Production of liquids and gases from Savage, Montana lignite by hydrogenation with a nickel tungsten catalyst

by Jack Dean Olson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Chemical Engineering

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Abstract:
Eastern Montana and the adjacent states are a vast source of untapped hydrocarbon fuel reserves in the form of coal. The area contains nearly 700 million tons of coal reserves that could provide 300 years of liquid fuels to the United States if converted.

Present conversion methods being investigated by the Office of Coal Research are tending to aim at only moderate conversions, around 60 percent, and would not be suitable in the Montana economic environment unless a use for the char was found other than as a boiler fuel for electrical production. The process described in this paper leads to a conversion from 75 to 95 percent of the coal and would not require use of the char as a' boiler fuel for electrical production.

The equipment used in this study is based around a high pressure autoclave operated in batch fashion. Supporting equipment allows the autoclave to be charged while it is at operating temperature and also discharged at operating conditions. The gas stream is sampled to determine hydrocarbon gas percentages, the liquid stream is vacuum distilled into a fraction boiling below 325°C and a heavy liquid that is reused as a recycle oil, and the sludge is separated by benzene extraction to determine the amount of coal unconverted.

Data obtained from 94 runs were used to obtain correlations of the various yields with operating conditions. A suitable correlation using the main effects, the second order interactions, and the third order interaction of reaction time, temperature, and catalyst concentration was found. Second order terms were not considered due to the limited scope of the data. An overall yield term based on a linear combination of the products was defined and an equation determined. The units of dollars per hundred pounds of moisture and ash free (MAF) lignite were set for the overall yield and the approximate values of each of the products used as linear multipliers. While all yields were found to vary considerably for various recycle numbers, a discussion of recycle three appears to have the best merits.

For operation of a commercial plant, the oil boiling below 325°C would be the main product and could not be withdrawn from the process at a rate greater than the rate of total oil formation from the coal. Using these criteria, a set of conditions were obtained at which the process could be operated continuously. For recycle three, operation at 468.9°C for one hour at 4 percent catalyst concentration would allow 95.8 lbs. of lignite (MAF) and 4.16 lbs. of hydrogen to be processed into: 6.2 lbs. unconverted char, 13.2 lbs. hydrocarbon gas, 12.2 lbs. of reaction water, and 68.4 lbs. of oil boiling below 325°C.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES, Cont.

LIST OF FIGURES

LIST OF FIGURES, Cont.

ABSTRACT

Eastern Montana and the adjacent states are a vast source of untapped hydrocarbon fuel reserves in the form of coal. The area contains nearly 700 million tons of coal reserves that could provide 300 years of liquid fuels to the United States if converted.

Present conversion methods being investigated by the Office of Coal Research are tending to aim at only moderate conversions, around 60 percent, and would not be suitable in the Montana economic environment unless a use for the char was found other than as a boiler fuel for electrical production. The process described in this paper leads to a conversion from 75 to 95 percent of the coal and would not require use of the char as a boiler fuel for electrical production.

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Data obtained from 94 runs were used to obtain correlations of the various yields with operating conditions. A suitable correlation using the main effects, the second order interactions, and the third order interaction of reaction time, temperature, and catalyst concentration was found. Second order terms were not considered due to the limited scope of the data. An overall yield term based on a linear combination of the products was defined and an equation determined. The units of dollars per hundred pounds of moisture and ash free (MAF) lignite were set for the overall yield and the approximate values of each of the products used as linear multipliers. While all yields were found to vary considerably for various recycle numbers, a discussion of recycle three appears to have the best merits.

For operation of a commercial plant, the oil boiling below 325°C would be the main product and could not be withdrawn from the process at a rate greater than the rate of total oil formation from the coal. Using these criteria, a set of conditions were obtained at which the process could be operated continuously. For recycle three, operation at 468.9°C for one hour at 4 percent catalyst concentration would allow 95.8 lbs. of lignite (MAF) and 4.16 lbs. of hydrogen to be processed into: 6.2 lbs. unconverted char, 13.2 lbs. hydrocarbon gas, 12.2 lbs. of reaction water, and 68.4 lbs. of oil boiling below 325°C.

FORWARD

This doctoral thesis is written a little differently than most in style and format. The first major portion is designed to present the problem, a possible soltuion, and important conclusions from the experimental data. This first major portion is kept as brief as possible and is fairly well self-contained to allow a wide readership without bogging down in the details of the data. But, the second portion presumes that the first has been read.

The second major portion is contained in the appendix. Here the reader should be able to find as much detail about the experimental run data as he desires. Background literature is pointed out that would allow a reader to become fairly expert in the field of coal hydrogenation. Some of the experimental procedures have been expanded to show what weaknesses in technique could be improved upon. Two computer programs are described and their output is listed. The output from these programs details in tabular form all the data collected in this research program. The second program is one in which the data are correlated and the output is yield equations based on the experimental data. A results section discusses the equations and graphs drawn from them in a detail that is not available in the first portion.

I. INTRODUCTION

Montana is a land of vast coal reserves that stretch from the Wyoming border to the Canadian border almost everywhere east of Forsyth. The Fort Union coal formation in Montana and adjacent states contains an estimated 700 billion tons of coal,[1] or putting it in terms of liquid fuels, enough liquid fuel could be produced to supply the United States for 320 years at the present rate of 12 million barrels per day consumption. Considering the dimishing rate of oil discovery compared to the consumption rate, there is a possibility of the domestic supply becoming shorter than the demand sometime in the 1980's.[2] Such an occurrance would demand that fuel be produced either from increased oil imports or from one of the synthetic fuel sources, e.g., coal, tar sands, or shale.

Oil companies realize that they may have to move into the synthetic fuel market sometime in the future and are aligning themselves through mergers with existing coal companies or acquiring coal leases of their own. Thus, Continental Oil Company merged with Consolidation Coal, Gulf Oil Company with Pittsburg and Midway, and Sohio acquired Ben Ben Coal. In addition to these, Standard of New Jersey has spent nearly 25 million dollars leasing lands in Illinois, Montana, and Wyoming.[3] All the aforementioned companies also are engaged in research to improve the technology of coal refining. Project Coed, Project Gasoline, and H-Coal are well known joint ventures of private companies with the Office of Coal Research. Other companies are engaged in private research and results from their work are not generally available.

The Department of Chemical Engineering at Montana State University has always been interested in development of the natural resources of the state. A series of theses and articles has been published in the past decade on low temperature carbonization of coal to produce a low volatile char, possibly usable as a coke substitute in some of the local phosphorus and mining industries. Because of the potential rewards that a synthetic fuel coal refinery would involve for the state, a decision to begin exploratory research in coal refining was made in October 1964. General goals of such research were to find, (1) if coal could be refined into low molecular weight fuels at moderate hydrogenation pressures, (2) if a catalyst could be found that would give high yields of oil with low amounts of gas production, (3) if products from such hydrogenation would have desirable properties, and (4) if such products could compete with fuels from petroleum crudes. This article is directed at answering these questions.

Presumably, our goals are similar to those of Project Gasoline, Project Coed, and H-Coal. Because of basic differences in technique we shall briefly describe these processes.

Project Gasoline is a two-step process wherein coal is dissolved at low pressure in a solvent which is then filtered to remove ash and solid coal and then hydrogenated in a catalyst bed at pressures around 3000-5000 psig. Conversion is expected to be about 60% based on the MAF (moisture and ash free) coal. The solid residue would be used as a boiler feed for electric power production.[4]

Project Coed uses a low pressure carbonization of the coal in a multi-stage bed to remove all volatile matter. The remaining char is then used as a boiler feed and the volatile matter is processed by hydrogenation at moderate pressures into liquid fuels.[5] Conversion is slightly lower than that of Project Gasoline and probably is highly dependent on the type of coal used.

H-Coal is a project using a single-stage ebullated bed with coal slurry passed upwards through the bed. Reaction takes place on the catalyst surface to a conversion of about 90% with bituminous coal. Total liquid yield is 70% for bituminous coal. The process produces a wide range of distillates that would have to be further processed into usable fuels.[6]

Economics for the first two of the above projects require a ready sale of the residual char as a boiler feed. Consideration of ash in the char as well as the potential of a greater supply of char from one large coal refinery than could be used by the presently existing 180 megawatt power plant in Billings, Montana, forces a re-evaluation in terms of conversion. The process described in this article attains conversions between 75 and 97% and hence would not require being operated in conjunction with a power plant. Use of a single step process would lower the cost of building a plant and simplify its maintenance. Such a savings appears to be offset by other advantages of the two-step process, as will be shown later, and so may not be realistic.

The cost of hydrogen is a very large factor in the economics of coal hydrogenation. While the development of pressure coal gasification by Texaco Development Corporation will lower the costs well below that for natural gas reforming, further research work will need to lower the cost even more.[10]

II. EQUIPMENT AND PROCEDURE

The availability of equipment, specified to a large degree, the procedures. Since only limited funds were available, the process uses salvage equipment donated by Monsanto Chemical Company and Dow Chemical Company. Shown below is a simplified flow diagram of the system which is basically a batch autoclave with auxillary equipment necessary to allow efficient operation. The entire project is placed in an enclosure eight by ten feet with an L shaped, six foot high, concrete wall built for fire protection. Instrumentation and remote controls allow complete operation from outside the enclosure during the time the equipment is pressurized.

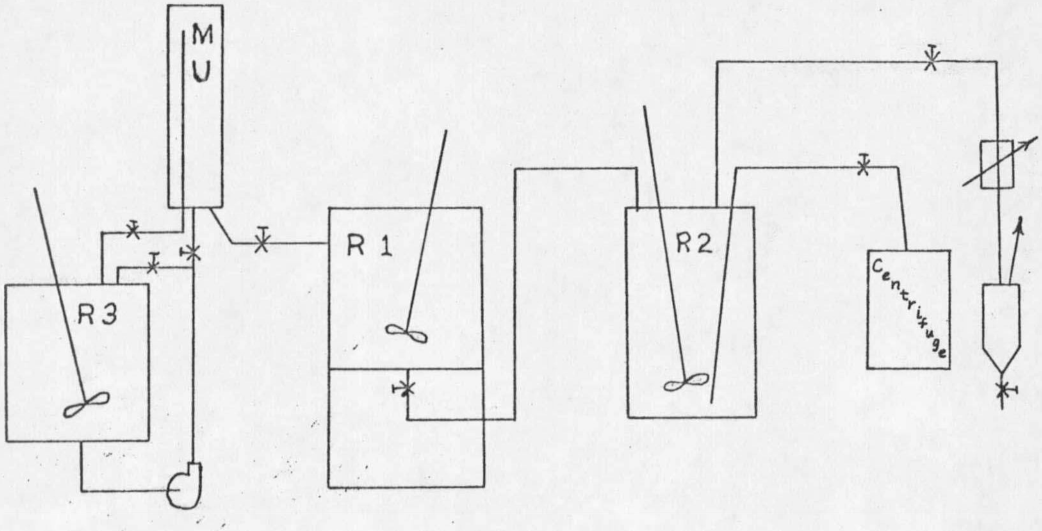


Figure 1. Experimental Equipment Layout

Lignite coal used in this study was obtained ground and partially dried from the Lewis & Clark generating station of Montana-Dakota Utilities. The coal was fed slowly into 130°C recycle oil in the slurry tank labeled R 3, until a 20% by weight of raw coal slurry had been reached. The mixture was then kept stirred and mixed by a stirrer and recirculating pump. A portion of the mixture would then be introduced into the measuring unit (MU in figure) which allowed approximately 1475 ml to be pressured into the hot main reactor (R 1). Within six minutes of the time the slurry was introduced to the main reactor, hydrogen and catalyst dust were injected until the pressure reached 2500 psig. At the end of the reaction time (one, two, or four hours) the slurry was released through the bottom dump valve into another prewarmed pressure reactor (R 2). A vent valve released the unused hydrogen and hydrocarbon gases through a condenser and out the roof. While the gas was being released, a sample was taken from the vent line beyond the condenser to determine the composition of the hydrocarbon gases. When the slurry in R 2 dropped to approximately 240°C, it was pressured by nitrogen into a spinning centrifuge bowl where it remained for about ten minutes. The measured quantities of solids, recycle liquids, oils boiling below 325°C, reaction water, and hydrocarbon gases were used to determine mass balance, conversion, and various yields.

III. DISCUSSION AND RESULTS

A. Preliminary Research

A year of research was spent using a small rocking bomb autoclave experimenting with various slurry oils and catalysts. Conversion of the coal to a benzene soluble material was found to be very dependent on the slurry oil media and catalyst type. Low boiling slurry media showed almost no conversion. Also, dry coal with impregnated molybdenum or tungsten catalyst showed little conversion. Tetralin worked well as a solvent with tungsten catalysts, but tetralin tends to revert to naphthalene in the presence of molybdenum. The best slurry media found was Dowtherm A., but later experiments proved that the Dowtherm was unstable at the hydrogenation conditions and broke down into a two layer liquid. Since the size of charge in the rocking bomb and lack of a good stirring mechanism prevented any product identification, we decided to build the present process system.

B. Reaction Model

Considering the problem of coal hydrogenation from a commercial viewpoint, we can define certain parameters that may affect yields and hence should be well known before a plant is designed. Thus, yield would be: Y = F (temperature, pressure, catalyst type, catalyst amount, recycle number, coal particle size, slurry oil type, slurry concentration, reaction time, and other variables needed to specify equipment design). This article will not specify all the required data, but some of the parameters have been thoroughly studied.

The coal particle size was found in preliminary research to have a definite inverse affect on conversion. It was found that by grinding up a batch of coal and screening it into various size fractions that conversion was better (by 6 to 7%) in the -150 + 200 mesh size than in the -200 +325 mesh size. The reason for this is involved in the brittleness of the fusain constituents of coal compared to the other petrographic components. Therefore, the smaller coal particles are enriched in fusain, a very difficult to hydrogenate constituent, compared to the larger coal particles. Applying the commercial criteria that all coal would be ground small enough to react sufficiently and then the finer dust must also be carried into the reaction, it is necessary only to identify a suitable size coal particle which is small enough to easily react and yet can be produced without excessive grinding costs. The coal grinding that is standard procedure with the Lewis and Clark Station (80% -200 mesh) was found to be very satisfactory. Larger particle sizes may also be satisfactory, but were not investigated.

Above slurry concentrations of 33%, the one-fourth inch inlet lines to the reactor were found to frequently plug up. To safeguard the equipment, we were forced to use only a 20% slurry and thus were unable to determine the effect of slurry concentration. Other literature sources indicate that a 60% coal slurry is manageable in special paste pumps. In a project for the Office of Coal Research, Spencer Chemical Company has s shown that anthracene oil outperforms a number of other possible slurry media media as a coal dissolver at low pressures.[7] Since this anthracene oil is a coke oven by-product it probably imitates, as closely as anything else, our recycle oil. This brings up a problem that was of primary concern throughout our investigations. A commercial plant must obviously use some type of heavy product oil from the coal that is regenerated as fast as it is consumed by the hydrogenation process. Since this oil is not available to start the research, we must somehow produce it and show that it would be usable as the recycle oil for another batch of coal. This is the basis of the recycle number, i.e., how many times has the slurry oil been recycled.

After concerning ourselves with the problem of showing the process to be continuous through several recycles, we did not have time to include studies of more than one catalyst system. The catalyst chosen was Harshaw's 4401 E 1/10 inch catalyst, a 6% nickel and 19% tungsten catalyst on a silica-alumina base. The catalyst was ball-milled in an argon atmosphere to prevent oxidation of the nickel and tungsten sulfides. All handling of the catalyst was done in an argon atmosphere except for a short time during which the catalyst bed was being attached to the hydrogen inlet line to the reactor. No attampt was made to measure viscosity, filtering, or centrifuging rates of the crude product oils. Pressure limitations on the available equipment required all work to be carried out below 3000 psig, and we felt that the data on the hydrogenation below 2500 psig to be of secondary importance.

The reaction model has now been trimmed to a function of temperature, reaction time, catalyst amount, and recycle number. Previous research recorded in the literature as well as equipment limitations provide limits for the first three parameters. Temperatures below 425°C produce lower than 70% conversion and thus are unacceptable. On the other hand, temperatures above 475°C must be used with short reaction time or they produce an unacceptable high gas production. Reaction times of less than one hour are not feasible in our equipment, since the oil requires from fifteen to forty minutes to heat up to the reaction temperature. Reaction times over four hours would undoubtedly be very expensive in terms of equipment sizing in a commercial operation compared to the small additional yield they may give. The amount of catalyst studied was between zero and 4% based on the MAF coal in the charge. The recycle oil was carried through two cycles after the initial anthracene oil start.

C. Empirical Model

In presenting the data it is well to emphasize that the applicable model is Y = F (temperature, time, catalyst amount and recycle number), and therefore, should be viewed as a five dimensional equation. A rigorous mathematical model could be used to describe the yield in terms of the effects and their interactions. More practically, a model expressing yield in terms of a polynomial function of the variables could be used to express an approximate relation.

Experimental work was designed to use a series of runs to determine the effects of temperature, time, and catalyst amount each at three levels. This requires a 3 x 3 x 3 facorial experiment; but because the slurry oil for a series must be produced in the previous series, the number of runs per series varies. The first series contained 38 runs using anthracene oil as the slurry media. The next series contained 23 runs, and the third series 21 runs. The model to which we then fit the resulting data is of the form:

$$Y = b_o + b_1X_1 + b_2X_3 + b_3X_3 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 + b_{123}X_1X_2X_3$$

where X_1 is the natural logarithm of time in hours, X_2 is temperature °C, and X_3 is the natural logarithm of the catalyst concentration plus ore. The logarithms of time and catalyst concentration are taken since the yield is expected to flatten out at high values of either variable.

D. Data Interpretation

After a run has been completed, there are three places from which product must be collected and analyzed. The vented gas stream is analyzed for hydrocarbon gases by chromatography to obtain mole percents of methane, ethane, propane, iso-butane, and n-butane. The liquid is separated from the solids in the centrifuge. An assumption is made that the liquids admixed with the centrifuge solid residue have the same characteristics as the liquid from the centrifuge. The centrifuge sludge is extracted with benzene in a Soxhlet extractor for about 24 hours to determine the fraction of solids. After removal of reaction water from the liquid, the remainder was distilled at an absolute pressure of 20 mm Hg to a cut off point of 197°C, which corresponds to 325°C at atmospheric pressure.[8]

Due to the variability in the amount of slurry transferred to the reactor at the start of the run, a mass balance was performed around each run to determine the amount of material that could be assumed as the input amount. While this forces any true losses to be considered as an input variation, it does help in normalizing the data.

Product oil is defined through this mass balance as being the amount of oil coming out of the reactor minus the amount assumed to have entered the reactor in the slurry oil. This product oil contains no limitation in terms of boiling points and can be broken into a heavy and light portion by subtracting the amount of oil boiling below 197°C at twenty mm Hg that was found experimentally. Under some conditions, this would force the heavy oil to be negative, i.e., more light oil was produced from the slurry than heavy oil was produced from the coal.

The data generated by the total of 94 runs are too voluminous to be presented here. Variations due to scattering, as well as the inability of the model to entirely fit the real data make graphical presentation of the original data difficult. Therefore, the run data has been correlated using the method of multiple linear regression to determine the yields as functions of the operating conditions. Specifically the data were fitted to the proposed model as discussed earlier.

In order to arrive at a graphic equation we shall define a new yield that is a linear combination of the six experimental yield functions. To make this new function a meaningful combination, a set of values is taken as the coefficients that relates the value of each product to the other products. Arbitrary units of dollars per pound are assumed for the coefficient values. One hundred pounds of MAF lignite is taken as the basis. A set of values that would be valid for the eastern half of Montana has been used with the knowledge that every other locality would need a different set of values. Raw coal cost is taken as $1.50 per ton, a value that is valid for low overburden ratios and moderate seam thicknesses such as occur in the Savage, Montana area. The residual unreacted char is assumed to be usable only as a boiler feed stock and therefore is valued at half the cost of the raw coal. Heavy recycle oil boiling above 325°C could be used as a feedstock for further hydrocracking, or essentially a heavy synthetic crude oil. A value of \$2.52 per barrel, corresponding to 90% of the value of the crude oil, is taken for this analysis. The light distillate boiling below 325°C is assumed to be worth nine cents per gallon (\$3.78 per barrel). This value would allow about one and one-half cents per gallon for final processing into gasoline. Hydrocarbon gas is a very valuable by-product in some areas near centers of population. We assume it to be worth 14.1 cents per thousand standard cubic feet, which was the average value in the field for the general region of the Dakotas.[9] Hydrogen is assumed to be produced from a pressure gasification of char or coal in a process which leads to a cost of 25.6 cents per thousand standard cubic feet.[10]

The overall yield equation can now be written in the following form:

$$\text{Yield} = -.1152 + .000576Y_1 + .0080(Y_2-Y_5) + .003162Y_3 + .01384Y_5 - .0191Y_6$$

where: yield is dollars per hundred pounds MAF lignite

Y_1 = percent unconverted coal

Y_2 = percent product oil

Y_3 = percent gas

Y_5 = percent oil boiling below 325°C

Y_6 = grams H_2 used per run

Since the yields Y_1 through Y_6 were obtained in equation form by use of the multiple linear regression analysis, the overall yield equation can also be determined as a function of the operating conditions. The correlation coefficients for the overall yield are shown in Table I. It must be noted that the overall yield makes no provision for the cost of catalyst or operating conditions. Neither does it take into account capital costs and so must be considered as just an overall yield function derived for the purpose of describing the reaction surface.

TABLE I. Coefficients for Overall Yield Equations

Re-cycle	b_0	b_1	b_2	b_3	b_{12}	b_{13}	b_{23}	b_{123}
1	2.7303	-0.3044	-0.0046	-1.1940	0.0003	1.1724	0.0027	-0.0025
2	0.1081	0.3062	0.0010	-0.3976	-0.0007	0.3985	0.0010	-0.0010
3	-1.3087	2.2610	0.0044	0.4810	-0.0055	-0.1559	-0.0011	0.0004

Graphs depicting the effect of the various operating conditions on the overall yield are shown in the series of Figures 2 through 7. While this new yield gives us the ability to speak of the effects of the operating conditions, it must be remembered that the equation is describing a five dimensional surface. The graphs have been drawn with the dependent yield as a function of two or three of the parameters and the other one or two parameters must be compared by viewing two or more sets of graphs.

Consider Figures 2 through 5 which show the effect of recycle number on the yield. The most obvious fact that can be obtained from these graphs is that the recycle number has a fairly large effect on determining what operating conditions will maximize the yield. Whatever the cause of this effect, it demonstrates the need to pilot plant a process thoroughly before scaling it up into a commercial plant. Apparently a small change in the operating conditions of a continuous plant could produce a change in the recycle oil that in turn could lead to a condition of insufficient recycle oil to continue the cycle. This could be a real problem, especially with lignite which requires at least a partial coking of the heavy asphaltene portion of the recycle oil to keep the viscosity low. From a theoretical standpoint, the effect of the recycle oil may be explained on the basis of the amount of hydrogen held by the oil that is transferable. It has been shown in the literature that tetralin will give up four hydrogen atoms to larger condensed ring structures and in the process change into naphthalene. Hydrogenation of the coal is presumed to be carried out by a transfer of the hydrogen atoms of some oils to the coal and then a rehydrogenation of the depleted oil back to its original state. Assuming a number of the substituted two and three ring oils are present in the recycle oil, the previous conditions under which they were formed should greatly affect their relative hydrogen transferability. Basic study into the reaction rates of the pure chemical species likely to be found in the recycle oil would help to predict this sort of behavior. In summary, the recycle number effect on the yields is essentailly due to the history of the recycle oil.

Recycle number three has been chosen as the recycle to show the effects of catalyst, temperature, and time on the yields, since it is most nearly representative of the coal. Figures 6 and 7 show all three parameters graphed on different axes. The figures show that yield may in general be maximized at low reaction times and high temperatures. The negative effect of catalyst in this range is an indication that at the short times and high temperatures more gas is produced when a catalyst is present. Specifically, for one hour at 475°C, the yield of gas is increased by 250% with 4% catalyst over no catalyst. Further, while the yield of product oil decreases by 14%, the yield of oil boiling below 325°C increases by 180% for the change in catalyst. Similarly, the hydrogen consumption at the higher catalyst concentration is increased nearly twenty-fold. This points out that our catalyst is a good gasifier as well as a good liquifier, and under the assumed values of gas and hydrogen it is possible to react the coal to such an extent that the dollar yield passes a maximum.

A secondary effect of catalyst that is not shown on this graph is that the recycle oil quality may vary depending on the catalyst concentration. Thus, operation at low catalyst concentrations may not allow the recycle oil fraction to pick up enough excess hydrogen to allow the process to continue through subsequent recycles. Further consideration should be given to keep the conversion per pass of the recycle oil as high as possible in order to keep equipment requirements low.

E. Commercial Considerations

Thus far the discussion has been concerned with description of the surface described by the experimental data. Further discussion of the surfaces in terms of the individual yields of product oil, gas, reaction water, conversion, and oil boiling below 325°C will be found in the appendix.

From a commercial view, it is obvious that we cannot produce more oil boiling below 325°C and remove it from the process than we make as product oil. This is equivalent to requiring the input recycle oil to be less than or equal to the recycle oil coming from the process. Thus, whether the low boiling product was produced from the coal directly or from the slurry oil is a moot point as long as enough slurry oil is produced from the coal to replace in all respects the slurry oil that was used up.

The equations of yield were solved for the temperature, catalyst, and time required for the product oil to equal the oil boiling below 325°C. Since the temperature is the easiest to change, the other two operating conditions are stepped through the region in which the research was conducted and the temperature required was determined. For recycle number three, there are three combinations that could be used to make a continuous system. Operation at 471°C with no catalyst for two hours would lead to an overall yield of 51.4 cents per hundred pounds MAF lignite as the potential income. Similarly, operation at 0.5% catalyst at 464°C and two hours leads to a potential of 51.7; and operation at 4% catalyst at 469°C for one hour leads to a potential of 68.6 cents per hundred pounds MAF lignite.

The best choice from a commercial view of the process would be operation at 469°C and 4% catalyst. At these conditions, a 95.8 lb. charge of MAF lignite plus 4.16 lbs. hydrogen would be processed into: 6.16 lbs. unconverted coal, 13.24 lbs. of natural gas, 12.15 lbs. of water, and 68.44 lbs. of oil boiling below 325°C. Since no attempt was made in correlating the yield functions to force the total yield to equal 100%, the mass balance is extremely good.

Operation at these conditions for the other recycle numbers would not in general produce oil boiling below 325°C in equal quantities with the total product oil. The equilibrium point at which recycle oil is produced in quantity equal to that used, for 4% catalyst and one hour is

442°C for recycle one. This lower temperature is expected since the anthracene oil used as a slurry oil for recycle one is much more easily broken into oil boiling below 325°C than the later recycle oil produced from the lignite. The similar equilibrium point for series two is 490°C which is slightly outside our operating conditions. The 4% and two hour equilibrium point for recycle two is 450°C. The evidence is that a continuous system could be operated at temperatures near 468°C and reaction time between one and two hours, with 4% catalyst, since, at these conditions recycle oil is produced in amounts equal to the consumption of the incoming recycle oil.

F. Liquid Analysis

The oil boiling below 325°C at atmospheric pressure was analyzed by a series of tests on 31 of the early runs. Refractive index of all products is in the neighborhood of 1.6 and shows no correlation with run conditions. Reid vapor pressures, flash points, viscosities, pour points, bromine numbers, aniline points, and total sulfur were found to have no correlation with run conditions. Values for the first portion of the first recycle are shown in Table II. Probably the small variations found in these tests were more a function of small errors in the operation of the vacuum distillation equipment to produce the fractions. API gravity was found to decrease with increased run time. ASTM distillation data and average molecular weights tend to indicate that increased reaction time decreases the average molecular weights. ASTM distillation data are presented in Table III, and Figures 8 and 9 show the variation of the ASTM curves with catalyst concentration and operating time. Increasing run length and catalyst concentration tends to slightly increase the average molecular weights. Average molecular weights ranged from 143 to 167.

The conclusions of the tests on product quality are that the product is highly aromatic, as indicated by the pour points, aniline points, and refractive indices, and changes little with run conditions or recycle numbers. The lack of change with recycle number is an indication that the products of lignite coal liquifaction are very similar to those from the degradation of coal tar obtained from bituminous coals, as represented in the anthracene slurry oil used to start the process. Probably most coals contain very similar condensed ring structures with the number of nitrogen and oxygen atoms acting as bridges between clumps of ring structures increasing with decreasing rank. The lignite coal used in this research contained 20.9% oxygen on a MAF basis.

IV. CONCLUSIONS

The research results shown in this paper indicate that the hydrogenation of coal is a complex reaction that can be described by certain empirical models. The models described by the data ignore some very important variables should commercial operation be the objective. These ignored variables are catalyst type, pressure, coal particle size, slurry concentration, and the myriad physical properties of each reaction product stream needed to design the handling equipment.

The research results show a large degree of interaction between reaction conditions on the yields. While these interactions make a description of the reaction difficult, they also serve to form a warning about quick jumping to conclusions based on a few runs. Despite a fairly large recycle number and reaction conditions interaction, the data indicate that a continuous process could be operated at a temperature near 468°C at 4% catalyst concentration and reaction times between one and two hours. The potential income for operation at these conditions would be between 56 and 74 cents per hundred pounds MAF lignite processed. Remember that this number does not include capital costs or catalyst costs, nor such operating costs as heating, cooling, etc.

V. RECOMMENDATIONS

(1) Further research should study the effects of various catalysts using some type of process system that will lend itself easily to recovery of the catalyst.

(2) Further research emphasis should be on quickly determining the best catalyst system from a number of possibles by operating in a region where product oil is equal to the oil removed by distillation to 325°C. If the catalyst system is of the same magnitude of activity as that described in this paper, the conditions of 465°C and one to two hours reaction time would be a good first guess.

(3) Further research should attempt to measure the amounts of CO and CO_2 gas evolved and attempt to make an oxygen balance. This factor was ignored in this research but apparently around seven to ten percent of the coal weight leaves as CO and CO_2.

(4) Further research should consider using a flow type reactor in which a space velocity defined in pounds of coal per cubic foot of catalyst can be used as a single flow parameter instead of the two parameter reaction time and catalyst concentration model necessary in the present reactor set up.

(5) Final experimentation on the coal hydrogenation system after the best catalyst of a number has been selected should be directed at describing the reaction surface with the quadratic terms as well as the interactions.

TABLE II. Test Results for Recycle Number One

Run Number	Product (grams)	Reid Vapor Pressure (psia)	Refractive Index	Gravity (°API)	Flash Point (°F)	Viscosity (cst)
L-NT-J-1	186.9	0.40	1.5948	7.40	–	5.32
L-NT-J-2	315.2	0.45	1.5980	8.75	105	3.17
L-NT-J-3	170.9	0.45	1.5941	8.20	160	4.94
L-NT-J-4	255.8	0.80	1.6016	8.30	115	3.29
L-NT-J-5	301.7	0.25	1.5893	10.00	100	4.00
L-NT-J-6	133.8	0.45	1.5944	8.50	150	4.88
L-NT-J-7	216.0	0.40	1.6013	7.50	150	3.75
L-NT-J-8	247.3	0.60	1.6093	6.25	125	3.47
L-NT-J-9	251.1	0.60	1.6086	6.10	155	4.09
L-NT-J-10	287.5	0.45	1.6058	6.50	125	2.86
L-NT-J-11	342.3	0.85	1.5996	8.80	130	2.89
L-NT-J-12	241.2	0.65	1.6030	6.90	155	4.09

Run Number	Total Sulfur (wt%)	Pour Point (°C)	Bromine Number	Aniline Point (°C)	Average Molecular Weight	Calculated Cetane Index
L-NT-J-1	0.051	below -20°C	34.9	below -10°C	167	-23.5
L-NT-J-2	0.074	below -20°C	22.5	below -10°C	151	-4.7
L-NT-J-3	0.087	below -20°C	17.7	below -10°C	158	-4.3
L-NT-J-4	0.125	below -20°C	20.8	below -10°C	148	-6.4
L-NT-J-5	0.072	below -20°C	11.6	below -10°C	150	-3.9
L-NT-J-6	0.084	below -20°C	35.4	below -10°C	150	-4.8
L-NT-J-7	0.191	below -20°C	10.2	below -10°C	152	-6.6
L-NT-J-8	0.108	below -20°C	17.0	below -10°C	149	-7.9
L-NT-J-9	–	below -20°C	23.0	below -10°C	154	-7.3
L-NT-J-10	–	below -20°C	26.1	below -10°C	146	-10.0
L-NT-J-11	0.028	below -20°C	20.4	below -10°C	143	-6.1
L-NT-J-12	0.033	below -20°C	20.2	below -10°C	148	-6.1

TABLE III. ASTM Distillation Data

		% Recovered											
ASTM	IBP	5	10	20	30	40	50	60	70	80	90	95	EP
J-1	331	392	414	449	478	506	530	548	561	587	618	636	636
2	170	301	360	400	431	463	484	506	534	564	585	-	636
3	180	347	380	422	451	469	494	510	536	562	616	628	634
4	-	291	349	390	425	449	475	496	520	546	606	-	614
5	-	297	354	394	427	459	475	514	532	550	573	587	612
6	-	329	355	400	433	459	486	506	528	552	571	597	589
7	170	327	368	406	435	463	486	572	536	558	583	-	632
8	-	254	348	400	433	459	488	508	532	556	626	-	644
9	190	398	376	410	441	469	496	518	540	566	597	-	640
10	170	276	346	390	421	437	470	496	526	558	587	-	636
11	-	246	331	384	410	443	471	494	518	542	568	585	628
12	170	291	366	402	437	469	496	522	538	556	583	599	630
K-1	190	368	402	443	480	518	532	560	573	587	607	623	644
2	170	376	398	421	443	465	475	510	532	560	583	-	618
3	190	341	374	400	429	459	471	506	528	550	573	579	609
4	170	317	366	402	441	476	502	518	540	558	585	604	618
5	170	304	358	398	425	449	474	496	522	554	589	-	626
6	170	331	368	402	435	465	496	522	540	560	577	581	593
8	-	305	346	384	410	435	459	482	504	542	573	-	618
L-1	170	305	352	386	410	437	463	484	514	552	587	-	626
2	190	301	368	396	427	457	484	506	534	552	585	597	610
3	-	307	348	386	415	443	461	506	528	552	573	-	630
4	196	298	356	388	412	437	465	490	512	540	560	583	620
5	196	333	378	425	461	490	514	534	550	564	591	612	632
6	186	319	358	394	419	443	463	488	512	536	568	593	624
7	196	344	382	408	437	473	492	516	534	554	587	598	604
O-2	210	340	378	423	465	494	520	540	556	583	606	-	664
5	170	348	378	406	441	475	506	542	556	575	589	599	605
7	-	-	-	-	-	-	-	-	-	-	-	-	-
8A	190	317	360	382	406	433	459	490	532	560	-	-	600

