DOE/ET/13015-T2

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DoE-FURNISHED DATA ACQUISITION SYSTEM

INSTALLATION, OPERATION AND MAINTENANCE

ET/3015

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September, 1978
Final Technical Report

Prepared for:

U. S. Department of Energy
Laramie Energy Technical Center
P.O. Box 3395, University Station
Laramie, Wyoming 82071

Under Contract Number ~~ET-77-C-03-1765~~

AC03-78ET/3015

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SUMMARY

Successful installation, operation, and maintenance of the Department of Energy (DoE)-furnished data acquisition system was reduced by the full year delay between the time the project was planned until the contract was signed. The main objective, operation of this DoE system concurrently with (Office of Naval Research) ONR retorting operations, could not be met because the DoE computer was not delivered to Anvil Points until ONR operations were completed. Nevertheless, in spite of delays in obtaining the final contract and subsequent delays by the Laramie Energy Technical Center (LETC) delivery of the computer, signal wiring, and final program software, data have been obtained from the system before termination of the DoE contract.

Although the DoE-furnished data acquisition was not fully automated and bugs remained in the program, the system was operated and the data were compared with that obtained by Paraho data processing. On-stream analyses were not operational during the computer operation. The Hewlett-Packard (HP) gas chromatograph had provided valid data earlier. Maintenance and repairs of subsequent malfunctions by DEI, HP, and LETC personnel failed to provide valid, on-stream GC analyses. The software program and options, controlled by LETC, could not be completely debugged during the short operating period. Routines, devised by DEI, were established to circumvent the program bugs and to obtain valid data.

Data were obtained for fifteen 24-hour test days during June-July, 1978 and compared with Paraho's. Air and gas flows compared within the accuracy of measurement. Total carbon and weight balances generally agreed within 1-2%. Results from these comparisons show that both systems - the DoE-furnished data acquisition and Paraho data processing - do provide valid data.

PREFACE

This work was performed under Department of Energy (DoE) Contract No. ET-77-C-03-1765 by Development Engineering, Inc. (DEI), a subsidiary of Paraho Development Corporation. In this report, the reference by DEI to the Paraho Semi-Works Retort or to other equipment by the manufacturer's name does not imply endorsement by DoE of the Paraho technology or other equipment identified by brand name.

DOE-FURNISHED COMPUTER DATA ACQUISITION SYSTEM
INSTALLATION, OPERATION AND MAINTENANCE

TABLE OF CONTENTS

	<u>Page</u>
SUMMARY	1
PREFACE	2
1.0 INTRODUCTION	5
1.1 General	5
1.2 Computer System	5
1.3 Signal System	7
2.0 EXPERIMENTAL	12
2.1 General	12
2.2 Installation	12
2.3 Operation	14
2.4 Maintenance	17
3.0 RESULTS AND DISCUSSION	19
3.1 Operating Data	19
3.2 Data Evaluation	19
4.0 CONCLUSIONS	26
5.0 APPENDIX	
5.1 Monthly Progress Reports	28
5.2 On-Stream Analyzers - Gas Chromatograph and Net Oil Analyzer	41
5.2.1 On-Stream Analyzers, Sept., 1977	42
5.2.2 Gas Chromatograph Modifications, Dec., 1977	62
5.2.3 On-Stream GC Operations, May, 1977	71

LIST OF ILLUSTRATIONS

	<u>Page</u>
FIGURE	
1.1 Block Diagram - Computer System	11
TABLE	
1.1 DoE-Furnished Computer Equipment	6
1.2 Semi-Works Retort Temperature Measurements	8
1.3 Semi-Works Retort Pressure Measurements	9
1.4 Semi-Works Retort Miscellaneous Measurements	10
1.5 DoE-Furnished Instrumentation and On-Stream Analyzers	13
3.1 DoE Data Acquisition Systems, Data Comparisons, June, 1978	20
3.2 DoE Data Acquisition Systems, Data Comparisons, July, 1978	22
3.3 Error Analysis, DoE DAQ vs. DEI Data	23
3.4 Factors Influencing Flow Calculations	25

1.0 INTRODUCTION

1.1 General

This final report is written in compliance with the Department of Energy (DoE) Contract No. ET-77-C-03-1765 (formerly Energy Research and Development Administration Contract No. EN-77-C-04-4000). This report details the installation, operation and maintenance of the DoE-furnished automated data acquisition system. This system monitored the oil shale retorting operations as performed by the Paraho Semi-Works Retort at the Anvil Points Oil Shale Research Facility near Rifle, Colorado.

1.2 Computer System

A Hewlett-Packard 2100 computer system, supplied by DoE, was used for data acquisition and data report generation. The associated hardware included: a disc unit (4.9 megabyte capacity) with power supply; a crossbar scanner (200 signal capacity) with power unit; paper tape punch and reader units; a chronolog clock; a magnetic tape unit; a high speed printer; a central processing unit (CPU) with 32K storage capacity. This system was housed in a mobile communications trailer. This trailer was equipped with a small heater and air-conditioning system. The trailer was housed inside a building constructed adjacent to the north side of the retort control building. An available five-ton central air-conditioning unit was relocated to provide temperature control and positive pressure to the retort control building and data acquisition building. This system protected the computer system from temperature variations and gaseous and particulate emissions. A complete list of ERDA-furnished computer equipment is given in Table 1.1.

The computer system had two working terminals. The terminal located in the communications trailer, consisting of a cathode ray tube (CRT) and thermal printer, was used to access the CPU. This access permitted data, not obtained automatically, to be entered into the system and permitted errors in the data storage to be corrected. The second terminal, located in the retort control building, consisted of a CRT. This terminal, essentially an operating tool,

TABLE 1.1

DoE-FURNISHED COMPUTER

EQUIPMENT

A. Computer Building

B. Computer System:

- 1 - Computer Trailer
- 1 - HP2100A Central Processor
- 1 - HP7900A Disc Drive
- 1 - HP13210A Disc Controller
- 1 - HP7970B Digital Tape Unit
- 1 - HP13181A Mag Tape Controller
- 1 - HP2313B A/D Subsystem consisting of:
 - 1 - 12750B Sample and Hold
 - 1 - 12751B Relay High Level Multiplex
 - 1 - 12752B Control Card
 - 1 - 12761A Relay Low Level Multiplex
 - 1 - 12768A Main Frame
 - 1 - 12769A Power Supply
- 1 - HP2911B Cross-Bar Scanner
- 1 - Chrono Log 70-145-512 Digital Clock
- 1 - HP29404B Cabinet
- 1 - HP2155A I/O Extender
- 1 - HP2748B Tape Reader
- 1 - HP2895B Tape Punch
- 1 - HP2615A CRT Terminal
- 1 - HP2640B CRT Terminal with:
 - 1 - Opt. 20 Ext. Asyn. DC Card
 - 1 - 130234A 4K Memory Card
 - 1 - 12880/001 CRT Interface Card
- 1 - T1733 KSR Terminal
- 3 - HP12531D/001/002 High Speed Terminal Interface Kits
- 1 - HP2767A Line Printer
- 1 - HP12597A/002 Extended Arithmetic Unit
- 1 - HP12597A/005 Extended Arithmetic Unit

C. Deltec Uninterruptible Power Supply (UPS):

- 1 - 5250A UPS
- 1 - Lead Calcium Battery Pack (30 minutes) 120 volts
- 1 - RD704-7 Battery Pack
- 1 - Spare Module and Parts Kit
- 1 - 5125514 Transformer: 270 VAC, 60HZ to 230/115 VAC, 60 HZ
- 1 - Ventilation Fan
- 1 - 100 Amp Circuit Breaker with Enclosure

permitted the retort operators to obtain a visual display of retort temperature profiles. A third terminal, a teletype, was located in the communications trailer as a backup for the two working terminals.

The system also included an uninterruptable power supply (UPS). The UPS was housed in a partitioned section of the data acquisition building which was vented to prevent accumulation of storage battery gases. The UPS provided the necessary power to the computer and auxiliaries and protected them against any power outages up to 20-30 minutes. A longer outage causes the loss of data acquisition. Data stored on the discs are not lost, but the program must be re-entered.

The software program was developed by LETC personnel. This program permitted the computer system to acquire, sort, and store data and computer yields and balances. The program also permitted operators to obtain temperature profiles. Although the data acquisition system was operated and maintained by the DEI computer operator, the software program remained under LETC control.

1.3 Signal System

A variety of process measurements was made around the Paraho Semi-Works retort and auxiliary equipment. These measurements were made to insure stable and efficient retorting operations and to acquire information for data processing to determine product yields and material and heat balances. The measurements included: temperatures (see Table 1.2); pressures, static and differential (see Table 1.3); and others, such as shale rate and the sequential on-stream gas chromatograph (see Table 1.4). The measurements in these classifications total 80 signals. In order to be used in the computer-based data acquisition system, the signals from the Semi-Works retort were conditioned, or converted into an electrical (millivolt) signal using the proper transducer. A flow diagram, locating the Semi-Works signal sources, is shown in Figure 1.1.

