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DEVELOPMENT OF MILD GASIFICATION PROCESS

Quarterly Report
for the period October-December, 1987

By

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DISCLAIMER

EXECUTIVE SUMMARY

Modifications to the mild gasification unit, MGU, are now approximately 95% complete. All major components (reactor tube, char chamber, coal feed system, and condensing system) have been modified and installed. Associated items such as the vacuum pump, oil recirculation pumps, heat exchangers, etc. have also been installed.

The char chamber, reactor tubes, and condensing system were pressure tested. Leaks discovered during pressure testing have been sealed. These three areas are now tight and leak proof.

Results were received from Virginia Polytechnic Institute and State University (VPI) on LC -^{1}H NMR, static ^{1}H NMR, and static ^{13}C NMR analyses performed on coal-liquids from UCC Research Corporation's (UCCRC) mild gasification unit (reactor tube diameter tests) and coal liquids produced by Coalite using United Coal Company coals. Samples from UCCRC's MGU were from reactor diameter tests #1-8"Ø, #7-4"Ø, and #9-6"Ø (8-, 4-, and 6-inch diameter reactor tubes respectively). Samples produced in Coalite's test retorts were with Wellmore No.8 coal and Sharples Coal.

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INTRODUCTION

Oil currently accounts for over 42% of the total U.S. energy consumption and over 40% of the nations oil is imported from foreign countries. The remaining oil reserve available in this country constitutes less than 6% of the proven total U.S. recoverable fossil energy reserves while coal represents over 90% of the proven total U.S. fossil energy reserves (1)*. Total coal resources in the U.S. are estimated at more than 3.9×10^{12} tons (2). Just the demonstrated coal reserve alone, the coal reserve that is proven and can be economically mined using today's technologies and mining techniques, amounts to 488×10^{9} tons. At the current annual U.S. coal production rate of about 900×10^{6} tons, the demonstrated coal reserve alone will last more than 500 years. In light of this contrast in available resources, coal vs. oil, it is very desirable to make good use of our abundant coal resource in our ever more difficult pursuit of energy independence.

Most of the high-severity coal conversion processes that have been developed or are being developed are too complicated, too expensive or both, largely because of their reliance on very severe operating conditions and heavy uses of expensive hydrogen.

While conventional coal devolatilization (or "mild gasification") processes are among the oldest methods for obtaining liquid fuels from coal, they are also technically among the least complex. Mild gasification also has the advantages of higher thermal efficiencies than those of other routes to liquid synfuels from coal. Efficiencies of 85-90% can be expected from mild gasification processes, in contrast to only 50 to 70% for high-severity, indirect and direct liquefaction processes (3). Recent papers reporting various coal liquid qualities and hydrotreatment requirements also indicate that mild gasification liquids are generally superior in quality to those produced from high-severity coal liquefaction processes and require a substantially lesser degree of hydrotreating (3-8).

However, in the existing mild gasification processes, the relative quantities and properties of the co-products are not optimized to make the technology economically and environmentally viable. Many times, either the liquid yield is too low or the liquid quality is poor; and the main product, char (representing 65-75 wt.% coal feedstock), often cannot find its proper marketplace.

Under a previous contract with Morgantown Energy Technology Center (METC), Department of Energy (DOE) Contract No. DE-AC21-84MC21108, UCC Research Corporation (UCCRC) built and tested a 1500 lb/day Mild Gasification Process Development Unit (MGU). The MGU, as tested under the previous contract, is shown in Figure 1. Testing completed under the previous contract showed that good quality hydrocarbon liquids and good quality char can be produced in the MGU. However, the MGU is not optimized. The primary objectives of the current project are to optimize the MGU and determine the suitability of char for several commercial applications. The program consists of four tasks; Task 1-Test Plan; Task 2-Optimization of Mild Gasification Process; Task 3-Evaluation of Char and Char/Coal Blends as a Boiler/Blast Furnace Fuel; and Task 4-Analysis of Data and Preparation of Final Report. Task 1 has been completed while work continued on Task 2.

*Numbers in parentheses designate references at the end of this report.