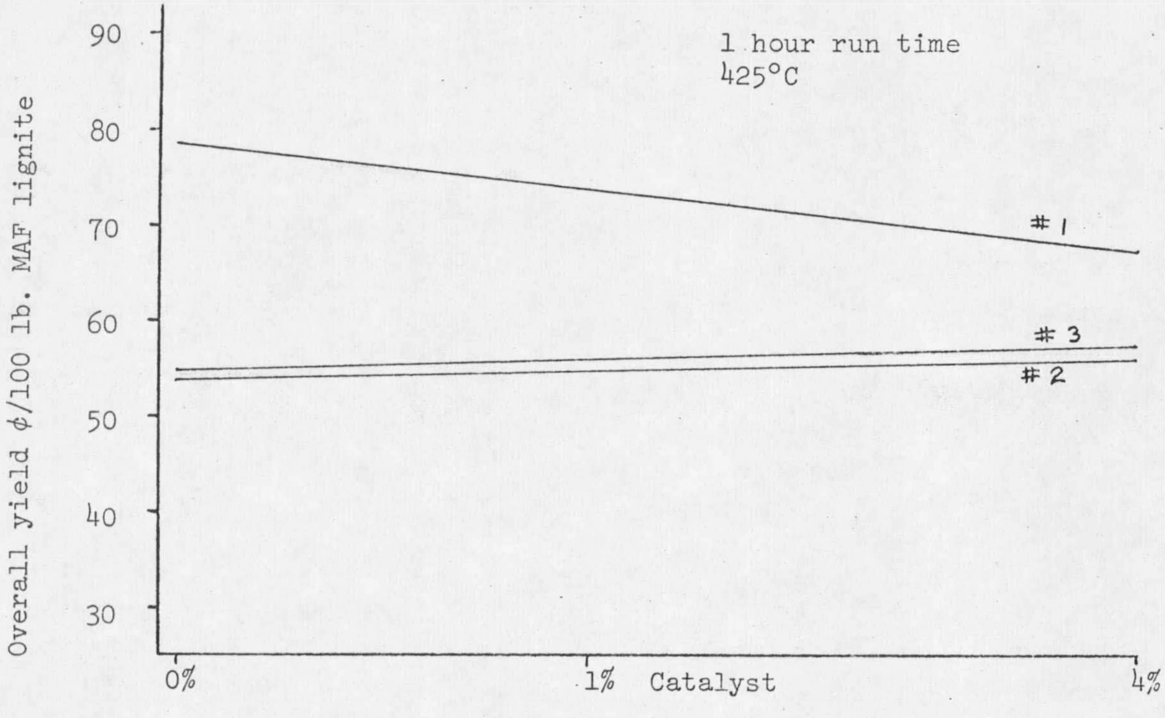


Figure 2. Effect of Catalyst and Recycle Number on Overall Yield

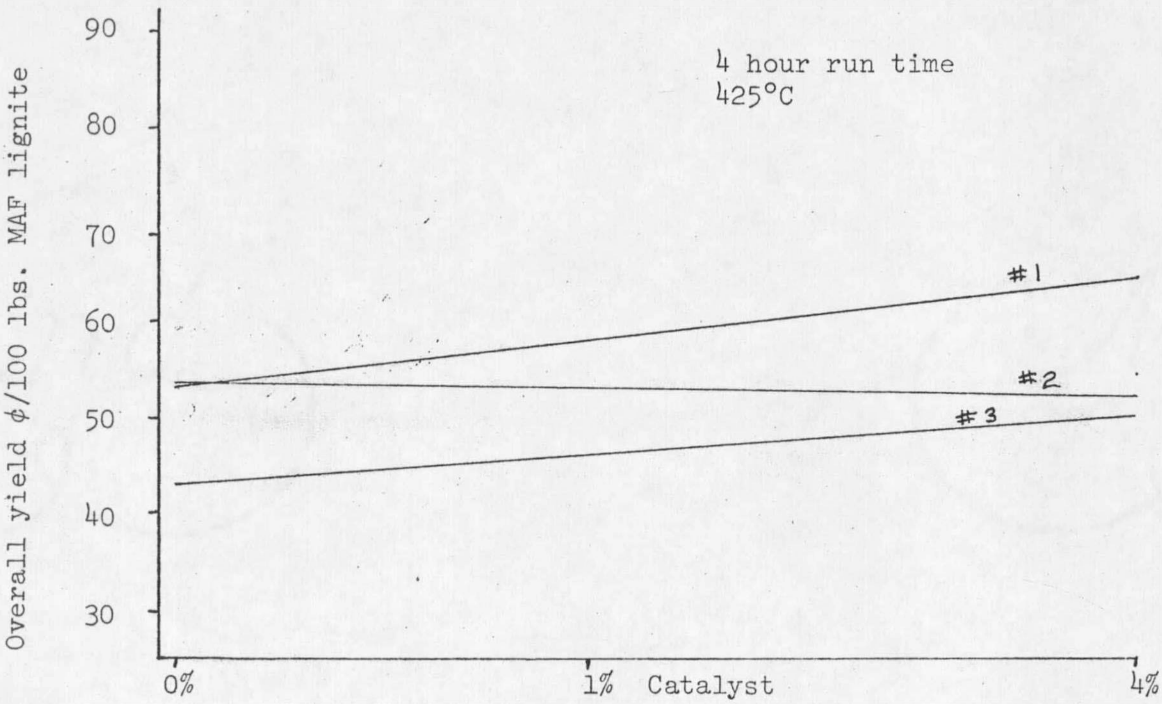


Figure 3. Effect of Catalyst and Recycle Number on Overall Yield

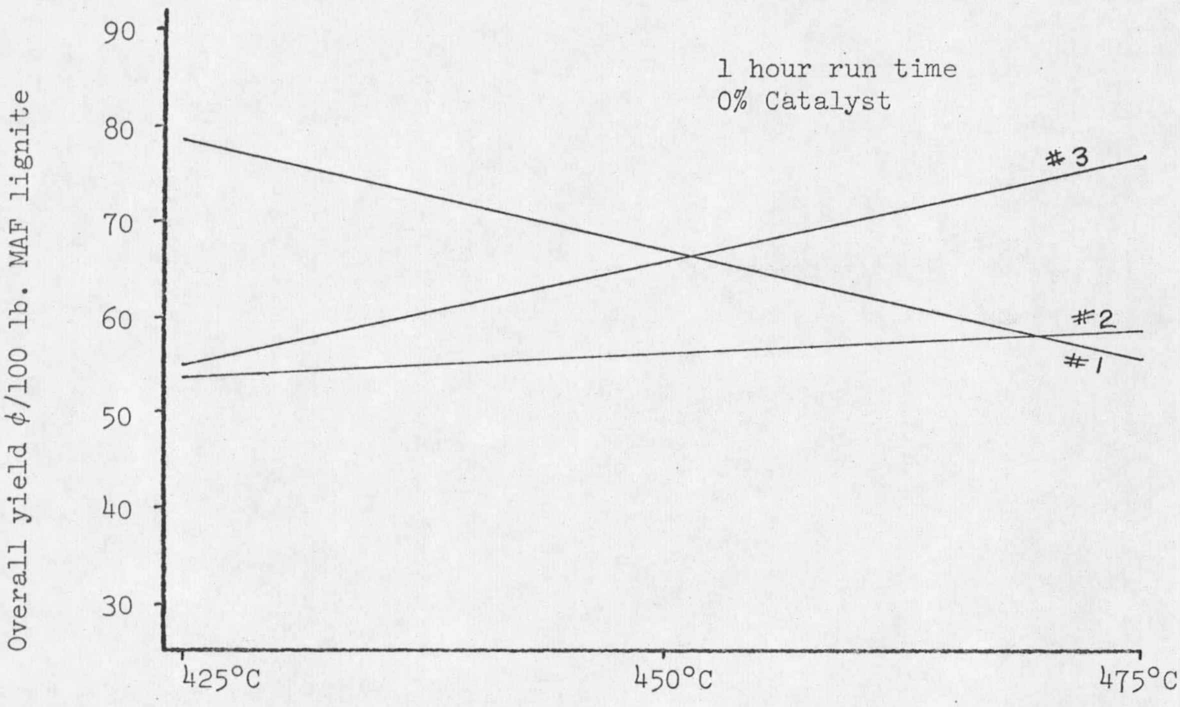


Figure 4. Effect of Temperature and Recycle Number on Overall Yield

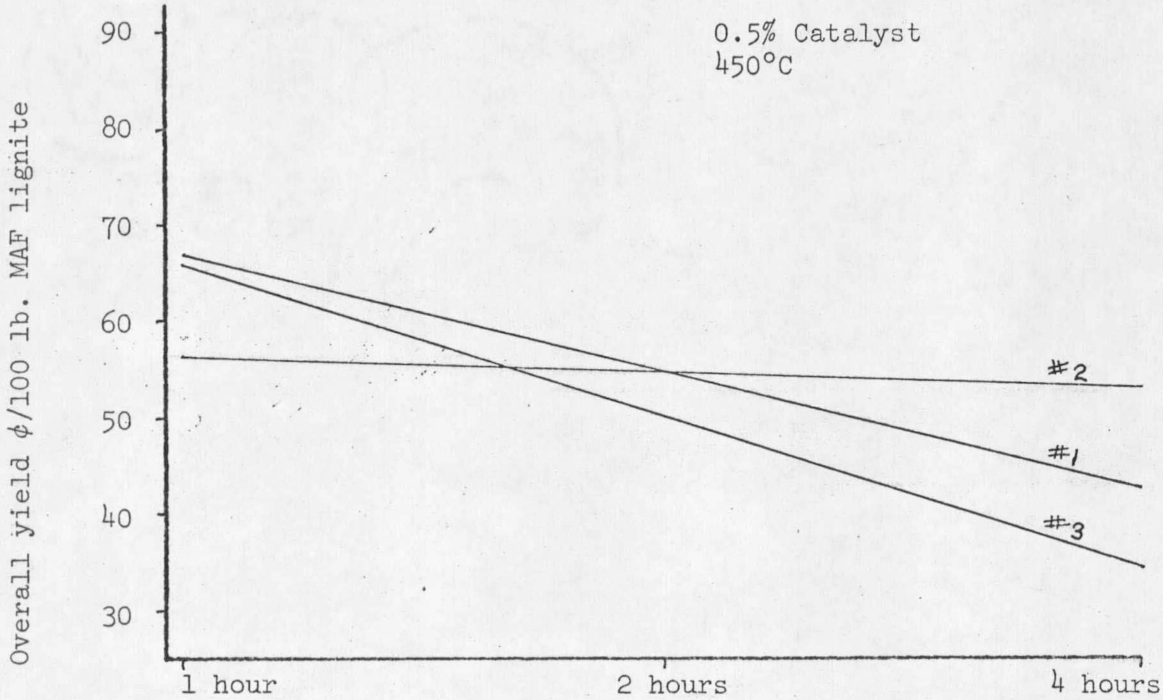


Figure 5. Effect of Time and Recycle Number on Overall Yield

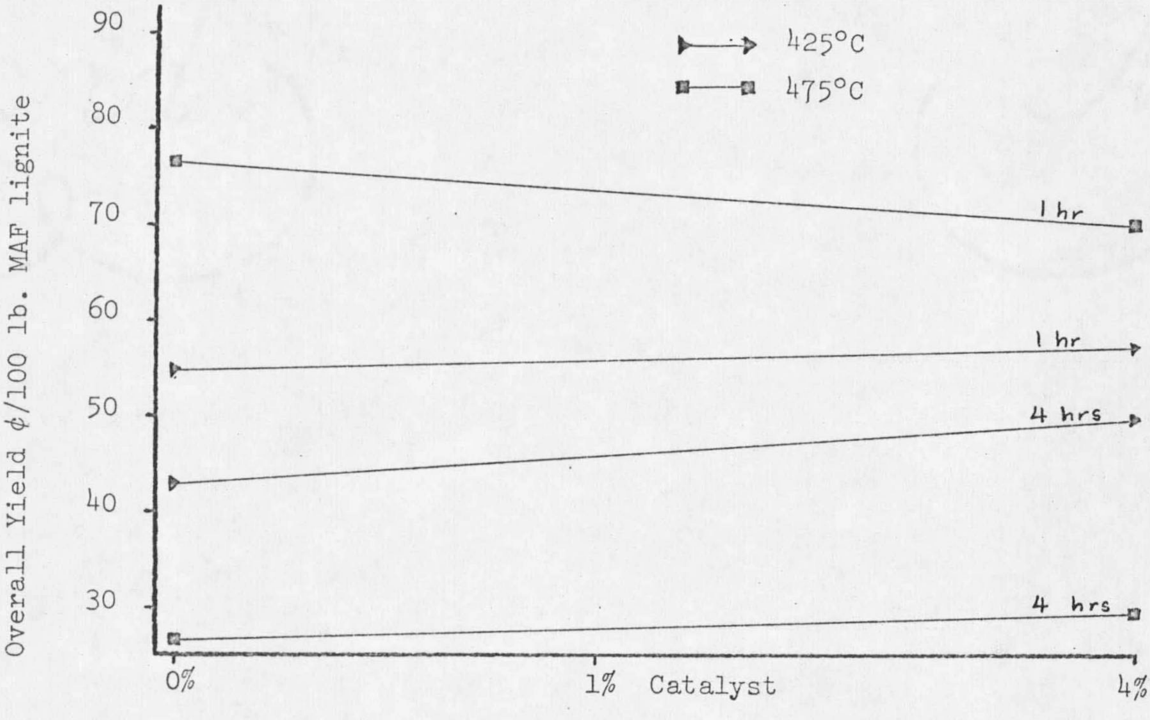


Figure 6. Overall Yield Versus Catalyst for Recycle No. 3.

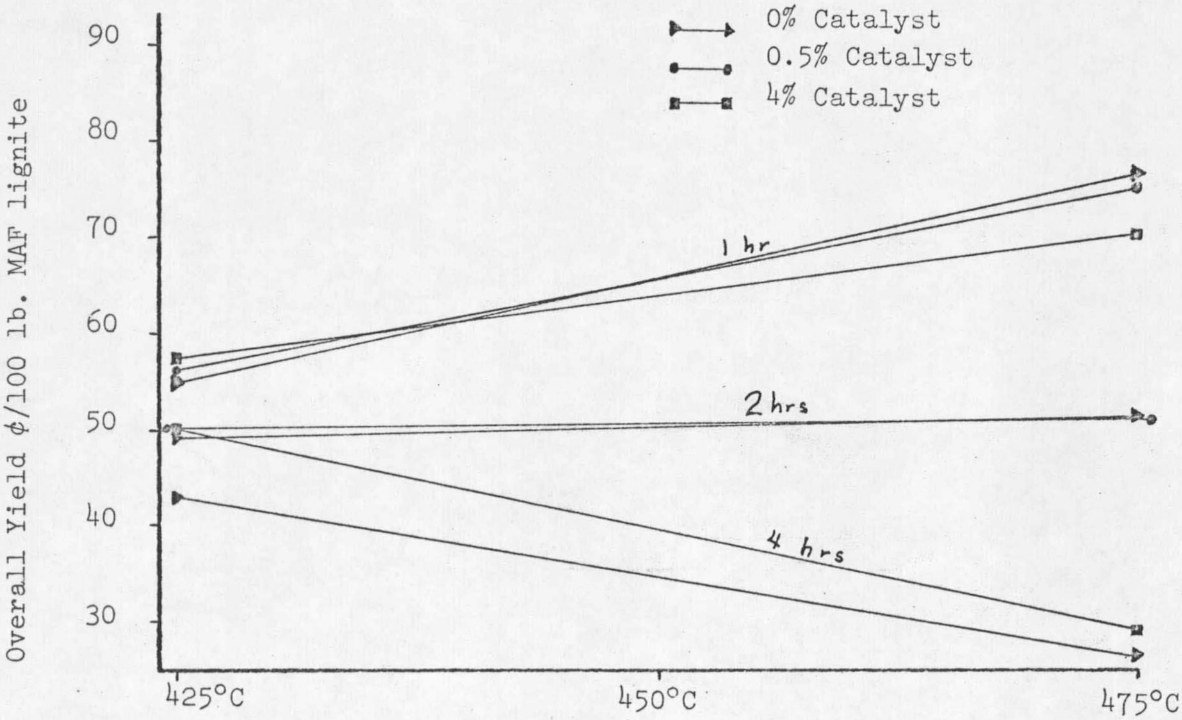


Figure 7. Overall Yield Versus Temperature for Recycle No. 3.

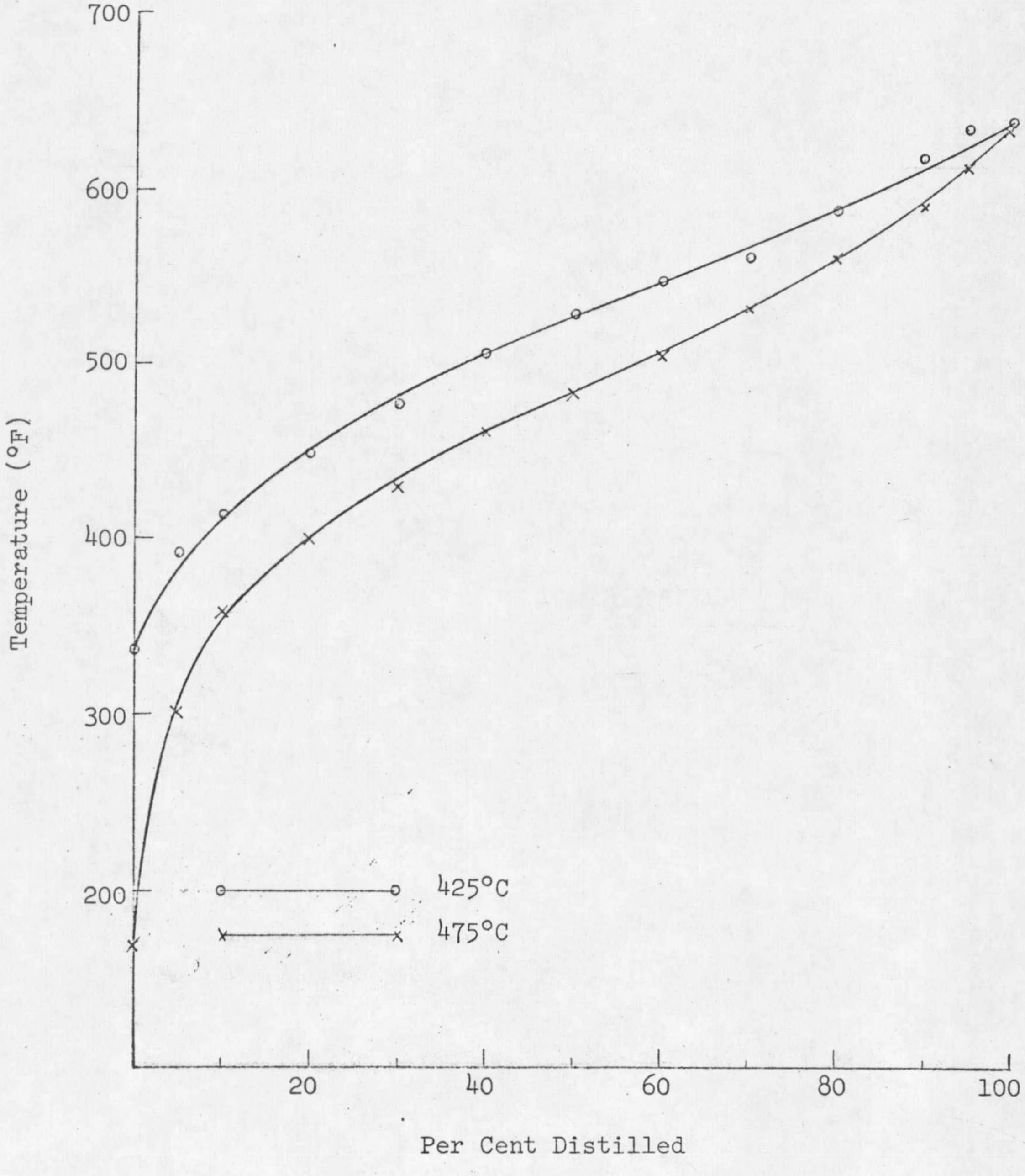


Figure 8. ASTM Distillations for Recycle Number One Products at 3.6 wt% Catalyst Concentration.

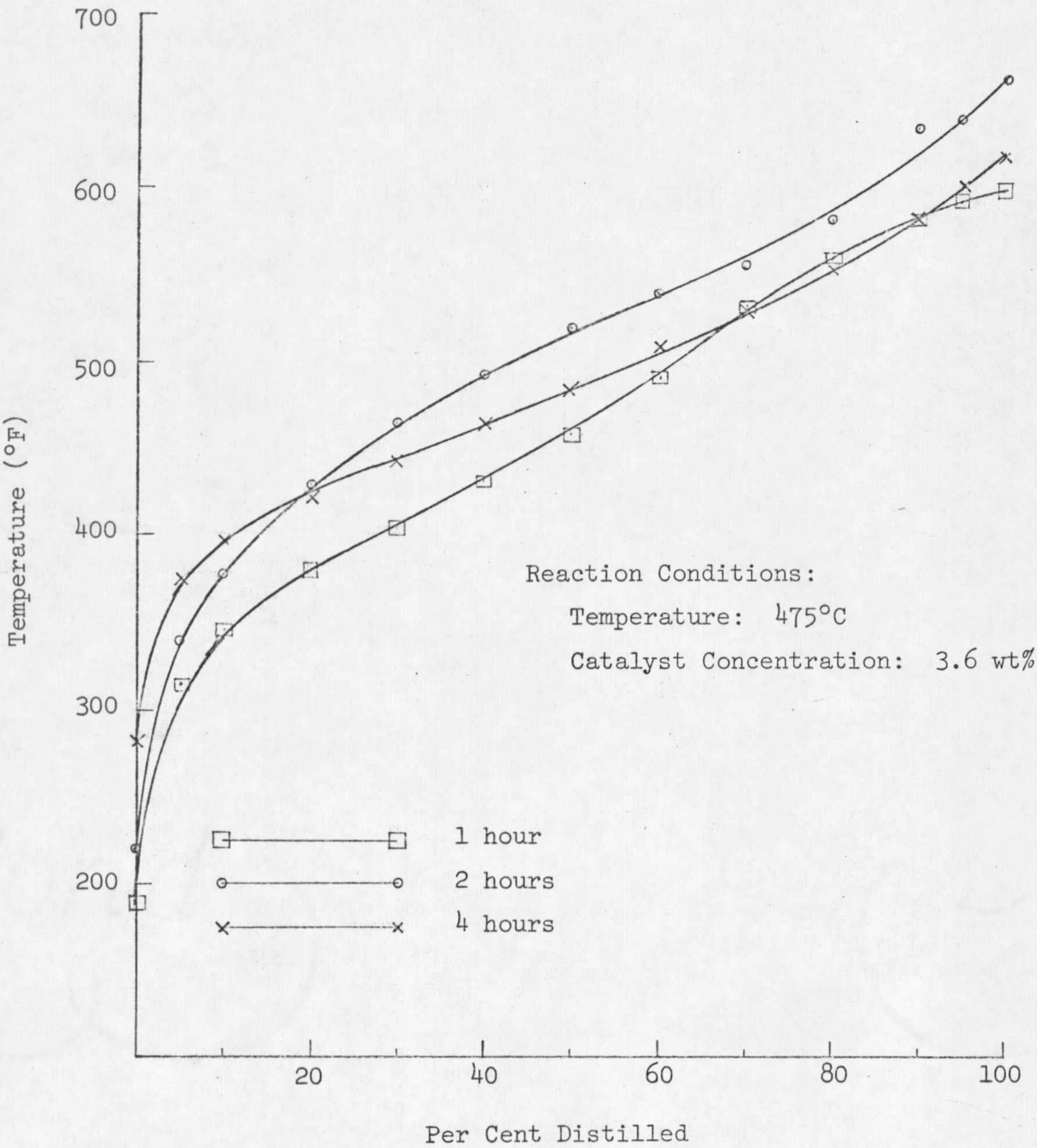


Figure 9. Effect of Run Length on ASTM Distillation of Reaction Products.

APPENDIX

APPENDEX A.

I. BACKGROUND LITERATURE

The German Army during most of World War II was operated on liquid fuels produced from coal. Two processes for the liquifaction of coal were developed and operated in the 1930's. The Fischer-Tropsch process gasified coal into CO and H_2 and then reacted the two gases over a catalyst to produce liquids. The Bergius process reacted coal in a recycle oil slurry at hydrogen pressures ranging to 10,000 psig. After the war, most of the German documents and process descriptions were used to design a coal hydrogenation pilot plant in Louisiana, Missouri. Data and comments about the operation of this pilot plant facility form a major portion of the Bureau of Mines publications on coal hydrogenation from 1949 to 1953. After termination of the demonstration plant in 1953, work was continued in laboratory and pilot-plant scale operations by the Bureau of Mines. Further detailed information on these processes can best be obtained by reading the very excellent chapter on Hydrogenation of Coal and Tar by E.E. Donath.[11]

The Russian coal hydrogenation processes were primarily an outgrowth of moving existing plants in Germany to new locations in Siberia for production of aviation fuels. Chemistry and Technology of Synthetic Liquid Fuels by I. B. Rapoport is a textbook detailing the Soviet experiences in coal hydrotreating.[12] A large number of articles on coal hydrogenation is produced every year in Russia as they continue their studies into coal liquifaction.

The major problem with the background literature in the general field of hydrogenation of coal is not a lack of literature, but more a sorting out of the meaningful portions and comparing from one source to another. Nearly 10,000 articles, papers, or books have been made available on the hydrogenation of liquid fuels. Comparison of results is often confusing, probably because of the complex nature of the reaction. As explained in the body of this thesis, the interaction of reaction conditions with each other is very significant. Comparison of results between researchers is difficult primarily because this interaction term is not often reported.

One of the interesting facts derived from the literature is the proposed coal structure. Figures 10 and 11 show two proposed coal models[13, 14] and comparison of the model for fusain with the model for a typical high volatile coal indicates the probable difficulties encountered in breaking up fusain compared to the total high volatile coal. This is not to say that the fusain is unconvertible; it was shown many years ago that nearly all forms of carbon that occur in a natural process from carbohydrate material may be hydrogenated and broken into liquid hydrocarbons. Oxygen, sulfur, and nitrogen bonds appear to be the easiest points at which to break the coal macromolecule, and thus the fusain with very few points for hydrogen to attach is difficult to break.

In addition to a great amount of research directed at improving the Bergius process, a number of other coal hydrogenation methods have been investigated. The corona hydrogenation of coal was studied by General Electric and promises operation at pressures near atmospheric.[15] Electric arc processing leads to acetylene and hydrogen from high volatile coals.[16] Underground methods for hydrogenation that would work for deep mines have been partially studied.[17] Use of coal as a solid fuel for direct electrical production in a fuel cell is also being studied.[18]

A Bibliography detailing about 1600 articles that have been published from 1960 to 1967 is available from the Office of Coal Research.[19] The vast amount of research in this field is an indication that a process will be available to produce liquids from coal at a competitive price with petroleum in the near future.

The projected fuel usages and oil discoveries indicate that some type of synthetic fuel will probably be needed by 1980.

> George Fumich Jr., director, Office of Coal Research, in remarks to the United Mine Workers Convention in Denver last month, (in November, 1968) projected possible use for coal in the liquid fuel markets totaling 200 million annual tons by 1980. The future forecast would be 400 to 500 million tons by 2000.[20]

C.G. Herrington, Vice President and Director of Humble Oil and Refining Company feels, "The future of coal as a synthetics source probably depends more on energy economics and energy politics than on technological capability for carrying out the conversion step."[21] While this will have a large bearing on when the plants will be built, this author feels that the demonstration of adequate technology for a given type of coal will have a definite affect on plant location. Freight costs for hauling coal to a plant are considerably larger than the costs of shipping a liquid fuel to market, especially for lignite coals that have a 30 to 40% moisture content. Also, lignite is very inexpensive to mine in Montana and the Dakotas and appears to be easier to hydrogenate than bituminous coals. The water in the lignite may even be usable to produce the hydrogen required to carry out the hydrogenation and thus cut down on the water requirements of a plant.

II. EQUIPMENT AND PROCEDURES EXPANDED

The equipment used in the research work has been adequately described by G. R. Haab.[22] The only equipment changes made have been to use a De Laval laboratory disk and bowl centrifuge in place of a pressure filter.

Operational procedures grew from a consideration of safety and getting the maximum number of runs through the equipment in a given time. Pulverized coal was added to the hot recycle slurry oil very slowly over a period of about four hours. The partially dried lignite contained approximately 15% water and caused extensive foaming of the slurry oil until the water had been vaporized out. A commercial plant would have to dry the coal to 5% or less moisture in order to allow reasonably fast coal slurry mixing.

At the start of a run, coal slurry was pumped into the measuring unit by the recirculating pump until the oil flowed over the top of the standpipe and back into the slurry reservoir. After blowing the return line free of oil with nitrogen, the measuring unit was pressurized and the enclosure posted as off limits for all personnel. The oil was then pressured into the main reactor, hydrogen and catalyst added, and the pressure noted at intervals. When pressure dropped to 2200 to 2350 psig, additional hydrogen was added to bring the pressure back to 2550 or 2600 psig. Before the end of a run, the second reactor was preheated by a gas burner to about 180°C and the burner shut off. The hot oil and gas was then dumped through the bottom valve into the second reactor and allowed to cool slightly before the hydrogen and waste gases were vented. The gas was vented through a condenser, the condensate trapped in a reservoir, a gas sample was taken for chromatographic analysis (done immediately to prevent diffusion from significantly changing the composition).

Approximately four minutes after the dump of the reaction products, they were cooled down to 220° to 240°C. They were then pressured by low nitrogen pressure (less than 20 psig) through a three-eights inch dip tube into the spinning centrifuge. Nitrogen was slowly added until a small amount of oil vapor smoke was seen to leave the top of the centrifuge. The centrifuge was left spinning under power for about nine minutes, after which the power was cut and the bowl allowed to slow to a stop. The bowl holds nearly all of the reaction products and had to be disassembled after each run. The liquid portion was removed by inverting the bowl over a stainless steel beaker for four to five minutes; and then after removing a one gram sample for Soxhlet analysis, the solids were removed from the side of the bowl by scraping with a spatula.

Analysis of the liquid portion was carried out while the next run was being made. First the condensate was distilled to separate the water fraction. The remaining oil in the condensate was combined with the centrifuge liquid and they were vacuum distilled at 20 mm Hg until the cutoff point of 197°C had been reached. The light oil was saved for further analysis if desired, but the recycle oil was combined with the other recycle oil from previous runs in the series. Upon completion of a series, the combined recycle oils were cleaned up by vacuum distillation at 2-5 mm Hg to a temperature in excess of 1000°F. The residual coke comprised about 30% ash. Part of the four hour run data for recycle numbers two and three was obtained with raw recycle oil that was not coked free of asphaltenes. This caused confounding of some recycle effects with the four hour effects but was necessary to provide the number of runs needed for regression analysis.

Due to a chromatograph malfunction, some of the data on the first recycle gas stream were lost. About half of the missing data were estimated from similar runs in the same recycle set, and the rest were estimated from the trends shown in the first portion of the series. Generally, the method for analysis of the gas was to inject a sample into a Porapak Q column (one-eighth inch by ten feet) at 100°C and detecting the hydrocarbon gases by a hydrogen flame ionization detector. At first, a calibration curve was determined for the gases by injection of a series of standard gas samples of known concentrations. Later, it was found that the results were very dependent upon carrier gas flow rate which was very difficult to reset at the same point. The calibration procedure was then changed to require running of a couple standard gas samples during the same hour as the unknown sample was run. Sample sizes of the standard gas were taken that made the peak heights of the standard nearly the same as the unknown. Calculation was then based on linear interpolation.

III. MASS BALANCE PROGRAM DESCRIPTION

The mass balance program is shown on pages 59 thru 62. Basically it changes the mole percent data obtained from the chromatograph into absolute weights of each hydrocarbon gas by assuming that the ideal gas law holds. Pressure and temperature data was taken as the last observation before dumping the reactor. An assumption of no build up of coke in the reactor had to be made, although evidence points to a fairly large buildup. After the total output was determined, a loss was calculated based on an assumed input charge of 1475 ml at 1.13 grams per ml. Output data then is normalized by basing the percentage of output streams formed on the total output weight.

The run by run printout of the program results is pretty much self explanatory and covers pages 63 through 179. It should be noted that the pressure of the run is the pressure at the end of the run; all runs can be considered to be at a nominal 2500 psig except run L-NT-0-8, which was at 1500 psig. This run, not considered in the regression analysis, resulted from excessive leakage through the main seal of the reactor. Two tables for each series summarize the main data from the runs in terms of percents or grams. The data from these tables were combined to form the input data to the multiple linear regression program. The runs all use the code L-NT as a prefix standing for lignite coal and the Harshaw nickel-tungsten catalyst. The letter portion of the run number is its series designation. Series J, K, and L were run at four hours and correspond to recycles 1, 2, and 3 respectively. This set of series did not use a coking operation on the recycle oil. Series M, O, P, and Q were run with most points at one or two hours, with just a few at four hours.

IV. MULTIPLE LINEAR REGRESSION PROGRAM DESCRIPTION

This program was written by Dr. Glenn Ingram and others on the computer staff at Montana State University. It is available in an undated version to all users of Montana State University's Sigma 7 system and information about it can be obtained from the Computer Department. The program is not listed in this thesis, but the output for the regression analysis of our data is listed in full.

Input data for this program was obtained by combining run series J with M, K with O, L with P, and leaving Q by itself, to form recycle numbers one through four respectively. Six runs were found to be greatly variable, compared to the other runs in their series, and were removed from consideration before the regression was made. These runs were K-7, M-10, O-7, O-8, O-9, and P-7. The three runs in O were probably bad due to the leakage problem experienced about that time.

A total of ninety-four runs were left for regression analysis. They are spread through the four recycles such that recycle one (from combined series J and M), has thirty-eight runs. Recycle two (from combined K and O series), has twenty-three runs. Recycle three (from combined L and P series), has twenty-one runs. Recycle four (from series Q only), has twelve runs.

Output data from the regression program are listed on pages 180 through 199. Basically it consists of three sets of tables for each of the four recycle numbers. The first table gives the mean, standard deviation, variance and sum of squares for each of the thirteen variables.

Variable one is defined as the natural logarithm of the reaction time. Variable two is the temperature in °C. Variable three is defined as the natural logarithm of one plus the catalyst concentration in percent (i.e., it varies from ln (1.0) to ln (5.0) as catalyst goes from 0 to 4% based on MAF coal). Variable four is a yield variable defined as the percent unconverted coal. Variable five is percent product oil as defined by the mass balance program. Variable six is percent gas and variable seven is percent reaction water. Variable eight is percent oil boiling below 325°C. Variable nine is the grams of hydrogen used per run. Variable ten is the product of variable one with two with three. Variable eleven is the product of one and two; twelve is the product of one and three; and thirteen is the product of two and three.

The second table is a table of correlations of the entire set of variables with each other. The third set of tables is the most important, as it gives the equations for the multiple linear regression of the yield variables with the six independent variables one, two, three, ten, eleven, twelve, and thirteen. Certain statistical tests for the goodness of fit of the regressed equations to the data are given. The F tests are all significant to 95% in the first three recycles with the worst degree of fit being that of reaction water, variable seven, to the reaction conditions. Recycle four just does not have enough samples to adequately specify the equations for conversion (variable four), product oil (variable five), or reaction water. The other yields are fitted quite well.

V. DISCUSSION OF RESULTS

The discussion in the body of the thesis centered around the presentation of an overall yield function that could be used to describe the reaction surface. A total of six yields can be identified and correlated with the operating conditions. The percent coal that remained as an unconverted solid will be considered a quasi yield for this discussion. Second is the yield of product oil defined by the measure of oil leaving the reactor minus the assumed amount entering the reactor. The total yield of gas, as found by chromatographic methods, is considered the third yield. Oil boiling below 197°C at 20 mm Hg, and the percent reaction water, are the fourth and fifth yields respectively. The sixth is another quasi yield defined as the amount of hydrogen required per run in grams.

These six yields were fitted by multiple linear regression to the equation arrived at earlier:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 + b_{123}X_1X_2X_3$$

Table IV lists the b's for each of the four series and each of the six yield functions. Further data relating the degree of fit and the various statistical parameters can be found in the output of the multiple linear regression program starting on page 180. It is important to note here that the interaction terms are definitely a large factor in describing the effect of the operating conditions on the yield.

Graphs of the equations can be drawn if two parameters are held fixed, one parameter is taken as the independent axis, and the fourth parameter plotted as a contour. This has been done on Figures 12 through 17, which show the effect of recycle number on the six yields at the intermediate conditions of temperature (450°C) and catalyst concentration (0.5%). In general, the figures show that the recycle number affects the yield. An apparent exception to this is seen in Figure 16 where recycle numbers two, three and four indicate the same yields at the same time slope as recycle number one. This appears to be an indication that the anthracene oil produces a considerably larger amount of oil boiling below 325°C than does the later recycle oil; however, the reaction time affects the amount produced in the same manner for all recycles. Examination of just one figure would lead to the erroneous conclusion that the recycle number effect had stabilized. That this conclusion is erroneous is obvious from the other five figures in this set.

Another observation that is apparent from the set of figures is that recycle number three is usually in the middle portion of the variation due to recycle number. Partly because of this and partly because the third recycle should be expected to have little residual anthracene oil remaining, the third recycle was chosen to discuss the effect of the operating conditions on the yields. The fourth recycle is not used since it contained only twelve runs which cannot adequately define the reaction surfaces.

Beginning with Figure 18, a set of graphs is presented that show the effect of operating conditions on the six yields. The even numbered figures have the reaction time as the independent axis on a log scale, and show the reaction surface by contour lines at the extremes of temperature and catalyst concentration. The odd numbered figures have the reaction temperature as the independent axis and show the surface by contour lines at the extremes of time and catalyst concentration.

Catalyst is seen in Figures 18 and 19 to decrease the amount of coal that is unconverted. Increased run time at low temperature values also decreases the amount unconverted but not at high temperatures. The proposed reason for this slight increase in unconverted coal at high temperature and long reaction time is that the dissolved coal must be repolymerizing and coking. A good test for this hypothesis would be to treat extracted coal oil at a high temperature and long reaction time to see if some coke would be formed.

Product oil formation can be seen in Figures 20 and 21 to be at its maximum at either large catalyst concentrations and low temperatures, with long times or at short times, with low catalyst concentration and high temperature. This is caused by a number of interacting effects. It will be seen in Figures 22 and 23 that gas production increases greatly with increased time at the high temperatures but not at the low temperatures. This removes some of the product oil that was formed at the start of the reaction time and causes the amount of product oil at the end of the reaction to decrease. On the other hand, at short reaction time and no catalyst the product oil is not formed soon enough for the temperature to greatly break it down into gases. Another cause is that the heatup time to bring the oil to reaction temperature is a significant portion of the one hour run time at high temperatures since the reactor is operating fairly near its upper temperature limit.

Reaction water was not correlated very well with reaction conditions, so conclusions drawn from the indicated equations may not be of great value.

The mean of all conditions is about 10.5% coal ending up as water with the maximum variations in the order of 3% of the coal weight. This would correspond to variations in the original data of about 8 grams of water. Very possibly our technique of separating water from light oil in the condensate could lead to measurement variations of 2-3 grams, which would explain the poor degree of fit. Nevertheless, Figures 24 and 25 indicate that reaction water is increased slightly with time and temperature. There is a possibility of a large third order interaction term which counteracts the other effects.

The third, most easily obtained, quantity in operation of the equipment is that of oil boiling below 325°C. The most easily obtained (though not easy to calculate by hand) is the percent coal that is converted into gas. Problems of calibration on the chromatograph have given some concern for error in this number. The second most easily obtained is that of percent unconverted coal. However, this was found to have an interaction between temperature and time. From Figure 16 it can be seen that the percent of oil boiling below 325°C has little variation due to recycle number after the first recycle. The evidence in Figures 26 and 27 points to a minimal of interaction effects for the reaction conditions on this yield. This yield is increased greatly by catalyst, temperature, and reaction time. Thus, it appears that a maximum of information might well be obtained by examination of just this one variable when trying to determine the best catalysts to be used in the system. This conclusion is further strengthened by the fact that this product would be the most salable and hence is a rough determinant of overall yield. It should be noted however, that the maximum obtainable overall yield is not consistent with the maximum obtainable product boiling below 325°C. Nevertheless, for obtaining the information about which catalyst of many is the best, the yield of oil boiling below 325°C should be given highest priority, unless the funds are available to carry out a complete study of each.

Hydrogen used to produce the gases and liquids from the coal can be seen in Figures 28 and 29 to be most affected by the length of run. The effect of temperature on hydrogen usage appears to be more due to the interaction term of time and temperature. Catalyst also has a large effect on the hydrogen usage as would be expected.