The temperature signals, obtained from thermocouples, required no conditioning. These signals were transmitted into a junction box in the retort control building and cabled to the data acquisition building. All cables used for

TABLE 1.2

SEMI-WORKS RETORT TEMPERATURE MEASUREMENTS

<u>Location</u>	<u>Data Points</u>
Raw Shale Inlet	1
Offgas Line	1
Recycle Gas Blower: Suction	1
Discharge	1
Orifices: Air	3
Recycle Gas	3
Product Gas	1
Distributor Inlets	3
Coolers, Oil Side	
Spray and Wash Oil (In and Out)	2
Product Oil (Out Only)	1
Coolers, Water Side:	
Distributors (In and Out)	2
Spray and Wash Oil (In and Out)	2
Product Oil (Out Only)	1
Retorted Shale Discharge	1
Retort Center Probe:	
Above Top Distributor	4
Above Mid Distributor	3
Above Bottom Distributor	4
Offgas Collectors	4
Retort Grate	2
Retort Wall	4
Thermal Oxidizer	1

TABLE 1.3

SEMI-WORKS RETORT PRESSURE MEASUREMENTS

	<u>Data Points</u>
Static:	
Retort: Top	1
Bed	3
Bottom	1
Orifices: Air	3
Recycle Gas	3
Product Gas	1
Recycle Gas Blower: Suction	1
Discharge	1
Distributor Inlets	3
Offgas Line	1
Spares	3
Spares	1
Differential:	
Orifices: Air	3
Recycle Gas	3
Product Gas	1
Distributor Cooling: Water	1
Coalescer	1
Electrostatic Precipitator	1
Spares	2

TABLE 1.4

SEMI-WORKS RETORT MISCELLANEOUS MEASUREMENTS

	<u>Data Points</u>
Gas:	
Recycle Gas Analysis	1
Solids:	
Raw Shale Weight Belt	1
Atmospheric:	
Relative Humidity	1
Barometric Pressure	1
Ambient Temperature	1

FIGURE 1.1

Block Diagram - Computer System

signal transmission consisted of shielded bundles of twisted pairs of wire in well-grounded conduits.

Pneumatic pressure signals are used in routine DEI retort operations. Pneumatic-to-electrical transducers (see Table 1.5) were installed at each pressure tap. Second taps had been installed under the ONR Contract #N00014-C-1074; thus, installation of these transducers did not cause any interruption of retort operations. Signals from these transducers were then fed directly into the communications trailer using the same system of shielded and grounded cable described under thermocouples.

Signals from the gas, solid, and atmospheric measurements listed in Table 1.4 were fed from the measuring device or instrument to the communications trailer located in the data acquisition building. Most of these signals were electrical; but, whenever required, a proper transducer was installed (see Table 1.5). Again, the shielded and grounded cables were used for signal transmission.

2.0 EXPERIMENTAL

2.1 General

In this section, the installation and operation of the DoE-furnished computer data acquisition system (DAQ) is discussed. See Appendix 5.1, "Monthly Progress Reports", for a detailed chronology of events. Reports of the on-stream analyzers are presented in Appendix 5.2.

2.2 Installation

Preparations for the installation of the DoE-furnished computer data acquisition system were started during the ONR refurbishment contract in late 1976. Although there were many delays due to lack of equipment availability and funding, preparations for installation continued through mid-1977 both at Anvil Points and the Laramie Energy Technical Center (LETC).

TABLE 1.5

DOE-FURNISHED INSTRUMENTATION

AND

ON-STREAM ANALYZER

A. Instrumentation:

- 1 - Foxboro Target Flow Meter, Model 13T1: 4-inch line size, 250 gpm maximum flow of oil and water with Foxboro Meter Mountable Airset, Model 1AS-AE.
- 3 - Foxboro Pressure to Current Transmitters, Model E92-F-21: 3-15 psig, 4-20 MADC.
- 1 - Texas Electronics, Inc. Remote Reading Relative Humidity System, Model 2013-2.
- 1 - Barometric Pressure Transmitter.
- 14 - Bell & Howell Static Pressure Transmitters, Type 4-403-0006: 0-10 psi, vented gage. 13 spares on hand.
- 6 - Bell & Howell Differential Pressure Transmitters, Type 4-454-0003: 0-100 inches water.
- 11 - Beckman Differential Pressure Transmitters, Type 8611-1241-0100: 0-20 inches water.
- 3 - Beckman Differential Pressure Transmitters, Type 8611-1241-0900: + 20 inches water.
- 1 - 24 Volt Power Supply.

B. On-Stream Analyzers:

- 1 - Hewlett Packard Gas Chromatograph, Model 5832A with CO₂ cryogenic oven, 16 stream input, and computer interface.
- 1 - Halliburton Net Oil Analyzer with 1/2" turbine flow meter (1-10 gpm) and capacitance probe.

The contract was signed in October, 1977. Needed equipment was purchased by DEI. Contract electricians were hired to help with wiring the uninterruptable power supply (UPS), power to the various units, and wiring the signal transmission lines. All wiring was completed.

Reports of the on-stream analyzers, the gas chromatograph and the net oil analyzer are presented in Appendix 5.2. A report issued Sept., 1977 showed that the Halliburton Net Oil Analyzer could measure total liquid production, but could not distinguish oil from water. This same report showed that the Hewlett-Packard (HP) 5832A Gas Chromatograph (GC) was operational. At the request of the Technical Project Officer (TPO), the GC was reprogrammed and wired into the UPS system. A letter, dated Dec., 1977, reported the completion of the additional work. A report issued May, 1978 showed that the GC was operational during Jan., 1978 and produced data which compared well with that obtained by the Paraho Laboratory. However, subsequent malfunctions, in spite of the combined efforts of DEI, HP, and LETC personnel, prevented automated operation of the GC. No on-stream analyzers were used with the DoE computer.

The computer was not delivered to Anvil Points until January, 1978. Final wiring (from panel boxes to the computer), originally scheduled to be installed by LETC technicians, was changed by the TPO to be done by DEI electricians. LETC's technical personnel approved the final wiring, corrected some problems, and planned to reschedule system start-up from January to March, 1978.

Delays in obtaining the computer program and repeated failures of the on-stream GC caused further delays in the start-up of the computer data acquisition system. In May, the computer program was checked out in the DoE computer at Anvil Points and debugged by LETC technical personnel. DEI technicians, hired to operate the DoE-furnished computer, were trained by LETC personnel. Repeated attempts at repairing and correcting the on-stream GC failed. Using gas data obtained by the Paraho Laboratory, the DoE-furnished computer data acquisition system was operational on June 11, 1978.

2.3 Operation

Operation of the DoE-furnished computer data acquisition system (DAQ) began June 11, 1978. Operations were carried out on a 7-day/week schedule during

June and July. A manual was prepared to assist DEI technicians in operating the DoE DAQ system. This manual provided the necessary details of routine operations and computer program usage.

The DoE computer operation is controlled by a program called COM2. COM2 is the computer's command processor. It controls the operation of the data acquisition system, and schedules certain other display and summary programs. COM2 is scheduled whenever any key is touched on the system CRT's keyboard.

Twelve options are available under COM2. They are:

1. PLOT - DISPLAYS THE RETORT'S TEMPERATURE PROFILE.
2. DATE - DISPLAY CURRENT TIME
3. IDAT - DISPLAYS THE STATUS OF ALL ACTIVE PROGRAMS
4. EDST - DISPLAYS THE STATUS OF THE COMPUTER'S DEVICES.
5. DBKUP - ALLOWS THE BACKUP OF THE COMPUTER'S DATA FILE ON DEMAND.
NOTE: DBKUP IS ALSO SCHEDULED AS PART OF THE REGULAR DATA ACQUISITION SEQUENCE. FOR FURTHER INFORMATION SEE DATA BACKUP PROCEDURES.
6. OFF - THIS OPTION ALLOWS THE OPERATOR TO MANUALLY SHUT OFF ANY OF COM2'S PROGRAMS. THIS OPTION IS REQUIRED IF A PROGRAM DOES NOT TERMINATE CORRECTLY.
7. DASET - THIS OPTION INITIALIZES THE COMPUTER FILE'S DATA BASE. THE OPTION SHOULD ONLY BE EXECUTED DURING THE INITIAL SET UP OF THE DATA ACQUISITION SYSTEM. DO NOT USE THIS OPTION UNLESS INSTRUCTED TO DO SO.
8. ONDAT - TURNS ON THE DATA ACQUISITION AND BACKUP PROGRAMS.
9. OFDAT - TURNS OFF THE DATA ACQUISITION PROGRAMS. USE THIS OPTION IF THE RETORT IS SHUT DOWN & THERE IS NO NEED FOR DATA COLLECTION.
10. SUMRY - TURNS ON THE DATA SUMMARY AND DATA FILE EDITING PROGRAMS.
11. ABORT - SHUTS OFF THE DATA SUMMARY SEQUENCES. THIS OPTION WILL ABORT A DATA SUMMARY WHICH IS ALREADY IN PROGRESS.
12. EDTC - THIS OPTION PERMITS EDITING OF THE COEFFICIENTS WHICH CONVERT TRANSDUCER VOLTAGE INTO THE REQUIRED DATA FILE UNITS. FOR FURTHER INFORMATION SEE TRANSDUCER CALIBRATION.

During the daily operation of the automated data acquisition system, signals from each of the individual sources were received and stored by the computer. The magnetic disc was used for this temporary data storage. This disc only had enough data storage capacity to hold fourteen days of operating data. On a daily basis, data (from fourteen days prior) was transferred from the disc to magnetic tape for permanent data storage; thus, opening up a location on the disc for the next day's operating data.

Daily operating procedures for the DEI computer operator consisted of the following:

1. Inspect the computer room to be sure it is clean and air-conditioned for trouble-free operation.
2. List out 24-hour computer log sheet using the SUMRY option.
3. Compare computer log sheet with Paraho's operator log sheets, note significant differences, and submit report to data processing supervisor.
4. Between 0900 and 1530 hours, turn off tape drive, replace TQUIK magnetic tapes with the DBKUP magnetic tape.
5. Run DBKUP option.
6. Replace DBKUP magnetic tape with the original TQUIK magnetic tape and turn on tape drive.