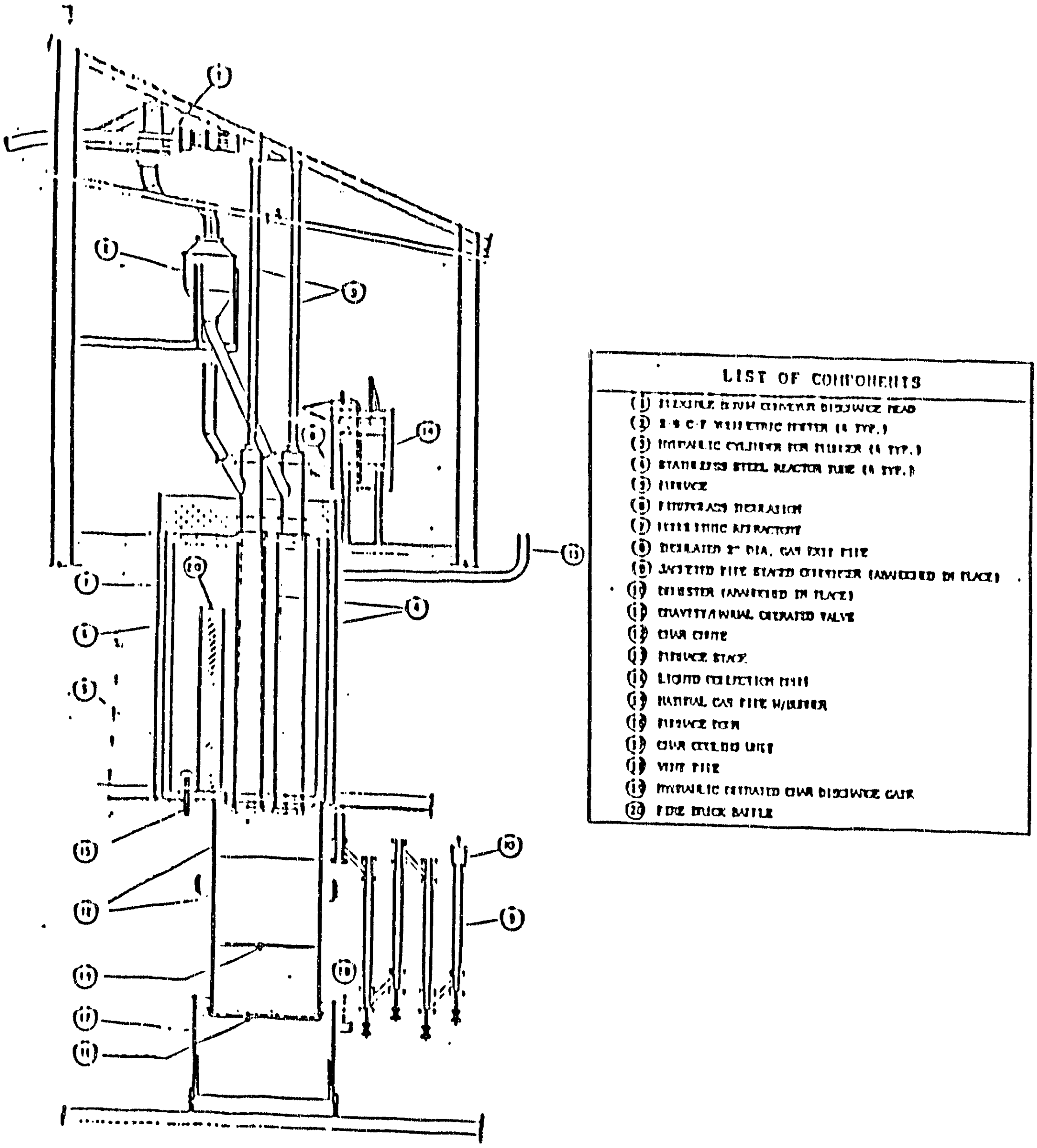

Figure 1. Unmodified Mild Gasification Process Development Unit (MGU)

Task 1. Test Plan

Objective

The objective wa to develop a test plan for optimizing the mild gasification process.

Discussion

The test plan has been completed and was submitted to the Department of Energy in March, 1087.

Task 2. Optimization of the Mild Gasification Process

Objective

The objective of this task are to (A) modify the MGU to optimize the unit operation; (B) conduct parametric tests to determine the effect of process parameters on product (gas, condensible, and char) quantity and quality; and (C) produce enough char and hydrocarbons in order to evaluate these products in various commercial applications.

Discussion

The MGU was moved by Radford Construction Company to UCCRC's new research facility. Work was initiated on MGU modifications and is now approximately 95% complete. All major components (reactor tubes, sweep gas heaters, condensing system, coal feed system, and char chamber) have been installed. Associated items, such as the new vacuum pump, oil recirculation pumps, heat exchangers, firebrick baffle, thermocouples, hydraulic plungers, water lines, product gas lines, temperature indicators, and pressure gauges, have also been installed. The natural gas burners were modified so that ambient air can be blown into the furnace at the end of a test to help prevent temperature overruns. This will also help protect the burners from overheating after the natural gas is turned off. The furnace layout, equipment layout, floor plan, flowsheet, and new components for the modified MGU are shown in Figures 2-8.

Although MGU modifications are not 100% complete and thus integrated plant shakedown tests are not yet possible, partial shakedown tests have been conducted for the plant sections which are complete. The condensing system has been pressure tested for leaks. No major leaks were found but there were a few minor leaks at some of the welds. The leaks were closed as they were discovered. The condensing system is now tight and leak proof. The char chamber area and the reactor tubes were pressure tested for leaks. Several minor leaks were found where the char chamber is welded to the skirt around the bottom of the furnace. Some major leaks were discovered at the bottom welds supporting the reactor tubes. All leaks in the char chamber and reactor tube areas have been sealed.

Results were received from Virginia Polytechnic Institute and State University (VPI) on LC-^{1}H NMR, static ^{1}H NMR, and static ^{13}C NMR analyses performed on coal liquids from UCCRC's mild gasification unit (reactor tube diameter tests) and on coal liquids produced by Coalite using UCC coals. Samples from UCCRC's MGU were from reactor diameter tests #1-8"Ø, #7-4"Ø, and