The data analyzed and shown in the graphs give a fairly complete picture of coal hydrogenation. The obvious weaknesses and limitations due to the large effects of recycle oil would require a very extensive program to correct in the present equipment. Since the preliminary economic evaluations indicate the largest cost factor in operation will be that of supplying catalyst under the present process, it appears that further research should center on finding a process and catalyst system that can be easily regenerated. The only alternate to a regeneratable catalyst system can be pieced out from the data and figures presented by assuming the use of no catalyst in the primary reactor and using a catalytic second stage to treat what would essentially be an ash-free depolymerized coal. For no catalyst this primary reactor should operate at high temperatures and low times, and the recycle oil probably should be a heavy fraction of the product from the secondary reactor operating at moderate temperature and moderate reaction time.

APPENDIX B.

Summary of Experimental Data

The data for the production of liquids and gases from Savage, Montana lignite by hydrogenation with a nickel tungsten catalyst is presented in figures and tables in the body of this thesis and on the following pages.

TABLE IV. Correlation Coefficients

Recycle	b_0	b_1	b_2	b_3	b_{12}	b_{13}	b_{23}	b_{123}
Yield of Unconverted Coal								
1	-76.2298	49.8876	0.19871	99.3487	-0.18398	-83.0717	-0.22839	0.18002
2	228.7664	-173.3031	-0.46131	-58.6548	0.36458	4.9832	0.11093	0.00202
3	246.5610	-207.6150	-0.50478	-79.8243	0.44438	62.7541	0.16531	-0.13644
4	73.0136	16.6950	-0.13686	41.5186	-0.05133	-82.6024	-0.10133	0.18924
Yield of Product Oil								
1	367.0112	32.6911	-0.66249	-93.2437	-0.10953	127.0477	0.20916	-0.27106
2	13.6935	186.9961	0.11152	30.0779	-0.40733	28.1540	-0.05223	-0.08022
3	-90.7450	410.2590	0.35642	125.4877	-0.93428	-118.7959	-0.27814	0.26839
4	113.1289	131.4176	-0.08716	-20.6711	-0.29355	-50.3067	0.05607	0.10749
Yield of Gases								
1	-193.835	-57.2747	0.45014	-4.7861	0.15984	-38.5660	0.01536	0.08180
2	-125.053	11.7130	0.29402	21.1606	-0.01914	-52.2407	-0.04526	0.12083
3	-43.396	-177.2635	0.10345	-41.3977	0.42388	22.0322	0.09907	-0.05212
4	-100.022	-136.8690	0.23789	13.6081	0.31655	91.6620	-0.03208	-0.20187
Yield of Reaction Water								
1	4.5041	-23.0855	0.00990	0.0791	0.05819	-8.6610	0.00055	0.01634
2	-16.5032	-23.6216	0.05373	8.3655	0.05667	15.0471	-0.01577	-0.03359
3	-10.0039	-10.7457	0.03951	-6.7457	0.03094	30.8955	0.01920	-0.07293
4	10.7746	-4.1455	-0.00759	-29.6988	0.01146	30.7824	0.06685	-0.07090

TABLE IV. Correlation Coefficients - Cont.

Recycle	b_0	b_1	b_2	b_3	b_{12}	b_{13}	b_{23}	b_{123}
Yield of Oil Boiling Below 325°C								
1	-73.198	-136.635	0.27605	-19.9904	0.35476	40.9181	0.07956	-0.09090
2	-147.109	-94.158	0.39314	-74.7700	0.25188	12.8891	0.19091	-0.01476
3	-150.447	-142.403	0.40391	-100.5532	0.35380	67.8295	0.25356	-0.14538
4	-107.569	-254.582	0.31270	-111.4393	0.60853	156.0379	0.26284	-0.33569
Hydrogen Consumption								
1	-52.0495	-20.1274	0.12720	19.5472	0.07065	-4.5449	-0.03101	0.00955
2	-64.7380	30.2172	0.14884	12.2878	-0.04786	-13.6262	-0.01840	0.03297
3	-21.2686	-25.6895	0.04580	-12.6309	0.08963	-15.3184	0.03993	0.03350
4	-52.6246	-97.5637	0.12231	74.7075	0.22730	33.5353	-0.15816	-0.06918
Overal Yield in \$ Per Hundred Pounds MAF Lignite								
1	2.73074	-0.30436	-0.00458	-1.19395	0.00029	1.17236	0.00265	-0.00252
2	0.10808	0.30615	0.00101	-0.39761	-0.00072	0.39845	0.00097	-0.00097
3	-1.30874	2.26101	0.00437	0.48104	-0.00552	-0.15585	-0.00109	0.00042
4	0.89254	1.00297	-0.00053	-2.17614	-0.00217	0.11054	0.00485	-0.00031

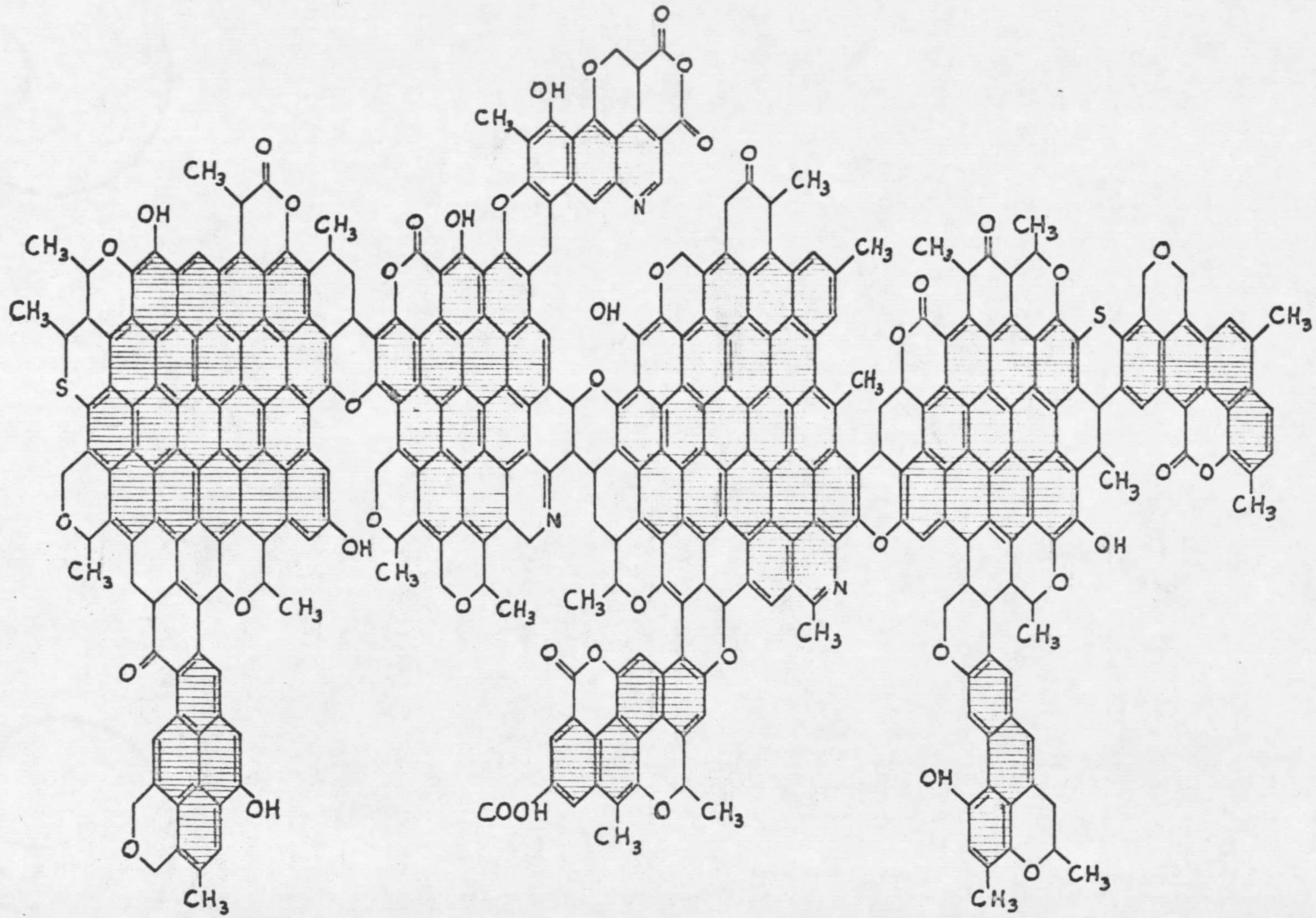
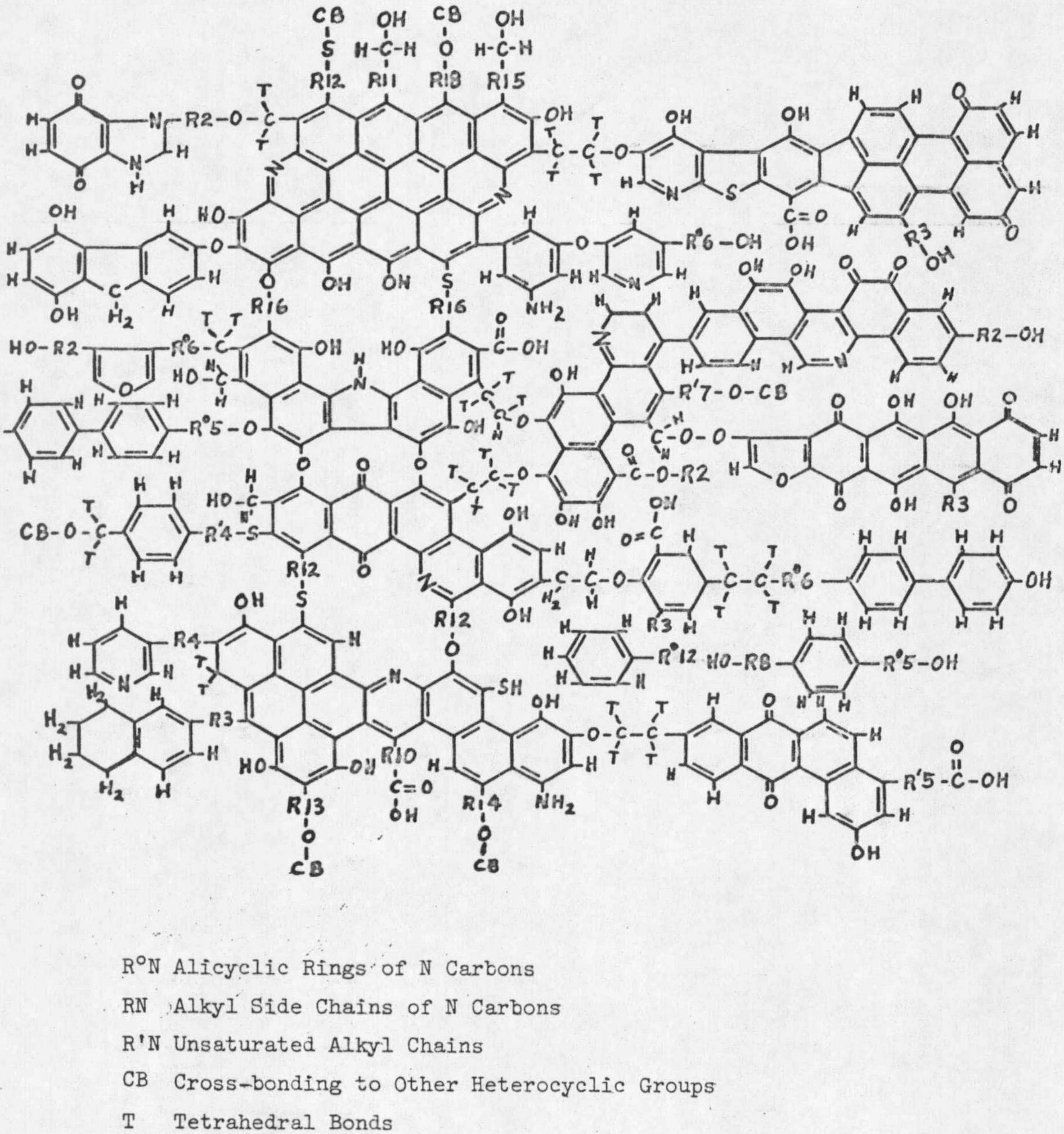


Figure 10. Macromolecular Model for Fusain from Angrenski Coal[13]



$R^{o}N$ Alicyclic Rings of N Carbons

RN Alkyl Side Chains of N Carbons

R'N Unsaturated Alkyl Chains

CB Cross-bonding to Other Heterocyclic Groups

T Tetrahedral Bonds

Figure 11. Typical Cross-Bonded Structure for High Volatile Coal[14]