For a test day, DOE's quick summary portion of the SUMRY option was programmed to calculate hourly heat and material balances, to integrate these hourly results, and to print out a 15-page heat and material balance and data summary. The lab data were input into the first hour of the test day. The program would then use these data for each hourly balance. However, the results obtained were incorrect for several items due to bugs in the program. This caused the bottom

gas rate to be about ten times too high and the middle, top and product gas rates to be about one-half their correct values. These errors, of course, also caused large errors in the balances. Thus, the quick summary portion, as programmed, could not be used for the 24-hour test data. The quick summary worked fine when run on a single hour's data. Therefore, the following test day procedures were used in which all data were edited into hour 24 of the day preceeding the test day. This procedure caused all data previously recorded and stored into this hour to be lost. However, it was the only way the quick summary would produce valid numbers. This procedure was approved by the TPO.

Test day operating procedures consisted of the following:

- 1) The full set of Paraho Laboratory data, the DoE computer's log sheet averages, and the wet oil (GPH) and shale rate (TPH), adjusted by the current weighbelt factor, were input into hour 24 of the previous day.
- 2) Any of these data which were incorrect due to transducer errors, incorrect averages caused by pulses or zeroes, etc. were replaced using averages from Paraho's operator log sheets.
- 3) A quick summary was then run using the SUMRY option for hour 24 of the previous day which prints out a 15-page summary of operating conditions and heat and material balances calculated from these input values.
- 4) These summaries were then compared with Paraho's heat and material balances and data summaries.

(Comparison data may be found in Tables 3.1 to 3.2 of the Results Section of this report.)

2.4 Maintenance

Routine housekeeping maintained a proper environment for operation of the computer. Modifications were made to the central air-conditioning system so

that cool air was drawn directly into the communications trailer housing the computer. A return duct from the data acquisition building to the central air-conditioning system reduced the need for a fresh air supply, thus reducing dust loading on the filters. Filters were checked daily and changed when necessary. This maintenance provided a cool, dust-free environment for computer operation.

Routine maintenance by instrument repairmen consisted, for the most part, of calibrating and servicing the various signal sources. All pressure transducers were calibrated initially in the instrument shop. After the transducers were installed at the various pressure taps, a field calibration was made to assure valid data output. As pointed out under Operations, raw data from the DoE computer and DEI data processing were compared. When significant differences were noted, the signal source in question was located by instrument repairmen and recalibrated, serviced, or replaced as needed.

Special maintenance by DEI instrument repairmen was required to correct a series of pulses which appeared in the DoE temperature measurements. These pulses occurred in the afternoon (between 1 PM and 10 PM) only with the Type J thermocouples. Readings from the Type K thermocouples were unaffected. The problem was traced to a defective Type J cold junction. Ambient temperature increases in the afternoon caused the temperature measurements to rise. Repair of the defective cold junction on July 9, 1978, solved the problem and DoE temperature measurements were valid throughout the day.

Only one failure of the data acquisition equipment occurred during the operation of the DoE system. This failure occurred on July 11, 1978. After attempts by DEI computer operators to bring the system back on line failed, LETC was notified about the problem. About one week later, the problem was corrected by technical personnel from LETC. The disc drive light bulb, used to determine the position of the disc, had failed. According to the LETC technical representative, this is a common failure in this system. No other failures occurred during the operation.

3.0 RESULTS AND DISCUSSION

3.1 Operating Data

Prior to startup of the DoE DAQ system, DEI made an analysis of the noise levels in the calculated Paraho air and gas flows. This noise resulted from errors in measuring the temperature ($\pm 2^{\circ}\text{F}$), pressure (± 0.1 In. Hg), differential pressure (± 0.1 In. #1 Fluid), and gas specific gravity (± 0.05). The noise levels (high minus low) for the flows (SCFM) were: bottom gas, 154; middle gas, 17; top gas, 23; product gas, 86; middle air, 8; and top air, 9. Whenever the difference between the calculated DoE and DEI values exceed these noise levels, the differences, or errors, are considered to be significant.

The data obtained from the DoE DAQ and DEI data processing systems are compared in Tables 3.1 and 3.2. Data are compared for fifteen test days during the periods in which the data acquisition system was operated. These paired data include air and gas rates (SCFM), shale rate (TPH), and three key material balances (total carbon, total weight and atmospheric nitrogen). For the most part, the difference between the paired air and gas flows fall within the noise level or the experimental error of the measurement. Total carbon and weight balances, computed by DoE system and by Paraho data processing, generally agree within 1-2%.

3.2 Data Evaluation

An error analysis of these paired data is shown in Table 3.3. These error values are calculated by dividing DoE's DAQ measurement by DEI's measurement and subtracting 1 from this ratio. Therefore, the closer this error value is to zero, the better the agreement in measurement between the two systems. A negative error value means that DoE's measurement was less than DEI's. The converse is true for a positive error value.

A statistical analysis was applied to the error values listed in Table 3.3. The mean error ($\bar{E}$) and standard error (S.E.) were calculated for each item listed in the table, except bottom air, according to the equations:

TABLE 3.1

DoE Data Acquisition System
Data Comparisons
June, 1978

	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI
Date	6-11-78	6-11-78	6-13-78	6-13-78	6-15-78	6-15-78	6-18-78	6-18-78	6-19-78	6-19-78	6-20-78	6-20-78
Air Btm SCFM	0	0	0	0	0	0	N.A.	58	15	50	16	49
Mid SCFM	151	153	172	159	171	159	162	161	167	161	165	164
Top SCFM	641	693	718	715	732	721	721	718	706	716	708	718
Gas Btm SCFM	2660	2084	2311	2171	2246	2148	2147	2112	2176	2110	2123	2093
Mid SCFM	210	236	254	247	250	248	253	248	246	248	251	248
Top SCFM	216	243	277	260	275	259	264	259	260	259	267	255
Prod SCFM	1084	1261	1349	1337	1331	1338	1380	1358	1333	1350	1409	1385
Shale Rate TPH(wet)	11.86	11.63	12.63	12.09	12.56	11.98	12.56	12.00	12.50	11.98	12.25	11.93
Balances												
Total Carbon	103.5	108.3	92.9	96.3	95.1	96.8	93.7	97.0	116.4	118.8	93.0	91.3
Total Weight	99.9	102.0	95.3	96.5	97.6	98.6	95.2	96.9	100.0	100.8	98.7	98.1
ATM N2	90.4	91.5	91.5	100.1	88.9	95.5	90.8	95.0	87.0	95.5	92.6	100.1

TABLE 3.1
DoE Data Acquisition System
Data Comparisons
June, 1978
Page 2

	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI
Date	6-21-78	6-21-78	6-27-78	6-27-78	6-28-78	6-28-78						
Air Btm SCFM	15	49	0	0	0	0						
Mid SCFM	168	164	216	210	218	211						
Top SCFM	710	718	720	719	726	720						
Gas Btm SCFM	2174	2108	2246	2125	2155	2129						
Mid SCFM	256	247	250	252	254	253						
Top SCFM	277	259	267	262	276	263						
Prod SCFM	1465	1369	1411	1382	1464	1385						
Shale Rate TPH(wet)	12.60	11.88	N.A.	11.99	12.40	11.94						
Balances												
Total Carbon	100.8	100.4	97.4	96.4	100.3	99.4						
Total Weight	98.8	96.9	97.8	97.7	99.4	98.8						
ATM N2	89.6	95.2	91.2	92.4	96.9	96.7						

TABLE 3.2
CoE Data Acquisition System
Data Comparisons
July, 1978

	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI	DoE DAQ	DEI
Date	7-2-78	7-2-78	7-3-78	7-3-78	7-20-78	7-20-78	7-21-78	7-21-78	7-24-78	7-24-78	7-25-78	7-25-78
Air Btm SCFM	28	88	32	96	29	98	32	97	104	99	103	99
Mid SCFM	144	144	137	136	170	161	164	161	164	161	163	158
Top SCFM	716	717	718	711	733	733	735	738	740	740	739	742
Gas Btm SCFM	2160	2145	2232	2201	2186	2056	2188	2080	2147	2034	2176	2044
Mid SCFM	194	194	159	160	251	252	246	249	245	247	248	251
Top SCFM	266	264	271	261	244	244	242	244	231	227	234	231
Prod SCFM	1388	1341	1339	1293	1316	1344	1319	1353	1336	1343	1354	1363
Shale Rate TPH(wet)	12.35	11.94	12.38	11.92	12.37	11.85	12.50	12.02	12.28	11.93	12.13	11.9
Balances												
Total Carbon	100.0	99.1	103.7	103.0	96.6	98.9	88.1	89.1	89.5	92.8	91.4	94.0
Total Weight	99.6	98.2	100.0	98.7	97.8	97.7	96.8	96.2	96.0	97.3	96.2	97.0
ATM N2	101.1	92.9	95.4	89.1	89.9	88.6	93.6	85.6	86.8	87.7	88.5	88.0

