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HETEROGENEOUS CATALYTIC PROCESS FOR ALCOHOL FUELS FROM SYNGAS

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1. Executive Summary

The principal objectives of this project are to discover and evaluate novel heterogeneous catalysts for conversion of syngas to oxygenates having use as fuel enhancers, to explore novel reactor and process concepts applicable in this process, and to develop the best total process for converting syngas to liquid fuels.

The project is being pursued as two concurrent tasks. Task 1 involves catalyst research and development and is being largely conducted by catalyst chemists and analytical specialists. Task 2 is largely an engineering activity, and includes process conceptualization and economics and bench-scale process evaluation of systems developed in Task 1.

The current goal of the catalyst development program is to increase selectivities to oxygenates to greater than 90% with methanol making up less than 70% of the oxygenates, increase rates to 20 lb/ft³/hr, and have conversions of greater than 20%. Earlier work in this organization has shown that a potassium-modified Zn-Cr-Mn-O based catalyst system had alcohol selectivities as high as 70-80 wt%, but the overall alcohol yield was only 11 lb/ft³/hr..

The effects of the precipitation pH on surface area, porosity, and thermal characteristics of the mixed metal oxide component were examined. A designed experiment showed that the precipitation pH was an important factor influencing the BET surface area, and the calcination temperature had a negative effect on the surface area as expected. The optimal surface area for a given calcination temperature would be achieved at a pH of around 10.2. Other interesting results from the models were that calcination time did not affect any of the physical properties measured and only calcination temperature affected the mean pore diameter of the solid.

The preparation of catalysts has been simplified and should result in higher reproducibility of the catalyst preparations and higher productivity of the labs. A problem with an incompatibility of starting materials used in the impregnation was discovered. A new impregnation method was developed that uses the metal nitrate and the tetraamine nitrate salts. Preparation of the finished catalysts is proceeding and will be finished in the near future.

Considerable effort has been spent in re-commissioning the reactor system. Hardware: replacement of system operating gases, several reactor lines and filters, the fabrication of new reactor tubes, reactivation and testing of the ESD system and a pressure check of the entire system for leaks. Analyzers: calibration of the product gas G.C. and learning to operate and program the capillary G.C. Data handling: the analyzers utilize both CALS for data acquisition and the VAX for data reduction and all the methods for performing these tasks had to be renovated or constructed. Existing data and computer programs: programs already located in the VAX directory and operating files in CALS have been identified, defined and cataloged.

The analyzer system received a lot of attention. A single Varian 3700 gas chromatograph is used for off-gas analysis. Inorganics (hydrogen, nitrogen, carbon monoxide and carbon dioxide) are separated out on a 10' x 1/8" 80/100 mesh Carbosieve S-2 column (from Supelco) and detected by thermal conductivity. All organics products are resolved on a 12' x 1/8" 80/100 mesh Tenax column (from Alltech) and detected using flame ionization. A check gas containing both inorganic feed gases and likely organic products is used for calibration purposes. No problems arose with the organic analysis; however, the inorganic analysis was plagued by the presence of double peaks for every component in the check gas and pure feed gas(es) that were used. The phenomenon of peak doubling on the TC side of the GC analyzer was finally traced to the sample injection system which has now been modified to remove this effect.

A standard methanol catalyst has been run in the microreactor system. Reassuringly, it made methanol with adequate selectivities ($> 90\%$) and activities ($> 30 \text{ lb/ft}^3/\text{hr}$) under the test conditions (285°C , 1050 psi, H_2/CO ratio = 1, flow rate = 200 cc/min.). The test was repeated twice to ensure reproducibility.

Four higher alcohol catalysts consisting of copper metal on a cobalt/chromium spinel oxide promoted with Na, Zn, Ce and Th have been tested. These catalysts show selectivities to alcohols as high as 68% and activities as high as $3.2 \text{ lb/ft}^3/\text{hr}$ with an Anderson-Schulz-Flory (ASF) distribution of linear alcohol products. However, this type of low temperature, modified methanol catalyst is unlikely to meet our goals of selectivities to oxygenates $> 90\%$ with activities $> 20 \text{ lb/ft}^3/\text{hr}$. It was decided to concentrate future efforts on higher temperature ($\sim 400^\circ\text{C}$) novel spinel oxide materials giving a non ASF alcohol distribution.