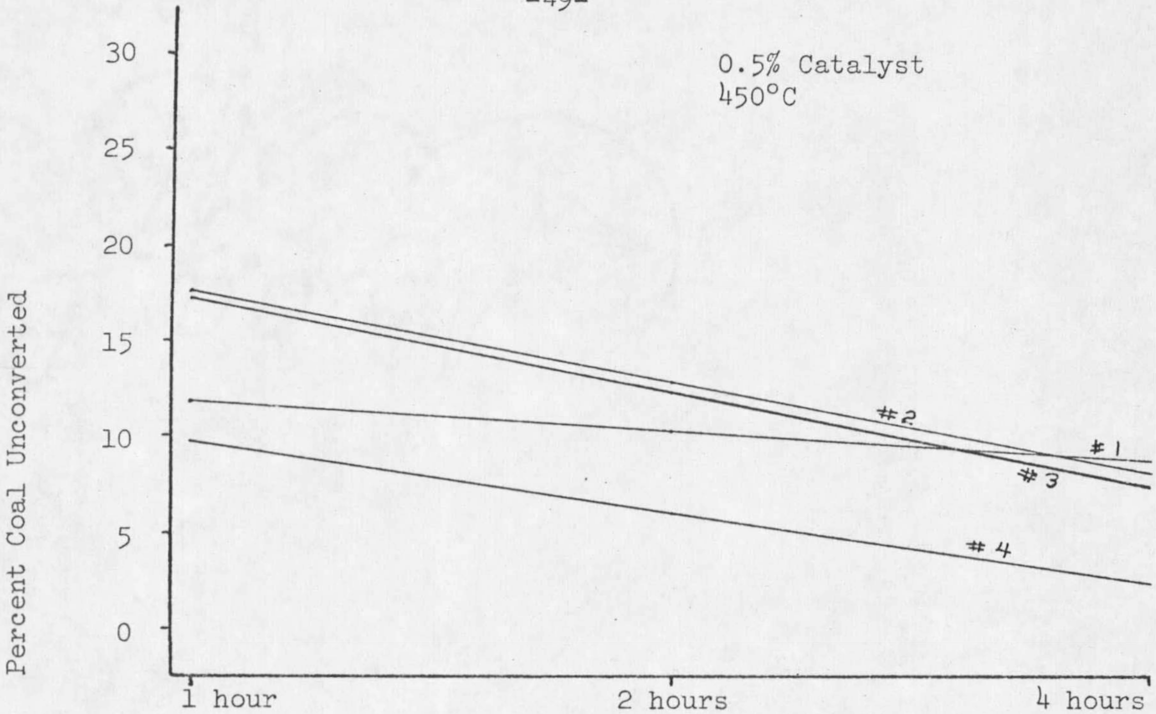


Figure 12. Effect of Time and Recycle Number on Percent Unconverted

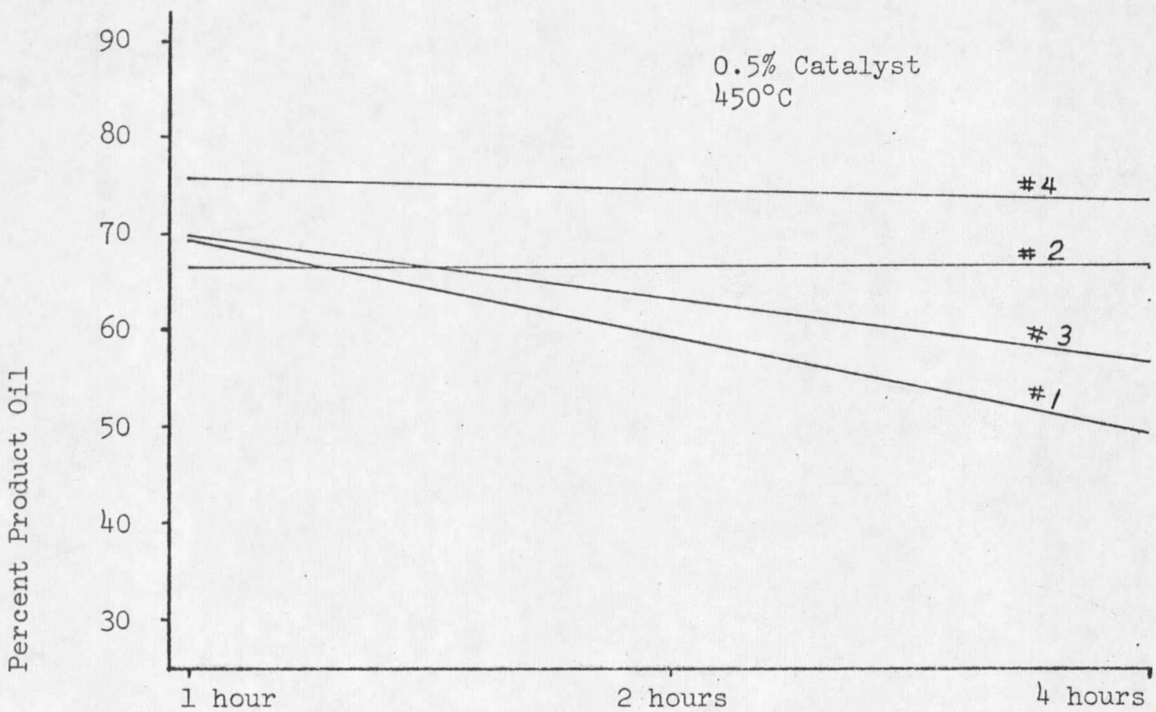


Figure 13. Effect of Time and Recycle Number on Product Oil Yield

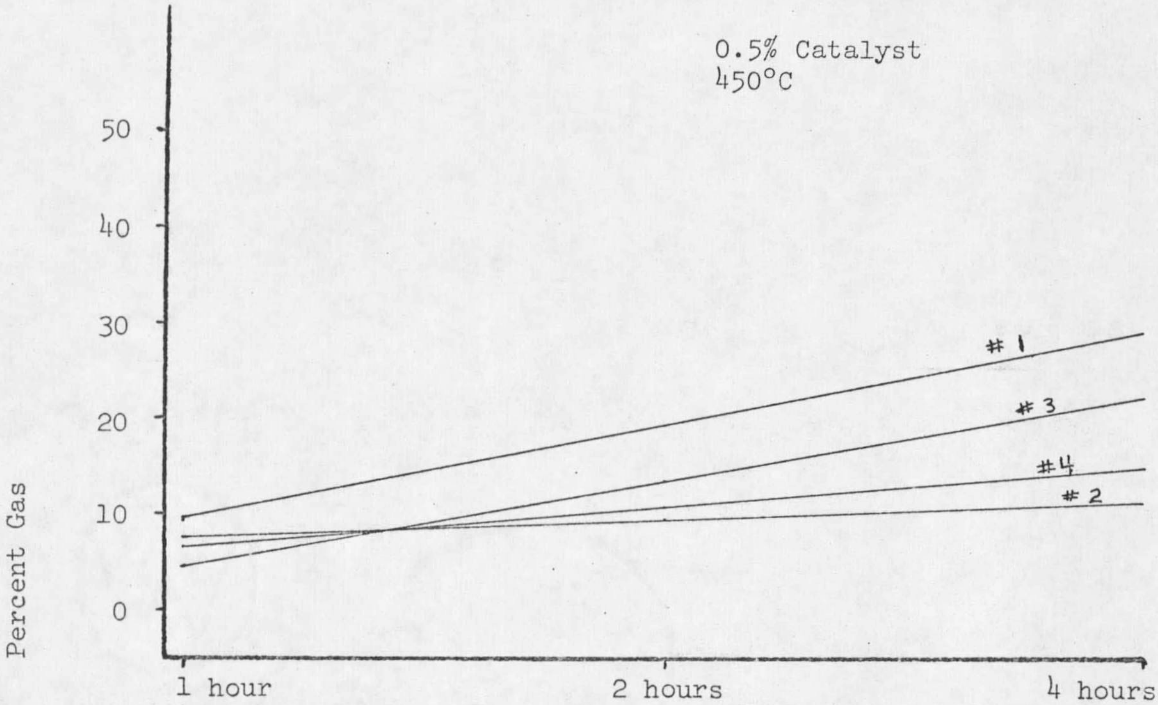


Figure 14. Effect of Time and Recycle Number on Gas Yield

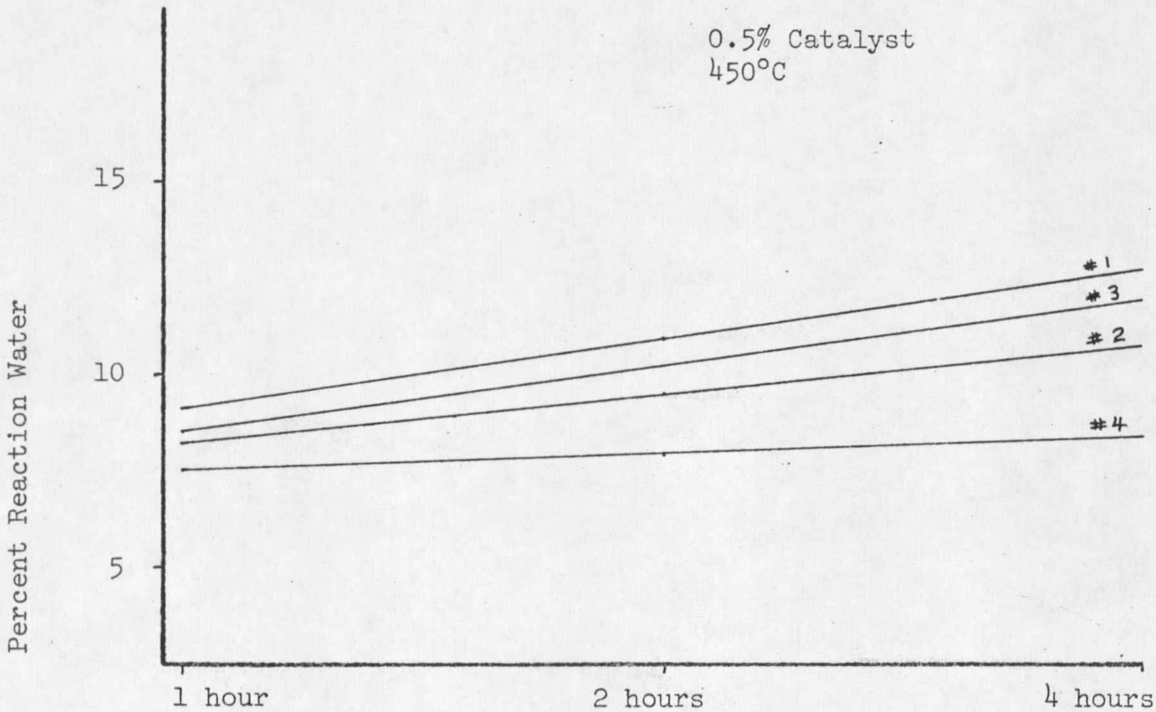


Figure 15. Effect of Time and Recycle Number on Reaction Water

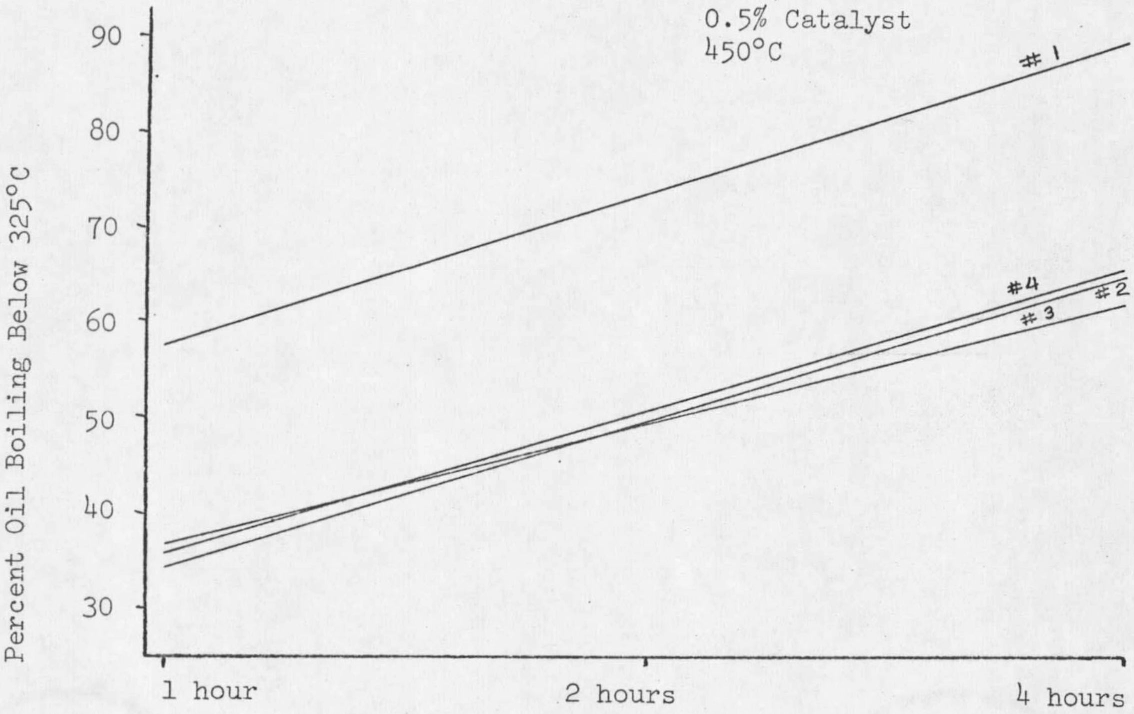


Figure 16. Effect of Time and Recycle on Oil Boiling Below 325°C

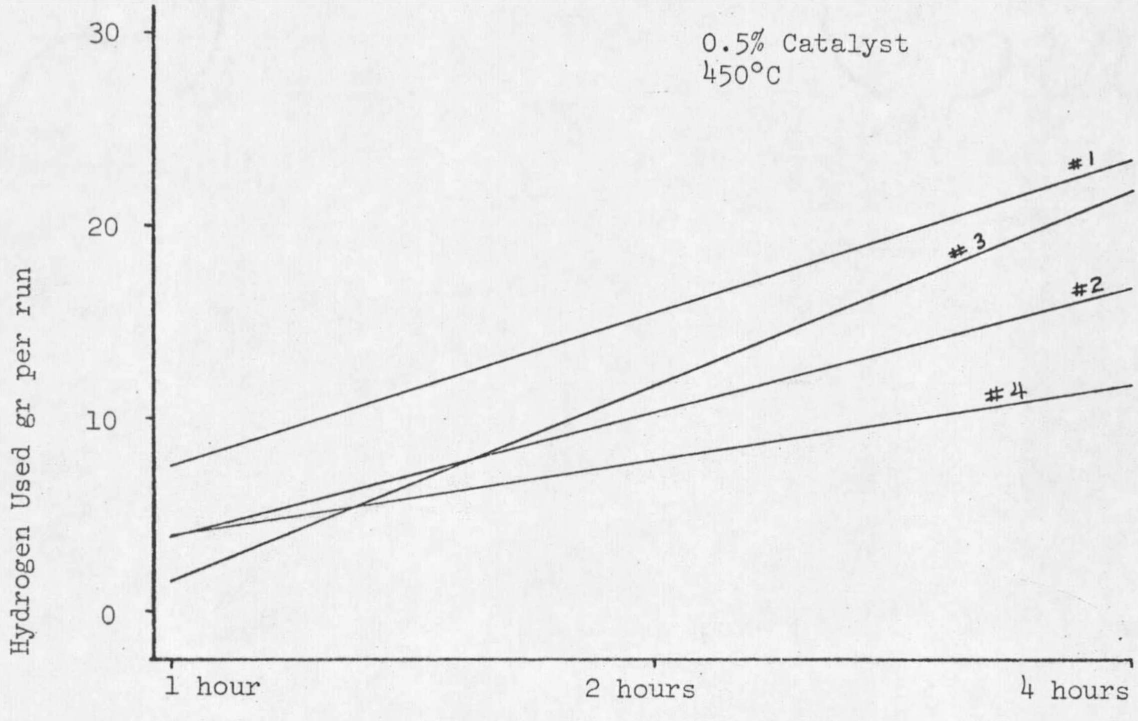


Figure 17. Effect of Time and Recycle on Hydrogen Consumption

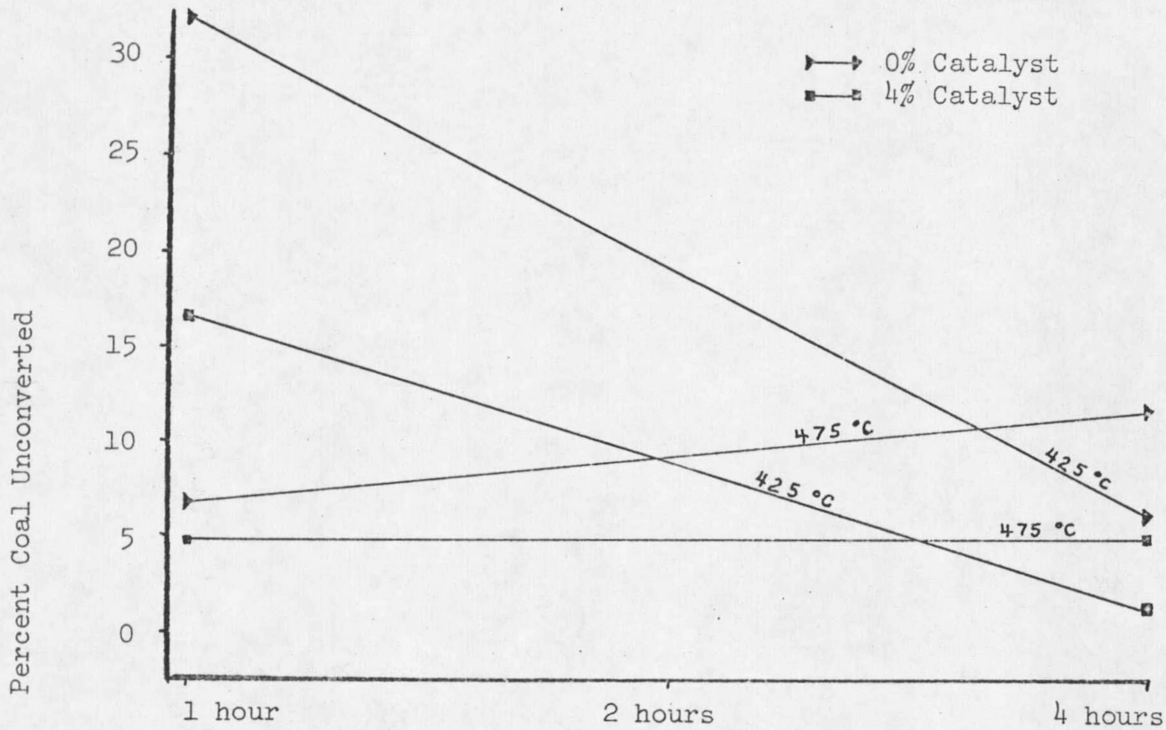


Figure 18. Effect of Time on Conversion in Recycle Number 3

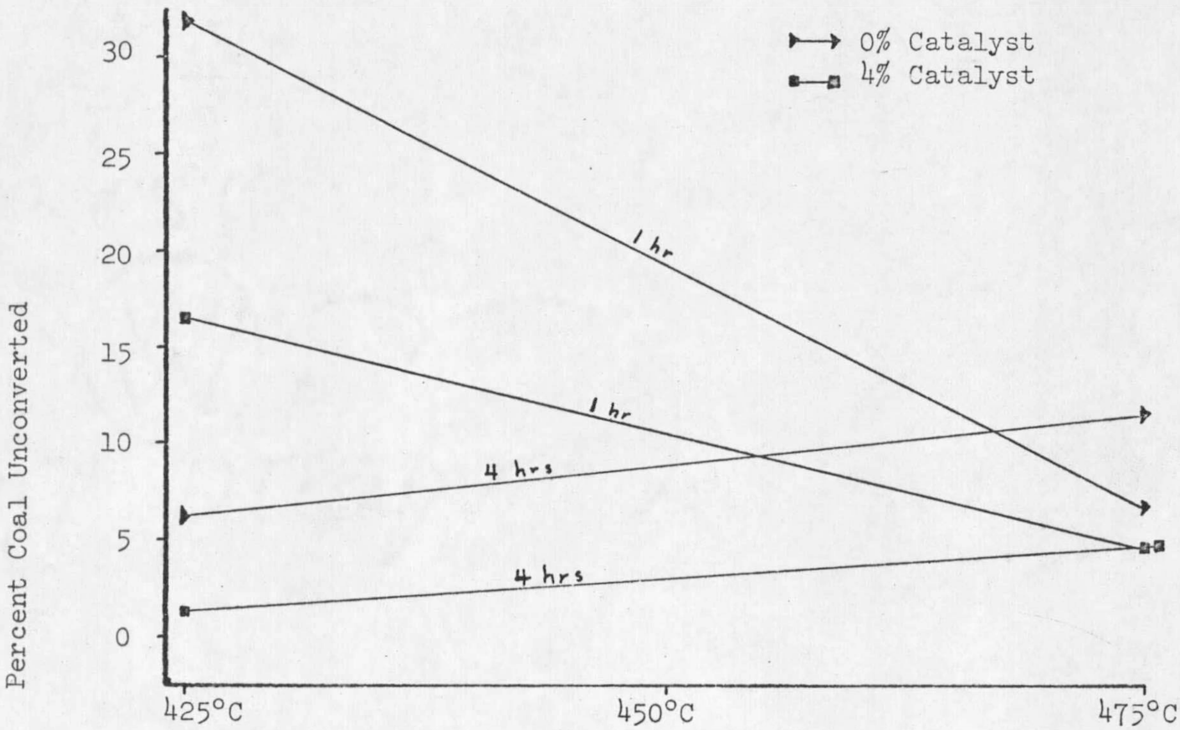


Figure 19. Effect of Temperature on Conversion in Recycle Number 3

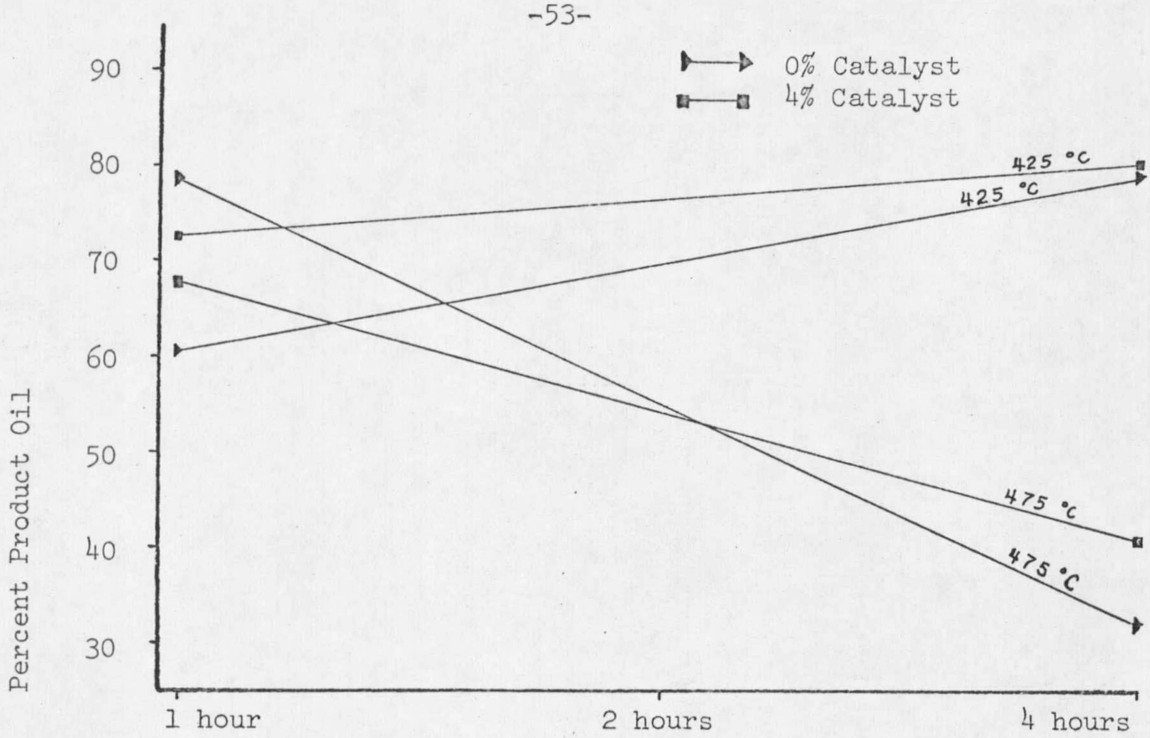


Figure 20. Effect of Time on Product Oil Yield for Recycle Number 3

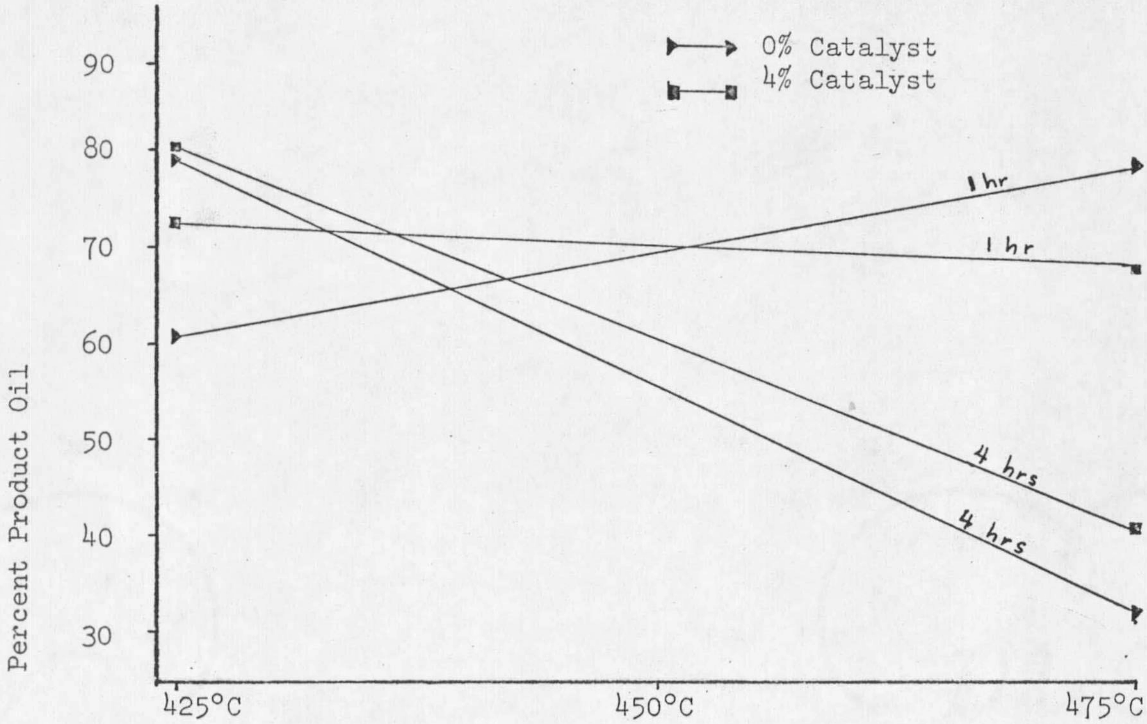


Figure 21. Effect of Temperature on Product Oil Yield for Recycle 3

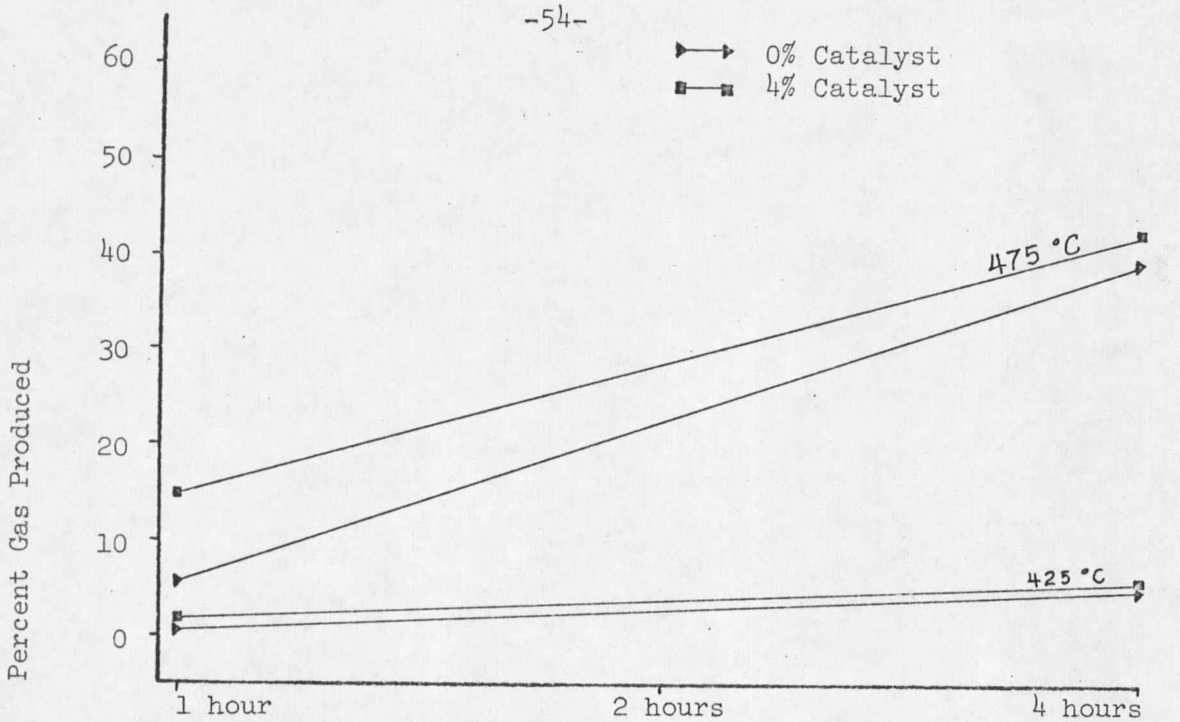


Figure 22. Effect of Time On Gas Yield for Recycle Number 3

Figure 23. Effect of Temperature on Gas Yield for Recycle Number 3

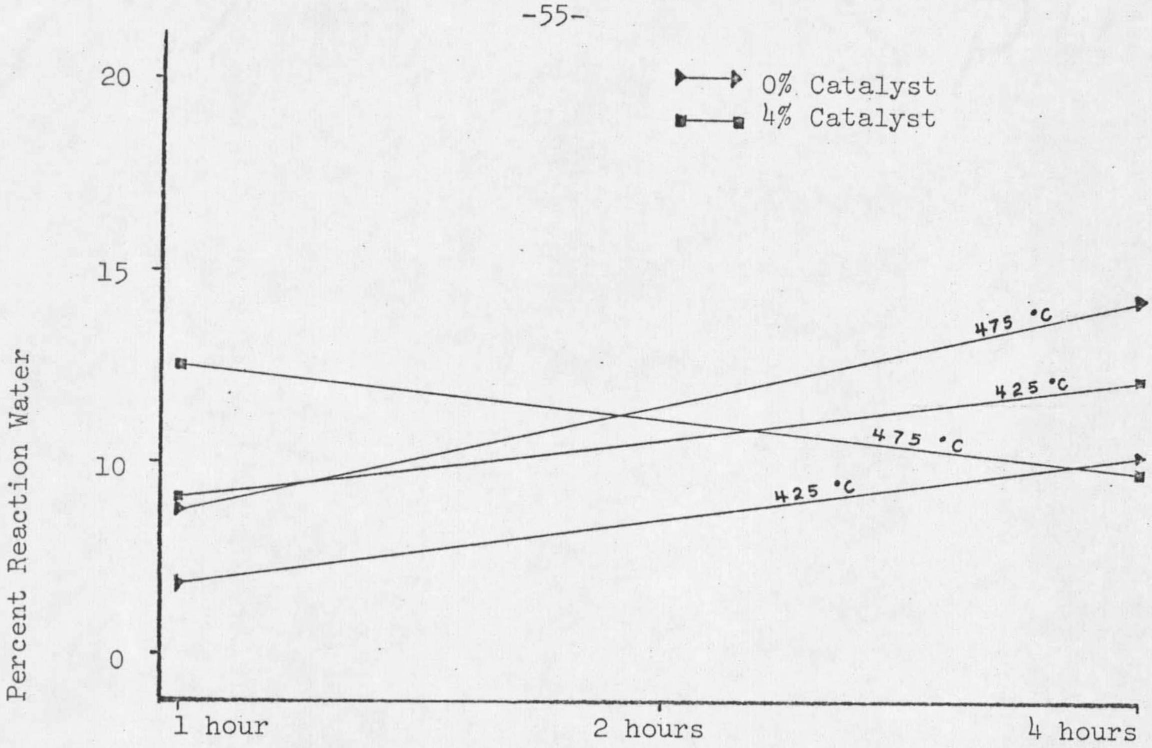


Figure 24. Effect of Time on Reaction Water Yield for Recycle Number 3

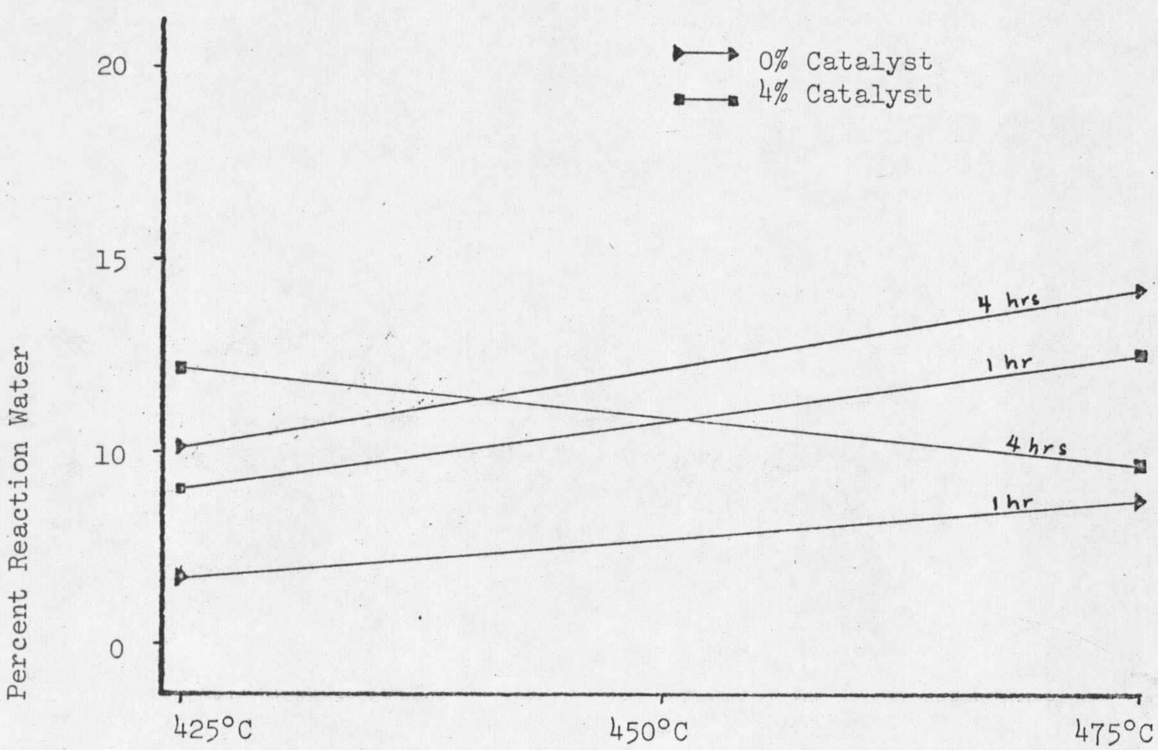


Figure 25. Effect of Temperature on Reaction Water for Recycle Number 3

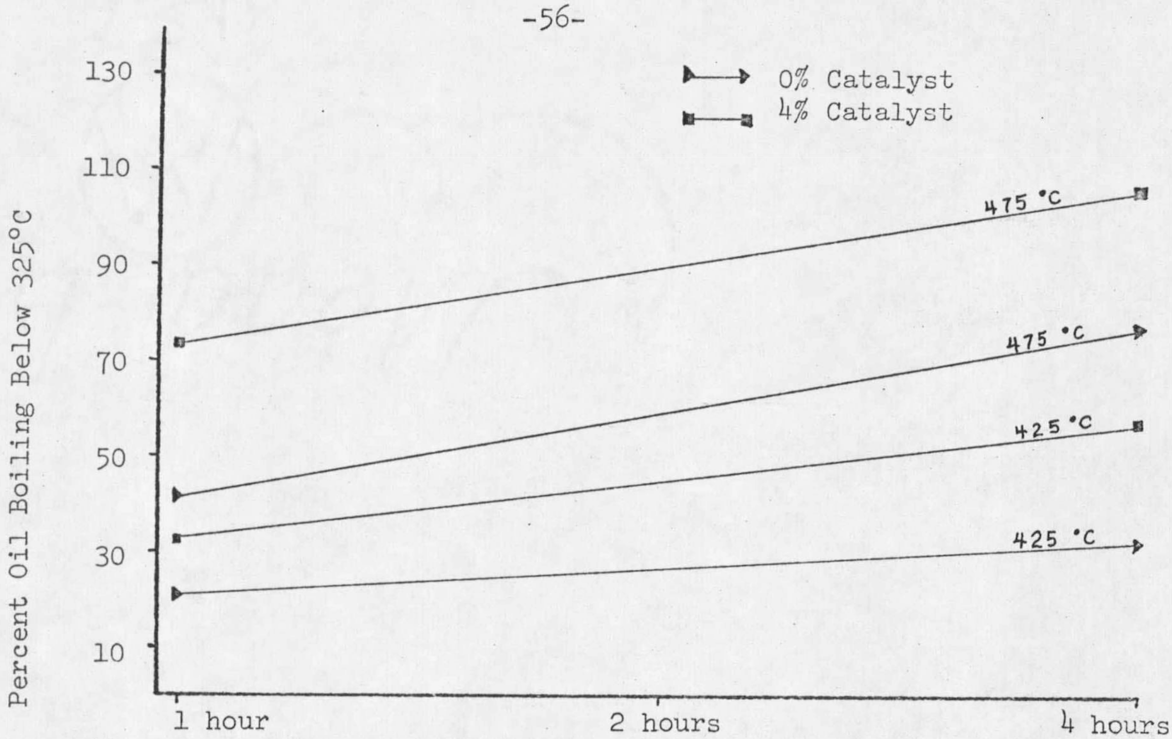


Figure 26. Effect of Time on Oil Boiling Below 325°C, Recycle Number 3

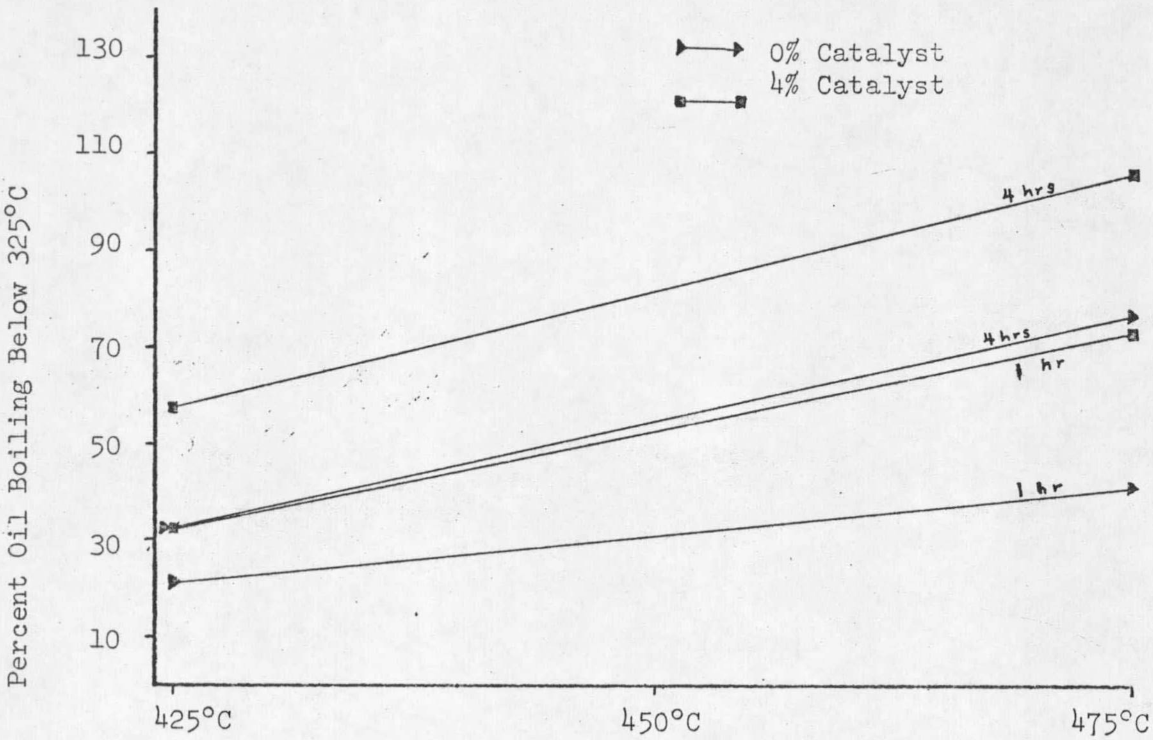


Figure 27. Effect of Temperature on Oil Boiling Below 325°C, Recycle 3

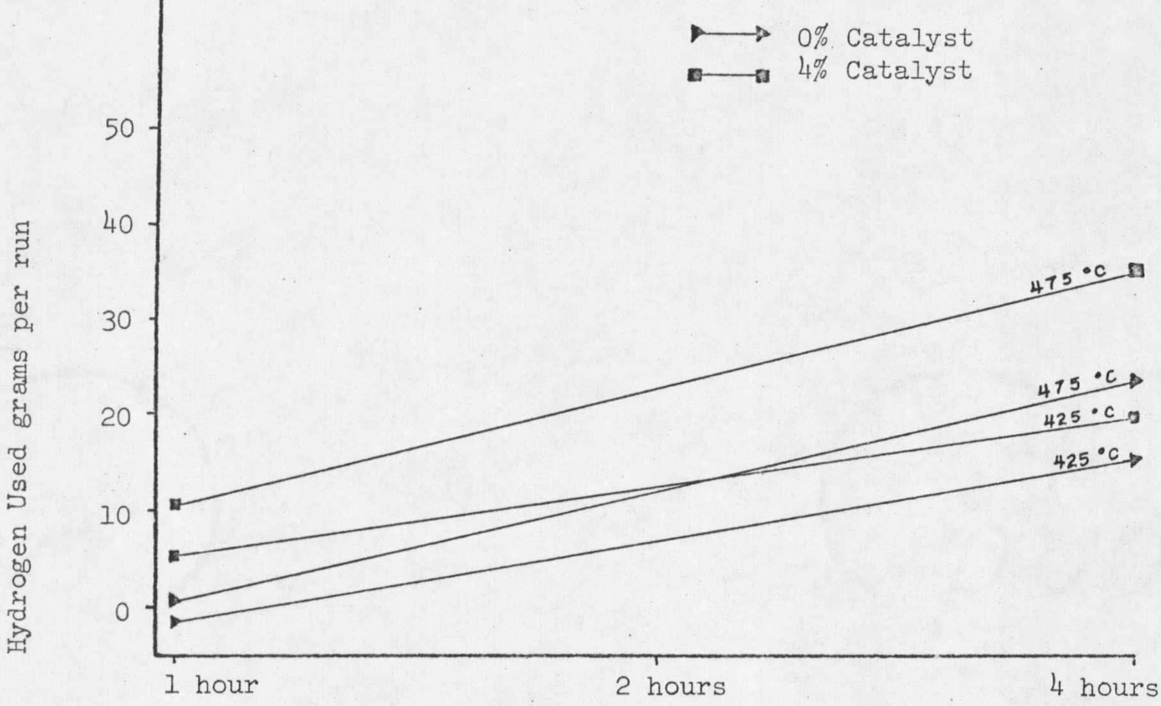


Figure 28. Effect of Time on Hydrogen Consumption, Recycle Number 3

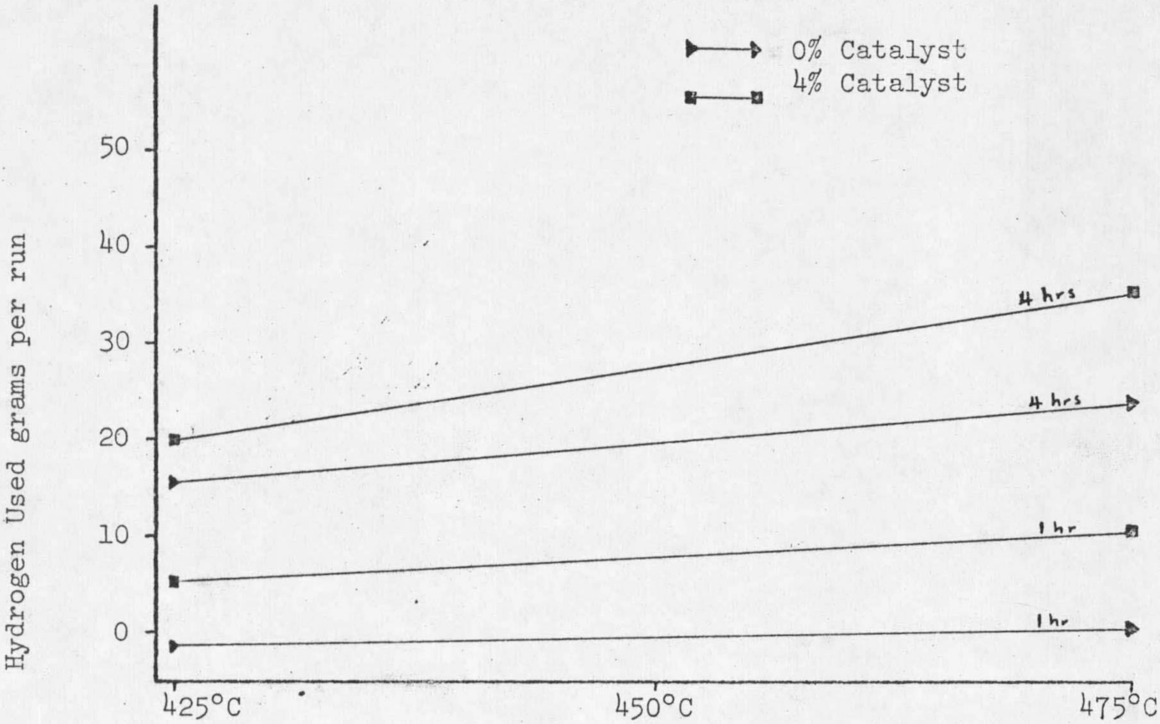


Figure 29. Effect of Temperature on Hydrogen Consumption, Recycle 3

APPENDIX C.

Computer Output

TABLE V. Computer Listing of Mass Balance Program

```
C     THIS PROGRAM IS DESIGNED TO MAKE A MASS BALANCE AROUND N COAL
C     HYDROGENATION RUNS
      IMPLICIT REAL ( M )
      INTEGER RUN1(30),RUN2(30),RUN3(30),DATE1,DATE2,TIME(30)
      DIMENSION T(30),GRL325(30),H2USED(30),DIFF(30),PRODOL(30),PEROL(30
     1),PERUN(30),PERH2O(30),PERGAS(30),CATCN(30),GRPER(30)
      DATA L/'L-NT'/
    2 READ 1,NUM
    1 FORMAT (I2)
      I=1
      IF (NUM) 4,4,999
    4 READ 5,RUN1(I),RUN2(I),RUN3(I),DATE1,DATE2,T(I),P,TIME(I),PASTE,
     1DENSIT,COLPER,COL,ASHES
    5 FORMAT (3A4,2A4,F6.1,F7.1,A4,F7.1,4F6.3)
      IF(RUN1(I) .NE.L) GO TO 399
      READ 30,PRESS
   30 FORMAT (F10.3)
      READ 40,MMETH,METH,MPROP,MBUT,CAT,GRG325,GRL325(I),WTBOWL,WTSOX,
     1WTLES,WTH2O
   40 FORMAT (4F7.4,7F6.1)
C     OBTAINING GRAMS OF MAF COAL
      CAL = COLPER*(ASHES+COL)
      COAL=PASTE*DENSIT*COLPER
      WATER=0.0
      ASH=COAL*ASHES
      MAF=COAL*COL
      RECYC=PASTE*DENSIT-COAL*(ASHES+COL)
C     CALCULATIONS TO FIND HYDROGEN ADDED AND GAS STREAM WEIGHTS
C     ASSUMING IDEAL GAS LAW
      TK=T(I)+273.
      Q=6.04/(1.208*TK)
      H2=PRESS*Q*2.
      METHAN=Q*MMETH*16.*P
      ETHANE=Q*METH*30.*P
```

TABLE V. Computer Listing of Mass Balance Program - Cont.

```
      PRØPAN=Q*MPRØP*44.*P
      BUTANE=Q*MBUT*58.*P
      GAS=METHAN+ETHANE+PRØPAN+BUTANE
      MH2=1.00-MMETH-METH-MPRØP-MBUT
      ZHYD=Q*MH2*2.*P
      H2USED(I)=H2-ZHYD
C     CALCULATE ØUTPUT STREAMS
      ASCACØ=WTBØWL*WTLES /WTSØX
      CENØIL=WTBØWL-ASCACØ
      ØILØUT=GRG325+GRL325(I)+CENØIL
      REAH2Ø=WTH2Ø-WATER
      PASS=PASTE*DENSIT+H2USED(I)
      PUTT=WTBØWL-CAT+GRG325+GRL325(I)+REAH2Ø+GAS
      DIFF(I)=((PASS-PUTT)/PASS)*100.
      CF=PUTT/PASS
      MAFC=MAF*CF+H2USED(I)
      PRØDØL(I)=ØILØUT-(RECYC*CF)
      ASH1=ASH*CF
      RECYCØ=GRG325+CENØIL
      PERØL(I)=(PRØDØL(I)/MAFC)*100.
      GRPER(I)=(GRL325(I)/MAFC)*100.
      UNCØN=ASCACØ-ASH1-CAT
      PERUN(I)=(UNCØN/MAFC)*100.
      PERH2Ø(I)=(REAH2Ø/MAFC)*100.
      PERMET=(METHAN/MAFC)*100.
      PERETH=(ETHANE/MAFC)*100.
      PERPRØ=(PRØPAN/MAFC)*100.
      PERBUT=(BUTANE/MAFC)*100.
      PERGAS(I)=PERMET+PERETH+PERPRØ+PERBUT
      CATCN(I)=(CAT/(MAFC-H2USED(I)))*100.
      WAT=1.-ASHES-CØL
C     FØRMAT FØR PRINTING THE RESULTS
      IF(NUM) 310,180,180
```

TABLE V. Computer Listing of Mass Balance Program - Cont.

```
180 PRINT 200,RUN1(I),RUN2(I),RUN3(I),DATE1,DATE2,P
200 FØRMAT(1H1,36X,'CØAL HYDRØGENATIØN MASS BALANCE',//,13X,'RUN NUMBE
   1R',2X,3A4,10X,'CØNDITIØNS ØF RUN      ',/,13X,'DATE ØF RUN',2X,2A4,
   212X,'PRESSURE - - - - - - - - '    ,F7.1,1X,'PSI')
    PRINT 210,T(I),TIME(I),CAL,CAT,CATCN(I)
210 FØRMAT (46X,'TEMPERATURE- - - - - - - '    ,F6.1,' C',/,46X,'TIME
   1- - - - - - - - - - - '    ,A4,' HRS:MIN',/,46X,'CØAL CØNCENTRATIØN
   2- - - '    ,F6.3,' ',/,46X,'CATALYST CØNCENTRATIØN - '   ,F4.1,' GR
   3;',F7.3,'% MAF',/)
    PRINT 220,MAF,UNCØN,PERUN(I)
220 FØRMAT(13X,'INPUT IN GRAMS',33X,'ØUTPUT IN GRAMS',//,13X,'MAF CØAL
   1 - - -',2X,F6.1, 5X,'UNREACTED CØAL',2X,F5.1,6X,F6.2,'% ØF MAF CØA
   2L AND H2')
    PRINT 230,PRØDØL(I),PERØL(I),GRL325(I), GRPER(I)
230 FØRMAT (40X,'PRØDUCT ØIL -',3X,F5.1,6X,F6.2,'% ØF MAF CØAL AND H2'
   1,/,44X,'ØIL < 325C',2X,F5.1,6X,F6.2,'% ØF MAF CØAL AND H2')
    PRINT 240,GAS,PERGAS(I),METHAN,PERMET,ETHANE,PERETH,PRØPAN,PERPRØ,
   1BUTANE,PERBUT
240 FØRMAT (40X,'GAS - - - - -',2X,F6.1,6X,F6.2,'% ØF MAF CØAL AND H2'
   1,/,44X,'METHANE -',2X,F6.1,'(',F5.2,'%)',/,44X,'ETHANE- -',2X,F6.1
   2,'(',F5.2,'%)',/,44X,'PRØPANE -',2X,F6.1,'(',F5.2,'%)',/,44X,'BUTA
   3NE- -',2X,F6.1,'(',F5.2,'%)')
    PRINT 245,REAH2O,PERH2Ø(I)
245 FØRMAT (40X,'REACTIØN WATER',2X,F5.1,6X,F6.2,'% ØF MAF CØAL AND H2
   1',/)
    PRINT 250,ASH,ASH1
250 FØRMAT(13X,'ASH- - - - - -',2X,F6.1,21X,'ASH - - - - -',2X,F6.1,/)
    PRINT 260,WATER,WATER
260 FØRMAT(13X,'WATER- - - -',2X,F6.1,21X,'WATER - - - -',2X,F6.1,/)
    PRINT 270,RECYC,RECYCØ
270 FØRMAT(13X,'RECYCLE ØIL -',3X,F6.1,21X,'RECYCLE ØIL-',3X,F6.1,/)
    PRINT 290,H2,H2USED(I),ZHYD
290 FØRMAT(13X,'HYDRØGEN- - -',3X,F6.1,21X,'HYDRØGEN',/,56X,'CØNSUMED
   1- -',3X,F6.1,/,56X,'UNUSED - - -',3X,F6.1,/)
```

TABLE V. Computer Listing of Mass Balance Program - Cont.

```
      PRINT 280,CAT,CAT
  280 FØRMAT(13X,'CATALYST- - -',3X,F6.1,21X,'CATALYST - -',3X,F6.1,//)
      PRINT 300,PASS,PUTT,DIFF(I)
  300 FØRMAT (13X,'TØTAL MASS BALANCE',10X,'GRAMS IN - -   ',F6.1,/,41X,'
     1GRAMS ØUT- -   ',F6.1,/,41X,'% DIFF - - -   ',F6.1)
  310 I=I+1
      GØ TØ 4
  399 PRINT400
  400 FØRMAT (1H1,////,
     1  ///,13X,'RUN',9X,'TIME',5X,'TEMP',8X,'CATCN',5X,'% UNCØN',4X,
     2'% ØIL',6X,'% GAS',6X,'% H2Ø',//)
      I9=I-1
      DØ 451 K=1,I9
      PRINT 450,RUN1(K),RUN2(K),RUN3(K),TIME(K),T(K),CATCN(K),PERUN(K),
     1PERØL(K),PERGAS(K),PERH2Ø(K)
  450 FØRMAT (13X,4A4,4X,F7.2,5(3X,F8.3))
  451 CØNTINUE
      PRINT 480
  480 FØRMAT (1H1,////,
     1  ///,13X,'RUN',9X,'TIME',5X,'TEMP',8X,'CATCN',4X,'PRØDUCT',4X,
     2'<325C',7X,'H2USED',6X,'LØSS',//)
      DØ 491 K=1,I9
      PRINT 450,RUN1(K),RUN2(K),RUN3(K),TIME(K),T(K),CATCN(K),PRØDØL(K),
     1GRL325(K),H2USED(K),DIFF(K)
      PUNCH 510,TIME(K),T(K),CATCN(K),PERUN(K),PERØL(K),PERGAS(K),PERH2Ø
     1(K),GPPER(K),H2USED(K),DIFF(K)
  510 FØRMAT (A1,2X,9F8.3)
  491 CØNTINUE
      GØ TØ 2
  999 END FILE 106
      END FILE 106
      CALL EXIT
      END
```

TABLE VI. Coal Hydrogenation Mass Balance

I. Individual Output Balance Sheets - Series J.

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-1
DATE OF RUN 03-18-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2250.0 PSI
TEMPERATURE- - - - - - - -	425.0 C
TIME - - - - - - - - - - -	4:04 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	8.9 GR; 4.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	4.1		1.68% OF MAF COAL AND H2
PRODUCT OIL -	206.4		83.89% OF MAF COAL AND H2
OIL < 325C	186.9		75.96% OF MAF COAL AND H2
GAS - - - - -	20.2		8.21% OF MAF COAL AND H2
METHANE -	5.6	(2.26%)	
ETHANE- -	3.5	(1.43%)	
PROPANE -	2.6	(1.04%)	
BUTANE- -	8.6	(3.48%)	
REACTION WATER	12.9		5.24% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - - -	31.7
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1262.6
HYDROGEN- - -	54.4	HYDROGEN	
		CONSUMED - -	23.5
		UNUSED - - -	30.9
CATALYST- - -	8.9	CATALYST - -	8.9

TOTAL MASS BALANCE

GRAMS IN - -	1690.3
GRAMS OUT- -	1518.5
% DIFF - - -	10.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-2
DATE OF RUN 03-18-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	8.5 GR; 3.666% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	50.8
CATALYST- - -	8.5

OUTPUT IN GRAMS

UNREACTED COAL	14.5	5.46% OF MAF COAL AND H2
PRODUCT OIL -	53.7	20.29% OF MAF COAL AND H2
OIL < 325C	315.2	119.03% OF MAF COAL AND H2
GAS - - - - -	154.5	58.35% OF MAF COAL AND H2
METHANE -	70.6(26.67%)	
ETHANE- -	47.1(17.80%)	
PROPANE -	27.6(10.44%)	
BUTANE- -	9.1(3.44%)	
REACTION WATER	40.0	15.10% OF MAF COAL AND H2

ASH - - - - -	33.1
WATER - - - -	0.0
RECYCLE OIL-	1034.0
HYDROGEN CONSUMED - -	32.9
UNUSED - - -	17.9
CATALYST - -	8.5

TOTAL MASS BALANCE

GRAMS IN - -	1699.7
GRAMS OUT- -	1591.3
% DIFF - - -	6.4

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-3
DATE OF RUN 03-19-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2400.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	4:02 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.9 GR; 0.820% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	15.4	5.99% OF MAF COAL AND H2
		PRODUCT OIL -	180.3	70.25% OF MAF COAL AND H2
		OIL < 325C	170.9	66.58% OF MAF COAL AND H2
		GAS - - - - -	35.2	13.70% OF MAF COAL AND H2
		METHANE -	11.0(4.29%)	
		ETHANE- -	7.8(3.05%)	
		PROPANE -	7.0(2.71%)	
		BUTANE- -	9.4(3.65%)	
		REACTION WATER	24.2	9.43% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - -	33.0	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1303.6	
HYDROGEN- - -	56.9	HYDROGEN		
		CONSUMED - -	25.0	
		UNUSED - - -	31.8	
CATALYST- - -	1.9	CATALYST - -	1.9	

TOTAL MASS BALANCE

GRAMS IN - -	1691.8
GRAMS OUT- -	1582.3
% DIFF - - -	6.5

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-4
DATE OF RUN 03-21-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2250.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:04 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.9 GR; 0.895% MAF

INPUT IN GRAMS / OUTPUT IN GRAMS

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	4.2	1.74% OF MAF COAL AND H2
		PRODUCT OIL -	134.3	55.51% OF MAF COAL AND H2
		OIL < 325C	255.8	105.69% OF MAF COAL AND H2
		GAS - - - - -	63.4	26.18% OF MAF COAL AND H2
		METHANE -	31.0(12.83%)	
		ETHANE- -	15.3(6.34%)	
		PROPANE -	11.9(4.92%)	
		BUTANE- -	5.1(2.09%)	
		REACTION WATER	35.9	14.83% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - -	30.3	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1064.9	
HYDROGEN- - -	54.1	HYDROGEN CONSUMED - -	29.7	
		UNUSED - - -	24.5	
CATALYST- - -	1.9	CATALYST - -	1.9	

TOTAL MASS BALANCE

GRAMS IN - -	1696.4
GRAMS OUT- -	1454.5
% DIFF - - -	14.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-5
DATE OF RUN 03-28-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2240.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	4:01 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.5 GR; 4.152% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	56.4
CATALYST- - -	9.5

OUTPUT IN GRAMS

UNREACTED COAL	-6.2	-2.37% OF MAF COAL AND H2
PRODUCT OIL -	170.9	65.73% OF MAF COAL AND H2
OIL < 325C	301.7	116.06% OF MAF COAL AND H2
GAS - - - - -	63.0	24.22% OF MAF COAL AND H2
METHANE -	31.7(12.20%)	
ETHANE- -	16.6(6.40%)	
PROPANE -	10.6(4.06%)	
BUTANE- -	4.0(1.56%)	
REACTION WATER	29.9	11.50% OF MAF COAL AND H2

ASH - - - - -	32.6
WATER - - - -	0.0
RECYCLE OIL-	1147.5
HYDROGEN CONSUMED - -	31.1
UNUSED - - -	25.3
CATALYST - -	9.5

TOTAL MASS BALANCE

GRAMS IN - -	1697.9
GRAMS OUT- -	1568.6
% DIFF - - -	7.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-6
DATE OF RUN 03-28-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2200.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	4:04 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	24.9	10.02% OF MAF COAL AND H2
		PRODUCT OIL -	174.6	70.11% OF MAF COAL AND H2
		OIL < 325C	133.8	53.73% OF MAF COAL AND H2
		GAS - - - - - -	24.9	10.00% OF MAF COAL AND H2
		METHANE -	12.6(5.06%)	
		ETHANE- -	6.6(2.66%)	
		PROPANE -	4.0(1.61%)	
		BUTANE- -	1.6(0.66%)	
		REACTION WATER	23.7	9.52% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	33.3	
WATER- - - - - -	0.0	WATER - - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1345.0	
HYDROGEN- - -	44.8	HYDROGEN		
		CONSUMED - -	15.6	
		UNUSED - - -	29.3	
CATALYST- - -	0.0	CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1682.3
GRAMS OUT- -	1585.7
% DIFF - - -	5.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER	L-NT-J-7
DATE OF RUN	04-06-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2310.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - - -	4:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	29.8	11.62% OF MAF COAL AND H2
		PRODUCT OIL -	107.5	41.95% OF MAF COAL AND H2
		OIL < 325C	216.0	84.33% OF MAF COAL AND H2
		GAS - - - - - -	79.1	30.89% OF MAF COAL AND H2
		METHANE -	44.7(17.46%)	
		ETHANE- -	18.2(7.11%)	
		PROPANE -	12.7(4.94%)	
		BUTANE- -	3.5(1.37%)	
		REACTION WATER	38.7	15.11% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	33.5	
WATER- - - - - -	0.0	WATER - - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1203.3	
HYDROGEN- - -	45.8	HYDROGEN CONSUMED - -	21.3	
		UNUSED - - -	24.4	
CATALYST- - -	0.0	CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1688.1
GRAMS OUT- -	1600.3
% DIFF - - -	5.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-8
DATE OF RUN 04-08-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2340.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:02 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	44.0
CATALYST- - -	0.0