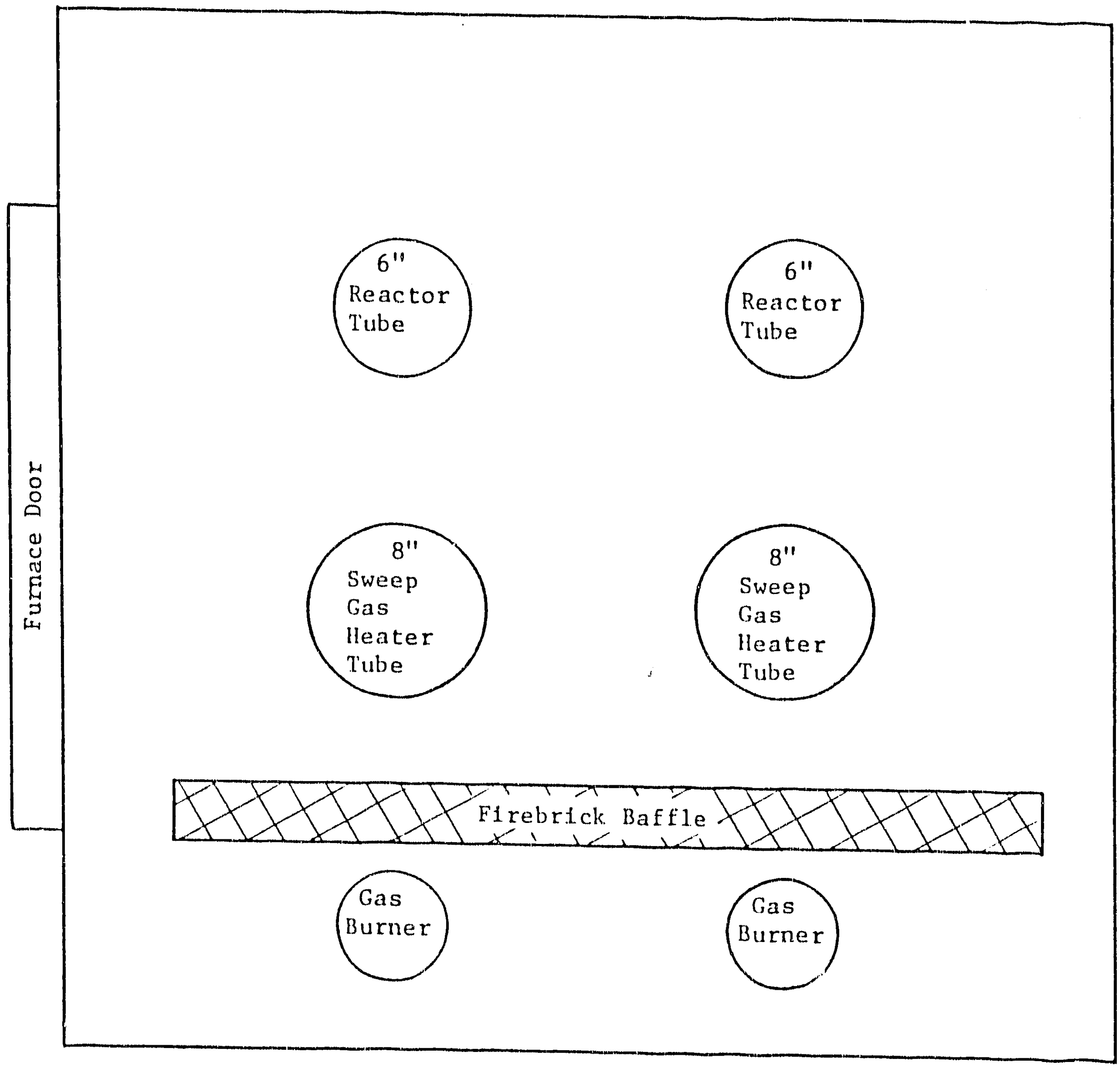

Figure 2. Furnace Layout for Modified MGU

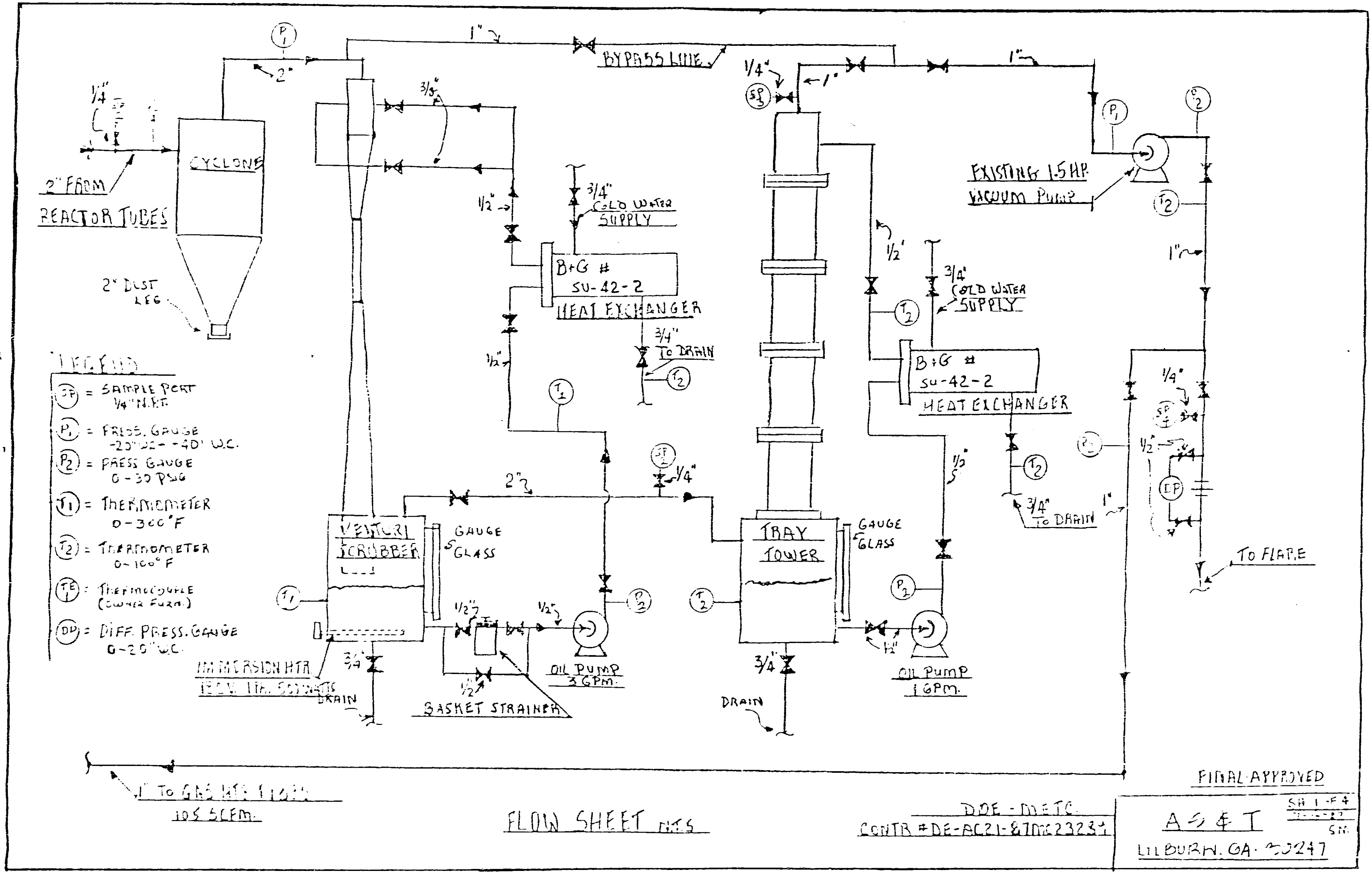

Figure 3. Modified MGU Flowsheet

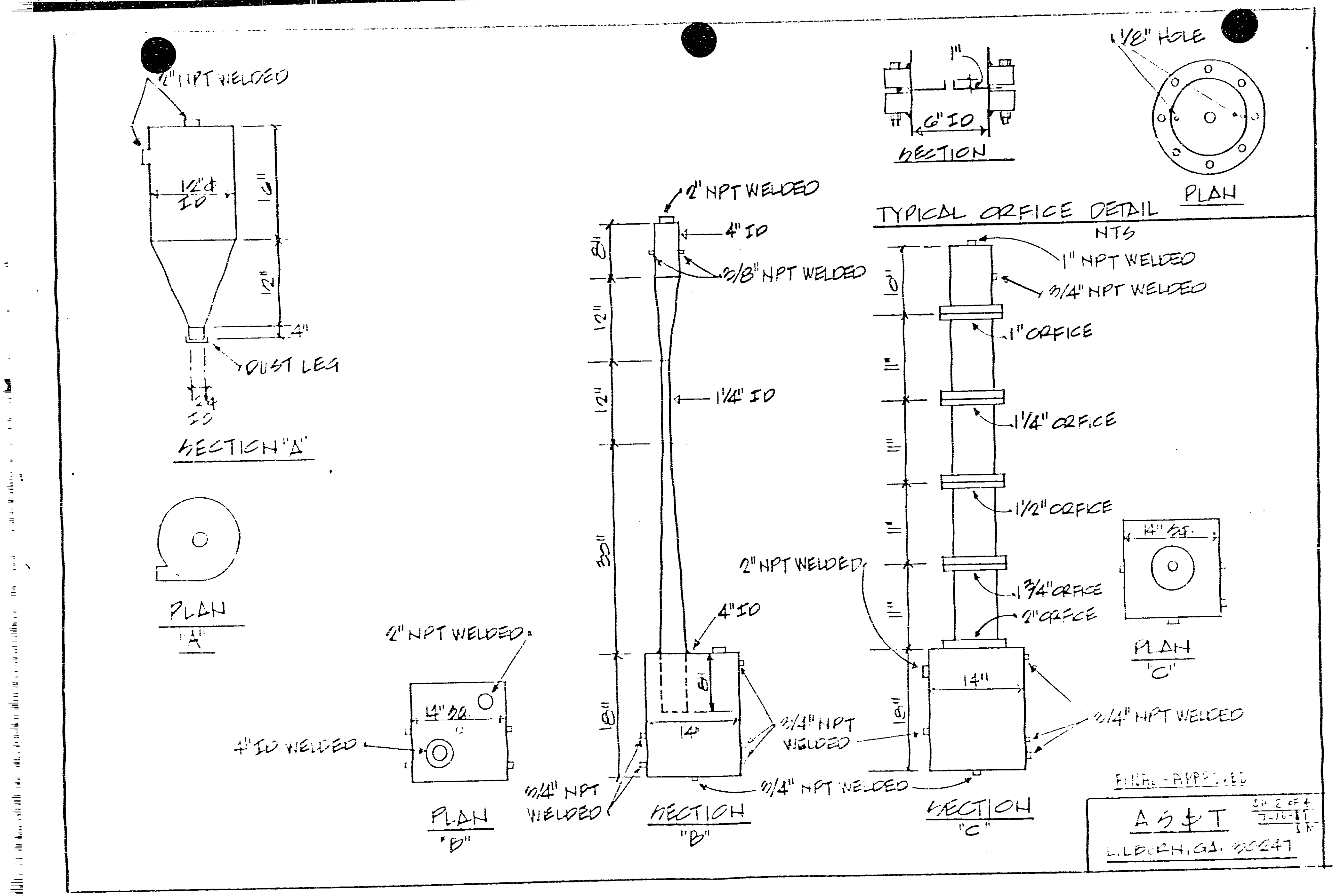

Figure 4. Liquid Recovery System for Modified MGU

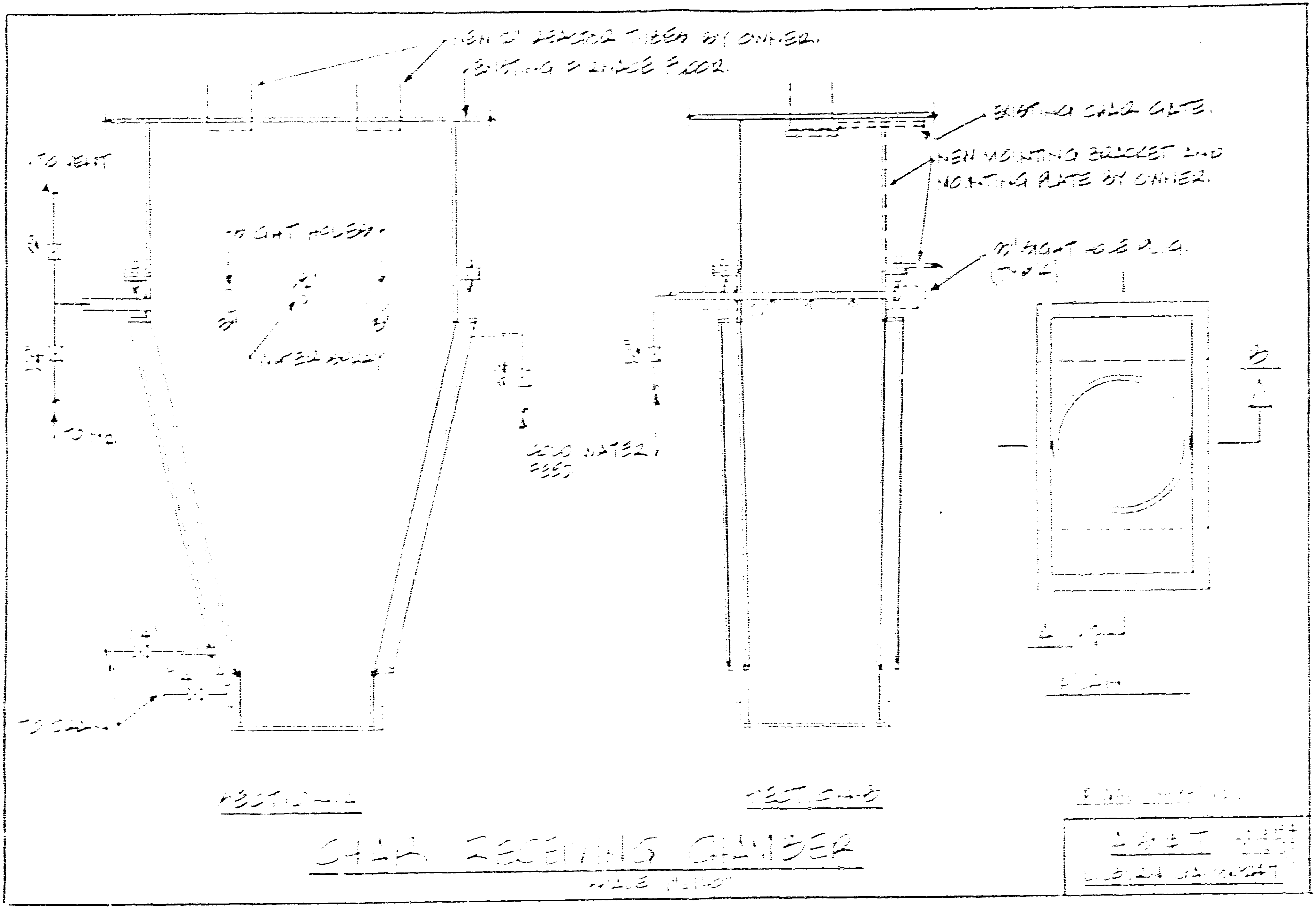

Figure 5. Char Receiving and Quenching Chamber for Modified MWI

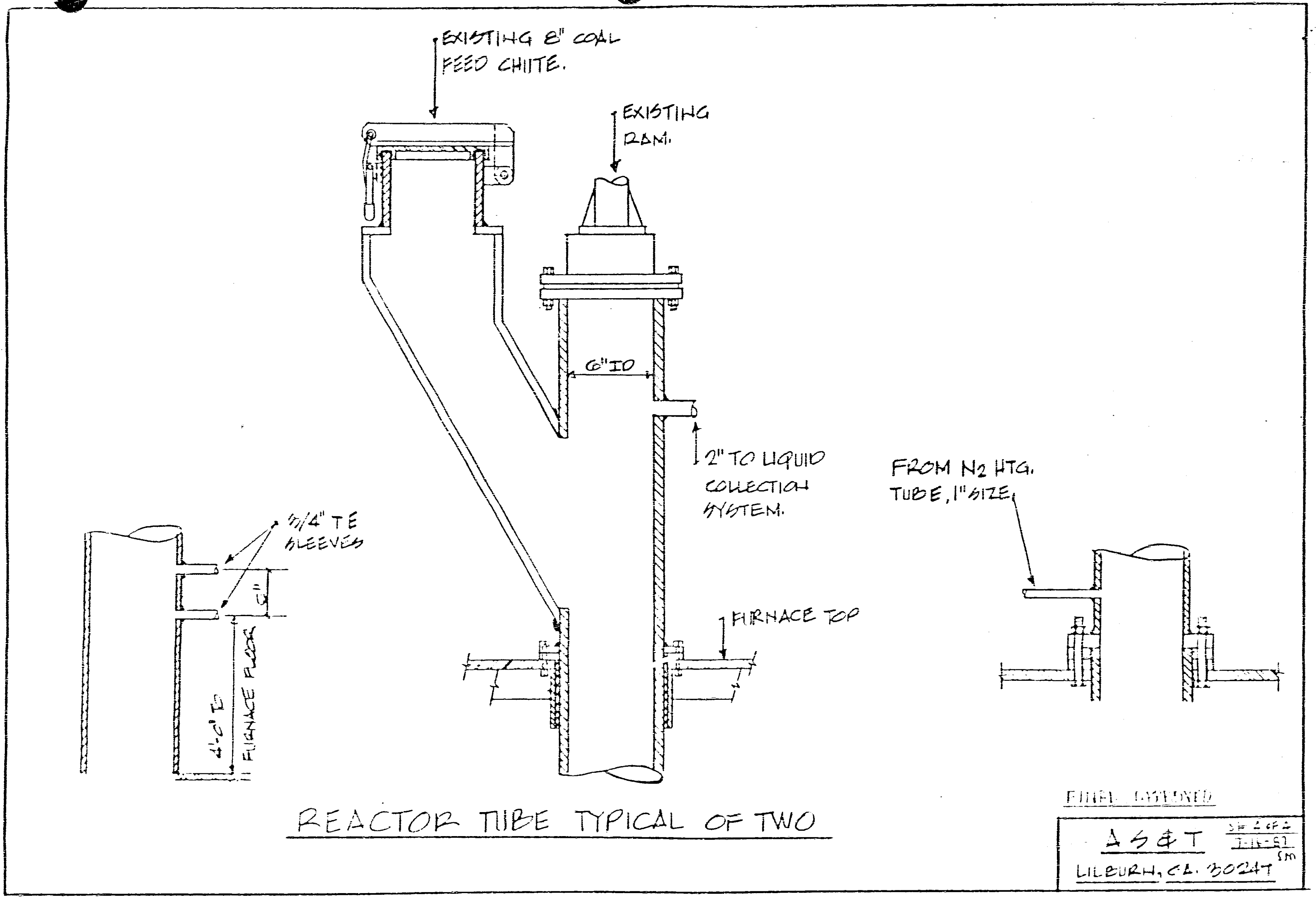

Figure 6. Reactor Tube Details for Modified MGU

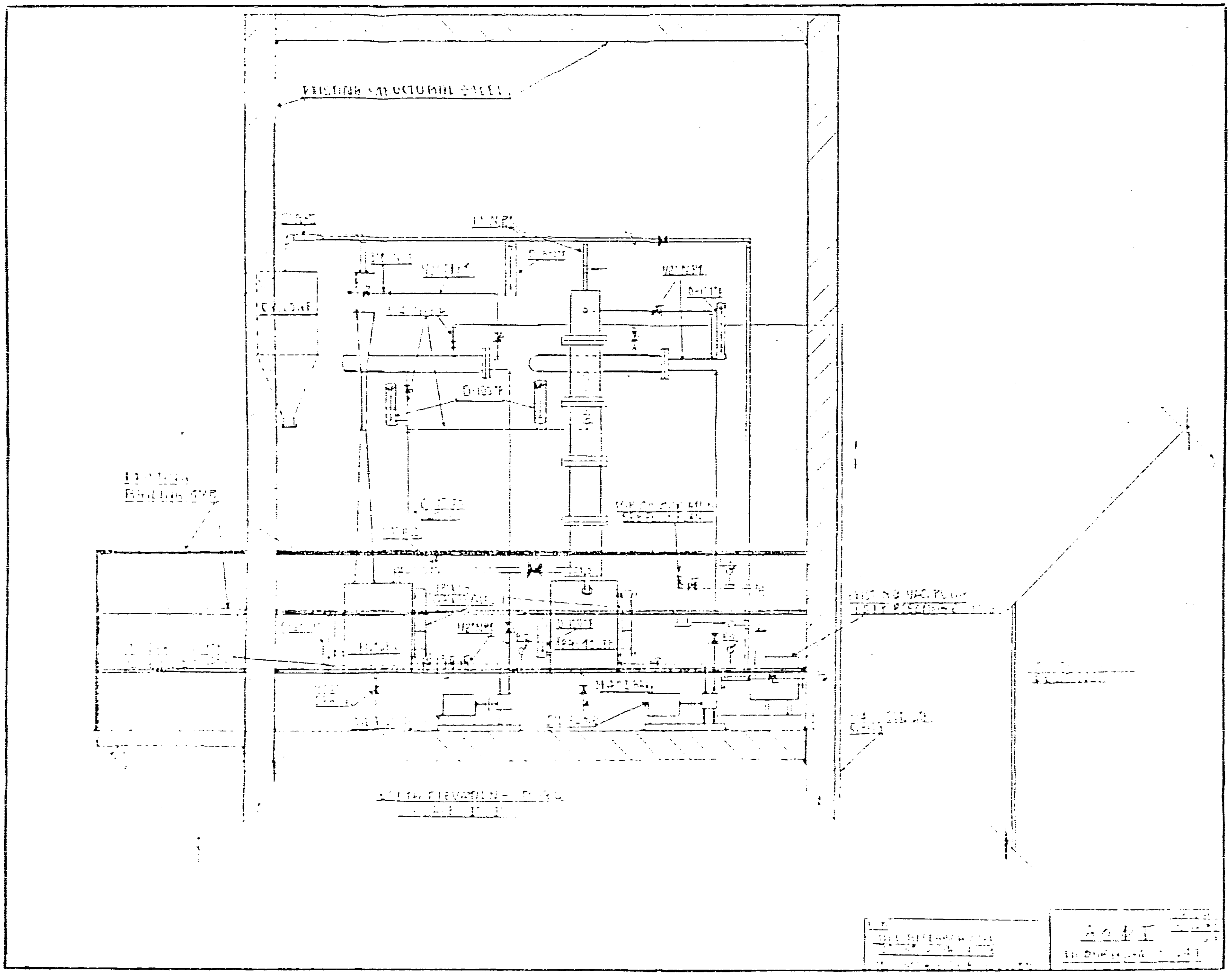

Figure 7. Equipment Layout, Third Floor of Modified MGU

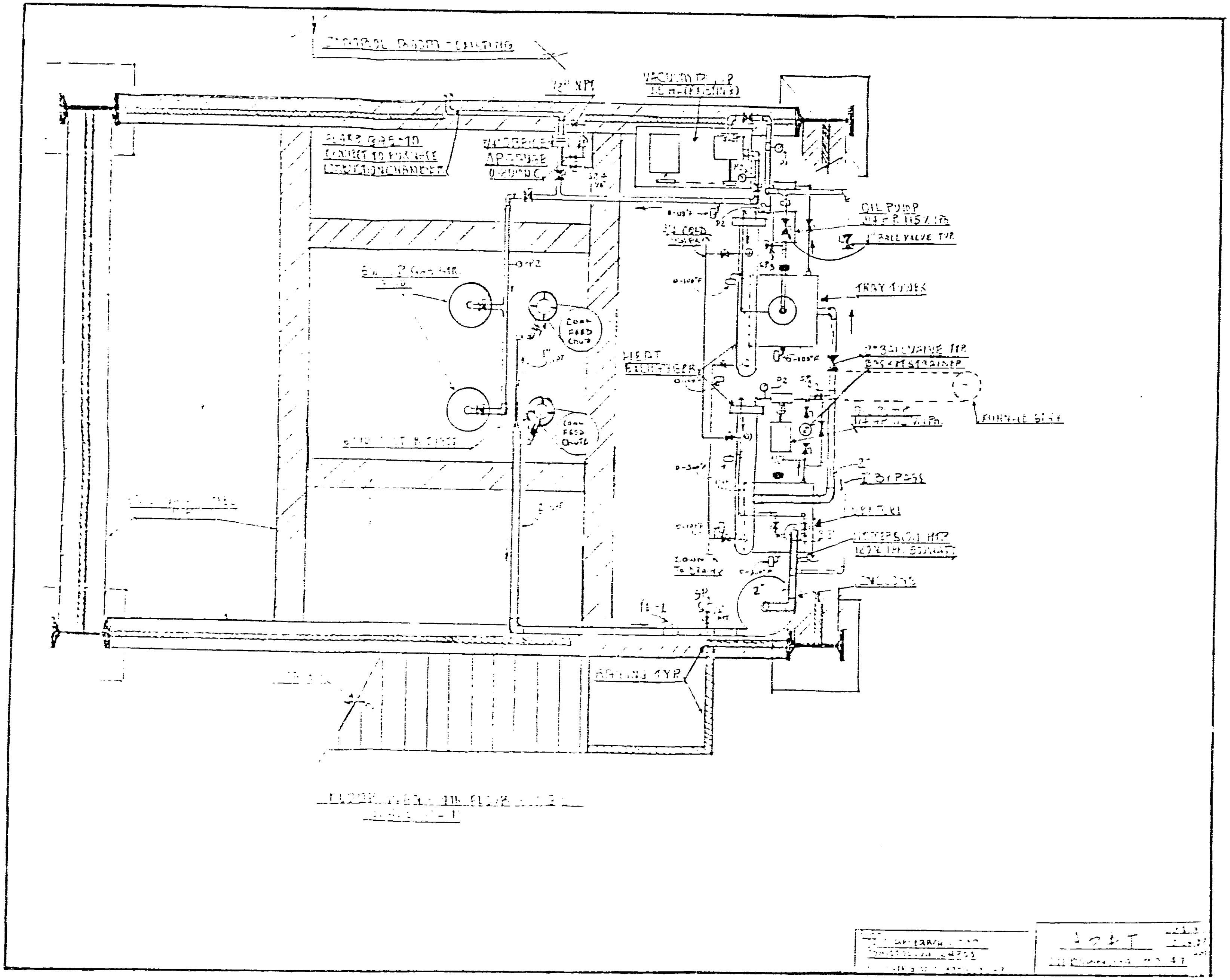

Figure 8. Floor Plan, Third Floor of Modified MGU

#9-6"Ø (8-, 4-, and 6-inch diameter reactor tubes respectively). Samples produced in Coalite's test retorts were with Wellmore No.8 coal and Sharples coal. In addition to the raw coal liquid samples, distillation cuts of <350 °F and 350-650 °F from the #7-4"Ø and Coalite Sharples liquids were analyzed. The results are summarized in Table I.