A series of blank experiments was run: (a) the empty reactor tube, (b) the reactor tube with an activated carbon filter bed, (c) the reactor tube with the activated carbon and quartz beads and (d) the reactor tube and quartz beads only. The empty tube produced a very small amount of hydrocarbons; the only activity noted for the production of alcohols was when the activated carbon was present and this was small ($\sim 0.5 \text{ lb/ft}^3/\text{hr}$).

Task 2 work under this contract will obtain kinetic data and evaluate commercially feasible reaction schemes using the best catalysts identified in Task 1. A slurry reactor system is now being prepared for operation and a methanol catalyst will soon be tested as our standard. Work has also begun on identifying process schemes for converting coal to syngas and the syngas to alcohol fuels, and we have been in contact with Texaco to discuss their coal gasification process.

A base case for fuel alcohols production from coal gasification has been identified for further evaluation. For computer simulation of the process, thermodynamic models have been selected for use within the AspenPlus Simulation Program.

2. Project Objectives

- To discover, study, and evaluate novel heterogeneous catalytic systems for the production of oxygenated fuel enhancers from synthesis gas. In particular, novel heterogeneous catalysts will be studied and optimized for the production of: (a) C₁-C₅ alcohols using conventional methanol synthesis conditions, and (b) methanol and isobutanol mixtures which may be used for the downstream synthesis of MTBE or related oxygenates.
- To explore, analytically and on the bench scale, novel reactor and process concepts for use in converting syngas to liquid fuel products.
- To develop on the bench scale the best combination of chemistry, catalyst, reactor, and total process configuration to achieve the minimum product cost for the conversion of syngas to liquid products.

3. Project Organization

This project has been divided into two tasks.

Task 1 is concerned with catalyst identification, preparation, performance evaluation, and characterization. This work is being largely conducted by catalyst chemists and analytical specialists. Chemical studies to support the engineering effort in Task 2 are included in this task, but fundamental aspects of the catalytic chemistry are emphasized in this effort.

Task 2 includes process conceptualization and economics, and bench-scale process evaluation of systems developed in Task 1. This is largely an engineering activity.

These tasks are being carried out concurrently throughout the project.

4. Technical Progress

4.1. Task 1 – Catalyst Studies

4.1.1. Catalyst Synthesis

4.1.1.1. Introduction

Synthesis gas can be converted into mixtures of methanol and higher alcohols by use of alkali-modified methanol synthesis catalysts known for many years. Interest in higher alcohol synthesis from syngas has stemmed from the desire to use the alcohol mixtures as high-octane blending stock for gasoline. Currently refining modifications and the use of oxygenated petrochemicals such as methyl tert-butyl ether (MTBE) have been implemented as alternatives. The production of a mixture of methanol and isobutanol is of interest due to its possible use as a feedstock in the production of other oxygenates such as MTBE and related ethers.

Previous work at UCC on a methanol-isobutanol catalyst used consecutive Hyper-Greco-Latin Squares to identify and bracket levels of important variables in catalyst formulation and preparation. Catalysts with alcohol selectivities as high as 70-80 wt% were developed, but the overall alcohol yield was only 11 lb/ft³/hr. It was shown that catalyst performance is more dependent on the catalyst formulation than the catalyst preparation techniques.

Last quarter we reported that a 16-run, 8-variable fractional factorial design had been set up to study the variables in the catalyst formulation and preparation of an isobutanol catalyst system. The variables included in the designed set were Zn/(Mn+Cr) and Mn/Cr ratios, calcination temperature, calcination time, potassium level, palladium level, cerium level, and reduction temperature. The effect of precipitating pH, calcination temperature and time on surface area, porosity, and powder x-ray diffraction pattern were examined in a preliminary 3x3 designed set. Our immediate goal is to map the response surface of the crucial variables using fractional factorial experimental designs. The goal of the catalyst development program is to increase selectivities to oxygenates to greater than 90% with methanol making up less than 70% of the oxygenate mixture, increase rates to 20 lb/ft³/hr, and have conversions of greater than 20%.

The findings of the preliminary 3x3 design and our progress on the fractional factorial designed set are reported here, as well as numerous difficulties and changes in the catalyst testing procedure.

4.1.1.2. Catalyst Synthesis Results

The first item of business that we accomplished was streamlining the constant pH, basic coprecipitation of the Zn, Cr, and Mn salts to form the bulk mixed metal oxide catalyst. This

modified procedure has increased the productivity of the laboratory and enhanced the quality and reproducibility of the catalyst preparation.