TABLE 3.3

ERROR ANALYSIS OF THE DoE DAO VS DEI DATA IN TABLES 3.1 AND 3.2

Date	Air			Gas				Shale Rate	Balances		
	Btm**	Mid	Top	Btm	Mid	Top	Prod		Total Carbon	Total Weight	Atm. N ₂
6-11-78		-0.013	-0.075*	0.276*	-0.110*	-0.111*	-0.140*	0.020	-0.044	-0.021	-0.012
6-13-78		0.082	0.004	0.064	0.028	0.065	0.009	0.045	-0.035	-0.012	-0.086
6-15-78		0.075	0.015	0.046	0.008	0.062	-0.005	0.048	-0.018	-0.010	-0.069
6-18-78	N.A.	0.006	0.004	0.017	0.020	0.019	0.016	0.047	-0.034	-0.017	-0.045
6-19-78	N.A.	0.037	-0.014	0.031	-0.008	0.003	-0.013	0.043	-0.020	-0.008	-0.090
6-20-78	-0.673	0.006	-0.014	0.014	0.012	0.047	0.017	0.027	0.018	0.006	-0.075
6-21-78	-0.694	0.024	-0.011	0.031	0.036	0.069	0.070	0.061	0.004	0.020	-0.059
6-27-78		0.029	0.001	0.057	-0.008	0.019	0.021	N.A.	0.010	0.001	-0.013
6-28-78		0.033	0.008	0.012	0.004	0.049	0.057	0.039	0.009	0.006	0.002
7-2-78	-0.682	0.000	-0.001	0.007	0.000	0.008	0.035	0.034	0.009	0.014	0.088
7-3-78	-0.668	0.007	0.010	0.014	-0.006	0.038	0.036	0.039	0.007	0.013	0.071
7-20-78	-0.704	0.056	0.000	0.063	-0.004	0.000	-0.021	0.044	-0.023	0.001	0.015
7-21-78	-0.671	0.019	-0.004	0.052	-0.012	-0.008	-0.025	0.040	-0.011	0.006	0.093
7-24-78	0.057	0.019	0.000	0.056	-0.008	0.018	-0.005	0.029	-0.036	-0.013	-0.010
7-25-78	0.040	0.032	-0.004	0.065	-0.012	0.013	-0.007	0.029	-0.028	-0.015	0.001
Average Error		0.027	-0.0004	0.038	0.004	0.029	0.017	0.039	-0.013	-0.002	-0.013
Standard Error		0.038	0.008	0.043	0.015	0.038	0.040	0.040	0.024	0.012	0.060

$$\text{Error (E)} = \left(\frac{\text{DAO}}{\text{DEI}} - 1 \right)$$

$$\text{Mean Error (E)} = \frac{1}{N} \sum_{i=1}^N \text{error}_i$$

$$\text{Standard Error (S.E.)} = \left[\frac{1}{N} \sum_{i=1}^N (\text{error}_i)^2 \right]^{1/2}$$

* These error values are not included in the error averages. The transducers were checked and recalibrated.

** No average error analysis was done for btm air. The btm air orifice size used in the DoE program was incorrect until 7-24-78 when the correct orifice size was input (0.589" changed to 1.736").

$$\bar{E} = \frac{1}{N} \sum_{i=1}^N E_i$$

$$S.E. = \sqrt{\frac{1}{N} \sum_{i=1}^N (E_i)^2}$$

The mean error is a measure of the bias. The standard error is a measure of the spread of the individual errors.

The most accurate measurement obtained during operation of the DoE DAQ system was the top air with a bias, or mean error ($\bar{E}$) of + 0.04 and a spread, or standard error (S.E.), of 0.8. The least accurate measurement was the shale rate with a mean error of + 3.9 and a standard error 4.0.

Significant differences do appear at times in the paired data, particularly in the calculated air and gas flows. These calculated flows (W) depend primarily on the differential pressure (ΔP), the static pressure (P) and the specific gravity (G). In Table 3.4, these quantities are compared. No ΔP are shown because the quick summary portion of the SUMRY option listed only zeroes for these values. Individual gas and air pressures, measured by DoE, are compared against the blower discharge pressures, used by DEI. DoE calculated gas specific gravity using calculated water vapor concentrations. The calculated concentrations ranged from 16.49 to 32.50 vol % whereas the measured concentrations ranged from 17.00 to 21.72 vol %. DEI uses a constant value of 0.97 for the gas specific gravity. DoE calculated the air specific gravity taking into consideration changes in the relative humidity and temperature. DEI uses a constant value of 1.00. In order to assess the effects of P and G on W, the following relationship was used:

$$W_{DEI} = W_{DoE} \cdot \sqrt{\frac{P_{DEI}}{G_{DEI}} \cdot \frac{G_{DoE}}{P_{DoE}}}$$

If the error in the calculated flow rates (W) were caused solely by errors in static pressures (P) and specific gravity (G), the above equation should balance. Any difference (or error) still remaining would be caused primarily by errors in the differential pressure (ΔP). Applying the equation to the available data, the error (or difference) between the calculated DoE and DEI flow rates was reduced significantly. Thus, errors in the static pressure and specific gravity data, and not the differential pressure, are mainly responsible for differences between the DoE and DEI calculated flow rates.

TABLE 3.4 FACTORS INFLUENCING FLOW CALCULATIONS

	<u>Gas Static Pressures (In. Hg)</u>					<u>Air Static Pressure (In. Hg)</u>				DoE** Calculated Gas Specific Gravity
	DEI Rec. Blw. <u>Dischg.</u>	<u>DoE Orifice Static Pressures</u>				DEI Air Blw. <u>Dischg.</u>	<u>DoE Orifice Static Pressures</u>			
		<u>Btm</u>	<u>Mid</u>	<u>Top</u>	<u>Prod</u>		<u>Btm</u>	<u>Mid</u>	<u>Top</u>	
6-11-78	7.9	7.63	7.65	7.60	7.46	12.1	-	11.54	11.53	0.998
6-13-78	7.8	7.48	7.51	7.46	7.50	11.9	-	11.22	11.44	0.914
6-15-78	7.7	7.42	7.46	7.36	7.55	12.1	-	11.75	11.68	0.958
6-18-78	7.6	7.60*	7.60*	7.60*	7.60*	11.5	-	11.50*	11.50*	0.935
6-19-78	7.6	7.26	7.30	7.20	7.40	11.3	8.69	10.49	10.43	0.942
6-20-78	7.6	7.41	7.41	7.31	9.13	11.3	8.96	10.55	10.46	0.934
6-21-78	7.5	7.25	7.30	7.20	9.02	11.4	8.76	10.65	10.70	0.894
6-27-78	7.2	6.90	6.97	6.88	9.46	11.3	-	11.13	11.06	0.958
6-28-78	7.2	7.20*	7.20*	7.20*	10.00	11.4	-	11.40*	11.40*	0.946
7-2-78	7.4	7.61	7.19	7.08	9.30	11.5	9.82	11.17	11.08	0.961
7-3-78	7.4	7.56	7.20	7.07	8.90	11.5	12.26	11.25	11.20	0.965
7-20-78	7.8	8.00	7.65	7.48	8.06	11.7	11.70*	11.13	11.26	0.961
7-21-78	7.8	8.00	7.63	7.51	8.29	11.8	11.80*	11.16	11.17	0.978
7-24-78	7.9	8.04	7.68	7.63	7.90*	11.7	11.70*	11.33	11.31	1.001
7-25-78	7.9	8.04	7.63	7.58	7.90*	11.7	11.70*	10.99	11.13	0.976

* These pressures were edited using DEI data.

** DEI used a constant specific gravity of 0.97.

4.0 CONCLUSIONS

1. Although gas data, oil flow, and tank gaging had to be inserted manually, the operation of the DoE system was successful.
 - ° Two full-time, fully trained computer operators can operate and maintain the system on a 7-day-a-week basis.
 - ° Minimum maintenance was required.
 - ° Data obtained from the automated DoE system agree quite well with data obtained by DEI data processing.
2. Some changes in past operation were needed to meet contract schedule and to provide more fully automated data acquisition.
 - ° Delivery of the computer and software programs should coincide with the schedule.
 - ° Additional research is needed to assure trouble-free, valid operation of the net oil analyzer and on-stream gas chromatograph in monitoring retort streams.
 - ° Instrumentation, to monitor tank levels automatically, is needed.
3. In addition to those items listed under CONCLUSION 2 (those items needed to improve past operations), future operation of the DoE system could be improved by including:
 - ° The DEI computer operator should be able to investigate and debug any malfunctioning option of the DoE system.

- The CPU should be expanded to permit:
 - more information retrieval at the operations terminal;
 - opportunity for on-line programming;
 - expanded long-term data retrieval.

APPENDIX 5.1

MONTHLY PROGRESS REPORTS

PROGRESS REPORT
August, 1977
Anvil Points Oil Shale Facility
Contract No. EY-77-C-04-4000

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operation of the ERDA-furnished computer controlled data acquisition system.

A. Overall Progress

1. One meeting was held with L.E.R.C. personnel to discuss compatability of the Paraho signal sources and the ERDA-furnished computer.

B. Current Problems

1. None

C. Planned Activities

1. Prepare requisitions for capital items so that orders can be placed as soon as the contract is signed.

PROGRESS REPORT
September, 1977
Anvil Points Oil Shale Facility
Contract No. EY-77-C-04-4000

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operation of the ERDA-furnished computer controlled data acquisition system.

A. Overall Progress

1. Orders have been placed for some of the electrical supplies.
2. A meeting was held with L.E.R.C. personnel to discuss the operation of on-stream instrumentation.

B. Current Problems

1. None

C. Planned activities

1. Complete the orders of the electrical supplies.
2. Schedule and start the installation of the electrical equipment.
3. Prepare the site and install the ERDA-furnished computer.

PROGRESS REPORT
October, 1977
Anvil Points Oil Shale Facility
Contract No. EY-77-C-04-4000

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operation of the ERDA-furnished computer controlled data acquisition system.

A. Overall Progress

1. All orders for electrical supplies have been placed.
2. Installation of the electrical conduits has been started.

B. Current Problems

1. A verbal change order, by the TPO, was made to change the junction boxes in the Data Acquisition Building and to have DEI perform a portion of the installation previously assigned to LERC personnel. These changes delay DEI's receiving the equipment by several weeks, add nearly \$1,000 to the capital cost and increase the electrical-signal installation by about 80 man-hours.

C. Planned Activities

1. Schedule the installation of the electrical-signal wiring.
2. Prepare the site for the ERDA-furnished computer (scheduled for delivery in mid-December).

PROGRESS REPORT
November, 1977
Anvil Points Oil Shale Facility
Contract No. EY-77-C-04-4000

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operation of the ERDA-furnished computer controlled data acquisition system.

A. Overall Progress

1. Materials have arrived on schedule, wiring and installation plans have been made. A PERT diagram for installation has been drawn.
2. Contract electricians should be at the Anvil Points site by Dec. 1 to complete the wiring.
3. Transducers are being installed.