The raw coal liquids from UCCRC's MGU were highly aromatic. ^{13}C aromaticity was greater than 86% in each case. The raw liquids from #7-4"Ø and #9-6"Ø were composed mainly of monocyclic and dicyclic aromatics. For liquids from #1-8"Ø, the monocyclic aromatic fraction was decreased and the dicyclic and tricyclic aromatic fractions were increased. For all three samples, there were short chain alkyl substitutions in the aromatic fractions.

The <350 °F distillation fraction from #7-4"Ø contained a high percentage (59.2) of monocyclic aromatics, while the 350-650 °F cut contained a high percentage (68.6) of dicyclic aromatics. Short chain alkyl substitutions were present in the aromatic fractions of both samples. In the 350-650 °F fraction indene, acenaphthene, and dibenzofuran are present. These compounds are all in addition to the substituted benzenes, naphthalenes, fluorenes, and phenanthrenes.

The coal liquids (Coalite Wellmore #8 and Coalite Sharples) produced in Coalite retorts were somewhat different than the UCCRC MGU liquids. This is especially interesting since the Coalite, Wellmore No.8 liquids and the liquids from UCCRC tests #1-8"Ø, #7-4"Ø, and #9-6"Ø were all produced from the same coal. One possible explanation for the difference is that the Coalite liquids were produced using a test retort. The test retorts are not full size, the coal charge being ~15 lbs. The samples from the Coalite test retorts had substantially higher alkane contents than samples from UCCRC's MGU. Longer chain alkyl substitutions in the aromatic fractions were also noted for the Coalite produced liquids. It is interesting to note that the Coalite Sharples distillation fractions did not contain indene, acenaphthene, or dibenzofuran.