The 3x3 design was carried out to determine best values for the precipitating pH and the range for calcination temperature and time to obtain high surface area and porosity. The designed set as well as the analytical results are shown in Table 1.

The analytical data clearly show that the BET surface area is dependent on the calcination temperature as expected. The pH has a very strong effect on the surface area. These two parameters are the main factors influencing the resulting surface area within this design. This is graphically shown in Figure 1.

Statistical analysis of the data yielded a model for the BET surface area, pore volume, and pore diameter in terms of pH and temperature. Importantly, calcination time was not a significant factor in any model. Numbers in parentheses below the equations are t-ratios, which indicate the relative significance of the corresponding term in the model.

$$\begin{aligned} \text{BET Surface Area} = & 71.19 + 11.72(\text{pH}-9.33) - 0.198(\text{Temp} - 400) - 7.6(\text{pH}-9.33)**2 \\ & (4.6) \qquad (4.5) \qquad (3.0) \\ & R^{**2} = 0.922 \qquad RSD = 10.7 \end{aligned}$$

$$\begin{aligned} \text{Pore Volume} = & 0.373 + 0.085(\text{pH}-9.33) - 0.000317(\text{Temp} - 400) - 0.0232(\text{pH}-9.33)**2 \\ & (15.4) \qquad (3.4) \qquad (4.3) \\ & R^{**2} = 0.922 \qquad RSD = 10.7 \end{aligned}$$

$$\begin{aligned} \text{Pore Diameter} = & 24.86 + 0.057(\text{Temp} - 400) \\ & (4.3) \\ & R^{**2} = 0.722 \qquad RSD = 3.27 \end{aligned}$$

Therefore from these models (see Figures 2 and 3) the optimal pH to achieve the maximum surface area would be around 10.0-10.3. Calcination time is not a factor in these models and therefore could be removed as a variable in the fractional factorial design.

Unfortunately due to the unexpectedly long turnaround time, work on the 16-run, 8-variable fractional factorial design was started before the results above were obtained. Therefore Zn/(Mn+Cr), Mn/Cr, calcination temperature, calcination time, potassium level, palladium level, cerium level, and reduction temperature were kept as variables as originally planned and a pH of 9.0 was used in the coprecipitation.

A spreadsheet was designed so that the amounts of metal salts required for a particular impregnation are automatically calculated once the surface area of the metal oxide is known.

Currently all of the base mixed-metal oxide catalysts have been made. Four catalysts have been impregnated using the incipient wetness technique. We are now using different

metal salts in the impregnation due to an incompatibility that we found between the cerium nitrate and potassium formate. Our initial attempts to impregnate the $\text{Zn}_a\text{Cr}_b\text{Mn}_c\text{O}_x$ with K, Pd, and Ce were complicated by an incompatibility between KHCO_2 and $\text{Ce}(\text{NO}_3)_3$. In water the Ce^{3+} rapidly reacts with the HCO_2^- anion to form an insoluble salt. Upon seeing this, we looked up solubility constants of cerium salts and found that cerium oxalate is only very slightly soluble in water. This prevents using these materials for a simple one-step co-impregnation, but suggested the possibility of doing a sequential impregnation in which the salts are precipitated within the pores during the impregnation. This was tried on one sample in which the $\text{Ce}(\text{NO}_3)_3$ was first impregnated onto the support, followed by a second impregnation of the KHCO_2 . The resulting catalyst visually looked fine, although there were areas of the metal oxide that were covered with a white powder. Other complicating issues in the original impregnation method were discovered and it was decided that a new impregnation method was needed.

Our new method still uses the aqueous incipient wetness technique, but now KNO_3 , $\text{Ce}(\text{NO}_3)_3$ and $\text{Pd}(\text{NH}_3)_4(\text{NO}_3)_2$ will be used. Due to the limited solubility of KNO_3 , both the impregnating solution and the metal oxide will be heated to slow down KNO_3 precipitation during the impregnation and drying steps. Knowing that the Ce- HCO_2 complex precipitates may be useful in future studies as we study other impregnation methods such as precipitation methods.

The initial samples using potassium formate were submitted for catalyst performance testing. The catalysts were used to test for diffusional limitations by testing different mesh sizes of the catalyst. These results show that there are diffusional limitations but they are not large (see next section of this report).