OUTPUT IN GRAMS

UNREACTED COAL	32.5	12.75% OF MAF COAL AND H2
PRODUCT OIL -	45.7	17.93% OF MAF COAL AND H2
OIL < 325C	247.3	96.96% OF MAF COAL AND H2
GAS - - - - -	128.7	50.45% OF MAF COAL AND H2
METHANE -	70.6(27.67%)	
ETHANE- -	31.9(12.51%)	
PROPANE -	20.6(8.10%)	
BUTANE- -	5.5(2.17%)	
REACTION WATER	46.4	18.19% OF MAF COAL AND H2
ASH - - - - -	32.9	
WATER - - - -	0.0	
RECYCLE OIL-	1084.9	
HYDROGEN		
CONSUMED - -	24.8	
UNUSED - - -	19.2	
CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1691.5
GRAMS OUT- -	1572.7
% DIFF - - -	7.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-9
DATE OF RUN 04-09-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2150.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	4:04 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.648% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	13.7	5.40% OF MAF COAL AND H2
		PRODUCT OIL -	123.7	48.56% OF MAF COAL AND H2
		OIL < 325C	237.7	93.32% OF MAF COAL AND H2
		GAS - - - - -	82.4	32.33% OF MAF COAL AND H2
		METHANE -	47.6(18.68%)	
		ETHANE- -	17.8(7.00%)	
		PROPANE -	12.1(4.75%)	
		BUTANE- -	4.8(1.90%)	
		REACTION WATER	33.4	13.11% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - -	33.0	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1178.6	
HYDROGEN- - -	45.2	HYDROGEN		
		CONSUMED - -	23.3	
		UNUSED - - -	21.9	
CATALYST- - -	1.5	CATALYST - -	1.5	

TOTAL MASS BALANCE

GRAMS IN - -	1690.1
GRAMS OUT- -	1578.9
% DIFF - - -	6.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-10
DATE OF RUN 04-10-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2250.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - - -	4:01 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.7 GR; 0.724% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	51.7
CATALYST- - -	1.7

OUTPUT IN GRAMS

UNREACTED COAL	16.2	5.99% OF MAF COAL AND H2
PRODUCT OIL -	72.8	26.94% OF MAF COAL AND H2
OIL < 325C	287.5	106.44% OF MAF COAL AND H2
GAS - - - - -	143.9	53.26% OF MAF COAL AND H2
METHANE -	79.4(29.40%)	
ETHANE- -	35.6(13.20%)	
PROPANE -	21.8(8.08%)	
BUTANE- -	7.0(2.58%)	
REACTION WATER	35.5	13.14% OF MAF COAL AND H2

ASH - - - - -	33.5
WATER - - - -	0.0
RECYCLE OIL-	1097.7
HYDROGEN	
CONSUMED - -	35.2
UNUSED - - -	16.5
CATALYST - -	1.7

TOTAL MASS BALANCE

GRAMS IN - -	1701.9
GRAMS OUT- -	1614.3
% DIFF - - -	5.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-11
DATE OF RUN 04-11-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:01 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.7 GR; 4.185% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	54.8
CATALYST- - -	9.7

OUTPUT IN GRAMS

UNREACTED COAL	8.8	3.27% OF MAF COAL AND H2
PRODUCT OIL -	69.6	25.81% OF MAF COAL AND H2
OIL < 325C	342.3	126.97% OF MAF COAL AND H2
GAS - - - - -	154.2	57.19% OF MAF COAL AND H2
METHANE -	73.3(27.19%)	
ETHANE- -	46.1(17.11%)	
PROPANE -	26.7(9.91%)	
BUTANE- -	8.0(2.98%)	
REACTION WATER	34.6	12.83% OF MAF COAL AND H2

ASH - - - - -	33.1
WATER - - - -	0.0
RECYCLE OIL-	1022.3
HYDROGEN	
CONSUMED - -	37.8
UNUSED - - -	17.0
CATALYST - -	9.7

TOTAL MASS BALANCE

GRAMS IN - -	1704.5
GRAMS OUT- -	1595.3
% DIFF - - -	6.4

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-J-12
DATE OF RUN 04-12-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	4:03 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.8 GR; 0.803% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - - -	35.3
WATER- - - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	49.9
CATALYST- - -	1.8

OUTPUT IN GRAMS

UNREACTED COAL	15.9	6.37% OF MAF COAL AND H2
PRODUCT OIL -	121.8	48.77% OF MAF COAL AND H2
OIL < 325C	241.2	96.58% OF MAF COAL AND H2
GAS - - - - - -	76.6	30.69% OF MAF COAL AND H2
METHANE -	44.8(17.93%)	
ETHANE- -	17.7(7.07%)	
PROPANE -	10.5(4.20%)	
BUTANE- -	3.7(1.48%)	
REACTION WATER	33.0	13.21% OF MAF COAL AND H2
ASH - - - - - -	32.0	
WATER - - - -	0.0	
RECYCLE OIL-	1133.4	
HYDROGEN		
CONSUMED - -	25.5	
UNUSED - - -	24.4	
CATALYST - -	1.8	

TOTAL MASS BALANCE

GRAMS IN - -	1692.2
GRAMS OUT- -	1532.1
% DIFF - - -	9.5

II. Master Summary - Series J.

Summary of Experimental Results in Percent of Coal Going to Each Product

RUN	TIME	TEMP	CATCN	% UNCON	% OIL	% GAS	% H_2O
L-NT-J-1	4:04	425.00	4.000	1.678	83.895	8.212	5.243
L-NT-J-2	4:06	475.00	3.666	5.465	20.291	58.347	15.105
L-NT-J-3	4:02	425.00	0.820	5.990	70.247	13.704	9.428
L-NT-J-4	4:04	475.00	0.895	1.735	55.507	26.176	14.833
L-NT-J-5	4:01	450.00	4.152	-2.366	65.728	24.223	11.502
L-NT-J-6	4:04	425.00	0.000	10.018	70.110	9.996	9.517
L-NT-J-7	4:06	450.00	0.000	11.615	41.954	30.888	15.109
L-NT-J-8	4:02	475.00	0.000	12.747	17.932	50.446	18.192
L-NT-J-9	4:04	450.00	0.648	5.398	48.556	32.331	13.112
L-NT-J-10	4:01	475.00	0.724	5.986	26.936	53.264	13.143
L-NT-J-11	4:01	475.00	4.185	3.265	25.815	57.187	12.834
L-NT-J-12	4:03	450.00	0.803	6.370	48.765	30.685	13.214

Summary of Experimental Results in Grams of Product Found and Loss Variation

RUN	TIME	TEMP	CATCN (%)	PRODUCT (gm)	<325C (gm)	H_2USED (gm)	LOSS (%)
L-NT-J-1	4:04	425.00	4.000	206.427	186.900	23.549	10.163
L-NT-J-2	4:06	475.00	3.666	53.734	315.200	32.926	6.376
L-NT-J-3	4:02	425.00	0.820	180.309	170.900	25.030	6.473
L-NT-J-4	4:04	475.00	0.895	134.345	255.800	29.683	14.264
L-NT-J-5	4:01	450.00	4.152	170.866	301.700	31.144	7.617
L-NT-J-6	4:04	425.00	0.000	174.596	133.800	15.581	5.744
L-NT-J-7	4:06	450.00	0.000	107.460	216.000	21.333	5.199
L-NT-J-8	4:02	475.00	0.000	45.735	247.300	24.779	7.027
L-NT-J-9	4:04	450.00	0.648	123.682	237.700	23.345	6.582
L-NT-J-10	4:01	475.00	0.724	72.759	287.500	35.194	5.151
L-NT-J-11	4:01	475.00	4.185	69.595	342.300	37.793	6.410
L-NT-J-12	4:03	450.00	0.803	121.789	241.200	25.499	9.462

TABLE VI. Coal Hydrogenation Mass Balance

III. Individual Output Balance Sheets - Series K.

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-K-1
DATE OF RUN 04-17-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	4:04 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.7 GR; 0.791% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	43.8
CATALYST- - -	1.7

OUTPUT IN GRAMS

UNREACTED COAL	12.7		5.60% OF MAF COAL AND H2
PRODUCT OIL -	183.4		80.81% OF MAF COAL AND H2
OIL < 325C	129.5		57.06% OF MAF COAL AND H2
GAS - - - - -	14.2		6.28% OF MAF COAL AND H2
METHANE -	5.5	(2.42%)	
ETHANE- -	3.7	(1.61%)	
PROPANE -	3.5	(1.53%)	
BUTANE- -	1.6	(0.72%)	
REACTION WATER	15.0		6.61% OF MAF COAL AND H2

ASH - - - - -	30.7
WATER - - - -	0.0
RECYCLE OIL-	1254.7
HYDROGEN	
CONSUMED - -	12.0
UNUSED - - -	31.8
CATALYST - -	1.7

TOTAL MASS BALANCE

GRAMS IN - -	1678.8
GRAMS OUT- -	1456.8
% DIFF - - -	13.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-K-2
DATE OF RUN 04-18-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:03 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.3 GR; 4.096% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	41.6	16.39% OF MAF COAL AND H2
		PRODUCT OIL -	102.1	40.27% OF MAF COAL AND H2
		OIL < 325C	272.4	107.43% OF MAF COAL AND H2
		GAS - - - - - -	75.0	29.57% OF MAF COAL AND H2
		METHANE -	38.5(15.17%)	
		ETHANE- -	17.8(7.01%)	
		PROPANE -	13.5(5.32%)	
		BUTANE- -	5.3(2.08%)	
		REACTION WATER	32.7	12.90% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - -	32.4	
WATER- - - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1098.3	
HYDROGEN- - -	51.1	HYDROGEN CONSUMED - -	26.5	
		UNUSED - - -	24.6	
CATALYST- - -	9.3	CATALYST - -	9.3	

TOTAL MASS BALANCE

GRAMS IN - -	1693.3
GRAMS OUT- -	1552.3
% DIFF - - -	8.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-K-3
DATE OF RUN 04-19-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2260.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - - -	3:58 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.6 GR; 0.708% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	9.1	3.70% OF MAF COAL AND H2
PRODUCT OIL -	179.6	73.44% OF MAF COAL AND H2
OIL < 325C	176.6	72.23% OF MAF COAL AND H2
GAS - - - - -	29.9	12.22% OF MAF COAL AND H2
METHANE -	15.0(6.14%)	
ETHANE- -	6.8(2.80%)	
PROPANE -	5.5(2.25%)	
BUTANE- -	2.5(1.04%)	
REACTION WATER	24.4	9.98% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	32.3
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1266.0
HYDROGEN- - -	47.0	HYDROGEN	
		CONSUMED - -	18.4
		UNUSED - - -	28.6
CATALYST- - -	1.6	CATALYST - -	1.6

TOTAL MASS BALANCE

GRAMS IN - -	1685.2
GRAMS OUT- -	1538.2
% DIFF - - -	8.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-K-4
DATE OF RUN 04-19-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2220.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	4:09 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.1 GR; 4.310% MAF

INPUT IN GRAMS

MAF COAL - - - 247.7

OUTPUT IN GRAMS

UNREACTED COAL	9.8	4.22% OF MAF COAL AND H2
PRODUCT OIL -	181.3	77.68% OF MAF COAL AND H2
OIL < 325C	129.5	55.50% OF MAF COAL AND H2
GAS - - - - -	10.8	4.61% OF MAF COAL AND H2
METHANE -	4.8(2.07%)	
ETHANE- -	2.6(1.10%)	
PROPANE -	2.2(0.96%)	
BUTANE- -	1.1(0.47%)	
REACTION WATER	28.2	12.09% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	30.1
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1231.4
HYDROGEN- - -	53.1	HYDROGEN	
		CONSUMED - -	22.2
		UNUSED - - -	30.9
CATALYST- - -	9.1	CATALYST - -	9.1

TOTAL MASS BALANCE

GRAMS IN - - 1688.9
GRAMS OUT- - 1439.9
% DIFF - - - 14.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-K-5
DATE OF RUN 04-20-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2210.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.7 GR; 0.774% MAF

INPUT IN GRAMS

MAF COAL - - - -	247.7
ASH- - - - - - -	35.3
WATER- - - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	46.8
CATALYST- - -	1.7

OUTPUT IN GRAMS

UNREACTED COAL	22.0	9.10% OF MAF COAL AND H2
PRODUCT OIL -	127.6	52.70% OF MAF COAL AND H2
OIL < 325C	221.0	91.30% OF MAF COAL AND H2
GAS - - - - - -	58.1	24.00% OF MAF COAL AND H2
METHANE -	30.0(12.40%)	
ETHANE- -	13.8(5.71%)	
PROPANE -	10.4(4.30%)	
BUTANE- -	3.9(1.59%)	
REACTION WATER	31.8	13.14% OF MAF COAL AND H2
ASH - - - - -	31.3	
WATER - - - -	0.0	
RECYCLE OIL-	1133.1	
HYDROGEN		
CONSUMED - -	22.5	
UNUSED - - -	24.3	
CATALYST - -	1.7	

TOTAL MASS BALANCE

GRAMS IN - -	1689.3
GRAMS OUT- -	1497.3
% DIFF - - -	11.4

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-K-6
DATE OF RUN 04-20-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2100.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	4:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	45.4
CATALYST- - -	0.0

OUTPUT IN GRAMS

UNREACTED COAL	19.7	8.35% OF MAF COAL AND H2
PRODUCT OIL -	184.4	78.34% OF MAF COAL AND H2
OIL < 325C	84.0	35.69% OF MAF COAL AND H2
GAS - - - - - -	10.3	4.39% OF MAF COAL AND H2
METHANE -	5.0(2.13%)	
ETHANE- -	2.4(1.04%)	
PROPANE -	1.9(0.79%)	
BUTANE- -	1.0(0.44%)	
REACTION WATER	19.1	8.11% OF MAF COAL AND H2

ASH - - - - -	31.3
WATER - - - -	0.0
RECYCLE OIL-	1324.7
HYDROGEN	
CONSUMED - -	16.2
UNUSED - - -	29.2
CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1683.0
GRAMS OUT- -	1489.0
% DIFF - - -	11.5

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-K-7 L
DATE OF RUN 04-22-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2100.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - - -	1:21 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	11.5	4.91% OF MAF COAL AND H2
PRODUCT OIL -	198.1	84.19% OF MAF COAL AND H2
OIL < 325C	105.6	44.87% OF MAF COAL AND H2
GAS - - - - -	24.4	10.37% OF MAF COAL AND H2
METHANE -	14.3(6.08%)	
ETHANE- -	4.8(2.02%)	
PROPANE -	3.7(1.57%)	
BUTANE- -	1.6(0.69%)	
REACTION WATER	0.0	0.00% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	31.8
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1336.8
HYDROGEN- - -	38.4	HYDROGEN	
		CONSUMED - -	12.6
		UNUSED - - -	25.7
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1679.4
GRAMS OUT- -	1510.1
% DIFF - - -	10.1

CØAL HYDRØGENATIØN MASS BALANCE

RUN NUMBER L-NT-K-8
DATE ØF RUN 04-22-68

CØNDITIØNS ØF RUN

PRESSURE - - - - - - - -	2310.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - - -	4:02 HRS:MIN
CØAL CØNCENTRATIØN - - -	0.170
CATALYST CØNCENTRATIØN -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF CØAL - - -	247.7
ASH- - - - - - -	35.3
WATER- - - - - -	0.0
RECYCLE ØIL -	1383.7
HYDRØGEN- - -	44.7
CATALYST- - -	0.0

ØUTPUT IN GRAMS

UNREACTED CØAL	25.9	11.26% ØF MAF CØAL AND H2
PRØDUCT ØIL -	122.6	53.36% ØF MAF CØAL AND H2
ØIL < 325C	178.9	77.86% ØF MAF CØAL AND H2
GAS - - - - -	45.1	19.63% ØF MAF CØAL AND H2
METHANE -	24.1(10.48%)	
ETHANE- -	9.0(3.93%)	
PRØPANE -	8.5(3.70%)	
BUTANE- -	3.5(1.52%)	
REACTIØN WATER	33.6	14.62% ØF MAF CØAL AND H2

ASH - - - - -	30.2
WATER - - - -	0.0
RECYCLE ØIL-	1127.5
HYDRØGEN	
CØNSUMED - -	17.9
UNUSED - - -	26.8
CATALYST - -	0.0

TØTAL MASS BALANCE

GRAMS IN - -	1684.6
GRAMS ØUT- -	1441.2
% DIFF - - -	14.5

IV. Master Summary - Series K.

Summary of Experimental Results in Percent of Coal Going to Each Product

RUN	TIME	TEMP	CATCN	% UNCON	% OIL	% GAS	% H2O
L-NT-K-1	4:04	425.00	0.791	5.599	80.815	6.276	6.609
L-NT-K-2	4:03	475.00	4.096	16.388	40.273	29.572	12.896
L-NT-K-3	3:58	450.00	0.708	3.701	73.438	12.224	9.979
L-NT-K-4	4:09	425.00	4.310	4.220	77.682	4.610	12.085
L-NT-K-5	4:06	475.00	0.774	9.098	52.704	24.003	13.137
L-NT-K-6	4:07	425.00	0.000	8.355	78.341	4.394	8.115
L-NT-K-7 L	1:21	475.00	0.000	4.906	84.186	10.368	0.000
L-NT-K-8	4:02	475.00	0.000	11.259	53.363	19.631	14.623

Summary of Experimental Results in Grams of Product Found and Loss Variation

RUN	TIME	TEMP	CATCN (%)	PRODUCT (gm)	<325C (gm)	H2USED (gm)	LOSS (%)
L-NT-K-1	4:04	425.00	0.791	183.423	129.500	12.032	13.220
L-NT-K-2	4:03	475.00	4.096	102.119	272.400	26.505	8.325
L-NT-K-3	3:58	450.00	0.708	179.563	176.600	18.437	8.723
L-NT-K-4	4:09	425.00	4.310	181.266	129.500	22.191	14.748
L-NT-K-5	4:06	475.00	0.774	127.574	221.000	22.526	11.364
L-NT-K-6	4:07	425.00	0.000	184.396	84.000	16.238	11.524
L-NT-K-7 L	1:21	475.00	0.000	198.121	105.600	12.624	10.080
L-NT-K-8	4:02	475.00	0.000	122.616	178.900	17.890	14.450

TABLE VI. Coal Hydrogenation Mass Balance

V. Individual Output Balance Sheets - Series L.

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-L-1
DATE OF RUN 05-07-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2320.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:03 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	39.6	17.88% OF MAF COAL AND H2
PRODUCT OIL -	47.7	21.52% OF MAF COAL AND H2
OIL < 325C	172.9	78.00% OF MAF COAL AND H2
GAS - - - - - -	97.2	43.83% OF MAF COAL AND H2
METHANE -	62.0(27.98%)	
ETHANE- -	18.6(8.40%)	
PROPANE -	13.6(6.16%)	
BUTANE- -	2.9(1.30%)	
REACTION WATER	32.3	14.57% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	28.2
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	979.1
HYDROGEN- - -	45.3	HYDROGEN	
		CONSUMED - -	24.0
		UNUSED - - -	21.3
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1690.8
GRAMS OUT- -	1349.3
% DIFF - - -	20.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-L-2
DATE OF RUN 05-08-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2260.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - - -	4:03 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.661% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	14.1	5.63% OF MAF COAL AND H2
		PRODUCT OIL -	199.0	79.26% OF MAF COAL AND H2
		OIL < 325C	86.5	34.45% OF MAF COAL AND H2
		GAS - - - - -	13.6	5.43% OF MAF COAL AND H2
		METHANE -	7.3(2.89%)	
		ETHANE- -	2.9(1.16%)	
		PROPANE -	2.7(1.08%)	
		BUTANE- -	0.8(0.31%)	
		REACTION WATER	22.3	8.88% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - -	32.4	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1381.1	
HYDROGEN- - -	55.2	HYDROGEN		
		CONSUMED - -	24.0	
		UNUSED - - -	31.1	
CATALYST- - -	1.5	CATALYST - -	1.5	

TOTAL MASS BALANCE

GRAMS IN - -	1690.8
GRAMS OUT- -	1550.0
% DIFF - - -	8.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-L-3
DATE OF RUN 05-08-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2260.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:03 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	8.7 GR; 3.854% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	13.6	5.21% OF MAF COAL AND H2
		PRODUCT OIL -	106.0	40.51% OF MAF COAL AND H2
		OIL < 325C	238.8	91.30% OF MAF COAL AND H2
		GAS - - - - -	113.2	43.28% OF MAF COAL AND H2
		METHANE -	63.6(24.30%)	
		ETHANE- -	26.3(10.05%)	
		PROPANE -	18.6(7.12%)	
		BUTANE- -	4.7(1.81%)	
		REACTION WATER	25.6	9.79% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - -	32.2	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1128.2	
HYDROGEN- - -	55.3	HYDROGEN		
		CONSUMED - -	35.8	
		UNUSED - - -	19.5	
CATALYST- - -	8.7	CATALYST - -	8.7	

TOTAL MASS BALANCE

GRAMS IN - -	1702.6
GRAMS OUT- -	1551.6
% DIFF - - -	8.9

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-L-4
DATE OF RUN 05-09-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2210.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	4:03 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.658% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	49.2
CATALYST- - -	1.5

OUTPUT IN GRAMS

UNREACTED COAL	5.6	2.25% OF MAF COAL AND H2
PRODUCT OIL -	161.3	64.29% OF MAF COAL AND H2
OIL < 325C	144.5	57.61% OF MAF COAL AND H2
GAS - - - - -	43.4	17.32% OF MAF COAL AND H2
METHANE -	24.5(9.75%)	
ETHANE- -	9.6(3.84%)	
PROPANE -	7.1(2.81%)	
BUTANE- -	2.3(0.92%)	
REACTION WATER	38.7	15.43% OF MAF COAL AND H2
ASH - - - - -	32.5	
WATER - - - -	0.0	
RECYCLE OIL-	1290.9	
HYDROGEN		
CONSUMED - -	22.8	
UNUSED - - -	26.5	
CATALYST - -	1.5	

TOTAL MASS BALANCE

GRAMS IN - -	1689.5
GRAMS OUT- -	1555.7
% DIFF - - -	7.9

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-L-5
DATE OF RUN 05-09-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	3:59 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.2 GR; 4.309% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	53.2
CATALYST- - -	9.2

OUTPUT IN GRAMS

UNREACTED COAL	0.5	0.23% OF MAF COAL AND H2
PRODUCT OIL -	187.9	79.92% OF MAF COAL AND H2
OIL < 325C	145.1	61.71% OF MAF COAL AND H2
GAS - - - - -	15.8	6.71% OF MAF COAL AND H2
METHANE -	7.0(2.96%)	
ETHANE- -	4.1(1.74%)	
PROPANE -	3.2(1.36%)	
BUTANE- -	1.5(0.65%)	
REACTION WATER	27.9	11.87% OF MAF COAL AND H2

ASH - - - - -	30.5
WATER - - - -	0.0
RECYCLE OIL-	1235.6
HYDROGEN	
CONSUMED - -	21.6
UNUSED - - -	31.6
CATALYST - -	9.2

TOTAL MASS BALANCE

GRAMS IN - -	1688.4
GRAMS OUT- -	1455.4
% DIFF - - -	13.8

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-L-6
DATE OF RUN 05-10-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2260.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:00 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.8 GR; 1.137% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	58.1
CATALYST- - -	1.8

OUTPUT IN GRAMS

UNREACTED COAL	15.0	7.69% OF MAF COAL AND H2
PRODUCT OIL -	60.8	31.27% OF MAF COAL AND H2
OIL < 325C	175.3	90.16% OF MAF COAL AND H2
GAS - - - - -	86.0	44.25% OF MAF COAL AND H2
METHANE -	49.6(25.48%)	
ETHANE- -	20.4(10.49%)	
PROPANE -	13.3(6.84%)	
BUTANE- -	2.8(1.44%)	
REACTION WATER	19.6	10.08% OF MAF COAL AND H2
ASH - - - - -	22.6	
WATER - - - -	0.0	
RECYCLE OIL-	770.0	
HYDROGEN CONSUMED - -	36.1	
UNUSED - - -	22.0	
CATALYST - -	1.8	

TOTAL MASS BALANCE

GRAMS IN - -	1702.9
GRAMS OUT- -	1088.4
% DIFF - - -	36.1

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-L-7
DATE OF RUN 05-10-68

CONDITIONS OF RUN	
PRESSURE - - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - - -	425.0 C
TIME - - - - - - - - - - - -	4:01 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	14.1	5.93% OF MAF COAL AND H2
		PRODUCT OIL -	181.9	76.44% OF MAF COAL AND H2
		OIL < 325C	88.0	36.98% OF MAF COAL AND H2
		GAS - - - - -	16.0	6.71% OF MAF COAL AND H2
		METHANE -	8.2(3.44%)	
		ETHANE- -	3.8(1.61%)	
		PROPANE -	3.0(1.24%)	
		BUTANE- -	1.0(0.41%)	
		REACTION WATER	24.8	10.42% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	32.1	
WATER- - - - - -	0.0	WATER - - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1351.5	
HYDROGEN- - -	45.1	HYDROGEN		
		CONSUMED - -	12.9	
		UNUSED - - -	32.2	
CATALYST- - -	0.0	CATALYST - -	0.0	

TOTAL MASS BALANCE	
GRAMS IN - -	1679.7
GRAMS OUT- -	1526.5
% DIFF - - -	9.1

VI. Master Summary - Series L.

Summary of Experimental Results in Percent of Coal Going to Each Product

RUN	TIME	TEMP	CATCN	% UNCON	% OIL	% GAS	% H2O
L-NT-L-1	4:03	475.00	0.000	17.883	21.524	43.834	14.571
L-NT-L-2	4:03	425.00	0.661	5.631	79.257	5.434	8.881
L-NT-L-3	4:03	475.00	3.854	5.207	40.511	43.279	9.788
L-NT-L-4	4:03	450.00	0.658	2.246	64.286	17.321	15.428
L-NT-L-5	3:59	425.00	4.309	0.230	79.923	6.712	11.867
L-NT-L-6	4:00	475.00	1.137	7.690	31.273	44.252	10.080
L-NT-L-7	4:01	425.00	0.000	5.934	76.443	6.708	10.420

Summary of Experimental Results in Grams of Product Found and Loss Variation

RUN	TIME	TEMP	CATCN (%)	PRODUCT (gm)	<325C (gm)	H2USED (gm)	LOSS (%)
L-NT-L-1	4:03	475.00	0.000	47.712	172.900	24.019	20.198
L-NT-L-2	4:03	425.00	0.661	199.010	86.500	24.030	8.324
L-NT-L-3	4:03	475.00	3.854	105.958	238.800	35.842	8.868
L-NT-L-4	4:03	450.00	0.658	161.254	144.500	22.771	7.918
L-NT-L-5	3:59	425.00	4.309	187.910	145.100	21.613	13.799
L-NT-L-6	4:00	475.00	1.137	60.808	175.300	36.129	36.082
L-NT-L-7	4:01	425.00	0.000	181.932	88.000	12.909	9.120

TABLE VI. Coal Hydrogenation Mass Balance

VII. Individual Output Balance Sheets - Series M.

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-1 A
DATE OF RUN 07-02-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2250.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	33.4
CATALYST- - -	0.0

OUTPUT IN GRAMS

UNREACTED COAL	43.6	18.53% OF MAF COAL AND H2
PRODUCT OIL -	112.6	47.82% OF MAF COAL AND H2
OIL < 325C	140.7	59.74% OF MAF COAL AND H2
GAS - - - - -	54.9	23.33% OF MAF COAL AND H2
METHANE -	42.1(17.88%)	
ETHANE- -	8.6(3.64%)	
PROPANE -	3.6(1.55%)	
BUTANE- -	0.6(0.26%)	
REACTION WATER	23.5	9.98% OF MAF COAL AND H2
ASH - - - - -	32.3	
WATER - - - -	0.0	
RECYCLE OIL-	1235.4	
HYDROGEN CONSUMED - -	9.4	
UNUSED - - -	24.1	
CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1676.1
GRAMS OUT- -	1530.4
% DIFF - - -	8.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-2
DATE OF RUN 07-02-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	35.5	14.66% OF MAF COAL AND H_2
PRODUCT OIL -	171.4	70.84% OF MAF COAL AND H2
OIL < 325C	136.0	56.23% OF MAF COAL AND H2
GAS - - - - - -	8.4	3.49% OF MAF COAL AND H2
METHANE -	3.2(1.34%)	
ETHANE- -	3.2(1.34%)	
PROPANE -	1.6(0.67%)	
BUTANE- -	0.3(0.14%)	
REACTION WATER	26.3	10.87% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.6
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1350.0
HYDROGEN- - -	39.5	HYDROGEN	
		CONSUMED - -	6.6
		UNUSED - - -	33.0
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1673.3
GRAMS OUT- -	1589.7
% DIFF - - -	5.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-3
DATE OF RUN 07-03-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2280.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	4:08 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.0 GR; 3.625% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	11.8	4.27% OF MAF COAL AND H2
		PRODUCT OIL -	155.0	56.27% OF MAF COAL AND H2
		OIL < 325C	333.9	121.20% OF MAF COAL AND H2
		GAS - - - - - -	67.1	24.35% OF MAF COAL AND H2
		METHANE -	42.4(15.38%)	
		ETHANE- -	14.9(5.41%)	
		PROPANE -	8.0(2.90%)	
		BUTANE- -	1.8(0.66%)	
		REACTION WATER	41.7	15.14% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	35.4	
WATER- - - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1208.3	
HYDROGEN- - -	52.0	HYDROGEN		
		CONSUMED - -	27.2	
		UNUSED - - -	24.8	
CATALYST- - -	9.0	CATALYST - -	9.0	

TOTAL MASS BALANCE

GRAMS IN - -	1693.9
GRAMS OUT- -	1698.2
% DIFF - - -	-0.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-4
DATE OF RUN 07-03-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2330.0 PSI
TEMPERATURE- - - - - - - -	450.0 C
TIME - - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	19.6	8.24% OF MAF COAL AND H2
PRODUCT OIL -	149.3	62.75% OF MAF COAL AND H2
OIL < 325C	202.2	85.00% OF MAF COAL AND H2
GAS - - - - - -	35.1	14.75% OF MAF COAL AND H2
METHANE -	23.8(10.02%)	
ETHANE- -	7.3(3.05%)	
PROPANE -	3.3(1.40%)	
BUTANE- -	0.7(0.27%)	
REACTION WATER	33.1	13.91% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	32.5
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1219.5
HYDROGEN- - -	38.7	HYDROGEN	
		CONSUMED - -	10.1
		UNUSED - - -	28.6
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1676.9
GRAMS OUT- -	1542.0
% DIFF - - -	8.0

-100-

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-5
DATE OF RUN 07-04-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.7 GR; 0.730% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	18.2		7.53% OF MAF COAL AND H2
PRODUCT OIL -	190.3		78.65% OF MAF COAL AND H2
OIL < 325C	158.5		65.52% OF MAF COAL AND H2
GAS - - - - -	11.6		4.78% OF MAF COAL AND H2
METHANE -	6.9	(2.83%)	
ETHANE- -	3.0	(1.23%)	
PROPANE -	1.4	(0.60%)	
BUTANE- -	0.3	(0.13%)	
REACTION WATER	21.3		8.80% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.2
WATER- - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1332.2
HYDROGEN- - -	41.0	HYDROGEN	
		CONSUMED - -	9.2
		UNUSED - - -	31.8
CATALYST- - -	1.7	CATALYST - -	1.7

TOTAL MASS BALANCE

GRAMS IN - -	1675.9
GRAMS OUT- -	1575.0
% DIFF - - -	6.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-6
DATE OF RUN 07-05-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2360.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	14.3		6.30% OF MAF COAL AND H2
PRODUCT OIL -	186.5		81.83% OF MAF COAL AND H2
OIL < 325C	89.1		39.11% OF MAF COAL AND H2
GAS - - - - - -	4.9		2.14% OF MAF COAL AND H2
METHANE -	2.7	(1.19%)	
ETHANE- -	1.2	(0.53%)	
PROPANE -	0.8	(0.36%)	
BUTANE- -	0.1	(0.06%)	
REACTION WATER	21.8		9.57% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	31.9
WATER- - - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1348.5
HYDROGEN- - -	37.2	HYDROGEN	
		CONSUMED - -	3.9
		UNUSED - - -	33.4
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1670.6
GRAMS OUT- -	1510.6
% DIFF - - -	9.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-7
DATE OF RUN 07-06-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2250.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	36.4
CATALYST- - -	0.0

OUTPUT IN GRAMS

UNREACTED COAL	32.1	14.04% OF MAF COAL AND H2
PRODUCT OIL -	166.9	73.03% OF MAF COAL AND H2
OIL < 325C	125.7	55.00% OF MAF COAL AND H2
GAS - - - - -	16.5	7.23% OF MAF COAL AND H2
METHANE -	10.5(4.57%)	
ETHANE- -	3.8(1.67%)	
PROPANE -	1.9(0.84%)	
BUTANE- -	0.3(0.14%)	
REACTION WATER	12.3	5.38% OF MAF COAL AND H2

ASH - - - - -	31.6
WATER - - - -	0.0
RECYCLE OIL-	1279.5
HYDROGEN	
CONSUMED - -	6.9
UNUSED - - -	29.5
CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1673.7
GRAMS OUT- -	1497.7
% DIFF - - -	10.5

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-8
DATE OF RUN 07-07-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2250.0 PSI
TEMPERATURE- - - - - - - -	425.0 C
TIME - - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.3 GR; 3.789% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	35.6	13.80% OF MAF COAL AND H_2
		PRODUCT OIL -	192.9	74.77% OF MAF COAL AND H_2
		OIL < 325C	139.3	54.00% OF MAF COAL AND H_2
		GAS - - - - -	6.8	2.63% OF MAF COAL AND H_2
		METHANE -	3.5(1.35%)	
		ETHANE- -	1.8(0.69%)	
		PROPANE -	1.3(0.49%)	
		BUTANE- -	0.2(0.09%)	
		REACTION WATER	22.6	8.76% OF MAF COAL AND H_2
ASH- - - - - - -	35.3	ASH - - - - - -	35.0	
WATER- - - - - -	0.0	WATER - - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1424.9	
HYDROGEN- - -	44.1	HYDROGEN		
		CONSUMED - -	12.5	
		UNUSED - - -	31.6	
CATALYST- - -	9.3	CATALYST - -	9.3	

TOTAL MASS BALANCE

GRAMS IN - -	1679.3
GRAMS OUT- -	1664.2
% DIFF - - -	0.9

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-9
DATE OF RUN 07-12-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.6 GR; 0.686% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	29.1	12.03% OF MAF COAL AND H2
PRODUCT OIL -	172.2	71.19% OF MAF COAL AND H2
OIL < 325C	122.2	50.52% OF MAF COAL AND H2
GAS - - - - -	20.4	8.42% OF MAF COAL AND H2
METHANE -	5.6(2.32%)	
ETHANE- -	3.6(1.47%)	
PROPANE -	2.6(1.06%)	
BUTANE- -	8.6(3.57%)	
REACTION WATER	19.7	8.14% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - - -	33.3
WATER- - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1352.1
HYDROGEN- - -	40.0	HYDROGEN	
		CONSUMED - -	8.8
		UNUSED - - -	31.1
CATALYST- - -	1.6	CATALYST - -	1.6

TOTAL MASS BALANCE

GRAMS IN - -	1675.6
GRAMS OUT- -	1576.8
% DIFF - - -	5.9

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-10
DATE OF RUN 07-12-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:08 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.635% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	49.5	20.44% OF MAF COAL AND H2
PRODUCT OIL -	164.2	67.79% OF MAF COAL AND H2
OIL < 325C	84.4	34.84% OF MAF COAL AND H2
GAS - - - - - -	11.8	4.88% OF MAF COAL AND H2
METHANE -	7.0(2.89%)	
ETHANE- -	3.0(1.25%)	
PROPANE -	1.5(0.61%)	
BUTANE- -	0.3(0.13%)	
REACTION WATER	16.4	6.77% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.7
WATER- - - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1399.1
HYDROGEN- - -	38.6	HYDROGEN	
		CONSUMED - -	6.1
		UNUSED - - -	32.5
CATALYST- - -	1.5	CATALYST - -	1.5

TOTAL MASS BALANCE

GRAMS IN - -	1672.8
GRAMS OUT- -	1594.9
% DIFF - - -	4.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-11
DATE OF RUN 07-15-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2560.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - - -	0:59 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.6 GR; 4.243% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	2.8	1.16% OF MAF COAL AND H2
PRODUCT OIL -	159.0	65.52% OF MAF COAL AND H2
OIL < 325C	201.0	82.80% OF MAF COAL AND H2
GAS - - - - - -	70.3	28.94% OF MAF COAL AND H2
METHANE -	41.1(16.92%)	
ETHANE- -	16.2(6.66%)	
PROPANE -	9.6(3.97%)	
BUTANE- -	3.4(1.39%)	
REACTION WATER	9.2	3.79% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	32.3
WATER- - - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1222.0
HYDROGEN- - -	44.0	HYDROGEN	
		CONSUMED - -	16.5
		UNUSED - - -	27.5
CATALYST- - -	9.6	CATALYST - -	9.6

TOTAL MASS BALANCE

GRAMS IN - -	1683.3
GRAMS OUT- -	1537.6
% DIFF - - -	8.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-11 A
DATE OF RUN 07-18-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	2:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.3 GR; 4.047% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	22.5	9.03% OF MAF COAL AND H2
		PRODUCT OIL -	126.8	50.79% OF MAF COAL AND H2
		OIL < 325C	258.3	103.45% OF MAF COAL AND H2
		GAS - - - - - -	67.9	27.19% OF MAF COAL AND H2
		METHANE -	39.6(15.86%)	
		ETHANE- -	15.7(6.28%)	
		PROPANE -	9.3(3.74%)	
		BUTANE- -	3.3(1.31%)	
		REACTION WATER	31.0	12.42% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	32.8	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1152.3	
HYDROGEN- - -	44.1	HYDROGEN		
		CONSUMED - -	19.9	
		UNUSED - - -	24.2	
CATALYST- - -	9.3	CATALYST - -	9.3	