The predicted cetane values for the coal liquids were also reported by VPI. The predicted cetane values for the UCCRC MGU liquids were well below typical petroleum diesel cetane values of 40-50. This is due mainly to the high aromatic content and the low alkane content of the liquids. The predicted cetane values for the Coalite Wellmore No.8 and Coalite Sharples liquids were higher than the UCCRC MGU liquids but lower than the cetane values for petroleum-based diesel. This is due mainly to the higher content of alkanes and longer alkyl chains on the moncyclic aromatic fraction. With minimal blending, the cetane value of the 350-650 °F distillation cut could be brought within currently accepted ranges. The cetane values for the coal liquids are shown in Table I.

Task 3. Evaluation of Char and Char/Coal Blends as an Industrial Boiler/Blast Furnace Fuel

Objective

The objective of the task is to evaluate the MGU char product in three commercial applications. Tests will be conducted to determine the suitability of char in industrial/utility pulverized coal boiler, stoker coal boilers, and as a replacement for coke in foundry/blast furnaces.

Discussion

No work scheduled during this reporting period.

Task 4. Analyze Test Data and Prepare Final Report

Objective

The objective of the task is to analyze the test data generated during MGU testing and char evaluation. The performance of the individual process elements and overall process, including potential end uses for char, will be recommendations shall be made regarding further research and/or development of this mild gasification process.