Currently we are waiting for surface areas of the metal oxide component of the catalyst to proceed with the remaining impregnations. Problems with the instruments used in the BET surface area determinations have delayed our progress but the mechanical problems have been fixed and the results for our samples should be quickly determined.

Problems with data workup have prompted the design of an Excel-based spreadsheet that will determine catalyst activity and selectivity, into which CALS data can be directly input. This will simplify the data reduction process and expedite data reduction. There will be additional flexibility and the ability to handle unknown peaks showing up in the GC traces. The fast and easy data reduction will also facilitate catalyst testing since the technician will be able to see the catalytic results before the catalyst testing is finished and decide whether additional testing is required.

During this time it was discovered that blanks having glass beads and activated carbon and only glass beads had not been run during the reactor shake down and those blanks were run. The results of the blanks show that the glass beads are inert, but that the activated carbon is in fact a catalyst for syngas conversion (see next section). The activated carbon will not be included in the reactor in future tests.

It was also discovered that in the past, analysis of products dealt only with C₁-C₄ n-alkanes, C₁-C₄ alcohols (branched and normal), and did not include alkenes and ethers. Also due to normal variability in retention times, peak assignment at the higher retention times was somewhat arbitrary. A modified GC method that uses relative retention times and overlapping windows will be tried.

In addition, the new catalysts produced additional unidentified peaks having sizable peak areas, similar to those assigned to methanol and isobutanol. Therefore a standard having the C₂-C₆ 1-alkenes was run; their retention times were very close to and essentially coincided with those of the corresponding alkanes. Therefore the extra peaks may be due to ethers. In the future, a sample having such peaks in significant amounts will be submitted for GC-MS analysis to help identify the components.

Table 1. Designed set and analytical results for the $\text{Zn}_{1.25}\text{Mn}_{0.16}\text{Cr}_{0.47}\text{O}_{2.1}$ catalyst.

Sample		Temp	Time	BET	Pore	Pore
Reference	pH	(°C)	(hr)	S.A.	Volume	Diameter
				(m²/g)	(cc/g)	(nm)
3DAN79	7.5	300.0	4.0	36.6	0.19	20.9
3DAN79	7.5	400.0	11.0	16.1	0.10	25.1
3DAN79	7.5	500.0	18.0	20.2	0.13	26.1
3DAN69	9.5	300.0	18.0	98.2	0.41	16.6
3DAN69	9.5	400.0	4.0	74.7	0.39	20.9
3DAN69	9.5	500.0	11.0	46.0	0.36	31.1
3DAN75	11.0	300.0	11.0	97.9	0.49	20.0
3DAN75	11.0	400.0	18.0	63.0	0.45	28.5
3DAN75	11.0	500.0	4.0	47.8	0.41	34.5

Figure 1. Surface area of the $\text{Zn}_{1.25}\text{Mn}_{0.16}\text{Cr}_{0.47}\text{O}_{2.1}$ catalyst as a function of precipitation pH and calcination temperature.

Figure 2. Effects of precipitation pH and calcination temperature on BET surface area of the $\text{Zn}_{1.25}\text{Mn}_{0.16}\text{Cr}_{0.47}\text{O}_{2.1}$ catalyst.

Figure 3. Effects of precipitation pH and calcination temperature on pore volume of the $\text{Zn}_{1.25}\text{Mn}_{0.16}\text{Cr}_{0.47}\text{O}_{2.1}$ catalyst.

4.1.2. Catalyst Evaluation

4.1.2.1. Introduction

Project goals are to produce a catalyst for the production of higher alcohols (C_2 and greater) from syngas that has selectivities to oxygenates $> 90\%$ and with activities > 20 lb/ft³/hr. This catalyst would be utilized for synthesizing higher alcohols for use as a gasoline additive and octane enhancer. An effective way of making such a catalyst is to add alkali (~2 wt%) to a Cu/Zn/alumina catalyst used for methanol synthesis. A loss in catalyst activity results and both methanol and higher alcohols are produced. Typical operating conditions are 250-300°C, 1000 psi and a H_2/CO ratio of about 1:1. The quantity of a particular alcohol drops with increasing carbon number in a fashion similar to a Flory distribution for linear condensation polymerization. Ketones and esters are observed as secondary products formed by the further reaction of the alcohols.