B. Current Problems

1. The on-stream GC had been reprogrammed as suggested by the TPO. However, an apparent power disruption wiped out the memory which caused extensive damage. The GC will be repaired, but will not be brought on-stream until the UPS is operable.

C. Planned Activities

1. Complete all installation and wiring to coincide with the installation of the computer (Dec. 23, 1977).

PROGRESS REPORT
December, 1977
Anvil Points Oil Shale Facility
Contract No. ET-77-C-03-1765

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operation of the DoE-furnished computer controlled data acquisition system.

A. Overall Progress

1. Installation and wiring, required for the arrival of the DoE-furnished computer, have been completed.
2. The on-stream GC is operable.

B. Current Problems

1. None.

C. Planned Activities

1. Install the DoE-furnished computer and complete wiring.
2. Test and debug the computer-controlled data acquisition system.

PROGRESS REPORT
January, 1978
Anvil Points Oil Shale Facility
Contract No. ET-77-C-03-1765

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operation of the DoE-furnished computer controlled data acquisition system.

A. Overall Progress

1. The DoE-furnished computer has been placed in the Data Acquisition Building.
2. Approximately two-thirds of the additional wiring, requested by the TPO, is complete. This wiring is needed to complete the computer installation.

B. Current Problems

1. Although the project remains within the estimated budget, the project is not on schedule due to delays in receiving the computer. Some key components for the computer are still not available. Because of the additional work being done under installation, sufficient funds will not be available under the present contract to complete the specified operation.

C. Planned Activities

1. Complete the computer installation so that the system is ready for checkout using the services of an expert from LERC.
2. After the remaining key components have been delivered by LERC, the system will be debugged with the assistance of the LERC expert so that the data acquisition system is operational as soon as possible. Target for an operational system is March, 1978.

PROGRESS REPORT
February, 1978
Anvil Points Oil Shale Facility
Contract No. ET-77-C-03-1765

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operations of the DOE-furnished computer controlled data acquisition system.

A. Overall Progress

1. All wiring and instrument installation is complete. DEI has corrected polarity reversal within the computer.
2. Visits by Smith and Mones (LERC) have corrected most problems. They, reportedly, are pleased with DEI's effort in instrumentation and installation. All instruments will be hooked into the computer so that the system should be operational by mid-March.

B. Current Problems

1. None.

C. Planned Activities

1. Smith and Mones will be available to assist in operator training and system debugging for one-to-two weeks, as needed, in late March - early April. Actual scheduling depends upon start-up of the Semi-Works.

PROGRESS REPORT
March, 1978
Anvil Points Oil Shale Facility
Contract No. ET-77-C=03=1765

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operation of the DoE-furnished computer controlled data acquisition system.

A. Overall Progress

1. All transducers and target flow meters are in place. Calibration information is now available.

B. Current Problems

1. The Hewlett-Packard gas chromatograph is not operational at this time. The gas chromatograph has been sent to LERC for repairs.

C. Planned Activities

1. Schedule training session with LERC personnel for the operation of the computer data acquisition system.

PROGRESS REPORT
APRIL, 1978
Anvil Points Oil Shale Facility
Contract No. ET-77-C-03-1765

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operations of the DoE-furnished computer controlled data acquisition system.

A. Overall Progress

1. None

B. Current Problems

1. The H-P gas chromatograph is being repaired at LERC. It will be returned to Anvil Points when repaired.

C. Planned Activities

1. Schedule training session with LERC personnel for the operation of the computer data acquisition system.
2. Operate and debug data system.

PROGRESS REPORT
May, 1978
Anvil Points Oil Shale Facility
Contract No. ET-77-C-03-1765

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0223 by the installation, maintenance, and operations of the DoE-furnished computer controlled data acquisition system.

A. Overall Progress

1. Personnel have been hired to operate the DoE-furnished computer. They are being trained by LERC personnel.
2. The gas sampling room has been cleaned and prepared for the installation of the DoE-furnished H-P gas chromatograph.
3. The H-P GC has been repaired by LERC personnel and they are installing it at Anvil Points and calibrating the modified program.

B. Current Problems

1. None.

C. Planned Activities

1. Operate the DoE-furnished computer-controlled data acquisition system.
2. Determine the variability of data output from both the automated and normal systems so that noise can be distinguished from real differences in data comparisons.
3. File and compare data from the two systems.

PROGRESS REPORT
JUNE, 1978
Anvil Points Oil Shale Facility
Contract No. EP-77-C-03-1705

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operation of the DoE-furnished computer controlled data acquisition system.

A. Overall Progress

1. DoE-furnished computer-controlled data acquisition has been operated since June 11.
2. A log is being maintained to show data inputs, differences in results, and any corrective action taken.
3. Data from ten 24-hour test days are being filed and compared with the Paraho data processing system.

B. Current Problems

1. The on-stream GC continues to be inoperative. Needed parts have been ordered. In the meanwhile, full gas data is obtained by the Paraho Laboratory and manually input into the computer system.

C. Planned Activities

1. Continue present operations.

PROGRESS REPORT
July, 1978
Anvil Points Oil Shale Facility
Contract No. ET-77-C-03-1765

Objective:

Expedite the accumulation of data generated under ONR Contract No. N00014-77-C-0233 by the installation, maintenance, and operations of the DoE-furnished computer controlled data acquisition system.

A. Overall Progress

1. The DoE-furnished computer continues to work well; data are being compared with the DEI data processing.
2. The extension of the operation of the data acquisition system to coincide with retort operations was not approved. The computer was shut down July 27 and returned to LETC on July 31.

B. Current Problems

1. None.

C. Planned Activities

1. Continue the preparation of specified equipment, furnished by the government for the computer controlled data acquisition system, for return to LETC.
2. Write up final report.

APPENDIX 5.2

ON-STREAM ANALYZERS, GAS CHROMATOGRAPHS

AND

NET OIL ANALYZER

APPENDIX 5.2.1

ON-STREAM ANALYZERS

ON-STREAM ANALYZERS

(FINAL REPORT)

Submitted by Development Engineering, Inc.
to the Laramie Energy Research Center in
partial fulfillment of the LERC Purchase
Order PL 72394 .

September, 1977 .

TABLE OF CONTENTS

	<u>Page</u>
SUMMARY	1
INTRODUCTION	1
INSTALLATION	2
Gas Chromatograph	2
Net Oil Analyzer	3
RESULTS AND DISCUSSION	3
GC Calibration	3
NOA Calibration	4
GC Operation	4
NOA Operation	5
SUGGESTIONS FOR FUTURE WORK	5
TABLES	
I GC Operating Conditions	6
II Retention Times and Response Factors	7
III Repeatability - Retention Times	8
IV Repeatability - Peak Area	9
V Accuracy of GC Data	10
VI NOA Calibration	11
FIGURES	
1 Data Acquisition - Retort Control Complex	12
2 GC Sampling System	13
3 GC Printout	14
4 Net Oil Analyzer Installation	15
5 Frequency - Water Calibration Curve	16
6 NOA Volume % Water	17

ON-STREAM ANALYZERS

SUMMARY

1. The job described in the LERC Purchase Order PL 72404 has been completed.
2. The Hewlett-Packard 5832 A Gas Chromatograph has been installed and calibrated. The data are accurate; the mean difference between the on-stream GC data and laboratory GC data is 0.34 vol %.
3. The Halliburton Net Oil Analyzer has been installed and calibrated. Total liquid production, determined by the NOA, is within 3.0% of tank gaging data. Weight percent water in the oil, computed from the NOA data, does not agree with the laboratory data.
4. Cost of this job met that specified in the LERC Purchase Order PL 72404.
5. Some additional work should be done. The on-stream GC should be modified so that argon and individual C-3's and C-4's be detected and the operation be compatible with the data acquisition computer. An in-line homogenizer is needed to obtain valid water in oil data from the NOA.

INTRODUCTION

The on-stream analyzers have been installed, calibrated, and operated by Development Engineering, Inc. (D.E.I.) according to the job description in the Laramie Energy Research Center (LERC) Purchase Order No. PL 72404:

Installation, weekly calibration, and continuous operation of the ERDA-furnished, Hewlett-Packard 5832 Gas Chromatograph and the Halliburton Net Oil Analyzer in accordance with manufacturer's specifications for monitoring recycle gas composition and oil production during an eight week operation of the Semi-Works retort at the Anvil Points oil shale facility.

INSTALLATION

Gas Chromatograph The Hewlett-Packard 5832 A Gas Chromatograph (GC) has been installed in the gas sampling room located on the west end of the Retort Control Building (see Fig. 1). The gas flows are shown in the schematic drawing "GC Sampling System" (see Fig. 2).

The gas sampling system, as shown in Figure 2, is a two-inch, black iron pipe from the blower discharge to the up-stream side of the electrostatic precipitator. The loop is steam traced and insulated and maintains a temperature of 180-200°F. From the top of this loop is a steam traced, 1/4" stainless steel tube leading to the gas manifold. Eight 1/8" stainless steel, steam traced tubes take the gas sample to the heated 16-port stream selection valve (SSV). A primary gas standard also goes to the 16-port SSV. The heated 6-port gas sample valve (GSV) with a 0.5 cc gas sample loop delivers the gas sample via the 4-port backflush valve (BFV) to the B column. Air is used to accuate the valves and open the door louvers for cooling. Liquid CO₂ is used to cool the oven to -30°C.

The operating conditions set for the on-stream GC are listed in Table I. These conditions are designed to complete the entire sampling analysis cycle in less than 60 minutes and obtain the data required for operations. These data are:

Hydrogen	Ethylene
Nitrogen	Ethane
Oxygen	C-3's
Carbon Monoxide	C-4's
Methane	Water
Carbon Dioxide	C-5

The on-stream GC automatically prints the chromatograph and volume percent of all components (wet basis). A typical printout is shown in Figure 3. At the present time, the on-stream GC is dedicated solely to the Semi-Works retort providing hourly information of the recycle gas composition.