TOTAL MASS BALANCE

GRAMS IN - -	1686.7
GRAMS OUT- -	1564.8
% DIFF - - -	7.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-12
DATE OF RUN 07-18-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2160.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.5 GR; 4.225% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	15.6	6.43% OF MAF COAL AND H2
PRODUCT OIL -	135.1	55.85% OF MAF COAL AND H2
OIL < 325C	177.6	73.41% OF MAF COAL AND H2
GAS - - - - - -	59.3	24.50% OF MAF COAL AND H2
METHANE -	34.7(14.32%)	
ETHANE- -	13.6(5.64%)	
PROPANE -	8.1(3.36%)	
BUTANE- -	2.9(1.18%)	
REACTION WATER	30.4	12.57% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	32.1
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1213.8
HYDROGEN- - -	40.2	HYDROGEN	
		CONSUMED - -	17.1
		UNUSED - - -	23.2
CATALYST- - -	9.5	CATALYST - -	9.5

TOTAL MASS BALANCE

GRAMS IN - -	1683.8
GRAMS OUT- -	1528.7
% DIFF - - -	9.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-13
DATE OF RUN 07-19-68

CONDITIONS OF RUN
PRESSURE - - - - - - - - - 2270.0 PSI
TEMPERATURE- - - - - - - 475.0 C
TIME - - - - - - - - - - - 2:06 HRS:MIN
COAL CONCENTRATION - - - 0.170
CATALYST CONCENTRATION - 1.6 GR; 0.704% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	35.4	14.47% OF MAF COAL AND H2
		PRODUCT OIL -	90.2	36.89% OF MAF COAL AND H2
		OIL < 325C	193.6	79.19% OF MAF COAL AND H2
		GAS - - - - - -	94.6	38.69% OF MAF COAL AND H2
		METHANE -	38.6(15.79%)	
		ETHANE- -	15.2(6.22%)	
		PROPANE -	9.0(3.69%)	
		BUTANE- -	31.8(12.99%)	
		REACTION WATER	22.9	9.37% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - - -	32.4	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1166.2	
HYDROGEN- - -	40.2	HYDROGEN		
		CONSUMED - -	17.2	
		UNUSED - - -	23.0	
CATALYST- - -	1.6	CATALYST - -	1.6	

TOTAL MASS BALANCE

GRAMS IN - - 1684.0
GRAMS OUT- - 1545.1
% DIFF - - - 8.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-15
DATE OF RUN 07-22-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	1950.0 PSI
TEMPERATURE- - - - - - - -	450.0 C
TIME - - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.0 GR; 3.900% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	14.5	5.92% OF MAF COAL AND H2
		PRODUCT OIL -	184.8	75.52% OF MAF COAL AND H2
		OIL < 325C	216.1	88.30% OF MAF COAL AND H2
		GAS - - - - -	19.5	7.96% OF MAF COAL AND H2
		METHANE -	6.9(2.84%)	
		ETHANE- -	5.1(2.07%)	
		PROPANE -	4.8(1.96%)	
		BUTANE- -	2.7(1.09%)	
		REACTION WATER	25.0	10.22% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - -	32.9	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1258.0	
HYDROGEN- - -	39.4	HYDROGEN		
		CONSUMED - -	14.0	
		UNUSED - - -	25.5	
CATALYST- - -	9.0	CATALYST - -	9.0	

TOTAL MASS BALANCE

GRAMS IN - -	1680.7
GRAMS OUT- -	1566.0
% DIFF - - -	6.8

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-14 A
DATE OF RUN 07-23-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2250.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - - -	2:06 HRS;MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.647% MAF

INPUT IN GRAMS

MAF COAL - - - 247.7

OUTPUT IN GRAMS

UNREACTED COAL	28.6	11.61% OF MAF COAL AND H2
PRODUCT OIL -	154.1	62.47% OF MAF COAL AND H2
OIL < 325C	178.2	72.24% OF MAF COAL AND H2
GAS - - - - -	35.5	14.40% OF MAF COAL AND H2
METHANE -	11.1(4.50%)	
ETHANE- -	7.9(3.22%)	
PROPANE -	7.2(2.91%)	
BUTANE- -	9.3(3.77%)	
REACTION WATER	27.5	11.15% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.1
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1272.1
HYDROGEN- - -	43.2	HYDROGEN	
		CONSUMED - -	14.7
		UNUSED - - -	28.6
CATALYST- - -	1.5	CATALYST - -	1.5

TOTAL MASS BALANCE

GRAMS IN - -	1681.4
GRAMS OUT- -	1575.0
% DIFF - - -	6.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-16
DATE OF RUN 07-24-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	8.9 GR. 3.907% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	49.9
CATALYST- - -	8.9

OUTPUT IN GRAMS

UNREACTED COAL	13.0	5.30% OF MAF COAL AND H2
PRODUCT OIL -	192.0	78.16% OF MAF COAL AND H2
OIL < 325C	222.5	90.60% OF MAF COAL AND H2
GAS - - - - - -	11.0	4.47% OF MAF COAL AND H2
METHANE -	4.3(1.76%)	
ETHANE- -	3.2(1.32%)	
PROPANE -	2.6(1.04%)	
BUTANE- -	0.9(0.35%)	
REACTION WATER	28.2	11.48% OF MAF COAL AND H2

ASH - - - - - -	32.5
WATER - - - -	0.0
RECYCLE OIL-	1242.1
HYDROGEN	
CONSUMED - -	17.8
UNUSED - - -	32.0
CATALYST - -	8.9

TOTAL MASS BALANCE

GRAMS IN - -	1684.6
GRAMS OUT- -	1549.3
% DIFF - - -	8.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-17
DATE OF RUN 07-24-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2360.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.6 GR. 4.021% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	3.2	1.23% OF MAF COAL AND H2
PRODUCT OIL -	194.2	74.06% OF MAF COAL AND H2
OIL < 325C	247.0	94.20% OF MAF COAL AND H2
GAS - - - - -	50.1	19.09% OF MAF COAL AND H2
METHANE -	24.2(9.21%)	
ETHANE- -	14.6(5.56%)	
PROPANE -	8.8(3.34%)	
BUTANE- -	2.6(0.97%)	
REACTION WATER	13.9	5.30% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	34.1
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1281.1
HYDROGEN- - -	51.6	HYDROGEN	
		CONSUMED - -	23.4
		UNUSED - - -	28.2
CATALYST- - -	9.6	CATALYST - -	9.6

TOTAL MASS BALANCE

GRAMS IN - -	1690.2
GRAMS OUT- -	1629.4
% DIFF - - -	3.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-18
DATE OF RUN 07-25-68

CONDITIONS OF RUN
PRESSURE - - - - - - - - - 2290.0 PSI
TEMPERATURE- - - - - - - - 475.0 C
TIME - - - - - - - - - - - 2:05 HRS:MIN
COAL CONCENTRATION - - - 0.170
CATALYST CONCENTRATION - 0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	39.4
CATALYST- - -	0.0

OUTPUT IN GRAMS

UNREACTED COAL	39.4	16.61% OF MAF COAL AND H2
PRODUCT OIL -	102.9	43.40% OF MAF COAL AND H2
OIL < 325C	194.4	82.02% OF MAF COAL AND H2
GAS - - - - -	62.9	26.52% OF MAF COAL AND H2
METHANE -	36.7(15.50%)	
ETHANE- -	14.5(6.10%)	
PROPANE -	8.6(3.64%)	
BUTANE- -	3.0(1.28%)	
REACTION WATER	30.4	12.83% OF MAF COAL AND H2

ASH - - - - -	31.7
WATER - - - -	0.0
RECYCLE OIL-	1149.5
HYDROGEN	
CONSUMED - -	14.9
UNUSED - - -	24.6
CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - - 1681.6
GRAMS OUT- - 1508.3
% DIFF - - - 10.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-19
DATE OF RUN 07-25-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2290.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.6 GR; 0.682% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	37.6
CATALYST- - -	1.6

OUTPUT IN GRAMS

UNREACTED COAL	29.4	11.88% OF MAF COAL AND H2
PRODUCT OIL -	128.2	51.87% OF MAF COAL AND H2
OIL < 325C	152.6	61.74% OF MAF COAL AND H2
GAS - - - - -	62.2	25.17% OF MAF COAL AND H2
METHANE -	31.3(12.68%)	
ETHANE- -	16.4(6.65%)	
PROPANE -	10.4(4.22%)	
BUTANE- -	4.0(1.62%)	
REACTION WATER	26.7	10.80% OF MAF COAL AND H2

ASH - - - - -	33.5
WATER - - - -	0.0
RECYCLE OIL-	1286.3
HYDROGEN	
CONSUMED - -	12.6
UNUSED - - -	25.0
CATALYST - -	1.6

TOTAL MASS BALANCE

GRAMS IN - -	1679.3
GRAMS OUT- -	1590.6
% DIFF - - -	5.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-20
DATE OF RUN 07-26-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	4:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.646% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	17.9	6.95% OF MAF COAL AND H_2
PRODUCT OIL -	126.0	49.05% OF MAF COAL AND H_2
OIL < 325C	225.9	87.91% OF MAF COAL AND H_2
GAS - - - - - -	83.0	32.31% OF MAF COAL AND H_2
METHANE -	47.8(18.62%)	
ETHANE- -	18.4(7.15%)	
PROPANE -	12.4(4.82%)	
BUTANE- -	4.4(1.72%)	
REACTION WATER	28.5	11.09% OF MAF COAL AND H_2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.1
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1198.0
HYDROGEN- - -	48.5	HYDROGEN	
		CONSUMED - -	24.7
		UNUSED - - -	23.9
CATALYST- - -	1.5	CATALYST - -	1.5

TOTAL MASS BALANCE

GRAMS IN - -	1691.4
GRAMS OUT- -	1586.4
% DIFF - - -	6.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-12 A
DATE OF RUN 07-31-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2240.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.0 GR; 3.908% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	1.8	0.74% OF MAF COAL AND H2
		PRODUCT OIL -	149.0	60.11% OF MAF COAL AND H2
		OIL < 325C	261.7	105.60% OF MAF COAL AND H2
		GAS - - - - - -	61.5	24.81% OF MAF COAL AND H2
		METHANE -	35.9(14.50%)	
		ETHANE- -	14.1(5.71%)	
		PROPANE -	8.4(3.40%)	
		BUTANE- -	3.0(1.19%)	
		REACTION WATER	34.3	13.84% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	32.9	
WATER- - - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1173.8	
HYDROGEN- - -	41.6	HYDROGEN		
		CONSUMED - -	17.6	
		UNUSED - - -	24.0	
CATALYST- - -	9.0	CATALYST - -	9.0	

TOTAL MASS BALANCE

GRAMS IN - -	1684.3
GRAMS OUT- -	1566.0
% DIFF - - -	7.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-21
DATE OF RUN 07-31-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2250.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	4:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	22.5	8.67% OF MAF COAL AND H2
PRODUCT OIL -	124.6	48.08% OF MAF COAL AND H2
OIL < 325C	257.3	99.30% OF MAF COAL AND H2
GAS - - - - -	77.1	29.74% OF MAF COAL AND H2
METHANE -	43.6(16.81%)	
ETHANE- -	17.7(6.85%)	
PROPANE -	12.3(4.76%)	
BUTANE- -	3.4(1.32%)	
REACTION WATER	33.7	13.01% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.5
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1177.5
HYDROGEN- - -	48.4	HYDROGEN CONSUMED - -	24.6
		UNUSED - - -	23.8
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1691.3
GRAMS OUT- -	1601.5
% DIFF - - -	5.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-4 A
DATE OF RUN 08-05-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	2:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	21.5	9.04% OF MAF COAL AND H2
PRODUCT OIL -	151.8	63.71% OF MAF COAL AND H2
OIL < 325C	159.8	67.09% OF MAF COAL AND H2
GAS - - - - -	35.4	14.86% OF MAF COAL AND H2
METHANE -	24.1(10.10%)	
ETHANE- -	7.3(3.07%)	
PROPANE -	3.4(1.41%)	
BUTANE- -	0.7(0.28%)	
REACTION WATER	28.2	11.84% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	32.0
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1245.1
HYDROGEN- - -	42.7	HYDROGEN	
		CONSUMED - -	13.9
		UNUSED - - -	28.8
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1680.7
GRAMS OUT- -	1522.0
% DIFF - - -	9.4

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-21 A
DATE OF RUN 08-06-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - - -	4:08 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	27.2	10.57% OF MAF COAL AND H2
PRODUCT OIL -	116.3	45.20% OF MAF COAL AND H2
OIL < 325C	225.4	87.63% OF MAF COAL AND H2
GAS - - - - -	80.5	31.29% OF MAF COAL AND H2
METHANE -	45.5(17.69%)	
ETHANE- -	18.5(7.20%)	
PROPANE -	12.9(5.00%)	
BUTANE- -	3.6(1.39%)	
REACTION WATER	32.1	12.48% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.5
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1202.5
HYDROGEN- - -	47.3	HYDROGEN	
		CONSUMED - -	22.4
		UNUSED - - -	24.9
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1689.2
GRAMS OUT- -	1601.2
% DIFF - - -	5.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-22
DATE OF RUN 08-07-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2320.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	4:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	53.4	20.71% OF MAF COAL AND H2
PRODUCT OIL -	40.6	15.74% OF MAF COAL AND H2
OIL < 325C	254.6	98.75% OF MAF COAL AND H2
GAS - - - - - -	127.6	49.48% OF MAF COAL AND H2
METHANE -	70.0(27.14%)	
ETHANE- -	31.6(12.27%)	
PROPANE -	20.5(7.94%)	
BUTANE- -	5.5(2.13%)	
REACTION WATER	34.5	13.38% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.0
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1077.3
HYDROGEN- - -	45.7	HYDROGEN	
		CONSUMED - -	26.7
		UNUSED - - -	19.0
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1693.4
GRAMS OUT- -	1580.4
% DIFF - - -	6.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-M-23
DATE OF RUN 08-08-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2260.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	4:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	31.0	12.58% OF MAF COAL AND H2
PRODUCT OIL -	162.2	65.86% OF MAF COAL AND H2
OIL < 325C	145.8	59.19% OF MAF COAL AND H2
GAS - - - - -	25.6	10.38% OF MAF COAL AND H2
METHANE -	13.0(5.26%)	
ETHANE- -	6.8(2.76%)	
PROPANE -	4.1(1.68%)	
BUTANE- -	1.7(0.69%)	
REACTION WATER	26.8	10.88% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.3
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1321.2
HYDROGEN- - -	42.8	HYDROGEN CONSUMED - -	12.8
		UNUSED - - -	30.1
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1679.5
GRAMS OUT- -	1583.7
% DIFF - - -	5.7

VIII. Master Summary - Series M.

Summary of Experimental Results in Percent of Coal Going to Each Product

RUN	TIME	TEMP	CATCN	% UNCON	% OIL	% GAS	% H2O
L-NT-M-1 A	1:06	475.00	0.000	18.527	47.824	23.326	9.978
L-NT-M-2	2:07	425.00	0.000	14.664	70.840	3.487	10.873
L-NT-M-3	4:08	450.00	3.625	4.269	56.266	24.354	15.137
L-NT-M-4	2:06	450.00	0.000	8.241	62.754	14.748	13.914
L-NT-M-5	2:07	425.00	0.730	7.533	78.650	4.785	8.805
L-NT-M-6	1:05	425.00	0.000	6.298	81.834	2.136	9.568
L-NT-M-7	1:05	450.00	0.000	14.042	73.031	7.227	5.382
L-NT-M-8	1:06	425.00	3.789	13.796	74.772	2.628	8.761
L-NT-M-9	1:06	450.00	0.686	12.032	71.186	8.423	8.144
L-NT-M-10	2:08	425.00	0.635	20.444	67.786	4.882	6.770
L-NT-M-11	0:59	475.00	4.243	1.163	65.516	28.943	3.790
L-NT-M-11 A	2:05	475.00	4.047	9.029	50.788	27.192	12.416
L-NT-M-12	1:05	475.00	4.225	6.434	55.846	24.504	12.566
L-NT-M-13	2:06	475.00	0.704	14.473	36.890	38.689	9.367
L-NT-M-15	1:05	450.00	3.900	5.917	75.522	7.956	10.215
L-NT-M-14 A	2:06	450.00	0.647	11.607	62.467	14.401	11.148
L-NT-M-16	2:05	425.00	3.907	5.303	78.164	4.469	11.482
L-NT-M-17	2:06	450.00	4.021	1.226	74.058	19.094	5.301
L-NT-M-18	2:05	475.00	0.000	16.612	43.398	26.518	12.826
L-NT-M-19	1:06	475.00	0.682	11.882	51.873	25.174	10.802
L-NT-M-20	4:07	450.00	0.646	6.948	49.053	32.313	11.091
L-NT-M-12 A	1:05	475.00	3.908	0.744	60.111	24.807	13.840
L-NT-M-21	4:05	450.00	0.000	8.671	48.078	29.740	13.006
L-NT-M-4 A	2:07	450.00	0.000	9.041	63.714	14.856	11.839
L-NT-M-21 A	4:08	450.00	0.000	10.571	45.203	31.292	12.480
L-NT-M-22	4:05	475.00	0.000	20.714	15.736	49.478	13.381
L-NT-M-23	4:05	425.00	0.000	12.578	65.864	10.382	10.880

VIII. Master Summary - Series M., Cont.

Summary of Experimental Results in Grams of Product Found and Loss Variation

RUN		TIME	TEMP	CATCN (%)	PRODUCT (gm)	<325C (gm)	H2USED (gm)	LOSS (%)
L-NT-M-1	A	1:06	475.00	0.000	112.633	140.700	9.364	8.691
L-NT-M-2		2:07	425.00	0.000	171.352	136.000	6.579	4.996
L-NT-M-3		4:08	450.00	3.625	155.006	333.900	27.187	-0.251
L-NT-M-4		2:06	450.00	0.000	149.288	202.200	10.139	8.045
L-NT-M-5		2:07	425.00	0.730	190.268	158.500	9.154	6.022
L-NT-M-6		1:05	425.00	0.000	186.456	89.100	3.899	9.582
L-NT-M-7		1:05	450.00	0.000	166.918	125.700	6.916	10.513
L-NT-M-8		1:06	425.00	3.789	192.885	139.300	12.512	0.898
L-NT-M-9		1:06	450.00	0.686	172.198	122.200	8.823	5.896
L-NT-M-10		2:08	425.00	0.635	164.205	84.400	6.098	4.658
L-NT-M-11		0:59	475.00	4.243	159.048	201.000	16.526	8.656
L-NT-M-11	A	2:05	475.00	4.047	126.810	258.300	19.902	7.225
L-NT-M-12		1:05	475.00	4.225	135.110	177.600	17.073	9.213
L-NT-M-13		2:06	475.00	0.704	90.191	193.600	17.237	8.248
L-NT-M-15		1:05	450.00	3.900	184.829	216.100	13.964	6.827
L-NT-M-14	A	2:06	450.00	0.647	154.090	178.200	14.667	6.327
L-NT-M-16		2:05	425.00	3.907	191.967	222.500	17.808	8.031
L-NT-M-17		2:06	450.00	4.021	194.175	247.000	23.427	3.598
L-NT-M-18		2:05	475.00	0.000	102.861	194.400	14.876	10.310
L-NT-M-19		1:06	475.00	0.682	128.217	152.600	12.579	5.282
L-NT-M-20		4:07	450.00	0.646	126.049	225.900	24.657	6.206
L-NT-M-12	A	1:05	475.00	3.908	148.974	261.700	17.552	7.025
L-NT-M-21		4:05	450.00	0.000	124.576	257.300	24.596	5.314
L-NT-M-4	A	2:07	450.00	0.000	151.766	159.800	13.905	9.441
L-NT-M-21	A	4:08	450.00	0.000	116.265	225.400	22.431	5.209
L-NT-M-22		4:05	475.00	0.000	40.570	254.600	26.681	6.677
L-NT-M-23		4:05	425.00	0.000	162.237	145.800	12.777	5.707

TABLE VI. Coal Hydrogenation Mass Balance

IX. Individual Output Balance Sheets - Series O.

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-8-1
DATE OF RUN 09-04-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - - -	475.0 C
TIME - - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	22.4	8.89% OF MAF COAL AND H_2
PRODUCT OIL -	165.0	65.34% OF MAF COAL AND H2
OIL < 325C	133.8	52.99% OF MAF COAL AND H2
GAS - - - - - -	40.8	16.15% OF MAF COAL AND H2
METHANE -	19.1(7.56%)	
ETHANE- -	11.7(4.63%)	
PROPANE -	7.6(3.01%)	
BUTANE- -	2.4(0.95%)	
REACTION WATER	24.2	9.58% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	34.9
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1399.5
HYDROGEN- - -	35.4	HYDROGEN	
		CONSUMED - -	7.6
		UNUSED - - -	27.8
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1674.4
GRAMS OUT- -	1655.7
% DIFF - - -	1.1

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-9-2
DATE OF RUN 09-05-68

CONDITIONS OF RUN	
PRESSURE - - - - - - - - -	2240.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - - - -	2:09 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.4 GR; 4.052% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	9.4	3.75% OF MAF COAL AND H2
		PRODUCT OIL -	158.4	63.20% OF MAF COAL AND H2
		OIL < 325C	267.0	106.51% OF MAF COAL AND H2
		GAS - - - - - -	51.8	20.65% OF MAF COAL AND H2
		METHANE -	20.3(8.10%)	
		ETHANE- -	15.9(6.33%)	
		PROPANE -	11.5(4.57%)	
		BUTANE- -	4.1(1.65%)	
		REACTION WATER	29.9	11.93% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - - -	33.1	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1187.5	
HYDROGEN- - -	44.4	HYDROGEN CONSUMED - -	18.7	
		UNUSED - - -	25.7	
CATALYST- - -	9.4	CATALYST - -	9.4	

TOTAL MASS BALANCE		
	GRAMS IN - -	1685.4
	GRAMS OUT- -	1578.7
	% DIFF - - -	6.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-0-3
DATE OF RUN 09-06-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2210.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	1:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.1 GR; 4.023% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	40.0
CATALYST- - -	9.1

OUTPUT IN GRAMS

UNREACTED COAL	8.4		3.53% OF MAF COAL AND H2
PRODUCT OIL -	184.2		77.57% OF MAF COAL AND H2
OIL < 325C	138.1		58.15% OF MAF COAL AND H2
GAS - - - - -	21.4		9.01% OF MAF COAL AND H2
METHANE -	10.7	(4.49%)	
ETHANE- -	5.4	(2.26%)	
PROPANE -	4.0	(1.67%)	
BUTANE- -	1.4	(0.59%)	
REACTION WATER	22.5		9.47% OF MAF COAL AND H2

ASH - - - - -	32.3
WATER - - - -	0.0
RECYCLE OIL-	1309.7
HYDROGEN	
CONSUMED - -	11.3
UNUSED - - -	28.6
CATALYST - -	9.1

TOTAL MASS BALANCE

GRAMS IN - -	1678.1
GRAMS OUT- -	1532.4
% DIFF - - -	8.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-8-4
DATE OF RUN 09-06-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2290.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:05 HRS;MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	8.5 GR; 3.675% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	15.3	6.28% OF MAF COAL AND H2
		PRODUCT OIL -	187.0	76.88% OF MAF COAL AND H2
		OIL < 325C	155.7	64.00% OF MAF COAL AND H2
		GAS - - - - -	17.1	7.02% OF MAF COAL AND H2
		METHANE -	6.8(2.80%)	
		ETHANE- -	4.9(2.00%)	
		PROPANE -	3.8(1.54%)	
		BUTANE- -	1.6(0.67%)	
		REACTION WATER	23.1	9.49% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - -	33.0	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1323.5	
HYDROGEN- - -	43.4	HYDROGEN		
		CONSUMED - -	12.0	
		UNUSED - - -	31.4	
CATALYST- - -	8.5	CATALYST - -	8.5	

TOTAL MASS BALANCE

GRAMS IN - -	1678.8
GRAMS OUT- -	1567.7
% DIFF - - -	6.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-8-5
DATE OF RUN 09-07-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2200.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:04 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.6 GR; 0.696% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	27.6	11.37% OF MAF COAL AND H2
		PRODUCT OIL -	180.6	74.36% OF MAF COAL AND H2
		OIL < 325C	80.7	33.23% OF MAF COAL AND H2
		GAS - - - - - -	12.2	5.04% OF MAF COAL AND H2
		METHANE -	4.4(1.80%)	
		ETHANE- -	3.3(1.34%)	
		PROPANE -	3.4(1.40%)	
		BUTANE- -	1.2(0.50%)	
		REACTION WATER	21.5	8.85% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - -	32.8	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1384.9	
HYDROGEN- - -	43.4	HYDROGEN		
		CONSUMED - -	12.8	
		UNUSED - - -	30.6	
CATALYST- - -	1.6	CATALYST - -	1.6	

TOTAL MASS BALANCE

GRAMS IN - -	1679.6
GRAMS OUT- -	1559.7
% DIFF - - -	7.1

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-O-6
DATE OF RUN 09-09-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2150.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - - -	1:02 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.2 GR; 0.511% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	23.5		9.59% OF MAF COAL AND H2
PRODUCT OIL -	151.8		61.91% OF MAF COAL AND H2
OIL < 325C	111.0		45.27% OF MAF COAL AND H2
GAS - - - - - -	46.6		18.99% OF MAF COAL AND H2
METHANE -	22.4	(9.15%)	
ETHANE- -	13.5	(5.52%)	
PROPANE -	8.2	(3.33%)	
BUTANE- -	2.4	(0.99%)	
REACTION WATER	22.8		9.30% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.5
WATER- - - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1354.0
HYDROGEN- - -	34.8	HYDROGEN	
		CONSUMED - -	10.2
		UNUSED - - -	24.6
CATALYST- - -	1.2	CATALYST - -	1.2

TOTAL MASS BALANCE

GRAMS IN - -	1676.9
GRAMS OUT- -	1591.4
% DIFF - - -	5.1

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-8-7
DATE OF RUN 09-10-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2380.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.662% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	53.9	23.43% OF MAF COAL AND H_2
		PRODUCT OIL -	156.0	67.77% OF MAF COAL AND H2
		OIL < 325C	38.5	16.72% OF MAF COAL AND H2
		GAS - - - - -	4.8	2.07% OF MAF COAL AND H2
		METHANE -	2.3(1.02%)	
		ETHANE- -	1.6(0.69%)	
		PROPANE -	0.7(0.29%)	
		BUTANE- -	0.2(0.07%)	
		REACTION WATER	15.2	6.60% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	32.3	
WATER- - - - - -	0.0	WATER - - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1383.6	
HYDROGEN- - -	37.2	HYDROGEN		
		CONSUMED - -	3.6	
		UNUSED - - -	33.7	
CATALYST- - -	1.5	CATALYST - -	1.5	

TOTAL MASS BALANCE

GRAMS IN - -	1670.3
GRAMS OUT- -	1528.4
% DIFF - - -	8.5

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-0-8
DATE OF RUN 09-11-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	1380.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	8.4 GR; 3.635% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	19.3	8.12% OF MAF COAL AND H2
		PRODUCT OIL -	149.2	62.76% OF MAF COAL AND H2
		OIL < 325C	82.2	34.59% OF MAF COAL AND H2
		GAS - - - - - -	40.7	17.12% OF MAF COAL AND H2
		METHANE -	20.4(8.57%)	
		ETHANE- -	10.5(4.40%)	
		PROPANE -	7.5(3.14%)	
		BUTANE- -	2.4(1.00%)	
		REACTION WATER	28.1	11.82% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - -	33.0	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1357.8	
HYDROGEN- - -	21.4	HYDROGEN		
		CONSUMED - -	6.6	
		UNUSED - - -	14.8	
CATALYST- - -	8.4	CATALYST - -	8.4	

TOTAL MASS BALANCE

GRAMS IN - -	1673.4
GRAMS OUT- -	1561.1
% DIFF - - -	6.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-8-8A
DATE OF RUN 09-26-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2210.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.8 GR; 4.242% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	7.3	3.00% OF MAF COAL AND H2
		PRODUCT OIL -	175.7	72.62% OF MAF COAL AND H2
		OIL < 325C	138.4	57.21% OF MAF COAL AND H2
		GAS - - - - -	33.4	13.82% OF MAF COAL AND H2
		METHANE -	16.5(6.82%)	
		ETHANE- -	9.3(3.85%)	
		PROPANE -	5.9(2.43%)	
		BUTANE- -	1.7(0.72%)	
		REACTION WATER	24.8	10.25% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - -	33.0	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1328.0	
HYDROGEN- - -	37.4	HYDROGEN		
		CONSUMED - -	10.9	
		UNUSED - - -	26.5	
CATALYST- - -	9.8	CATALYST - -	9.8	

TOTAL MASS BALANCE

GRAMS IN - -	1677.6
GRAMS OUT- -	1564.8
% DIFF - - -	6.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-0-9
DATE OF RUN 09-25-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2190.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.634% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	14.4	5.88% OF MAF COAL AND H2
		PRODUCT OIL -	170.7	69.91% OF MAF COAL AND H2
		OIL < 325C	239.4	98.03% OF MAF COAL AND H2
		GAS - - - - -	21.9	8.95% OF MAF COAL AND H2
		METHANE -	7.8(3.20%)	
		ETHANE- -	5.7(2.33%)	
		PROPANE -	5.4(2.21%)	
		BUTANE- -	3.0(1.22%)	
		REACTION WATER	36.9	15.11% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	33.7	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1252.1	
HYDROGEN- - -	36.4	HYDROGEN		
		CONSUMED - -	7.8	
		UNUSED - - -	28.6	
CATALYST- - -	1.5	CATALYST - -	1.5	

TOTAL MASS BALANCE

GRAMS IN - -	1674.5
GRAMS OUT- -	1598.4
% DIFF - - -	4.5

CØAL HYDRØGENATIØN MASS BALANCE

RUN NUMBER L-NT-Ø-10
DATE ØF RUN 09-30-68

CØNDITIØNS ØF RUN

PRESSURE - - - - - - - - -	2270.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	2:06 HRS;MIN
CØAL CØNCENTRATIØN - - -	0.170
CATALYST CØNCENTRATIØN -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF CØAL - - -	247.7

ØUTPUT IN GRAMS

UNREACTED CØAL	24.7	10.77% ØF MAF CØAL AND H2
PRØDUCT ØIL -	147.9	64.42% ØF MAF CØAL AND H2
ØIL < 325C	113.7	49.54% ØF MAF CØAL AND H2
GAS - - - - - -	31.6	13.77% ØF MAF CØAL AND H2
METHANE -	13.5(5.88%)	
ETHANE- -	9.1(3.97%)	
PRØPANE -	6.6(2.89%)	
BUTANE- -	2.4(1.04%)	
REACTIØN WATER	24.7	10.76% ØF MAF CØAL AND H2

INPUT		ØUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	31.8
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE ØIL -	1383.7	RECYCLE ØIL-	1280.7
HYDRØGEN- - -	34.1	HYDRØGEN	
		CØNSUMED - -	6.4
		UNUSED - - -	27.7
CATALYST- - -	0.0	CATALYST - -	0.0

TØTAL MASS BALANCE

GRAMS IN - -	1673.2
GRAMS ØUT- -	1507.2
% DIFF - - -	9.9

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-0-11
DATE OF RUN 10-01-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2540.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	53.6	22.72% OF MAF COAL AND H2
		PRODUCT OIL -	158.9	67.29% OF MAF COAL AND H2
		OIL < 325C	59.5	25.20% OF MAF COAL AND H2
		GAS - - - - -	7.7	3.25% OF MAF COAL AND H2
		METHANE -	2.3(0.96%)	
		ETHANE- -	3.6(1.52%)	
		PROPANE -	1.3(0.54%)	
		BUTANE- -	0.5(0.23%)	
		REACTION WATER	15.8	6.69% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	33.4	
WATER- - - - - -	0.0	WATER - - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1406.2	
HYDROGEN- - -	38.0	HYDROGEN		
		CONSUMED - -	2.2	
		UNUSED - - -	35.8	
CATALYST- - -	0.0	CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1668.9
GRAMS OUT- -	1576.2
% DIFF - - -	5.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-0-12
DATE OF RUN 10-01-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2180.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	2:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.8 GR; 4.165% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	12.6	5.06% OF MAF COAL AND H2
		PRODUCT OIL -	175.8	70.57% OF MAF COAL AND H2
		OIL < 325C	136.9	54.97% OF MAF COAL AND H2
		GAS - - - - -	30.8	12.37% OF MAF COAL AND H2
		METHANE -	11.9(4.79%)	
		ETHANE- -	9.1(3.67%)	
		PROPANE -	7.0(2.82%)	
		BUTANE- -	2.7(1.08%)	
		REACTION WATER	29.2	11.73% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - -	33.6	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1353.5	
HYDROGEN- - -	41.4	HYDROGEN		
		CONSUMED - -	13.7	
		UNUSED - - -	27.6	
CATALYST- - -	9.8	CATALYST - -	9.8	

TOTAL MASS BALANCE

GRAMS IN - -	1680.5
GRAMS OUT- -	1596.6
% DIFF - - -	5.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-0-13
DATE OF RUN 10-02-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2400.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.3 GR; 0.570% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS			
MAF COAL - - -	247.7	UNREACTED COAL	36.0		15.59% OF MAF COAL AND H2
		PRODUCT OIL -	164.7		71.35% OF MAF COAL AND H2
		OIL < 325C	65.1		28.20% OF MAF COAL AND H2
		GAS - - - - - -	9.8		4.25% OF MAF COAL AND H2
		METHANE -	4.6	(1.98%)	
		ETHANE- -	2.9	(1.25%)	
		PROPANE -	1.8	(0.79%)	
		BUTANE- -	0.5	(0.23%)	
		REACTION WATER	20.1		8.71% OF MAF COAL AND H2
ASH- - - - - -	35.3	ASH - - - - -	32.5		
WATER- - - - -	0.0	WATER - - - -	0.0		
RECYCLE OIL -	1383.7	RECYCLE OIL-	1372.8		
HYDROGEN- - -	35.3	HYDROGEN			
		CONSUMED - -	2.9		
		UNUSED - - -	32.3		
CATALYST- - -	1.3	CATALYST - -	1.3		

TOTAL MASS BALANCE

GRAMS IN - -	1669.7
GRAMS OUT- -	1536.3
% DIFF - - -	8.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-8-14
DATE OF RUN 10-02-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - - -	425.0 C
TIME - - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	8.8 GR; 3.756% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	45.6	19.07% OF MAF COAL AND H2
PRODUCT OIL -	168.4	70.35% OF MAF COAL AND H2
OIL < 325C	51.0	21.31% OF MAF COAL AND H2
GAS - - - - -	4.3	1.78% OF MAF COAL AND H2
METHANE -	1.6(0.67%)	
ETHANE- -	1.3(0.52%)	
PROPANE -	1.1(0.46%)	
BUTANE- -	0.3(0.13%)	
REACTION WATER	20.8	8.69% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - -	33.4
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1426.2
HYDROGEN- - -	38.4	HYDROGEN	
		CONSUMED - -	5.1
		UNUSED - - -	33.3
CATALYST- - -	8.8	CATALYST - -	8.8

TOTAL MASS BALANCE

GRAMS IN - -	1671.8
GRAMS OUT- -	1581.4
% DIFF - - -	5.4

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-0-15
DATE OF RUN 10-03-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2460.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	44.4	19.00% OF MAF COAL AND H2
		PRODUCT OIL -	161.9	69.31% OF MAF COAL AND H2
		OIL < 325C	50.2	21.50% OF MAF COAL AND H2
		GAS - - - - - -	9.6	4.11% OF MAF COAL AND H2
		METHANE -	3.8(1.61%)	
		ETHANE- -	3.0(1.27%)	
		PROPANE -	2.2(0.94%)	
		BUTANE- -	0.7(0.29%)	
		REACTION WATER	17.5	7.49% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	32.9	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1401.2	
HYDROGEN- - -	36.0	HYDROGEN CONSUMED - -	2.7	
		UNUSED - - -	33.2	
CATALYST- - -	0.0	CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1669.5
GRAMS OUT- -	1555.8
% DIFF - - -	6.8

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-8-16
DATE OF RUN 10-03-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2450.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.698% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	37.5	17.12% OF MAF COAL AND H2
PRODUCT OIL -	155.5	70.91% OF MAF COAL AND H2
OIL < 325C	63.2	28.83% OF MAF COAL AND H2
GAS - - - - -	6.0	2.73% OF MAF COAL AND H2
METHANE -	2.0(0.93%)	
ETHANE- -	1.7(0.79%)	
PROPANE -	1.6(0.75%)	
BUTANE- -	0.6(0.26%)	
REACTION WATER	19.7	8.99% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	30.7
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1293.6
HYDROGEN- - -	38.8	HYDROGEN	
		CONSUMED - -	4.2
		UNUSED - - -	34.6
CATALYST- - -	1.5	CATALYST - -	1.5

TOTAL MASS BALANCE

GRAMS IN - -	1670.9
GRAMS OUT- -	1450.7
% DIFF - - -	13.2

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-0-17
DATE OF RUN 10-04-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2600.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	80.6	33.99% OF MAF COAL AND H2
		PRODUCT OIL -	136.7	57.66% OF MAF COAL AND H2
		OIL < 325C	78.6	33.16% OF MAF COAL AND H2
		GAS - - - - -	5.9	2.51% OF MAF COAL AND H2
		METHANE -	1.1(0.46%)	
		ETHANE- -	1.1(0.45%)	
		PROPANE -	1.0(0.40%)	
		BUTANE- -	2.8(1.20%)	
		REACTION WATER	13.8	5.82% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	33.7	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1376.3	
HYDROGEN- - -	38.0	HYDROGEN CONSUMED - -	1.1	
		UNUSED - - -	36.9	
CATALYST- - -	0.0	CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1667.8
GRAMS OUT- -	1588.8
% DIFF - - -	4.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-8-18
DATE OF RUN 10-04-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2360.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	2:08 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	26.9	15.23% OF MAF COAL AND H2
		PRODUCT OIL -	123.8	70.25% OF MAF COAL AND H2
		OIL < 325C	58.4	33.13% OF MAF COAL AND H2
		GAS - - - - - -	10.9	6.17% OF MAF COAL AND H2
		METHANE -	4.3(2.43%)	
		ETHANE- -	3.2(1.82%)	
		PROPANE -	2.5(1.44%)	
		BUTANE- -	0.8(0.48%)	
		REACTION WATER	13.7	7.77% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	24.7	
WATER- - - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1031.5	
HYDROGEN- - -	35.1	HYDROGEN		
		CONSUMED - -	3.4	
		UNUSED - - -	31.7	
CATALYST- - -	0.0	CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1670.1
GRAMS OUT- -	1166.0
% DIFF - - -	30.2