Discussion

No work scheduled during this reporting period.

Table I. Results of LC-^{1}H NMR Liquid Analysis by VPI

Sample	^{13}C Aromaticity	^{1}H Aromaticity	Alkanes	Monocyclic Aromatics	Dicyclic Aromatics	Tri-Cyclic Aromatics		Predicted Cetane
						Fluorenes	Phenanthrenes	
#7-4"Ø	86.1	55.9	4.8	58.5	36.7	0.0	0.0	4.03
#7-4"Ø <350 °F	78.7	45.5	9.9	59.2	28.9	1.4	0.5	-4.22
#7-4"Ø 350-650 °F	81.7	50.1	10.2	11.2	68.6	4.9	5.3	5.35
#9-6"Ø	86.3	56.7	3.9	79.4	16.7	0.0	0.0	4.85
#1-8"Ø	91.7	72.5	2.0	19.4	50.9	9.9	17.7	-0.23
Sharples (Coalite)	56.9	19.2	33.3	38.1	17.6	5.4	5.5	18.25
Sharples (Coalite) <350 °F	32.5	65.6	63.5	33.4	3.2	0.0	0.0	22.88
Sharples (Coalite) 350-650 °F	55.1	18.9	42.3	26.2	25.0	3.7	2.8	24.23
W#8 (Coalite)	64.9	22.5	48.2	27.6	24.2	0.0	0.0	19.33
Army Diesel Fuel	15.3	5.5	72.1	19.5	7.3	0.8	0.4	36.14

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