4.1.2.2. Microreactor System for Screening Catalysts

Considerable effort has been spent in re-commissioning the idle reactor system. This involved replacement of system operating gases and several reactor lines and filters, the fabrication of new reactor tubes, reactivation and testing of the ESD system, and a pressure check of the entire system for leaks. Early work was done on the calibration of the product gas G.C. and learning to operate and program the capillary G.C. Finally, the data handling procedure was developed. The analyzers utilize both CALS for data acquisition and the VAX for data reduction and all the methods for performing these tasks had to be renovated or constructed. Existing data and computer programs already located in the VAX directory and operating files in CALS have been identified, defined and cataloged.

4.1.2.3. Gas Chromatographic Analyses

The analyzer system received a lot of attention. A single Varian 3700 gas chromatograph is used for off-gas analysis. Inorganics (hydrogen, nitrogen, carbon monoxide and carbon dioxide) are separated out on a 10' x 1/8" 80/100 mesh Carbosieve S-2 column (from Supelco) and detected by thermal conductivity. All organic products are resolved on a 12' x 1/8" 80/100 mesh Tenax column (from Alltech) and detected using flame ionization. A check gas containing both inorganic feed gases and likely organic products is used for calibration purposes. No problems arose with the organic analysis; however, the inorganic analysis was plagued by the presence of double peaks for every component in the check gas and pure feed gas(es) that were used. The phenomenon of peak doubling on the TC side of the GC analyzer was finally traced to the sample injection system which has now been modified to remove this effect.

4.1.2.4. Standard Catalyst Tests

A standard methanol catalyst (CCI 6341) was tested in the microreactor system. Reassuringly, it made methanol with adequate selectivities ($> 90\%$) and activities (> 30 lb/ft³/hr) under the test conditions (285°C, 1050 psi, H₂/CO ratio = 1, flow rate = 200 cc/min). The test was repeated twice to ensure reproducibility. Small amounts of ethanol were observed and traces of n-propanol appeared later in the run.

Tests of crushed vs. 12/30 mesh samples of Zn/Cr and Zn/Mn/Cr spinel oxide catalysts showed some diffusional resistances. Selectivities remain unchanged, but the crushed material can be between 45 - 60% more active. This difference is not sufficiently large, however, to prevent meaningful catalyst screening with either form of catalyst.

4.1.2.5. Copper Metal Based Catalysts

Four higher alcohol catalysts consisting of copper metal on a cobalt/chromium spinel oxide promoted with Na, Zn, Ce and Th have been tested. These are similar to the IFP catalysts. This type of material combines a methanol synthesis metal (copper) with a Fischer-Tropsch metal (cobalt). The active phase is thought to be finely divided Cu/Co clusters produced *in situ* under reaction conditions.

These catalysts were tested under the following conditions: 250-290°C, 1000 psi, H₂/CO ratio = 1, flow rate = 100 cc/min. These catalysts show selectivities to alcohols as high as 68% and activities as high as 3.2 lb/ft³/hr with an Anderson-Schulz-Flory (ASF) distribution of linear alcohol products.

However, this type of low temperature catalyst is unlikely to meet our goals of selectivities to oxygenates $> 90\%$ with activities > 20 lb/ft³/hr. These catalysts are based on copper metal, which sinters rapidly above 300°C; thus, there is an effective ceiling imposed on using temperature as a lever to improve reaction rates. Selectivities are closer to target, but will inevitably decline as the catalyst is pushed harder. It was decided to concentrate future efforts on higher temperature ($\sim 400^\circ\text{C}$) novel spinel oxide materials giving a non ASF alcohol distribution.

4.1.2.6. Reactor Blanks

At this time, it was decided to run a series of blank experiments to determine the background characteristics of the reaction system. Four experiments were conducted under reaction gas and standard operating conditions with: (a) the empty reactor tube, (b) the reactor tube with an activated carbon filter bed, (c) the reactor tube with the activated carbon and quartz beads and (d) the reactor tube and quartz beads only.

The empty tube produced a very small amount of hydrocarbons, probably from some Fischer-Tropsch chemistry catalyzed by the stainless steel reactor walls. The only activity noted for the production of alcohols occurred when the activated carbon was present; this was small (~ 0.5 lb/ft³/hr).