Net Oil Analyzer The Halliburton Net Oil Analyzer (NOA) has been installed in the rundown line from the Semi-Works oil separation to the oil gaging tanks (see Fig. 4). A by-pass line, around the NOA, facilitates cleaning and maintenance without disrupting operations. The NOA readout, housed in the control box, is located in the Retort Control Room. The readout consists of a gage indicating present flow and two totalizers indicating cumulative oil flow and cumulative water flow. Every hour, the retort operators log these cumulative data on the Operation Log Sheet.

The NOA has three components. The control box contains the readout and the printed circuit cards. The 0.5 inch turbine meter determines the total liquid flow. The capacitance probe detects the amount of water in the liquid flow by a change in frequency. A calibration curve (see Fig. 5), relating frequency (KHz) to water (volume % in total liquid), is wired into the printed circuit cards.

RESULTS AND DISCUSSION

GC Calibration The on-stream GC was calibrated using four cylinders of calibrated gas mixes to obtain mean retention times and response factors (see Table II). The mixes closely match the composition of direct mode recycle gas.

Repeatability of the on-stream GC operation was tested by comparing pairs of chromatograms obtained during three separate days' operations. Retention times, the qualitative data used to identify components, are shown in Table III. The mean relative standard deviation ($RSD = 100\% \times \text{Standard deviation/mean}$) for response times is 0.14%. Peak areas, the quantitative data used to assess the concentration of individual components, are shown in Table IV. The mean relative standard deviation for peak areas is 4.51%. For this figure to be valid, it is assumed that there is no significant change in recycle gas composition during each of the three two-hour test periods.

The accuracy of the on-stream GC data was determined by comparing results with those from the laboratory GC and condensate data for three separate days. Results are shown in Table V. The data agree quite well; even water and the C-4 + (naphtha) data, which are known to be suspect from earlier laboratory studies, show fair agreement. The mean standard deviation for all twelve components from Table V is 0.34 vol %. From these results, it appears that the on-stream GC should provide valid, reliable information concerning recycle gas composition.

NOA Calibration Most of the calibration of the Halliburton Net Oil Analyzer has been done during the instrument design and installation. Calibration of the NOA was performed on-stream. Over a four-day period, the NOA data were compared with tank gage data and laboratory data (see Table VI). From the data in Table VI, it is apparent that the total volume measured by the NOA (barrels oil + barrels water) agrees with the tank gage data using four different tanks. The mean standard deviation from this four day period (11 data points) is 3.71 barrels. Total difference for the entire four-day production is 26.8 barrels. The percent water correlation is not apparent. First, the NOA data are in volumes while the laboratory data are in weight percent. Using the data acquisition computer, the following equation was established (since the NOA's basic design includes the zero point, the equation was restricted to $Y = mX$):

$$\text{Wt\% H}_2\text{O} = 0.45 \times \frac{\text{NOA water}}{\text{NOA oil} + \text{NOA water}}$$

This curve "fit" most of the eleven experimental data points (see Figure 6). There are two outliers. The mean difference between the nine "good" points are 0.62 wt % water. Agreement between NOA data and tank gage and laboratory data appears to be good.

GC Operation The on-stream Hewlett-Packard Gas Chromatograph has been operated routinely since the calibration studies. All printouts have been filed for reference. During this time, the data obtained during calibration

has been checked seven times during four separate days. Results obtained in Table V have been confirmed. The on-stream GC does provide accurate data.

NOA Operation The on-stream Halliburton Net Oil Analyzer has been operated routinely since the calibration studies. The NOA data are logged hourly on the Operation Log Sheet. Because of some uncertainty of the NOA data, frequent checks were made during this on-going operating period. It appears that the NOA total liquid is usually higher than the tank gage data. By subtracting 1.3 barrels/8 hours from the NOA data, the correlation is improved. The mean standard deviation from data shown in Table VI drops to 2.47 barrels and the total difference drops to 10.0 barrels for the four-day period. During recent operations, the difference for total oil production for eight days (nearly 1300 barrels) was 2.8 barrels. The on-stream NOA does provide accurate data on total liquid production.

Data obtained from the NOA for volume percent water does not agree with the data obtained from the laboratory. The data points (NOA computed values and lab results) are shown in Figure 6 as open circles. Using ± 1.5 vol % water as a "good fit" for all the data, it appears from Figure 6 that nearly one-third of the experimental data would be classified as outliers. At this time, it must be concluded that the on-stream NOA does not provide valid data for water content in the crude wet shale oil.

SUGGESTIONS FOR FUTURE WORK

1. The on-stream GC should be reprogrammed so that argon is identified, propylene and propane are separated quantitatively, and a C-5 + conglomerate is calculated.
2. Telephone conversations with Halliburton indicate that an in-line homogenizer is needed to obtain valid water data. The NOA works best with emulsions.

TABLE I

GC OPERATING CONDITIONS

Equipment

1/8" Stainless Steel	
Column	2 Chromosorb 102 80/100 mesh
Flowrate	30 cc/min
Carrier	8.5% Hydrogen 91.5% Helium
Detector	Dual Column Thermal Conductivity Detector
Oven	Cryogenic with Liquid Carbon Dioxide as Coolant
Valves	1 16-Port Stream Selection Valve - Steam Heated
	1 6-Port Gas Sample Valve - Heated
	1 4-Port Backflush Valve - Heated

Program CycleInstruction

Temp I (min col)	-30°C
Time	6 Minutes
Rate	30°C/Min
Temp II (max col)	200°C
Total	60 Minutes
Injection Temp	100°C
TCD Temp	200°C
Aux Temp	110°C
Oven Max	250°C
Chart Speed	0.50
Attenuation	28
TCD Signal	A-B
Slope Sensitivity	0.75
Area Reject	1
Option	15

Program Time (Min)Instruction

0.1	Vlv/Ext	1
0.2	Vlv/Ext	-1
3.2	TCD Signal	-A + B
3.3	Zero	
16.9	Vlv/Ext	2
17.0	Zero	
17.0	Slope Sensitivity	0.90
25.0	Vlv/Ext	-2
25.1	Chart Speed	0.00
26.0	Temp II (Hold)	50°C
26.0	Time II (Hold)	60.0 Minutes
30.0	Temp II (Cooling)	-30°C
30.0	Time II (Cooling)	28.1 Minutes
58.0	Stop	

TABLE II

RETENTION TIMES AND RESPONSE FACTORS

Element	R.T. (Minutes)	R.F. ($\times 10^{-5}$)
Hydrogen	2.62	303.36
Nitrogen	3.71	6.6589
Oxygen	4.35	7.7244
Carbon Monoxide	4.67	6.5558
Methane	8.98	7.9060
Carbon Dioxide	11.60	4.2611
Ethylene	13.10	3.6898
Ethane	13.70	3.2987
Water	14.90	1.7751
Propylene	16.05	2.4206
Propane	16.22	2.2839
*N-Butane	20.95	1.8847
Iso-Bentane	20.00	1.6063
N-Pentane	19.50	1.6063
N-Hexane	19.23	0.97907

* Start of Backflush

TABLE III

REPEATABILITY - RETENTION TIMES

Element	Day 1			Day 2			Day 3			Overall R.S.D.
	1(1)	2(1)	R.S.D.(2)	1(1)	2(1)	R.S.D.(2)	1(1)	2(1)	R.S.D.(2)	
Hydrogen	2.67	2.66	.27	2.67	2.67	0	2.58	2.58	0	.16
Nitrogen	3.80	3.79	.19	3.80	3.80	0	3.69	3.67	.77	.45
Oxygen	-	-	-	-	-	-	-	-	-	0
Carbon Monoxide	4.72	4.71	.15	4.73	4.72	.15	4.60	4.57	.46	.29
Methane	9.03	9.03	0	9.03	9.03	0	8.93	8.90	.24	.14
Carbon Dioxide	11.68	11.67	.06	11.68	11.68	0	11.63	11.61	.12	.08
Ethylene	13.15	13.14	.05	13.15	13.15	0	13.13	13.12	.05	.04
Ethane	13.75	13.75	0	13.75	13.75	0	13.75	13.73	.10	.06
Water	14.89	14.87	.10	14.87	14.89	.10	14.87	14.85	.10	.10
Propylene	16.18	16.11	.31	16.09	16.10	.04	16.11	16.11	0	.18
Propane	16.27	16.20	.30	16.27	16.27	0	16.29	16.29	0	.17
C ₄ 's	20.95	20.93	.08	20.96	20.95	.03	20.89	20.89	0	.05
Iso-Pentane	19.88	19.85	.11	19.89	19.87	.14	19.82	19.82	0	.10
Pentane	19.21	19.19	.07	19.22	19.21	.04	19.14	19.14	0	.05
C ₆ +	18.48	18.44	.15	18.46	18.48	.15	18.46	18.45	.04	.12