X. Master Summary - Series O.

Summary of Experimental Results in Percent of Coal Going to Each Product

RUN	TIME	TEMP	CATCN	% UNCON	% OIL	% GAS	% H2O
L-NT-O-1	1:06	475.00	0.000	8.888	65.343	16.152	9.583
L-NT-O-2	2:09	475.00	4.052	3.746	63.200	20.655	11.927
L-NT-O-3	1:07	450.00	4.023	3.532	77.568	9.012	9.474
L-NT-O-4	2:05	425.00	3.675	6.281	76.875	7.023	9.495
L-NT-O-5	2:04	425.00	0.696	11.373	74.360	5.035	8.853
L-NT-O-6	1:02	475.00	0.511	9.590	61.915	18.985	9.298
L-NT-O-7	1:05	425.00	0.662	23.425	67.766	2.074	6.602
L-NT-O-8	1:06	475.00	3.635	8.117	62.756	17.118	11.823
L-NT-O-8A	1:06	475.00	4.242	2.998	72.625	13.823	10.251
L-NT-O-9	2:06	450.00	0.634	5.880	69.910	8.954	15.111
L-NT-O-10	2:06	475.00	0.000	10.769	64.424	13.768	10.761
L-NT-O-11	2:06	425.00	0.000	22.717	67.294	3.246	6.692
L-NT-O-12	2:05	450.00	4.165	5.057	70.575	12.368	11.725
L-NT-O-13	1:06	450.00	0.570	15.591	71.345	4.254	8.708
L-NT-O-14	1:05	425.00	3.756	19.067	70.349	1.779	8.690
L-NT-O-15	1:05	450.00	0.000	19.003	69.314	4.110	7.493
L-NT-O-16	2:06	425.00	0.698	17.119	70.913	2.729	8.986
L-NT-O-17	1:06	425.00	0.000	33.992	57.657	2.507	5.822
L-NT-O-18	2:08	450.00	0.000	15.235	70.248	6.167	7.771

X. Master Summary - Series O., Cont.

Summary of Experimental Results in Grams of Product Found and Loss Variation

RUN	TIME	TEMP	CATCN (%)	PRODUCT (gm)	<325C (gm)	H2USED (gm)	LOSS (%)
L-NT-O-1	1:06	475.00	0.000	165.006	133.800	7.606	1.115
L-NT-O-2	2:09	475.00	4.052	158.434	267.000	18.699	6.335
L-NT-O-3	1:07	450.00	4.023	184.227	138.100	11.325	8.681
L-NT-O-4	2:05	425.00	3.675	187.037	155.700	12.007	6.616
L-NT-O-5	2:04	425.00	0.696	180.586	80.700	12.850	7.137
L-NT-O-6	1:02	475.00	0.511	151.826	111.000	10.178	5.103
L-NT-O-7	1:05	425.00	0.662	156.007	38.500	3.587	8.499
L-NT-O-8	1:06	475.00	3.635	149.150	82.200	6.606	6.709
L-NT-O-8A	1:06	475.00	4.242	175.696	138.400	10.898	6.724
L-NT-O-9	2:06	450.00	0.634	170.721	239.400	7.788	4.549
L-NT-O-10	2:06	475.00	0.000	147.874	113.700	6.421	9.919
L-NT-O-11	2:06	425.00	0.000	158.872	59.500	2.175	5.558
L-NT-O-12	2:05	450.00	4.165	175.756	136.900	13.717	4.991
L-NT-O-13	1:06	450.00	0.570	164.690	65.100	2.940	7.988
L-NT-O-14	1:05	425.00	3.756	168.379	51.000	5.072	5.411
L-NT-O-15	1:05	450.00	0.000	161.876	50.200	2.727	6.809
L-NT-O-16	2:06	425.00	0.698	155.456	63.200	4.190	13.182
L-NT-O-17	1:06	425.00	0.000	136.657	78.600	1.064	4.735
L-NT-O-18	2:08	450.00	0.000	123.844	58.400	3.383	30.187

TABLE VI. Coal Hydrogenation Mass Balance

XI. Individual Output Balance Sheets - Series P.

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-1
DATE OF RUN 10-15-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	1:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.6 GR; 4.184% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	39.1
CATALYST- - -	9.6

OUTPUT IN GRAMS

UNREACTED COAL	38.3	16.28% OF MAF COAL AND H2
PRODUCT OIL -	169.9	72.20% OF MAF COAL AND H2
OIL < 325C	90.3	38.38% OF MAF COAL AND H2
GAS - - - - - -	4.9	2.08% OF MAF COAL AND H2
METHANE -	1.7(0.72%)	
ETHANE- -	1.4(0.60%)	
PROPANE -	1.3(0.57%)	
BUTANE- -	0.4(0.19%)	
REACTION WATER	21.8	9.27% OF MAF COAL AND H2

ASH - - - - -	32.7
WATER - - - -	0.0
RECYCLE OIL-	1361.4
HYDROGEN	
CONSUMED - -	5.8
UNUSED - - -	33.3
CATALYST - -	9.6

TOTAL MASS BALANCE

GRAMS IN - -	1672.6
GRAMS OUT- -	1549.4
% DIFF - - -	7.4

-148-

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-2
DATE OF RUN 10-16-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2420.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	36.7
CATALYST- - -	0.0

OUTPUT IN GRAMS

UNREACTED COAL	27.0	11.60% OF MAF COAL AND H2
PRODUCT OIL -	161.3	69.33% OF MAF COAL AND H2
OIL < 325C	95.2	40.91% OF MAF COAL AND H2
GAS - - - - -	20.1	8.64% OF MAF COAL AND H2
METHANE -	7.8(3.35%)	
ETHANE- -	6.1(2.63%)	
PROPANE -	4.3(1.84%)	
BUTANE- -	1.9(0.81%)	
REACTION WATER	23.9	10.27% OF MAF COAL AND H2

ASH - - - - -	32.5
WATER - - - -	0.0
RECYCLE OIL-	1339.1
HYDROGEN	
CONSUMED - -	4.8
UNUSED - - -	31.8
CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1671.6
GRAMS OUT- -	1537.8
% DIFF - - -	8.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-3
DATE OF RUN 10-17-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2460.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.7 GR; 0.735% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - - -	35.3
WATER- - - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	36.4
CATALYST- - -	1.7

OUTPUT IN GRAMS

UNREACTED COAL	12.3	5.17% OF MAF COAL AND H2
PRODUCT OIL -	171.5	72.28% OF MAF COAL AND H2
OIL < 325C	111.2	46.87% OF MAF COAL AND H2
GAS - - - - - -	27.3	11.52% OF MAF COAL AND H2
METHANE -	11.9(5.04%)	
ETHANE- -	8.4(3.54%)	
PROPANE -	5.9(2.48%)	
BUTANE- -	1.1(0.47%)	
REACTION WATER	25.8	10.88% OF MAF COAL AND H2

ASH - - - - - -	33.0
WATER - - - - -	0.0
RECYCLE OIL-	1353.0
HYDROGEN	
CONSUMED - -	5.8
UNUSED - - -	30.5
CATALYST - -	1.7

TOTAL MASS BALANCE

GRAMS IN - -	1672.6
GRAMS OUT- -	1562.6
% DIFF - - -	6.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-4 G
DATE OF RUN 10-19-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2440.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	2:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	38.2
CATALYST- - -	0.0

OUTPUT IN GRAMS

UNREACTED COAL	9.1	3.90% OF MAF COAL AND H2
PRODUCT OIL -	161.4	69.61% OF MAF COAL AND H2
OIL < 325C	143.9	62.06% OF MAF COAL AND H2
GAS - - - - - -	34.0	14.65% OF MAF COAL AND H2
METHANE -	14.5(6.26%)	
ETHANE- -	9.8(4.22%)	
PROPANE -	7.1(3.07%)	
BUTANE- -	2.6(1.10%)	
REACTION WATER	26.6	11.47% OF MAF COAL AND H2

ASH - - - - -	31.9
WATER - - - -	0.0
RECYCLE OIL-	1265.4
HYDROGEN	
CONSUMED - -	8.5
UNUSED - - -	29.7
CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1675.2
GRAMS OUT- -	1510.8
% DIFF - - -	9.8

-151-

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-5
DATE OF RUN 10-21-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2420.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - - -	1:05 HRS;MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.651% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	37.1
CATALYST- - -	1.5

OUTPUT IN GRAMS

UNREACTED COAL	58.2		24.94% OF MAF COAL AND H2
PRODUCT OIL -	152.7		65.42% OF MAF COAL AND H2
OIL < 325C	59.7		25.59% OF MAF COAL AND H2
GAS - - - - -	4.6		1.97% OF MAF COAL AND H2
METHANE -	2.0	(0.87%)	
ETHANE- -	1.4	(0.59%)	
PROPANE -	1.2	(0.51%)	
BUTANE- -	0.0	(0.00%)	
REACTION WATER	17.7		7.59% OF MAF COAL AND H2

ASH - - - - -	32.9
WATER - - - -	0.0
RECYCLE OIL-	1380.7
HYDROGEN	
CONSUMED - -	2.8
UNUSED - - -	34.3
CATALYST - -	1.5

TOTAL MASS BALANCE

GRAMS IN - -	1669.6
GRAMS OUT- -	1553.8
% DIFF - - -	6.9

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-6
DATE OF RUN 10-22-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	1:05 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.7 GR; 4.159% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	39.7
CATALYST- - -	9.7

OUTPUT IN GRAMS

UNREACTED COAL	11.2	4.59% OF MAF COAL AND H2
PRODUCT OIL -	162.3	66.32% OF MAF COAL AND H2
OIL < 325C	160.4	65.54% OF MAF COAL AND H2
GAS - - - - - -	39.6	16.19% OF MAF COAL AND H2
METHANE -	15.2(6.20%)	
ETHANE- -	12.0(4.89%)	
PROPANE -	9.0(3.67%)	
BUTANE- -	3.5(1.43%)	
REACTION WATER	30.9	12.63% OF MAF COAL AND H2

ASH - - - - -	33.3
WATER - - - -	0.0
RECYCLE OIL-	1304.8
HYDROGEN	
CONSUMED - -	11.5
UNUSED - - -	28.2
CATALYST - -	9.7

TOTAL MASS BALANCE

GRAMS IN - -	1678.3
GRAMS OUT- -	1580.2
% DIFF - - -	5.8

-153-

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-7
DATE OF RUN 10-23-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2440.0 PSI
TEMPERATURE- - - - - - - -	450.0 C
TIME - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.6 GR; 0.678% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	26.3	10.61% OF MAF COAL AND H2
PRODUCT OIL -	129.9	52.34% OF MAF COAL AND H2
OIL < 325C	93.5	37.66% OF MAF COAL AND H2
GAS - - - - - -	70.0	28.20% OF MAF COAL AND H2
METHANE -	24.9(10.03%)	
ETHANE- -	19.6(7.91%)	
PROPANE -	17.4(7.00%)	
BUTANE- -	8.1(3.27%)	
REACTION WATER	21.4	8.62% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.7
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1355.0
HYDROGEN- - -	40.5	HYDROGEN	
		CONSUMED - -	12.3
		UNUSED - - -	28.3
CATALYST- - -	1.6	CATALYST - -	1.6

TOTAL MASS BALANCE

GRAMS IN - -	1679.0
GRAMS OUT- -	1599.9
% DIFF - - -	4.7

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-8
DATE OF RUN 10-30-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2240.0 PSI
TEMPERATURE- - - - - - - -	450.0 C
TIME - - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.147
CATALYST CONCENTRATION -	8.2 GR; 4.098% MAF

INPUT IN GRAMS

MAF COAL - - -	214.9

OUTPUT IN GRAMS

UNREACTED COAL	10.2	4.80% OF MAF COAL AND H2
PRODUCT OIL -	153.4	72.08% OF MAF COAL AND H2
OIL < 325C	140.9	66.19% OF MAF COAL AND H2
GAS - - - - -	22.8	10.69% OF MAF COAL AND H2
METHANE -	8.4(3.92%)	
ETHANE- -	6.9(3.25%)	
PROPANE -	5.5(2.59%)	
BUTANE- -	2.0(0.92%)	
REACTION WATER	25.6	12.03% OF MAF COAL AND H2

ASH- - - - - - -	30.7	ASH - - - - -	28.5
WATER- - - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1421.2	RECYCLE OIL-	1336.2
HYDROGEN- - -	41.9	HYDROGEN	
		CONSUMED - -	12.8
		UNUSED - - -	29.2
CATALYST- - -	8.2	CATALYST - -	8.2

TOTAL MASS BALANCE

GRAMS IN - -	1679.5
GRAMS OUT- -	1564.3
% DIFF - - -	6.9

-155-

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-9
DATE OF RUN 10-31-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2400.0 PSI
TEMPERATURE- - - - - - - -	425.0 C
TIME - - - - - - - - - -	2:07 HRS:MIN
COAL CONCENTRATION - - -	0.147
CATALYST CONCENTRATION -	8.0 GR; 3.980% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	214.9	UNREACTED COAL	26.3	12.61% OF MAF COAL AND H2
		PRODUCT OIL -	148.5	71.29% OF MAF COAL AND H2
		OIL < 325C	91.7	44.02% OF MAF COAL AND H2
		GAS - - - - - -	10.4	4.98% OF MAF COAL AND H2
		METHANE -	2.8(1.33%)	
		ETHANE- -	2.5(1.20%)	
		PROPANE -	3.6(1.72%)	
		BUTANE- -	1.5(0.73%)	
		REACTION WATER	22.7	10.90% OF MAF COAL AND H2
ASH- - - - - - -	30.7	ASH - - - - -	28.7	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1421.2	RECYCLE OIL-	1386.3	
HYDROGEN- - -	41.0	HYDROGEN CONSUMED - -	7.3	
		UNUSED - - -	33.7	
CATALYST- - -	8.0	CATALYST - -	8.0	

TOTAL MASS BALANCE

GRAMS IN - -	1674.1
GRAMS OUT- -	1566.0
% DIFF - - -	6.5

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-10
DATE OF RUN 10-31-68

CONDITIONS OF RUN
PRESSURE - - - - - - - - - 2350.0 PSI
TEMPERATURE- - - - - - - - 450.0 C
TIME - - - - - - - - - - 1:06 HRS:MIN
COAL CONCENTRATION - - - 0.147
CATALYST CONCENTRATION - 1.7 GR; 0.846% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	214.9	UNREACTED COAL	36.9	17.81% OF MAF COAL AND H2
		PRODUCT OIL -	139.6	67.40% OF MAF COAL AND H2
		OIL < 325C	69.0	33.33% OF MAF COAL AND H2
		GAS - - - - - -	10.7	5.18% OF MAF COAL AND H2
		METHANE -	4.2(2.01%)	
		ETHANE- -	3.1(1.51%)	
		PROPANE -	2.5(1.19%)	
		BUTANE- -	1.0(0.46%)	
		REACTION WATER	19.5	9.42% OF MAF COAL AND H2
ASH- - - - - - -	30.7	ASH - - - - - -	28.7	
WATER- - - - - -	0.0	WATER - - - - -	0.0	
RECYCLE OIL -	1421.2	RECYCLE OIL-	1399.6	
HYDROGEN- - -	37.8	HYDROGEN CONSUMED - -	6.1	
		UNUSED - - -	31.6	
CATALYST- - -	1.7	CATALYST - -	1.7	

TOTAL MASS BALANCE

GRAMS IN - - 1672.9
GRAMS OUT- - 1564.3
% DIFF - - - 6.5

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-11
DATE OF RUN 11-01-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2340.0 PSI
TEMPERATURE- - - - - - - -	475.0 C
TIME - - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.147
CATALYST CONCENTRATION -	9.9 GR; 4.985% MAF

INPUT IN GRAMS

MAF COAL - - -	214.9
ASH- - - - - - -	30.7
WATER- - - - - -	0.0
RECYCLE OIL -	1421.2
HYDROGEN- - -	47.3
CATALYST- - -	9.9

OUTPUT IN GRAMS

UNREACTED COAL	17.2	7.82% OF MAF COAL AND H2
PRODUCT OIL -	113.2	51.58% OF MAF COAL AND H2
OIL < 325C	261.6	119.22% OF MAF COAL AND H2
GAS - - - - - -	61.5	28.03% OF MAF COAL AND H2
METHANE -	20.6(9.40%)	
ETHANE- -	19.7(8.98%)	
PROPANE -	15.4(7.03%)	
BUTANE- -	5.8(2.63%)	
REACTION WATER	26.0	11.85% OF MAF COAL AND H2

ASH - - - - - -	28.3
WATER - - - - -	0.0
RECYCLE OIL-	1165.2
HYDROGEN	
CONSUMED - -	20.8
UNUSED - - -	26.5
CATALYST - -	9.9

TOTAL MASS BALANCE

GRAMS IN - -	1687.6
GRAMS OUT- -	1559.8
% DIFF - - -	7.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-12
DATE OF RUN 11-04-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2440.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - - -	1:07 HRS:MIN
COAL CONCENTRATION - - -	0.147
CATALYST CONCENTRATION -	9.7 GR; 4.848% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	214.9	UNREACTED COAL	17.4	8.18% OF MAF COAL AND H2
		PRODUCT OIL -	154.7	72.84% OF MAF COAL AND H2
		OIL < 325C	103.6	48.76% OF MAF COAL AND H2
		GAS - - - - -	18.6	8.74% OF MAF COAL AND H2
		METHANE -	7.9(3.72%)	
		ETHANE- -	5.4(2.54%)	
		PROPANE -	3.8(1.80%)	
		BUTANE- -	1.4(0.68%)	
		REACTION WATER	20.9	9.84% OF MAF COAL AND H2
ASH- - - - - -	30.7	ASH - - - - - -	28.5	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1421.2	RECYCLE OIL-	1374.7	
HYDROGEN- - -	44.5	HYDROGEN CONSUMED - -	12.4	
		UNUSED - - -	32.2	
CATALYST- - -	9.7	CATALYST - -	9.7	

TOTAL MASS BALANCE

GRAMS IN - -	1679.1
GRAMS OUT- -	1563.7
% DIFF - - -	6.9

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-13
DATE OF RUN 11-05-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - - -	475.0 C
TIME - - - - - - - - - - -	2:05 HRS;MIN
COAL CONCENTRATION - - -	0.147
CATALYST CONCENTRATION -	1.7 GR; 0.868% MAF

INPUT IN GRAMS

MAF COAL - - -	214.9

OUTPUT IN GRAMS

UNREACTED COAL	10.2		4.91% OF MAF COAL AND H2
PRODUCT OIL -	126.3		60.57% OF MAF COAL AND H2
OIL < 325C	161.8		77.58% OF MAF COAL AND H2
GAS - - - - - -	50.7		24.30% OF MAF COAL AND H2
METHANE -	20.4	(9.77%)	
ETHANE- -	15.7	(7.52%)	
PROPANE -	11.3	(5.42%)	
BUTANE- -	3.3	(1.59%)	
REACTION WATER	20.2		9.69% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	30.7	ASH - - - - - -	27.9
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1421.2	RECYCLE OIL-	1260.4
HYDROGEN- - -	39.2	HYDROGEN	
		CONSUMED - -	12.6
		UNUSED - - -	26.5
CATALYST- - -	1.7	CATALYST - -	1.7

TOTAL MASS BALANCE

GRAMS IN - -	1679.4
GRAMS OUT- -	1531.3
% DIFF. - - -	8.8

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-14
DATE OF RUN 11-05-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2480.0 PSI
TEMPERATURE- - - - - - -	425.0 C
TIME - - - - - - - - - -	2:05 HRS:MIN
COAL CONCENTRATION - - -	0.147
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	214.9	UNREACTED COAL	45.0	22.17% OF MAF COAL AND H2
		PRODUCT OIL -	135.9	66.92% OF MAF COAL AND H2
		OIL < 325C	61.3	30.20% OF MAF COAL AND H2
		GAS - - - - - -	6.1	2.98% OF MAF COAL AND H2
		METHANE -	1.8(0.88%)	
		ETHANE- -	1.8(0.90%)	
		PROPANE -	1.7(0.84%)	
		BUTANE- -	0.7(0.36%)	
		REACTION WATER	15.8	7.78% OF MAF COAL AND H2
ASH- - - - - - -	30.7	ASH - - - - -	28.4	
WATER- - - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1421.2	RECYCLE OIL-	1391.7	
HYDROGEN- - -	39.0	HYDROGEN		
		CONSUMED - -	3.9	
		UNUSED - - -	35.1	
CATALYST- - -	0.0	CATALYST - -	0.0	

TOTAL MASS BALANCE

GRAMS IN - -	1670.6
GRAMS OUT- -	1548.3
% DIFF - - -	7.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-P-15
DATE OF RUN 11-06-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2520.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.147
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

OUTPUT IN GRAMS

INPUT		OUTPUT		
MAF COAL - - -	214.9	UNREACTED COAL	11.9	11.04% OF MAF COAL AND H2
		PRODUCT OIL -	76.0	70.43% OF MAF COAL AND H2
		OIL < 325C	48.6	45.04% OF MAF COAL AND H2
		GAS - - - - -	9.6	8.92% OF MAF COAL AND H2
		METHANE -	4.3(3.97%)	
		ETHANE- -	3.0(2.76%)	
		PROPANE -	1.9(1.72%)	
		BUTANE- -	0.5(0.47%)	
		REACTION WATER	9.2	8.53% OF MAF COAL AND H2

ASH- - - - - - -	30.7	ASH - - - - - -	15.1
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1421.2	RECYCLE OIL-	725.9
HYDROGEN- - -	35.2	HYDROGEN	
		CONSUMED - -	2.3
		UNUSED - - -	32.9
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1669.1
GRAMS OUT- -	820.3
% DIFF - - -	50.9

XII. Master Summary - Series P.

Summary of Experimental Results in Percent of Coal Going to Each Product

RUN	TIME	TEMP	CATCN	% UNCON	% OIL	% GAS	% H2O
L-NT-P-1	1:07	425.00	4.184	16.277	72.199	2.076	9.266
L-NT-P-2	2:06	450.00	0.000	11.598	69.328	8.637	10.272
L-NT-P-3	1:05	475.00	0.735	5.168	72.278	11.517	10.876
L-NT-P-4 G	2:07	475.00	0.000	3.904	69.613	14.651	11.473
L-NT-P-5	1:05	425.00	0.651	24.940	65.425	1.965	7.586
L-NT-P-6	1:05	475.00	4.159	4.587	66.320	16.192	12.626
L-NT-P-7	2:06	450.00	0.678	10.606	52.340	28.203	8.619
L-NT-P-8	2:06	450.00	4.098	4.798	72.077	10.688	12.026
L-NT-P-9	2:07	425.00	3.980	12.609	71.286	4.980	10.897
L-NT-P-10	1:06	450.00	0.846	17.813	67.401	5.176	9.418
L-NT-P-11	2:06	475.00	4.985	7.821	51.580	28.031	11.849
L-NT-P-12	1:07	450.00	4.848	8.182	72.836	8.745	9.838
L-NT-P-13	2:05	475.00	0.868	4.912	60.570	24.297	9.686
L-NT-P-14	2:05	425.00	0.000	22.170	66.924	2.983	7.783
L-NT-P-15	1:06	475.00	0.000	11.035	70.430	8.922	8.526

XII. Master Summary - Series P., Cont.

Summary of Experimental Results in Grams of Product Found and Loss Variation

RUN	TIME	TEMP	CATCN (%)	PRODUCT (gm)	<325C (gm)	H2USED (gm)	LOSS (%)
L-NT-P-1	1:07	425.00	4.184	169.857	90.300	5.826	7.365
L-NT-P-2	2:06	450.00	0.000	161.312	95.200	4.824	8.003
L-NT-P-3	1:05	475.00	0.735	171.465	111.200	5.834	6.574
L-NT-P-4 G	2:07	475.00	0.000	161.400	143.900	8.493	9.818
L-NT-P-5	1:05	425.00	0.651	152.658	59.700	2.834	6.936
L-NT-P-6	1:05	475.00	4.159	162.301	160.400	11.513	5.842
L-NT-P-7	2:06	450.00	0.678	129.948	93.500	12.268	4.711
L-NT-P-8	2:06	450.00	4.098	153.428	140.900	12.751	6.862
L-NT-P-9	2:07	425.00	3.980	148.494	91.700	7.318	6.457
L-NT-P-10	1:06	450.00	0.846	139.552	69.000	6.130	6.490
L-NT-P-11	2:06	475.00	4.985	113.179	261.600	20.834	7.571
L-NT-P-12	1:07	450.00	4.848	154.741	103.600	12.361	6.875
L-NT-P-13	2:05	475.00	0.868	126.321	161.800	12.642	8.820
L-NT-P-14	2:05	425.00	0.000	135.862	61.300	3.886	7.325
L-NT-P-15	1:06	475.00	0.000	76.001	48.600	2.307	50.851

TABLE VI. Coal Hydrogenation Mass Balance

XIII. Individual Output Balance Sheets - Series Q.

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-O-1
DATE OF RUN 12-06-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2500.0 PSI
TEMPERATURE- - - - - - - -	425.0 C
TIME - - - - - - - - - - -	4:08 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.0 GR; 3.991% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	2.1		0.84% OF MAF COAL AND H2
PRODUCT OIL -	194.9		79.63% OF MAF COAL AND H2
OIL < 325C	150.7		61.56% OF MAF COAL AND H2
GAS - - - - - -	26.7		10.90% OF MAF COAL AND H2
METHANE -	13.0	(5.31%)	
ETHANE- -	7.1	(2.92%)	
PROPANE -	4.5	(1.85%)	
BUTANE- -	2.0	(0.81%)	
REACTION WATER	19.4		7.93% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	32.2
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1304.1
HYDROGEN- - -	52.7	HYDROGEN	
		CONSUMED - -	19.3
		UNUSED - - -	33.4
CATALYST- - -	9.0	CATALYST - -	9.0

TOTAL MASS BALANCE

GRAMS IN - -	1686.0
GRAMS OUT- -	1535.1
% DIFF - - -	9.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-2
DATE OF RUN 12-07-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	475.0 C
TIME - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

OUTPUT IN GRAMS

INPUT	GRAMS	OUTPUT	GRAMS	
MAF COAL - - -	247.7	UNREACTED COAL	8.2	3.46% OF MAF COAL AND H2
		PRODUCT OIL -	153.1	64.58% OF MAF COAL AND H2
		OIL < 325C	152.6	64.37% OF MAF COAL AND H2
		GAS - - - - -	56.4	23.79% OF MAF COAL AND H2
		METHANE -	24.7(10.41%)	
		ETHANE- -	17.6(7.43%)	
		PROPANE -	11.2(4.71%)	
		BUTANE- -	2.9(1.23%)	
		REACTION WATER	18.1	7.64% OF MAF COAL AND H2

INPUT	GRAMS	OUTPUT	GRAMS
ASH- - - - - - -	35.3	ASH - - - - -	31.9
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1251.3
HYDROGEN- - -	39.0	HYDROGEN	
		CONSUMED - -	13.2
		UNUSED - - -	25.9
CATALYST- - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1679.9
GRAMS OUT- -	1518.6
% DIFF - - -	9.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-3
DATE OF RUN 12-07-68

CONDITIONS OF RUN

PRESSURE	2310.0 PSI
TEMPERATURE	425.0 C
TIME	2:06 HRS:MIN
COAL CONCENTRATION	0.170
CATALYST CONCENTRATION	9.0 GR; 3.877% MAF

INPUT IN GRAMS

MAF COAL	247.7
ASH	35.3
WATER	0.0
RECYCLE OIL	1383.7
HYDROGEN	47.3
CATALYST	9.0

OUTPUT IN GRAMS

UNREACTED COAL	13.0	5.25% OF MAF COAL AND H2
PRODUCT OIL	204.0	82.46% OF MAF COAL AND H2
OIL < 325C	105.0	42.45% OF MAF COAL AND H2
GAS	12.3	4.98% OF MAF COAL AND H2
METHANE	5.1 (2.06%)	
ETHANE	3.6 (1.44%)	
PROPANE	2.7 (1.10%)	
BUTANE	0.9 (0.38%)	
REACTION WATER	17.1	6.91% OF MAF COAL AND H2
ASH	33.1	
WATER	0.0	
RECYCLE OIL	1395.8	
HYDROGEN CONSUMED	15.2	
HYDROGEN UNUSED	32.1	
CATALYST	9.0	

TOTAL MASS BALANCE

GRAMS IN	1682.0
GRAMS OUT	1576.3
% DIFF	6.3

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-4
DATE OF RUN 12-08-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2340.0 PSI
TEMPERATURE- - - - - - - -	450.0 C
TIME - - - - - - - - - -	1:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	8.7 GR; 3.754% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	14.6	6.09% OF MAF COAL AND H2
		PRODUCT OIL -	192.2	80.20% OF MAF COAL AND H2
		OIL < 325C	107.3	44.76% OF MAF COAL AND H2
		GAS - - - - - -	13.4	5.57% OF MAF COAL AND H2
		METHANE -	4.3(1.81%)	
		ETHANE- -	4.1(1.70%)	
		PROPANE -	3.6(1.50%)	
		BUTANE- -	1.4(0.56%)	
		REACTION WATER	19.0	7.93% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	33.1	
WATER- - - - - -	0.0	WATER - - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1379.8	
HYDROGEN- - -	39.3	HYDROGEN		
		CONSUMED - -	7.9	
		UNUSED - - -	31.3	
CATALYST- - -	8.7	CATALYST - -	8.7	

TOTAL MASS BALANCE

GRAMS IN - -	1674.7
GRAMS OUT- -	1567.2
% DIFF - - -	6.4

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-5
DATE OF RUN 12-09-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2460.0 PSI
TEMPERATURE- - - - - - - -	450.0 C
TIME - - - - - - - - - - -	2:07 HRS;MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	9.3 GR; 4.076% MAF

INPUT IN GRAMS		OUTPUT IN GRAMS		
MAF COAL - - -	247.7	UNREACTED COAL	8.1	3.34% OF MAF COAL AND H2
		PRODUCT OIL -	186.7	77.17% OF MAF COAL AND H2
		OIL < 325C	155.1	64.12% OF MAF COAL AND H2
		GAS - - - - - -	27.5	11.35% OF MAF COAL AND H2
		METHANE -	9.3(3.85%)	
		ETHANE- -	8.2(3.38%)	
		PROPANE -	6.9(2.86%)	
		BUTANE- -	3.1(1.26%)	
		REACTION WATER	18.6	7.69% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	32.5	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1306.2	
HYDROGEN- - -	45.6	HYDROGEN CONSUMED - -	13.7	
		UNUSED - - -	31.9	
CATALYST- - -	9.3	CATALYST - -	9.3	

TOTAL MASS BALANCE

GRAMS IN - -	1680.5
GRAMS OUT- -	1548.0
% DIFF - - -	7.9

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-6
DATE OF RUN 12-09-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2460.0 PSI
TEMPERATURE - - - - - - -	475.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	20.0		8.72% OF MAF COAL AND H2
PRODUCT OIL -	162.3		70.57% OF MAF COAL AND H2
OIL < 325C	97.3		42.32% OF MAF COAL AND H2
GAS - - - - -	30.4		13.24% OF MAF COAL AND H2
METHANE -	12.8	(5.55%)	
ETHANE - -	9.0	(3.93%)	
PROPANE -	6.4	(2.77%)	
BUTANE - -	2.3	(1.00%)	
REACTION WATER	16.7		7.26% OF MAF COAL AND H2

ASH - - - - - -	35.3	ASH - - - - -	32.1
WATER - - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL -	1320.2
HYDROGEN - - -	35.6	HYDROGEN	
		CONSUMED - -	5.2
		UNUSED - - -	30.3
CATALYST - - -	0.0	CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1672.0
GRAMS OUT - -	1516.7
% DIFF - - -	9.3

-171-

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-7
DATE OF RUN 12-10-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2380.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	4:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.7 GR; 0.751% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	7.2	2.99% OF MAF COAL AND H2
PRODUCT OIL -	179.3	74.61% OF MAF COAL AND H2
OIL < 325C	161.8	67.34% OF MAF COAL AND H2
GAS - - - - -	33.6	14.00% OF MAF COAL AND H2
METHANE -	9.5(3.95%)	
ETHANE- -	10.5(4.36%)	
PROPANE -	9.3(3.89%)	
BUTANE- -	4.3(1.81%)	
REACTION WATER	19.0	7.91% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - -	35.3	ASH - - - - -	32.3
WATER- - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1282.8
HYDROGEN- - -	44.3	HYDROGEN	
		CONSUMED - -	13.8
		UNUSED - - -	30.5
CATALYST- - -	1.7	CATALYST - -	1.7

TOTAL MASS BALANCE

GRAMS IN - -	1680.5
GRAMS OUT- -	1536.7
% DIFF - - -	8.6

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-8
DATE OF RUN 12-11-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2450.0 PSI
TEMPERATURE- - - - - - - -	425.0 C
TIME - - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.7 GR; 0.734% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	25.4		10.74% OF MAF COAL AND H2
PRODUCT OIL -	185.1		78.16% OF MAF COAL AND H2
OIL < 325C	77.8		32.85% OF MAF COAL AND H2
GAS - - - - - -	9.5		4.00% OF MAF COAL AND H2
METHANE -	3.8	(1.59%)	
ETHANE- -	2.8	(1.17%)	
PROPANE -	2.3	(0.97%)	
BUTANE- -	0.6	(0.27%)	
REACTION WATER	16.5		6.97% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.1
WATER- - - - - -	0.0	WATER - - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1402.0
HYDROGEN- - -	39.4	HYDROGEN	
		CONSUMED - -	5.1
		UNUSED - - -	34.3
CATALYST- - -	1.7	CATALYST - -	1.7

TOTAL MASS BALANCE

GRAMS IN - -	1671.8
GRAMS OUT- -	1564.3
% DIFF - - -	6.4

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-9
DATE OF RUN 12-12-68

CONDITIONS OF RUN

PRESSURE - - - - - - - - -	2350.0 PSI
TEMPERATURE- - - - - - - -	475.0 C
TIME - - - - - - - - - - -	1:07 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.5 GR; 0.644% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	34.8
CATALYST- - -	1.5

OUTPUT IN GRAMS

UNREACTED COAL	8.5	3.58% OF MAF COAL AND H2
PRODUCT OIL -	181.9	76.30% OF MAF COAL AND H2
OIL < 325C	109.3	45.85% OF MAF COAL AND H2
GAS - - - - -	28.3	11.89% OF MAF COAL AND H2
METHANE -	10.7(4.50%)	
ETHANE- -	8.4(3.52%)	
PROPANE -	6.6(2.79%)	
BUTANE- -	2.6(1.08%)	
REACTION WATER	19.3	8.10% OF MAF COAL AND H2

ASH - - - - -	33.2
WATER - - - -	0.0
RECYCLE OIL-	1372.9
HYDROGEN	
CONSUMED - -	5.6
UNUSED - - -	29.1
CATALYST - -	1.5

TOTAL MASS BALANCE

GRAMS IN - -	1672.4
GRAMS OUT- -	1571.5
% DIFF - - -	6.0

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-10
DATE OF RUN 12-12-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2450.0 PSI
TEMPERATURE- - - - - - - -	450.0 C
TIME - - - - - - - - - -	2:08 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	1.6 GR; 0.691% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7

OUTPUT IN GRAMS

UNREACTED COAL	8.7		3.64% OF MAF COAL AND H2
PRODUCT OIL -	187.9		78.41% OF MAF COAL AND H2
OIL < 325C	119.5		49.86% OF MAF COAL AND H2
GAS - - - - - -	24.5		10.22% OF MAF COAL AND H2
METHANE -	9.3	(3.87%)	
ETHANE- -	7.3	(3.05%)	
PROPANE -	6.0	(2.51%)	
BUTANE- -	1.9	(0.79%)	
REACTION WATER	18.0		7.51% OF MAF COAL AND H2

INPUT		OUTPUT	
ASH- - - - - - -	35.3	ASH - - - - - -	33.0
WATER- - - - - -	0.0	WATER - - - -	0.0
RECYCLE OIL -	1383.7	RECYCLE OIL-	1362.2
HYDROGEN- - -	40.0	HYDROGEN	
		CONSUMED - -	8.1
		UNUSED - - -	31.9
CATALYST- - -	1.6	CATALYST - -	1.6

TOTAL MASS BALANCE

GRAMS IN - -	1674.8
GRAMS OUT- -	1566.0
% DIFF - - -	6.5

-175-

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-11
DATE OF RUN 12-13-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2500.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	1:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.3 GR; 0.130% MAF

INPUT IN GRAMS

OUTPUT IN GRAMS

INPUT		OUTPUT		
MAF COAL - - -	247.7	UNREACTED COAL	27.1	11.51% OF MAF COAL AND H2
		PRODUCT OIL -	176.2	74.97% OF MAF COAL AND H2
		OIL < 325C	79.1	33.66% OF MAF COAL AND H2
		GAS - - - - -	14.6	6.19% OF MAF COAL AND H2
		METHANE -	5.9(2.50%)	
		ETHANE- -	4.5(1.91%)	
		PROPANE -	3.3(1.39%)	
		BUTANE- -	0.9(0.40%)	
		REACTION WATER	17.0	7.23% OF MAF COAL AND H2
ASH- - - - - - -	35.3	ASH - - - - - -	33.0	
WATER- - - - -	0.0	WATER - - - -	0.0	
RECYCLE OIL -	1383.7	RECYCLE OIL-	1391.0	
HYDROGEN- - -	36.8	HYDROGEN		
		CONSUMED - -	3.4	
		UNUSED - - -	33.4	
CATALYST- - -	0.3	CATALYST - -	0.3	

TOTAL MASS BALANCE

GRAMS IN - -	1670.2
GRAMS OUT- -	1561.8
% DIFF - - -	6.5

COAL HYDROGENATION MASS BALANCE

RUN NUMBER L-NT-Q-12
DATE OF RUN 12-13-68

CONDITIONS OF RUN

PRESSURE - - - - - - - -	2300.0 PSI
TEMPERATURE- - - - - - -	450.0 C
TIME - - - - - - - - - -	2:06 HRS:MIN
COAL CONCENTRATION - - -	0.170
CATALYST CONCENTRATION -	0.0 GR; 0.000% MAF

INPUT IN GRAMS

MAF COAL - - -	247.7
ASH- - - - - -	35.3
WATER- - - - -	0.0
RECYCLE OIL -	1383.7
HYDROGEN- - -	34.9
CATALYST- - -	0.0

OUTPUT IN GRAMS

UNREACTED COAL	7.9		5.94% OF MAF COAL AND H2
PRODUCT OIL -	98.1		73.66% OF MAF COAL AND H2
OIL < 325C	65.2		48.98% OF MAF COAL AND H2
GAS - - - - - -	12.7		9.54% OF MAF COAL AND H2
METHANE -	5.1	(3.84%)	
ETHANE- -	3.9	(2.94%)	
PROPANE -	2.9	(2.16%)	
BUTANE- -	0.8	(0.60%)	
REACTION WATER	12.5		9.39% OF MAF COAL AND H2

ASH - - - - -	18.4
WATER - - - -	0.0
RECYCLE OIL-	753.7
HYDROGEN	
CONSUMED - -	4.1
UNUSED - - -	30.8
CATALYST - -	0.0

TOTAL MASS BALANCE

GRAMS IN - -	1670.8
GRAMS OUT- -	870.4
% DIFF - - -	47.9

XIV. Master Summary - Series Q.

Summary of Experimental Results in Percent of Coal Going to Each Product

RUN	TIME	TEMP	CATCN	% UNCON	% OIL	% GAS	% H2O
L-NT-Q-1	4:08	425.00	3.991	0.842	79.632	10.896	7.925
L-NT-Q-2	2:06	475.00	0.000	3.463	64.580	23.788	7.635
L-NT-Q-3	2:06	425.00	3.877	5.255	82.463	4.982	6.914
L-NT-Q-4	1:07	450.00	3.754	6.094	80.197	5.570	7.926
L-NT-Q-5	2:07	450.00	4.076	3.343	77.168	11.351	7.689
L-NT-Q-6	1:06	475.00	0.000	8.716	70.568	13.241	7.263
L-NT-Q-7	4:06	450.00	0.751	2.993	74.611	13.998	7.907
L-NT-Q-8	2:06	425.00	0.734	10.739	78.157	3.999	6.967
L-NT-Q-9	1:07	475.00	0.644	3.577	76.299	11.885	8.096
L-NT-Q-10	2:08	450.00	0.691	3.640	78.413	10.217	7.511
L-NT-Q-11	1:06	450.00	0.130	11.513	74.967	6.192	7.233
L-NT-Q-12	2:06	450.00	0.000	5.937	73.657	9.540	9.390

XIV. Master Summary - Series Q., Cont.

Summary of Experimental Results in Grams of Product Found and Loss Variation

RUN	TIME	TEMP	CATCN (%)	PRODUCT (gm)	<325C (gm)	H2USED (gm)	LOSS (%)
L-NT-Q-1	4:08	425.00	3.991	194.927	150.700	19.282	8.954
L-NT-Q-2	2:06	475.00	0.000	153.088	152.600	13.157	9.603
L-NT-Q-3	2:06	425.00	3.877	203.962	105.000	15.213	6.281
L-NT-Q-4	1:07	450.00	3.754	192.244	107.300	7.939	6.421
L-NT-Q-5	2:07	450.00	4.076	186.663	155.100	13.747	7.887
L-NT-Q-6	1:06	475.00	0.000	162.251	97.300	5.239	9.285
L-NT-Q-7	4:06	450.00	0.751	179.277	161.800	13.799	8.558
L-NT-Q-8	2:06	425.00	0.734	185.094	77.800	5.080	6.433
L-NT-Q-9	1:07	475.00	0.644	181.878	109.300	5.633	6.030
L-NT-Q-10	2:08	450.00	0.691	187.921	119.500	8.071	6.498
L-NT-Q-11	1:06	450.00	0.130	176.192	79.100	3.426	6.492
L-NT-Q-12	2:06	450.00	0.000	98.056	65.200	4.101	47.907

TABLE VII. Statistical Variations.

