also, efforts should be directed to explore the advantages of iron over cobalt catalysts to produce a more versatile product slate including olefins. Finally, more fundamental study is needed to gain a better understanding of the iron catalyst behavior in a slurry phase F-T reactor. Data workup for the third run with a cobalt catalyst is now underway

Liquid Phase Dimethyl Ether (DME) The feasibility of liquid phase DME technology was first demonstrated by APCI at the LaPorte POC unit in 1991. Since then, there have been considerable industrial interests in this one-step syngas to DME technology, which could reduce the DME cost as a fuel or a precursor to chemicals. Recent work at bench scale unit has been aimed to further reduce the deactivation rate for the physical mixture of methanol synthesis and methanol dehydration catalysts present in a liquid phase reactor. Results obtained with APCI's improved proprietary dehydration catalyst appear encouraging (Parris, et al. 1996). The commercial demonstration of liquid phase DME technology at the Liquid Phase Methanol project site at Kingsport is tentatively scheduled for year 2000.

Synthesis Gas to Oxygenates and Chemicals Novel catalyst R&D has been underway to convert synthesis gas to oxygenates and chemicals under cost-shared contracts. The products include mixed alcohols including isobutanol (Xu, et al. 1996), vinyl acetate monomer (Tustin, et al. 1996), methyl methacrylate (Spivey, et al. 1996), and dimethyl carbonate (Hagen, 1996). The industrial participants in this program include APCI, Eastman Chemicals, RTI, Bechtel, and Amoco.

Commercial Liquid Phase Reactor Development

A recent media release indicates that Sasol has placed orders for seven SAS (Sasol Advanced Synthol) gas phase reactors with diameters up to 10.7 meters (Sasol 1996). It seems reasonable to assume that the same size reactor also can be used for slurry phase reactor applications. In an earlier DOE supported study, Bechtel has designed a commercial slurry phase reactor with a diameter of 4.8 meters (Fox, et al. 1990). At that time considerable considerations have been given to the reactor physical constraints including the weight of tube sheets holding the internal tube exchanger. It seems prudent that, in view of the Sasol announcement, the commercial slurry phase reactor design should be revisited to evaluate the various impacts of a larger reactor size.

Hurdles and Opportunities for the Early Commercialization of Indirect Liquefaction Technology

Due to the federal budget constraints, DOE has been exploring the use of "financial incentives" rather than "cost-sharing" to promote the commercial demonstration of slurry phase F-T technology. Preliminary results from this scoping study, conducted by Mitretek with DOE support, will be reported in a separate paper at this meeting (Gray, et al. 1997). Under this proposal, an industrial consortium would be formed to lead the effort, with DOE to cost-share the Phase Zero project feasibility study and to serve as an advocate for the use of incentives. Use of incentives is deemed necessary to mitigate the high risks associated with these projects. It is also consistent with our precedents to offer "limited" incentives to introduce a new domestic resource based transportation fuel because of its vital importance to the economic well-being of our country.

IGCC (integrated gasification combined cycle) system, which is an integrated part of the indirect liquefaction technology, has recently received more commercial interests, partly in response to the emerging trend in tighter environmental regulations (Rhodes 1996; Aalund, 1996). In these applications and others under considerations, a variety of carbonaceous feedstock are used to address the local need to dispose the environmentally disadvantageous materials. With more and more these IGCC systems in place, the opportunity to co-produce power, premium quality transportation fuels and/or chemicals could offer the best prospect for the early commercial deployment of the slurry phase F-T technology. With the learning experience gained from these operations, a transition to coal based IGCC/slurry phase F-T could be underway between 2010 and 2015 when coal liquid is projected to be competitive with crude (Gray, et al. 1996).

CONCLUSIONS

We have presented an updated summary of the work performed under DOE indirect liquefaction program since 1994. In the slurry phase F-T area, we also have identified areas for future R&D work. A "financial incentives" based approach, to be led by an industrial consortium, has been proposed to promote the commercial demonstration of slurry phase F-T technology. The early commercial deployment of this technology could be in the IGCC based power plants to co-produce power, premium quality transportation fuels, and/or chemicals. The DOE supported slurry phase F-T technology is tailored for co-production applications with enhanced system efficiency.

REFERENCES

Aalund, L.R., "Italian Refinery Gasification Project to Make Electricity, Steam, and Hydrogen from Tar", Oil & Gas Journal, P. 33, October 21, 1996

Bhatt, B.L., R. Frame, A. Hoek, K. Kinnari, V.U.S. Rao, and F.L. Tungate 1995 "Catalyst Processing Scale-up for Fischer-Tropsch Synthesis", Topics in Catalysis 2 (1995) 235-257.

Fox, J.M., B.D. Degen, G. Cady, F.D. Deslate, and R.L. Summers 1990 "Slurry Reactor Design Studies: Slurry vs. Fixed-Bed Reactors for Fischer-Tropsch and Methanol", Final Report, DOE/PC/89867/T2, June 1990

Gray, D., and G. Tomlinson 1996 "Incentives for the Commercialization of Liquefaction Technologies", Paper Presented at the First Joint Power & Fuel Systems Contractors Conference, Pittsburgh, PA, July 9-11, 1996

Gray, D., and G. Tomlinson 1997 "Opportunities for Early Commercial Deployment of Indirect Liquefaction", Paper to be Presented at the American Chemical Society Meeting, San Francisco, CA, 4/13-4/17, 1997

Hagen, G.P. 1996 "Synthesis of Oxygenate Products for High Volume Fuels Applications", Paper Presented at the First Joint Power & Fuel Systems Contractors Conference, Pittsburgh, PA, July 9-11, 1996

Parris, G.E., X.D. Peng, and B.A. Toseland 1996 "Some Advances in Catalysis for Alternate Fuels", Paper Presented at the First Joint Power & Fuel Systems Contractors Conference, Pittsburgh, PA, July 9-11, 1996

Rhodes, A.K., "Kansas Refinery Starts Up Coke Gasification Unit", Oil & Gas Journal, P. 31, August 5, 1996

Sasol 1996 Media Release: "Sasol Awards Contract to the Consortium of Hitachi Zosen and Marubeni for Seven Advanced Synthol Reactors", October 22, 1996

Shen, J., G. Stiegel, and A. Bose 1996 "DOE Indirect Coal Liquefaction Program - An Overview", Fuel Sciences & Technology Int'l, 14(4), 559-576 (1996)

Spivey, J.J., M.R. Gogate, J.R. Zoeller, R.D. Colberg, G.N. Choi, and S.S. Tam 1996 "Synthesis of Methyl Methacrylate from Coal-Derived Syngas", Paper Presented at the First Joint Power & Fuel Systems Contractors Conference, Pittsburgh, PA, July 9-11, 1996

Tustin, G.C., J.R. Zoeller, and L. DePew 1996 "Synthesis of Vinyl Acetate Monomer from Synthesis Gas", Paper Presented at the First Joint Power & Fuel Systems Contractors Conference, Pittsburgh, PA, July 9-11, 1996

Xu, M., B.L. Stephens, M.J.L. Gines, and E. Iglesia 1996 "Reaction Pathways and Catalyst Requirements in the synthesis of Isobutanol from CO and Hydrogen", Paper Presented at the First Joint Power & Fuel Systems Contractors Conference, Pittsburgh, PA, July 9-11, 1996