(1) Minutes

(2) $R.S.D. = 100 \times \frac{\text{Std Dev}}{\text{Mean}}$

TABLE IV
REPEATABILITY - PEAK AREA

Element	Day 1			Day 2			Day 3			Overall R.S.D.
	1 (1)	2 (1)	R.S.D. (2)	1 (1)	2 (1)	R.S.D. (2)	1 (1)	2 (1)	R.S.D. (2)	
Hydrogen	767	765	.18	761	741	1.86	1641	1462	8.19	4.85
Nitrogen	559700	535800	2.92	558000	565600	.94	1125000	1036000	5.83	3.82
Oxygen	0	0		0	0		0	0		0
Carbon Monoxide	32870	30410	5.37	311300	328300	3.75	54650	50530	5.54	4.95
Methane	14810	15840	4.76	16560	16300	1.10	27430	27670	.62	2.84
Carbon Dioxide	353700	316600	7.76	331600	334300	.57	727000	661700	5.66	5.56
Ethylene	17350	16800	2.28	13980	13020	5.04	17030	16880	.63	3.21
Ethane	6968	7850	8.37	8898	8828	.56	17060	17620	2.28	5.02
Water	1481000	1581000	4.64	1523000	1535000	.56	342000	396500	1.43	2.82
Propylene	7118	7150	.32	8088	7344	2.13	17370	15390	8.55	5.09
Propane	4156	4230	1.24	4859	4671	2.73	8762	8764	.01	1.73
C ₄ 's	2325	2076	8.00	8312	7910	3.45	14770	15570	3.73	5.47
C ₅ 's	0	0		0	0		8047	8796	6.29	6.29
C ₆ +	29000	26340	6.80	26690	26150	7.57	53650	59240	7.00	7.13

(1) Area (Voltage x Time)

(2) R.S.D. = 100% x $\frac{\text{Std Dev}}{\text{Mean}}$

TABLE V

ACCURACY OF G.C. DATA

COMPARISON WITH LAB G.C. DATA

Component	Day 1			Day 2			Day 3			Average S.D.
	Lab	On-Stream	S.D.	Lab	On-Stream	S.D.	Lab	On-Stream	S.D.	
Hydrogen	4.54	4.47	0.05	4.67	3.94	.52	4.16	3.92	.17	0.25
Nitrogen	50.37	52.05	1.19	60.16	59.55	0.43	54.67	55.54	0.64	0.75
Oxygen	0	.34	0.24	0.05	0	0.04	0.04	0	0.03	0.10
Carbon Monoxide	2.25	2.25	0	2.40	2.86	0.33	2.16	2.74	0.41	0.25
Methane	1.37	1.59	0.16	1.77	1.75	0.01	1.67	1.59	0.06	0.08
Carbon Dioxide	19.44	21.00	1.10	24.14	23.26	0.62	22.28	22.87	0.42	0.71
Ethylene	0.68	0.46	0.16	0.59	0.54	0.04	0.50	0.46	0.03	0.08
Ethane	0.21	0.39	0.13	0.42	0.45	0.02	0.39	0.41	0.01	0.05
Water	20.33	16.77	2.52	8.22	6.51	0.91	13.12	7.68	3.85	1.47
Propylene	0.22	0.25	0.02	0.27	0.29	0.01	0.25	0.25	0.00	0.01
Propane	0.12	0.16	0.03	0.15	0.15	0.00	0.15	0.14	0.01	0.01
C ₄ +	0.46	0.28	0.13	0.13	0.71	0.41	0.15	0.69	0.38	0.31

S.D. = Standard Deviation = $\frac{\Delta^2}{2}$ where Δ = Lab - On-Stream

Note: All data are in Vol %.

TABLE VI
NOA CALIBRATION

Date	Time	Tank Data		NOA Data		Lab Wt % H ₂ O
		Tank No.	Barrels (Gage)	Barrels Oil	Barrels H ₂ O	
8-23-77	0000-0800	523	51.18	44.88	6.70	5.31
8-23-77	0800-1600	524	49.42	44.47	6.39	9.74
8-23-77	1600-2400	523	49.77	44.85	5.75	4.16
8-24-77	0000-0800	524	50.65	47.65	6.85	6.23
8-24-77	0800-1600	523	41.60	33.79	5.31	7.47
8-24-77	1600-2400	524	53.87	47.55	8.90	7.92
8-25-77	0000-2400	517	160.19	143.08	24.57	7.04
8-26-77	0000-0800	523	51.71	46.93	7.05	13.94
8-26-77	0800-2400	515	118.77	108.74	17.72	5.30
8-27-77	0000-0800	523	58.95	52.56	7.81	6.30
8-27-77	0800-1300	524	36.71	33.07	4.97	7.00

FIGURE 1

DATA ACQUISITION-RETORT CONTROL COMPLEX

Figure 2
GC SAMPLING SYSTEM

Figure 3
GC PRINTOUT

RT	EXP RT	AREA	CAL #	AMT
2.62	2.62	1331	2	4.862
3.71	3.71	862400	1	56.929
4.35	4.35	13050	3	1.054
4.67	4.67	35140	4	2.312
8.98	8.98	31860	5	2.483
11.63	11.59	483600	6	20.642
13.12	13.10	57630	7	2.129
13.71	13.70	66600	8	2.177
14.94	14.85	28140	9	0.658
16.25	16.05	82660	10	1.921
16.22	16.22	83140	11	1.837
19.23	19.23	93800	12	0.998
19.99	20.00	117600	14	1.876
20.95	20.95	49630	15	0.922

MF: 1.0000 E+ 0

FIGURE 4

NET OIL ANALYZER INSTALLATION

FIGURE 5
FREQUENCY - WATER CALIBRATION CURVE

FIGURE 6
NOA VOLUME % WATER

APPENDIX 5.2.2

GAS CHROMATOGRAPH MODIFICATIONS

Development Engineering Incorporated ■ BOX A, ANVIL POINTS, RIFLE, COLORADO 81650 ■ PHONE 303-625-2100

December 20, 1977

Mr. B. C. Sudduth, TPO
Laramie Energy Research Center
U.S. Department of Energy
P.O. Box 3395, University Station
Laramie, WY 82071

Dear Mr. Sudduth:

The work described in your Purchase Order No. PL73793 is complete.

1. Electrical power has been supplied to the Data Acquisition Building. This electrical circuit will be completed after the trailer housing the data acquisition computer is located in the building.
2. The ERDA (DoE)-furnished Hewlett-Packard 5830 Gas Chromatograph has been modified and wired into the UPS system. A technical report describing the GC operation and data is attached.

The final cost statement is being prepared. This will complete all data acquisition work done under purchase orders. All future data acquisition work will be done under Contract No. EN 77-C-04-4000.

Sincerely,

R N Heistand
R. N. Heistand

RNH:oh

Attachment

cc: J. B. Jones, Jr.
J. B. Chatham

ON-STREAM GC REPORT

SUMMARY

1. The Hewlett-Packard Gas Chromatograph Model 5832A has been completely installed on-stream to monitor Semi-Works recycle gas 12 times during each 24-hour day. The entire cycle requires one hour for the analysis of 16 components.
2. The program provides adequate separation of the 16 components so that a qualitative identification of each component can be made using response times.
3. Paired data from the on-stream GC show that both the qualitative retention time data and the quantitative peak area data are repeatable. Mean relative standard deviations are: 0.19% (retention time); 5.69% (peak area).
4. Accuracy was determined by comparing the quantitative results of the on-stream GC with those obtained in the Paraho Laboratory. Mean standard error for the 16 components is 0.15 volume %.

INSTALLATION

Gas Chromatograph - The Hewlett Packard 5832A Gas Chromatograph (GC) has been installed in the gas sampling room located on the west end of the retort control building.

The gas sampling system is a two-inch, black iron pipe from the blower discharge to the up-stream side of the electrostatic precipitator. The loop is steam traced and insulated and maintains a temperature of 180-200°F. From the top of this loop, a steam traced, 1/4" stainless steel tube leads to the gas manifold. Eight 1/8" stainless steel, steam traced tubes take the gas sample to the heated 16-port valve (SSV). The heated 6-port gas sample valve (GSV) with 0.5 cc gas sample loop delivers the gas sample through the 4-port backflush valve (BFV) to the "B" column. Air is used to accuate the valves and open the door louvers for cooling. Liquid CO₂ is used to cool the oven to -45°C.

The operating conditions, set for the on-stream GC, are listed in Table I⁽¹⁾. These conditions are designed to complete the entire sampling analysis cycle in less than 60 minutes. This meets the conditions specified by the TPO⁽²⁾. The on-stream GC automatically prints the chromatograph and volume percent of all components (wet basis). At the present time, the on-stream GC is dedicated solely to the Semi-Works retort providing information of the recycle gas composition every two hours.

RESULTS AND DISCUSSION

GC Calibration - The on-stream GC was calibrated using three cylinders of calibrated gas mixes to obtain mean retention times and response factors (see Table II). The mixes closely match the composition of direct mode recycle gas.

Repeatability of the on-stream GC operation was tested by comparing pairs of chromatograms obtained during two separate day's operations. Retention times, the qualitative data used to identify components, are shown in Table III. The mean relative standard deviation ($RSD = 100\% \times \text{standard deviation/mean}$) for response times is 0.19%. The new conditions provide adequate separation of all peaks. Based on a statistical evaluation, the propylene-propane peaks (which often failed to separate under the old conditions) should separate 99.9% of the time.

The precision of the on-stream GC qualitative data was determined by evaluating peak areas in the same fashion as done previously for response times. Results are shown in Table IV. The mean R.S.D. for all components is 5.69%. These paired data show that the quantitative data are precise.

It is assumed that there is no significant change in recycle gas composition during both of the two test periods.

The accuracy of the on-stream GC data was also determined by comparing results with those from the laboratory GC and condensate data for two separate days. Results are shown in Table V. The data agree well. The mean standard deviation for all 16 components from Table V is 0.15% or about a 5% RSD. Thus, the results from the two GCs should agree within 0.15%.

REFERENCES

- (1) Hewlett-Packard, "5830A Gas Chromatograph Instrument Manual".
- (2) B. C. Sudduth, letter to R. N. Heistand, Sept. 6, 1977.