4.1.3. Task 1 Conclusions

The synthesis of the new set of isobutanol catalysts is proceeding. The preparation of the metal oxide component has been simplified and should result in higher reproducibility and productivity. The impregnation has been altered to assure that all components are in solution and multiple impregnations are not necessary. Six finished catalysts have been prepared and work on the others will continue. Work on the data analysis issues will continue to facilitate effective catalyst testing.

Future work will include copper-based catalysts, dealing with different aspects of the support, the impregnation of the metals, and choice of promoters. Preparation has begun of a spinel oxide, $\text{Co}_x\text{Cu}_{1-x}\text{Cr}_2\text{O}_4$, where x ranges from 0 to 1, for use as a support in the copper-based low temperature higher alcohol catalysts.

The reactor system for catalyst tests is up and running. Problems associated with the analyzer and data collection and reduction have been addressed. Future improvements in this area are planned.

A standard methanol catalyst has been tested as a standard and produces methanol at > 90% selectivity and at production rates of >30 lb/ft³/hr.

Some low temperature copper-based catalysts have been tested. None give adequate selectivities or activities. These catalysts are based on copper metal, which sinters rapidly above 300°C; thus, there is an effective ceiling imposed on using temperature as a lever to improve reaction rates. Selectivities are closer to target, but will inevitably decline as the catalyst is pushed harder.

Future catalyst testing will concentrate on novel spinel oxide materials, operating around 400°C, that give a non-ASF product distribution.

The empty tube produced a very small amount of hydrocarbons, probably from some Fischer-Tropsch chemistry catalyzed by the stainless steel reactor walls. This has no significant effect on the catalyst testing.

4.2. Task 2 – Engineering Studies

4.2.1. Reaction Engineering

4.2.1.1. Introduction

Task 2 work under this contract involves reaction engineering studies to examine the best catalysts identified in Task 1. New catalysts will be developed and screened in powder form in Task 1. We will develop scaleup and process strategies to make use of the best catalysts found in Task 1 and will develop kinetic models to describe their performance.

Since powders cannot be used commercially in a gas phase reactor (the type which will be used for initial screening studies), we will evaluate different strategies for utilizing new catalysts on an industrial scale. This may include pelletizing or tableting the powdered catalysts for use in gas phase reactors, using powdered catalysts in a gas-liquid-solid slurry reactor, or using solid pellets or powder in other types of three phase reactors, such as trickle bed reactors.

As another part of Task 2, we are developing process schemes for converting coal to synthesis gas and the resulting syngas to fuel alcohols. We are analyzing the economics based on changes in equipment size, coal feedrates, temperature, pressure, $H_2:CO$ ratio, and other variables.

In the last quarterly, we described the facilities available for Task 2 work. In this report, we give a brief update of our progress.

4.2.1.2. Reaction Engineering Activities

Our catalyst scaleup work has not yet started. We have been conducting literature searches and getting our slurry reactor and associated equipment ready while the Task 1 group develops new catalysts for our testing. We have ordered a new methanol catalyst from UCI which we will use as a standard to evaluate our system before testing new catalysts.

4.2.2. Mathematical Process Development

4.2.2.1. Introduction

Mathematical process development can be broken down into synthesis and simulation. Process synthesis determines which unit operations are needed and in what order. Once the structure is defined by the synthesis step, the process is simulated to determine the heat and material balance. Software tools available for process synthesis and simulation are used to:

- Optimize operating conditions
- Study process alternatives
- Evaluate potential of new technology developed in the laboratory
- Develop process economics
- Provide direction for further lab experiments

4.2.2.2. Mathematical Process Development Activities

A literature search was conducted for fuel alcohols processes as well as syngas generation from coal. A suitable base case was chosen for further process development.

An important aspect of the design is the acid gas removal system for the cleanup of H₂S and CO₂. Candidate processes have been identified to determine which is most suitable for cleanup of coal generated syngas.

4.2.2.3. Simulation Software

Testing of various thermodynamic models within the AspenPlus Simulation Program was conducted to determine the most suitable model. An equation of state was selected for the high pressure section of the process and a liquid activity coefficient model was selected for the alcohol recovery section.

4.2.3. Task 2 Conclusions

A slurry reactor system is being readied to test new catalysts developed under Task 1. We are also considering various process strategies for developing an economical coal-based fuel alcohols process.

A suitable base case was chosen for further mathematical process development. Candidate processes for the acid gas removal system for the cleanup of H₂S and CO₂ have been identified to determine which is most suitable for cleanup of coal generated syngas.

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