A. Recycle Number One.

MULTIPLE REGRESSION WITH 13 VARIABLES AND 38 OBSERVATIONS

I	MEAN	ST. DEVIATION	VARIANCE	SUM OF SQUARES
1	0.83907372E+00	0.58456248E+00	0.34171361E+00	0.12643406E+02
2	0.45328931E+03	0.19426804E+02	0.37740039E+03	0.13963820E+05
3	0.70628428E+00	0.69317406E+00	0.48049015E+00	0.17778137E+02
4	0.84267263E+01	0.52527466E+01	0.27591324E+02	0.10208792E+04
5	0.56188889E+02	0.18282181E+02	0.33423804E+03	0.12366813E+05
6	0.23588867E+02	0.15570796E+02	0.24244972E+03	0.89706406E+04
7	0.11269045E+02	0.30648708E+01	0.93934412E+01	0.34755737E+03
8	0.83193176E+02	0.21982162E+02	0.48321533E+03	0.17878969E+05
9	0.19239120E+02	0.83582716E+01	0.69860733E+02	0.25848477E+04
10	0.24064429E+03	0.34710547E+03	0.12048213E+06	0.44578400E+07
11	0.37940771E+03	0.26549951E+03	0.70490000E+05	0.26081310E+07
12	0.53037548E+00	0.76268357E+00	0.58168644E+00	0.21522400E+02
13	0.32179468E+03	0.31691357E+03	0.10043413E+06	0.37160640E+07

TABLE VIII. Correlations of All Variables With Each Other Recycle Number.

A. Recycle Number One.

I	J	K	CORRELATIONS OF VARIABLE I WITH VARIABLES J THROUGH K					
1	2	7	-0.084652	-0.157783	-0.162271	-0.440138	0.471690	0.460165
1	8	13	0.524660	0.732579	0.482117	0.997396	0.482076	-0.162795
2	3	8	0.125343	0.058163	-0.724559	0.751215	0.365073	0.514051
2	9	13	0.370681	0.045258	-0.026048	0.016129	0.170185	
3	4	9	-0.662508	0.175155	0.049974	-0.181039	0.457772	0.352710
3	10	13	0.610658	-0.152485	0.612305	0.998052		
4	5	10	-0.277505	-0.018729	0.076149	-0.477703	-0.447880	-0.594038
4	11	13	-0.154666	-0.600001	-0.664604			
5	6	11	-0.944790	-0.654094	-0.566525	-0.596983	-0.122393	-0.491766
5	12	13	-0.092754	0.143108				
6	7	12	0.540051	0.709614	0.754528	0.318207	0.522912	0.289457
6	13	13	0.084500					
7	8	13	0.539314	0.429332	0.089427	0.492304	0.069486	-0.162907
8	9	13	0.849788	0.647794	0.561254	0.631541	0.475576	
9	10	13	0.692821	0.759962	0.680939	0.362640		
10	11	13	0.489211	0.998700	0.605626			
11	12	13	0.486617	-0.155167				
12	13	13	0.604880					

TABLE IX. Regression Equations for Individual Yields and Their Degrees of Fit to the Equation.

A. Recycle Number One.

Y=VAR 4	I	B	SB	T	PAR R
	1	0.49863495E+02	0.33339798E+02	1.50	0.2634
	2	0.19866860E+00	0.76231718E-01	2.61	0.4297
	3	0.99323792E+02	0.30069351E+02	3.30	0.5164
	10	0.17995512E+00	0.69442153E-01	2.59	0.4277
	11	-0.11392790E+00	0.73700964E-01	-1.55	-0.2716
	12	-0.83040497E+02	0.31604782E+02	-2.63	-0.4325
	13	-0.22823530E+00	0.65943122E-01	-3.46	-0.5342
	0	-0.76210083E+02			

MULTIPLE R=0.8193, R SQUARE=0.6713 ST ERROR OF EST=0.33446207E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.68528467E+03	0.97897797E+02	8.75
ABOUT REG	30	0.33559448E+03	0.11186482E+02	
TOTAL	37	0.10208792E+04		

Y=VAR 5	I	B	SB	T	PAR R
	1	0.32660202E+02	0.72961853E+02	0.45	0.0815
	2	-0.66258001E+00	0.16682023E+00	-3.97	-0.5870
	3	-0.93279343E+02	0.65791336E+02	-1.42	-0.2506
	10	-0.27110833E+00	0.15192187E+00	-1.78	-0.3098
	11	-0.10946023E+00	0.16128939E+00	-0.68	-0.1230
	12	0.12706796E+03	0.69143112E+02	1.84	0.3181
	13	0.20923460E+00	0.14428318E+00	1.45	0.2559
	0	0.36705249E+03			

MULTIPLE R=0.9328, R SQUARE=0.8701 ST ERROR OF EST=0.73173418E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.10760508E+05	0.15372153E+04	28.71
ABOUT REG	30	0.16063047E+04	0.53543488E+02	
TOTAL	37	0.12366813E+05		

TABLE IX. Regression Equations - Recycle Number One., Cont.

Y=VAR 6 I	B	SB	T	PAR R
1	-0.57213181E+02	0.59206787E+02	-0.97	-0.1737
2	0.45026690E+00	0.13536626E+00	3.33	0.5191
3	-0.47265158E+01	0.53381256E+02	-0.09	-0.0162
10	0.81948578E-01	0.12329209E+00	0.66	0.1205
11	0.15969998E+00	0.13088262E+00	1.22	0.2174
12	-0.38634430E+02	0.56113068E+02	-0.69	-0.1247
13	0.15234061E-01	0.11706728E+00	0.13	0.0238
0	-0.19389128E+03			

MULTIPLE R=0.9392, R SQUARE=0.8820 ST ERROR OF EST=0.59398260E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.79121953E+04	0.11303135E+04	32.04
ABOUT REG	30	0.10584453E+04	0.35281509E+02	
TOTAL	37	0.89706406E+04		

Y=VAR 7 I	B	SB	T	PAR R
1	-0.23086868E+02	0.24433914E+02	-0.94	-0.1700
2	0.98958984E-02	0.55865441E-01	0.18	0.0323
3	0.78202128E-01	0.22031326E+02	0.00	0.0006
10	0.16341925E-01	0.50879117E-01	0.32	0.0585
11	0.58189306E-01	0.54013688E-01	1.08	0.1930
12	-0.86611423E+01	0.23156250E+02	-0.37	-0.0681
13	0.55026938E-03	0.48315592E-01	0.01	0.0021
0	0.45061827E+01			

MULTIPLE R=0.6939, R SQUARE=0.4815 ST ERROR OF EST=0.24509602E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.16734094E+03	0.23905838E+02	3.98
ABOUT REG	30	0.18021643E+03	0.60072136E+01	
TOTAL	37	0.34755737E+03		

TABLE IX. Regression Equations - Recycle Number One., Cont.

Y=VAR 8

I	B	SB	T	PAR R
1	-0.13668549E+03	0.95002686E+02	-1.44	-0.2541
2	0.27593875E+00	0.21721733E+00	1.27	0.2259
3	-0.20016632E+02	0.85670593E+02	-0.23	-0.0426
10	-0.90942681E-01	0.19782442E+00	-0.46	-0.0836
11	0.35486639E+00	0.21001267E+00	1.69	0.2948
12	0.40943359E+02	0.90034454E+02	0.45	0.0827
13	0.79614043E-01	0.18787903E+00	0.42	0.0771
0	-0.73149216E+02			

MULTIPLE R=0.9207, R SQUARE=0.8477 ST ERROR OF EST=0.95273228E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.15155875E+05	0.21651250E+04	23.85
ABOUT REG	30	0.27230938E+04	0.90769791E+02	
TOTAL	37	0.17878969E+05		

Y=VAR 9

I	B	SB	T	PAR R
1	-0.20126144E+02	0.25925461E+02	-0.78	-0.1403
2	0.12719947E+00	0.59275683E-01	2.15	0.3648
3	0.19545532E+02	0.23380737E+02	0.84	0.1509
10	0.95499568E-02	0.53988934E-01	0.18	0.0323
11	0.70646882E-01	0.57310637E-01	1.23	0.2196
12	-0.45444012E+01	0.24571609E+02	-0.18	-0.0337
13	-0.31010062E-01	0.51274981E-01	-0.60	-0.1098
0	-0.52049393E+02			

MULTIPLE R=0.9600, R SQUARE=0.9216 ST ERROR OF EST=0.25992699E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.23821616E+04	0.34030859E+03	50.37
ABOUT REG	30	0.20268604E+03	0.67562008E+01	
TOTAL	37	0.25848477E+04		

TABLE VII. Statistical Variations.

B. Recycle Number Two.

MULTIPLE REGRESSION WITH 13 VARIABLES AND 23 OBSERVATIONS

I	MEAN	ST. DEVIATION	VARIANCE	SUM OF SQUARES
1	0.66301125E+00	0.57151574E+00	0.32663018E+00	0.71858654E+01
2	0.44891284E+03	0.21948105E+02	0.48171924E+03	0.10597828E+05
3	0.71934724E+00	0.70405644E+00	0.49569559E+00	0.10905304E+02
4	0.11459901E+02	0.76020679E+01	0.57791397E+02	0.12714111E+04
5	0.67853088E+02	0.96979551E+01	0.94050323E+02	0.20691074E+04
6	0.10535774E+02	0.78341455E+01	0.61373795E+02	0.13502236E+04
7	0.96944714E+01	0.22438030E+01	0.50346603E+01	0.11076254E+03
8	0.52618591E+02	0.25215454E+02	0.63581909E+03	0.13988023E+05
9	0.11350904E+02	0.73263454E+01	0.53675308E+02	0.11808572E+04
10	0.21400594E+03	0.31892383E+03	0.10171231E+06	0.22376710E+07
11	0.29684863E+03	0.25789014E+03	0.66507313E+05	0.14631610E+07
12	0.47737962E+00	0.70756358E+00	0.50064647E+00	0.11014223E+02
13	0.32314014E+03	0.31822510E+03	0.10126719E+06	0.22278790E+07

TABLE VIII. Correlations of All Variables With Each Other Recycle Number.

B. Recycle Number Two.

I	J	K	CORRELATIONS OF VARIABLE I WITH VARIABLES J THROUGH K					
1	2	7	-0.065523	0.001154	-0.308789	-0.123050	0.285866	0.437806
1	8	13	0.507006	0.717549	0.574711	0.996936	0.576097	-0.001377
2	3	8	0.014603	-0.303257	-0.601065	0.856019	0.618943	0.588760
2	9	13	0.312748	0.016908	-0.003026	-0.019923	0.064488	
3	4	9	-0.466161	0.105599	0.199223	0.395518	0.432269	0.460966
3	10	13	0.609986	0.002700	0.610383	0.997614		
4	5	10	-0.377196	-0.343445	-0.485796	-0.487890	-0.583523	-0.303891
4	11	13	-0.301077	-0.316392	-0.469719			
5	6	11	-0.726863	-0.482036	-0.501727	-0.285090	-0.217618	-0.187937
5	12	13	-0.171642	0.067389				
6	7	12	0.751494	0.851935	0.662467	0.389941	0.344852	0.349198
6	13	13	0.245083					
7	8	13	0.750891	0.757330	0.509299	0.485258	0.493890	0.412976
8	9	13	0.828272	0.636813	0.550032	0.608357	0.465773	
9	10	13	0.744625	0.736224	0.732649	0.476016		
10	11	13	0.577357	0.997990	0.609878			
11	12	13	0.575098	0.003308				
12	13	13	0.606829					

TABLE IX. Regression Equations for Individual Yields and Their Degrees of Fit to the Equation.

B. Recycle Number Two.

Y=VAR 4

I	B	SB	T	PAR R
1	-0.17325826E+03	0.36127457E+02	-4.80	-0.7780
2	-0.46120846E+00	0.72333992E-01	-6.38	-0.8547
3	-0.58595520E+02	0.31830734E+02	-1.84	-0.4293
10	0.21696973E-02	0.77872157E-01	0.03	0.0072
11	0.36446387E+00	0.79884350E-01	4.56	0.7624
12	0.49166822E+01	0.35131622E+02	0.14	0.0361
13	0.11079484E+00	0.70442080E-01	1.57	0.3763
0	0.22872021E+03			

MULTIPLE R=0.9392, R SQUARE=0.8822 ST ERROR OF EST=0.31602345E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.11216050E+04	0.16022928E+03	16.04
ABOUT REG	15	0.14980615E+03	0.99870768E+01	
TOTAL	22	0.12714111E+04		

Y=VAR 5

I	B	SB	T	PAR R
1	0.18696550E+03	0.49375214E+02	3.79	0.6991
2	0.11146969E+00	0.98854601E-01	1.13	0.2795
3	0.30048981E+02	0.43491882E+02	0.69	0.1756
10	-0.80305994E-01	0.10643077E+00	-0.75	-0.1912
11	-0.40726334E+00	0.10917795E+00	-3.73	-0.6937
12	0.28193420E+02	0.48015411E+02	0.59	0.1499
13	-0.52167132E-01	0.96248984E-01	-0.54	-0.1386
0	0.13716894E+02			

MULTIPLE R=0.9298, R SQUARE=0.8646 ST ERROR OF EST=0.43217545E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.17889441E+04	0.25556343E+03	13.68
ABOUT REG	15	0.28016333E+03	0.18677551E+02	
TOTAL	22	0.20691074E+04		

TABLE IX. Regression Equations - Recycle Number Two., Cont.

Y=VAR 6

I	B	SB	T	PAR R
1	0.11693995E+02	0.28530197E+02	0.41	0.1052
2	0.29399008E+00	0.57116121E-01	5.15	0.7991
3	0.21142700E+02	0.25130676E+02	0.84	0.2123
10	0.12077254E+00	0.61495166E-01	1.96	0.4523
11	-0.19095656E-01	0.63085616E-01	-0.30	-0.0779
12	-0.52216614E+02	0.27743149E+02	-1.88	-0.4371
13	-0.45223776E-01	0.55614971E-01	-0.81	-0.2055
0	-0.12503906E+03			

MULTIPLE R=0.9648, R SQUARE=0.9308 ST ERROR OF EST=0.24958792E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.12567825E+04	0.17954034E+03	28.82
ABOUT REG	15	0.93441162E+02	0.62294102E+01	
TOTAL	22	0.13502236E+04		

Y=VAR 7

I	B	SB	T	PAR R
1	-0.23618668E+02	0.10846324E+02	-2.18	-0.4901
2	0.53742558E-01	0.21718509E-01	2.47	0.5384
3	0.83706217E+01	0.95570040E+01	0.88	0.2206
10	-0.33582710E-01	0.23379318E-01	-1.44	-0.3477
11	0.56661777E-01	0.23983222E-01	2.36	0.5208
12	0.15043187E+02	0.10547423E+02	1.43	0.3456
13	-0.15783709E-01	0.21149911E-01	-0.75	-0.1892
0	-0.16507202E+02			

MULTIPLE R=0.9370, R SQUARE=0.8780 ST ERROR OF EST=0.94911832E+00

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.97250137E+02	0.13892877E+02	15.42
ABOUT REG	15	0.13512405E+02	0.90082699E+00	
TOTAL	22	0.11076254E+03		

TABLE IX. Regression Equations - Recycle Number Two., Cont.

Y=VAR 8

I	B	SB	T	PAR R
1	-0.94152969E+02	0.13185646E+03	-0.71	-0.1813
2	0.39315295E+00	0.26395917E+00	1.49	0.3589
3	-0.74760529E+02	0.11613957E+03	-0.64	-0.1640
10	-0.14744934E-01	0.28422511E+00	-0.05	-0.0134
11	0.25186992E+00	0.29155952E+00	0.86	0.2177
12	0.12881731E+02	0.12822620E+03	0.10	0.0259
13	0.19089067E+00	0.25702041E+00	0.74	0.1883
0	-0.14711517E+03			

MULTIPLE R=0.9259, R SQUARE=0.8573 ST ERROR OF EST=0.11535554E+02

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.11991988E+05	0.17131411E+04	12.87
ABOUT REG	15	0.19960352E+04	0.13306900E+03	
TOTAL	22	0.13988023E+05		

Y=VAR 9

I	B	SB	T	PAR R
1	0.30208496E+02	0.38053802E+02	0.79	0.2008
2	0.14882046E+00	0.76182485E-01	1.95	0.4503
3	0.12280475E+02	0.33514008E+02	0.37	0.0942
10	0.32948680E-01	0.82004845E-01	0.40	0.1032
11	-0.47843009E-01	0.84144175E-01	-0.57	-0.1453
12	-0.13616356E+02	0.36995911E+02	-0.37	-0.0946
13	-0.18371675E-01	0.74167550E-01	-0.25	-0.0638
0	-0.64731247E+02			

MULTIPLE R=0.9269, R SQUARE=0.8592 ST ERROR OF EST=0.33295612E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.10145676E+04	0.14493823E+03	13.07
ABOUT REG	15	0.16628955E+03	0.11085970E+02	
TOTAL	22	0.11808572E+04		

TABLE VII. Statistical Variations.

C. Recycle Number Three.

MULTIPLE REGRESSION WITH 13 VARIABLES AND 21 OBSERVATIONS

I	MEAN	ST. DEVIATION	VARIANCE	SUM OF SQUARES
1	0.69314772E+00	0.57992762E+00	0.33631635E+00	0.67263279E+01
2	0.45238086E+03	0.22227188E+02	0.49404761E+03	0.98809531E+04
3	0.82799232E+00	0.71581191E+00	0.51238650E+00	0.10247731E+02
4	0.95540504E+01	0.67471113E+01	0.45523483E+02	0.91046997E+03
5	0.63880127E+02	0.15321429E+02	0.23474626E+03	0.46949258E+04
6	0.15066727E+02	0.13792003E+02	0.19021931E+03	0.38043867E+04
7	0.10626530E+02	0.19903822E+01	0.39616203E+01	0.79232422E+02
8	0.56852631E+02	0.23957779E+02	0.57397461E+03	0.11479496E+05
9	0.14041242E+02	0.10200671E+02	0.10405371E+03	0.20810745E+04
10	0.23400545E+03	0.33239722E+03	0.11048781E+06	0.22097570E+07
11	0.31274219E+03	0.26179956E+03	0.68538938E+05	0.13707800E+07
12	0.51793480E+00	0.73661584E+00	0.54260331E+00	0.10852068E+02
13	0.37380518E+03	0.32341089E+03	0.10459463E+06	0.20918930E+07

TABLE VIII. Correlations of All Variables With Each Other Recycle Number.

C. Recycle Number Three.

I	J	K	CORRELATIONS OF VARIABLE I WITH VARIABLES J THROUGH K					
1	2	7	-0.067216	-0.141612	-0.382468	-0.365365	0.489408	0.387295
1	8	13	0.365904	0.764591	0.564227	0.996824	0.564781	-0.140503
2	3	8	-0.050291	-0.322499	-0.569365	0.709427	0.325550	0.682484
2	9	13	0.281800	0.018897	-0.004077	-0.019103	0.005456	
3	4	9	-0.284985	0.069949	0.047568	0.130118	0.378967	0.247171
3	10	13	0.562535	-0.139749	0.563612	0.997278		
4	5	10	-0.171247	-0.218985	-0.467151	-0.438701	-0.448333	-0.469311
4	11	13	-0.376211	-0.473571	-0.301588			
5	6	11	-0.917494	-0.287832	-0.652748	-0.614451	-0.200005	-0.430088
5	12	13	-0.161580	0.034845				
6	7	12	0.393770	0.825786	0.778356	0.393703	0.552397	0.353802
6	13	13	0.091810					
7	8	13	0.457279	0.369990	0.183850	0.403103	0.190517	0.140124
8	9	13	0.674684	0.568173	0.417293	0.535813	0.423095	
9	10	13	0.689974	0.791880	0.669063	0.271204		
10	11	13	0.568442	0.997918	0.565110			
11	12	13	0.565199	-0.135324				
12	13	13	0.562487					

TABLE IX. Regression Equations for Individual Yields and Their Degrees of Fit to the Equation.

C. Recycle Number Three.

Y=VAR 4

I	B	SB	T	PAR R
1	-0.20767900E+03	0.48236694E+02	-4.31	-0.7667
2	-0.50490570E+00	0.10428554E+00	-4.84	-0.8020
3	-0.79884323E+02	0.42180832E+02	-1.89	-0.4650
10	-0.13659137E+00	0.98384023E-01	-1.39	-0.3593
11	0.44451910E+00	0.10584283E+00	4.20	0.7587
12	0.62823624E+02	0.44601425E+02	1.41	0.3639
13	0.16544443E+00	0.92503250E-01	1.79	0.4444
0	0.24661964E+03			

MULTIPLE R=0.8990, R SQUARE=0.8083 ST ERROR OF EST=0.36644430E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.73590405E+03	0.10512915E+03	7.83
ABOUT REG	13	0.17456592E+03	0.13428147E+02	
TOTAL	20	0.91046997E+03		

Y=VAR 5

I	B	SB	T	PAR R
1	0.41050830E+03	0.92946869E+02	4.42	0.7746
2	0.35692388E+00	0.20096624E+00	1.78	0.4419
3	0.12568144E+03	0.81273727E+02	1.55	0.3942
10	0.26883829E+00	0.18953675E+00	1.42	0.3661
11	-0.93482715E+00	0.20394659E+00	-4.58	-0.7860
12	-0.11900180E+03	0.85924927E+02	-1.38	-0.3586
13	-0.27856505E+00	0.17823404E+00	-1.56	-0.3977
0	-0.90976517E+02			

MULTIPLE R=0.9284, R SQUARE=0.8619 ST ERROR OF EST=0.70618544E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.40466187E+04	0.57808838E+03	11.59
ABOUT REG	13	0.64830713E+03	0.49869766E+02	
TOTAL	20	0.46949258E+04		

TABLE IX. Regression Equations - Recycle Number Three., Cont.

Y=VAR 6	I	B	SB	T	PAR R
	1	-0.17729515E+03	0.51369202E+02	-3.45	-0.6915
	2	0.10336792E+00	0.11104780E+00	0.93	0.2500
	3	-0.41435379E+02	0.44901321E+02	-0.92	-0.2479
	10	-0.52193712E-01	0.10474616E+00	-0.50	-0.1369
	11	0.42394668E+00	0.11271626E+00	3.76	0.7219
	12	0.22066864E+02	0.47485458E+02	0.46	0.1278
	13	0.99153161E-01	0.98469198E-01	1.01	0.2690
	0	-0.43360565E+02			

MULTIPLE R=0.9736, R SQUARE=0.9479 ST ERROR OF EST=0.39040585E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.36062449E+04	0.51517773E+03	33.80
ABOUT REG	13	0.19814185E+03	0.15241680E+02	
TOTAL	20	0.38043867E+04		

Y=VAR 7	I	B	SB	T	PAR R
	1	-0.10736432E+02	0.19706207E+02	-0.54	-0.1494
	2	0.39531048E-01	0.42599633E-01	0.93	0.2492
	3	-0.67382841E+01	0.17226044E+02	-0.39	-0.1079
	10	-0.72913289E-01	0.40182617E-01	-1.81	-0.4495
	11	0.30922834E-01	0.43240167E-01	0.72	0.1946
	12	0.30886719E+02	0.18216385E+02	1.70	0.4256
	13	0.19181814E-01	0.37776951E-01	0.51	0.1395
	0	-0.10011735E+02			

MULTIPLE R=0.7951, R SQUARE=0.6322 ST ERROR OF EST=0.14971514E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.50093369E+02	0.71561947E+01	3.19
ABOUT REG	13	0.29139053E+02	0.22414656E+01	
TOTAL	20	0.79232422E+02		

TABLE IX. Regression Equations - Recycle Number Three., Cont.

Y=VAR 8

I	B	SB	T	PAR R
1	-0.14234724E+03	0.13041565E+03	-1.09	-0.2897
2	0.40403581E+00	0.28189504E+00	1.43	0.3694
3	-0.10048965E+03	0.11397453E+03	-0.88	-0.2375
10	-0.14523512E+00	0.26590496E+00	-0.55	-0.1498
11	0.35367435E+00	0.28616321E+00	1.24	0.3243
12	0.67762253E+02	0.12054504E+03	0.56	0.1540
13	0.25342155E+00	0.24994725E+00	1.01	0.2707
0	-0.15050288E+03			

MULTIPLE R=0.9428, R SQUARE=0.8888 ST ERROR OF EST=0.99087219E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.10203121E+05	0.14575886E+04	14.85
ABOUT REG	13	0.12763750E+04	0.98182678E+02	
TOTAL	20	0.11479496E+05		

Y=VAR 9

I	B	SB	T	PAR R
1	-0.25698456E+02	0.59969482E+02	-0.43	-0.1180
2	0.45763321E-01	0.12963080E+00	0.35	0.0974
3	-0.12642279E+02	0.52415955E+02	-0.24	-0.0667
10	0.33474863E-01	0.12228036E+00	0.27	0.0757
11	0.89648366E-01	0.13158721E+00	0.68	0.1857
12	-0.15307638E+02	0.55434494E+02	-0.28	-0.0764
13	0.39956804E-01	0.11494863E+00	0.35	0.0960
0	-0.21258499E+02			

MULTIPLE R=0.9329, R SQUARE=0.8703 ST ERROR OF EST=0.45559950E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.18112322E+04	0.25874731E+03	12.47
ABOUT REG	13	0.26984229E+03	0.20757095E+02	
TOTAL	20	0.20810745E+04		

TABLE VII. Statistical Variations.

D. Recycle Number Four.

MULTIPLE REGRESSIØN WITH 13 VARIABLES AND 12 ØBSERVATIØNS

I	MEAN	ST. DEVIATIØN	VARIANCE	SUM ØF SQUARES
1	0.57762337F+00	0.49749976E+00	0.24750584E+00	0.27225657E+01
2	0.44999976E+03	0.18463730E+02	0.34090918E+03	0.37500039E+04
3	0.71924740E+00	0.68169278E+00	0.46470511E+00	0.51117582E+01
4	0.55093241E+01	0.32820568E+01	0.10771902E+02	0.11849097E+03
5	0.75892654F+02	0.47937050E+01	0.22979584E+02	0.25277560E+03
6	0.10471582E+02	0.53571167E+01	0.28698669E+02	0.31568555E+03
7	0.77046661E+01	0.65791720E+00	0.43285519E+00	0.47614088E+01
8	0.49843826E+02	0.11919749E+02	0.14208038E+03	0.15628848E+04
9	0.95572586E+01	0.52340450E+01	0.27395203E+02	0.30134741E+03
10	0.21634692E+03	0.29930444E+03	0.89583063E+05	0.98541400E+06
11	0.25559814E+03	0.21870854E+03	0.47833438E+05	0.52616800E+06
12	0.49793911E+00	0.69720811E+00	0.48609906E+00	0.53470917E+01
13	0.31690015E+03	0.29767798E+03	0.88612125E+05	0.97473400E+06

TABLE VIII. Correlations of All Variables With Each Other Recycle Number.

D. Recycle Number Four.

I	J	K	CORRELATIONS OF VARIABLE I WITH VARIABLES J THROUGH K					
1	2	7	-0.514494	0.265322	-0.580665	0.105618	0.211588	0.139253
1	8	13	0.658812	0.724975	0.731827	0.998530	0.726877	0.245276
2	3	8	-0.586022	-0.040502	-0.739647	0.667187	0.222266	0.161901
2	9	13	-0.365604	-0.648193	-0.477884	-0.654735	-0.560077	
3	4	9	-0.416647	0.755177	-0.392579	-0.169565	0.211361	0.644869
3	10	13	0.708150	0.237856	0.706011	0.998967		
4	5	10	-0.059159	-0.490134	-0.370892	-0.844341	-0.745831	-0.552952
4	11	13	-0.589305	-0.546670	-0.419902			
5	6	11	-0.824991	-0.169733	-0.283615	0.185263	0.480737	0.066603
5	12	13	0.483413	0.750405				
6	7	12	0.199213	0.700132	0.294276	-0.089225	0.249433	-0.095332
6	13	13	-0.387055					
7	8	13	0.348590	-0.118457	-0.114929	0.153687	-0.116895	-0.157341
8	9	13	0.721159	0.464930	0.683725	0.450529	0.217966	
9	10	13	0.840692	0.718667	0.838227	0.629420		
10	11	13	0.704005	0.999550	0.687685			
11	12	13	0.698138	0.219054				
12	13	13	0.684657					

TABLE IX. Regression Equations for Individual Yields and Their Degrees of Fit to the Equation.

D. Recycle Number Four.

Y=VAR 4 I	B	SB	T	PAR R
1	0.16630020E+02	0.72030487E+02	0.23	0.1147
2	-0.13701326E+00	0.94115019E-01	-1.46	-0.5885
3	0.41421906E+02	0.53912872E+02	0.77	0.3586
10	0.18906033E+00	0.14866316E+00	1.27	0.5366
11	-0.51193979E-01	0.15681291E+00	-0.33	-0.1611
12	-0.82522247E+02	0.66385483E+02	-1.24	-0.5279
13	-0.10112047E+00	0.11934513E+00	-0.85	-0.3901
0	0.73085373E+02			

MULTIPLE R=0.9456, R SQUARE=0.8941 ST ERROR OF EST=0.17712622E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.10594147E+03	0.15134495E+02	4.82
ABOUT REG	4	0.12549500E+02	0.31373749E+01	
TOTAL	11	0.11849097E+03		

Y=VAR 5 I	B	SB	T	PAR R
1	0.13144202E+03	0.11295827E+03	1.16	0.5029
2	-0.87153614E-01	0.14743763E+00	-0.59	-0.2834
3	-0.20641113E+02	0.84379044E+02	-0.24	-0.1214
10	0.10761905E+00	0.23279172E+00	0.46	0.2252
11	-0.29360044E+00	0.24591571E+00	-1.19	-0.5126
12	-0.50363419E+02	0.10396616E+03	-0.48	-0.2354
13	0.55997439E-01	0.18678117E+00	0.30	0.1482
0	0.11312685E+03			

MULTIPLE R=0.9375, R SQUARE=0.8789 ST ERROR OF EST=0.27663755E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.22216426E+03	0.31737747E+02	4.15
ABOUT REG	4	0.30611343E+02	0.76528358E+01	
TOTAL	11	0.25277560E+03		

TABLE IX. Regression Equations - Recycle Number Four., Cont.

Y=VAR 6

I	B	SB	T	PAR R
1	-0.13694221E+03	0.71785477E+02	-1.91	-0.6902
2	0.23782831E+00	0.93852758E-01	2.53	0.7850
3	0.13507530E+02	0.53805328E+02	0.25	0.1245
10	-0.20219952E+00	0.14824975E+00	-1.36	-0.5634
11	0.31671548E+00	0.15627843E+00	2.03	0.7118
12	0.91808868E+02	0.66200775E+02	1.39	0.5698
13	-0.31854659E-01	0.11910796E+00	-0.27	-0.1325
0	-0.99992447E+02			

MULTIPLE R=0.9800, R SQUARE=0.9605 ST ERROR OF EST=0.17662268E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.30320728E+03	0.43315323E+02	13.89
ABOUT REG	4	0.12478271E+02	0.31195679E+01	
TOTAL	11	0.31568555E+03		

Y=VAR 7

I	B	SB	T	PAR R
1	-0.41539497E+01	0.32740128E+02	-0.13	-0.0633
2	-0.76019727E-02	0.42802494E-01	-0.18	-0.0885
3	-0.29733719E+02	0.24553467E+02	-1.21	-0.5179
10	-0.70999980E-01	0.67664385E-01	-1.05	-0.4646
11	0.11481181E-01	0.71277142E-01	0.16	0.0803
12	0.30825394E+02	0.30215240E+02	1.02	0.4544
13	0.66925704E-01	0.54354079E-01	1.23	0.5243
0	0.10778976E+02			

MULTIPLE R=0.6745, R SQUARE=0.4550 ST ERROR OF EST=0.80545753E+00

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.21663589E+01	0.30947983E+00	0.48
ABOUT REG	4	0.25950499E+01	0.64876246E+00	
TOTAL	11	0.47614088E+01		

TABLE IX. Regression Equations - Recycle Number Four., Cont.

Y=VAR 8

I	B	SB	T	PAR R
1	-0.25484171E+03	0.84252289E+02	-3.02	-0.8341
2	0.31243455E+00	0.11004812E+00	2.84	0.8175
3	-0.11171187E+03	0.63042892E+02	-1.77	-0.6632
10	-0.33661622E+00	0.17379045E+00	-1.94	-0.6957
11	0.60910636E+00	0.18341845E+00	3.32	0.8566
12	0.15644775E+03	0.77608139E+02	2.02	0.7099
13	0.26345038E+00	0.13955641E+00	1.89	0.6864
0	-0.10745012E+03			

MULTIPLE R=0.9945, R SQUARE=0.9890 ST ERROR OF EST=0.20711546E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.15457258E+04	0.22081796E+03	51.48
ABOUT REG	4	0.17158936E+02	0.42897339E+01	
TOTAL	11	0.15628848E+04		

Y=VAR 9

I	B	SB	T	PAR R
1	-0.97490051E+02	0.45663528E+02	-2.13	-0.7298
2	0.12229431E+00	0.59602857E-01	2.05	0.7161
3	0.74685425E+02	0.34147537E+02	2.19	0.7380
10	-0.69276571E-01	0.94235480E-01	-0.74	-0.3450
11	0.22735429E+00	0.99415243E-01	2.29	0.7527
12	0.33577499E+02	0.42083282E+02	0.80	0.3705
13	-0.15811086E+00	0.75592637E-01	-2.09	-0.7228
0	-0.52617645E+02			

MULTIPLE R=0.9916, R SQUARE=0.9833 ST ERROR OF EST=0.11208820E+01

SOURCE	DF	SS	MS	F
DUE TO REG	7	0.29632178E+03	0.42331680E+02	33.69
ABOUT REG	4	0.50256348E+01	0.12564087E+01	
TOTAL	11	0.30134741E+03		

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