TABLE I
GC OPERATING CONDITIONS

Equipment

Same

Program Cycle

Instruction

Temp I (min col)	-45°C
Time I	7 minutes
Rate	15°C/min
Temp II (max col)	180°C
Time II (total time)	60 minutes
Injection Temp	100°C
TCD Temp	250°C
Aux. Temp	110°C
Oven (max)	250°C
Chart Speed	0.50
Attenuation	2 ⁶
TCD Signal	A-B
Slope Sensitivity	0.75
Area Reject	1
Flow A	30 cc/min
Flow B	30 cc/min
Option	1

Program Time (Min)

Instruction

0.1	VLV/Ext	1 (GSV)
0.5	VLV/Ext	-1 (GSV)
0.6	VLV/Ext	0 (SSV)
0.7	VLV/Ext	-0 (SSV)
0.8	VLV/Ext	0 (SSV)
0.9	VLV/Ext	-0 (SSV)
3.2	TCD Signal	-A + B
3.3	Zero	
7.1	Attenuation	2 ⁸
20.0	Slope Sensitivity	-
24.9	Slope Sensitivity	0.10
25.0	Attenuation	2 ⁶
25.1	Zero	
28.5	VLV/Ext	2 (BFV)
28.6	Zero	
28.7	Area Reject	0
36.9	Area Reject	1
37.0	VLV/Ext	-2 (BFV)
37.1	Chart Speed	0.00
37.1	Area Reject	-
37.5	Temp II	-45°C
37.5	Time II	20.6
58.0	Stop	

TABLE II
COMPONENTS, RETENTION TIMES, AND RESPONSE FACTORS

<u>Component</u>	<u>R.T. (Minutes)</u>	<u>R.F. ($\times 10^{-5}$)</u>
Hydrogen	2.60	450.70
Nitrogen	4.32	8.5990
Oxygen	5.20	10.319
Argon	5.58	6.0984
Carbon Monoxide	5.87	8.7270
Methane	11.95	10.5666
Carbon Dioxide	15.80	6.7474
Ethylene	18.08	6.5332
Ethane	19.05	5.9222
Water	20.58	1.7684
Propylene	22.72	2.6396
Propane	23.05	2.5709
Iso-Butane	26.35	2.2630
I-Butene	26.93	2.2752
N-Butane	27.39	2.0604
C ₅ +*	36.88	.20846

TABLE III

REPEATABILITY - RETENTION TIMES (Minutes)

Component	Day 1			Day 2		
	1	2	R.S.D.	1	2	R.S.D.
Hydrogen	2.60	2.59	0.27	2.56	2.57	0.28
Nitrogen	4.35	4.33	0.33	4.31	4.32	0.16
Oxygen	ND	ND	--	ND	ND	--
Argon	5.59	5.55	0.51	5.54	5.55	0.13
Carbon Monoxide	5.90	5.86	0.48	5.83	5.83	0.0
Methane	12.02	11.99	0.18	11.97	11.97	0.0
Carbon Dioxide	15.82	15.79	0.13	15.81	15.81	0.0
Ethylene	18.09	18.07	0.08	18.10	18.11	0.04
Ethane	19.06	19.05	0.04	19.08	19.09	0.04
Water	20.57	20.56	0.03	20.93	21.07	0.47
Propylene	22.75	22.73	0.06	22.79	22.79	0.0
Propane	23.03	23.01	0.06	23.08	23.09	0.03
Iso-Butane	26.42	26.38	0.10	26.49	26.51	0.05
I-Butene	26.95	26.93	0.05	27.03	27.05	0.05
N-Butane	27.46	27.43	0.08	27.55	27.56	0.03
C5+	36.88	36.88	0.0	36.86	36.88	0.04

TABLE IV
REPEATABILITY - PEAK AREA

Component	Day 1			Day 2			Overall R.S.D.
	1	2	R.S.D.	1	2	R.S.D.	
Hydrogen	795	724	6.61	721	711	.99	4.73
Nitrogen	644000	631400	1.40	563900	576200	1.53	1.47
Oxygen	ND	ND	--	ND	ND	--	--
Argon	7520	7322	1.89	6622	6640	.19	1.34
Carbon Monoxide	24820	24680	.40	21520	20310	4.09	2.91
Methane	14410	14240	.84	11990	11910	.47	.68
Carbon Dioxide	339900	328400	2.43	285000	308800	5.67	4.36
Ethylene	7552	7594	.39	6309	6039	3.09	2.20
Ethane	7012	6854	1.61	5797	5849	.63	1.49
Water	455500	494600	5.82	2866000	2515000	19.22	7.71
Propylene	6075	5995	.94	4289	4641	5.58	4.00
Propane	4385	4008	6.35	2934	2993	1.41	4.60
Iso-Butane	250	177	24.18	101	108	4.74	17.42
I-Butene	3445	3422	.47	2713	2751	.98	.77
N-Butane	3855	3781	1.37	2946	2813	3.27	2.51
C ₅ ⁺	233900	240700	2.03	203900	220300	5.47	4.13

TABLE V

ACCURACY OF GC DATA - COMPARISON WITH LAB GC DATA (Vol%)

Component	Day 1			Day 2		
	Lab GC	On-Stream GC	S.D.	Lab GC*	On-Stream GC	S.D.
Hydrogen	3.34	3.43	0.06	3.36	3.38	0.02
Nitrogen	50.49	50.35	0.10	55.16	55.23	0.05
Oxygen	0	0	0	0	0	0
Argon	0.42	0.42	0	0.46	0.47	0.01
Carbon Monoxide	1.97	2.13	0.11	2.05	2.05	0
Methane	1.63	1.54	0.06	1.51	1.46	0.03
Carbon Dioxide	18.88	19.70	0.58	20.57	20.46	0.08
Ethylene	0.52	0.50	0.01	0.47	0.47	0
Ethane	0.49	0.43	0.04	0.41	0.42	0.01
Water	21.20	20.55	0.46	15.36	15.13	0.16
Propylene	0.22	0.18	0.03	0.22	0.22	0
Propane	0.13	0.11	0.01	0.14	0.10	0.03
C ₄	0.06	0.07	0.01	0.06	0.06	0
C ₄ H ₁₀	0.03	0.08	0.04	0.03	0.07	0.03
C ₅ +	0.59	0.45	0.10	0.20	0.47	0.19

* Only one dry ice condenser vs. two condensers for the first run.

APPENDIX 5.2.3

ON-STREAM GC OPERATIONS

MEMO

TO: R. N. Heistand
SUBJECT: On-Stream G.C.

FROM: D. B. Jones.
DATE: May 1, 1978

The DOE-furnished on-stream gas chromatograph (G.C.) performed very well during the Pilot Plant operations of January 9, 1978 to January 26, 1978, using Paraho Method P-G-07

Table I shows the monthly average of the 16 components (wet basis) with their standard deviations (S.D.) and relative standard deviations (R.S.D.). The average S.D. is 1.43-vol % and the average R.S.D. is 21.7 %. The average S.D. on a dry basis is 0.58 and the corresponding R.S.D. is 26.1. The dry basis data are in Table II. Table III shows the comparison data between the teledyne oxygen analyzer, DEI on-stream G.C., and ORSAT analyzer for CO, O₂, and CO₂. These data show excellent agreement.

The main reason for the smooth operation of the G.C. is the lack of water problems. The only times that water posed a problem were during start-up and shut-down. Another reason was that the sample loop maintained a temperature of 245°F which prevented condensation.

D. B. Jones
D. B. Jones

DBJ:oh

Attachments

TABLE I
G.C. COMPILATION
VOL % WET BASIS

(Operations During January, 1978)

	<u>Mean</u>	<u>S.D.</u>	<u>R.S.D.</u>
Hydrogen	3.77	0.56	14.86
Nitrogen	51.66	3.13	6.05
Oxygen	0.01	0.02	-
Argon	0.50	0.03	6.84
Carbon Monoxide	2.35	0.31	13.00
Methane	1.67	0.37	22.38
Carbon Dioxide	19.80	1.85	9.34
Ethylene	0.47	0.08	17.48
Ethane	0.44	0.10	23.80
Water	18.26	4.35	23.84
Propylene	0.27	0.07	26.12
Propane	0.17	0.05	28.14
Iso-Butane	0.01	0.01	-
I-Butene	0.12	0.04	32.52
N-Butane	0.12	0.04	37.93
C ₅ ⁺	0.39	0.04	11.40

TABLE II
G.C. COMPILATION
VOL % DRY BASIS

(Operations During January, 1978)

	<u>Mean</u>	<u>S.D.</u>	<u>R.S.D.</u>
Hydrogen	4.63	0.71	15.4
Nitrogen	63.18	1.14	1.8
Oxygen	0.01	0.02	-
Argon	0.61	0.02	2.8
Carbon Monoxide	2.88	0.36	12.4
Methane	2.05	0.46	22.6
Carbon Dioxide	24.21	1.67	6.9
Ethylene	0.58	0.11	18.9
Ethane	0.54	0.13	25.0
Propylene	0.33	0.09	26.7
Propane	0.21	0.06	28.3
Iso-butane	0.01	0.01	-
I-butene	0.15	0.05	33.1
N-butane	0.14	0.06	38.5
C ₅ +	0.48	0.06	13.5

TABLE III
G.C. COMPARISONS⁽¹⁾
Teledyne⁽²⁾, DEI G.C.⁽³⁾, ORSAT⁽⁴⁾

VOL % DRY BASIS

(Operations During January, 1978)

	<u>Mean</u>				<u>S.D.</u>	<u>R.S.D.</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>		
Nitrogen	63.18	-	56.94	-	0.45	0.8
Oxygen	0.01	0.30	0.72	0.18	0.30	-
Carbon Monoxide	2.88	-	2.22	2.03	0.45	18.9
Methane	2.05	-	1.4	-	0.46	26.7
Carbon Dioxide	24.21	-	23.66	22.91	0.65	2.8
Ethylene	0.58	-	0.64	-	0.04	6.9
Ethane	0.54	-	0.48	-	0.04	7.8