Lawrence Livermore Laboratory

A COMPUTER PROGRAM FOR REDUCTION AND STORAGE OF FIELD DATA FROM AN
IN SITU COAL-GASIFICATION EXPERIMENT

C. W. Clausen and C. B. Thorsness

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NOMENCLATURE

<u>Symbol</u>		<u>Units</u>
a_i	Stoichiometric coefficient	—
A_c	Produced carbon	g-atoms
A_H	Produced hydrogen	g-atoms
A_O	Produced oxygen	g-atoms
f_I	Air-injection rate	scfm
f_P	Gas-production rate	scfm
F_I	Total air injection	scf
F_P	Total produced gas	scf
C_L	Fractional N_2 loss	—
I_i	Injected species i	g-moles
L_1	Produced water meter 1	gal
L_2	Produced water meter 2	gal
M_C	Molecular weight of pseudo-coal molecule $CH_{\alpha}O_{\beta}$	amu
P	Pressure	psia
ΔP	Pressure drop	psi
ΔQ	Gas flow in sample line	scf
R_1	Moles of coal processed per mole of O_2 consumed	—
R_2	Moles of coal processed per mole of H_2O involved in reaction	—
t	Time	min or d: h: min
T	Temperature	$^{\circ}C$
V_c	Volume of wet coal consumed	cf
w_a	Weight fraction of ash	—
w_w	Weight fraction of water	—
W_I	Total water influx	g-moles
W_L	Liquid water production	gal
W_P	Total produced water	g-moles
ΔW_s	Water collected in sample line	g
x_i	Produced gas mole fractions (wet basis)	—
y_i	Produced gas mole fractions (dry basis)	—
α, β	Stoichiometric coefficients in pseudo-coal molecule $CH_{\alpha}O_{\beta}$	—
ρ_c	Specific gravity of wet coal	—

Numerical Subscript

- 1 Refers to N_2
- 2 Refers to O_2
- 3 Refers to $H_2O(g)$
- 4 Refers to H_2
- 5 Refers to CH_4
- 6 Refers to CO
- 7 Refers to CO_2

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ABSTRACT

This report describes a computer program for on-site use during the first *in situ* coal-gasification experiment at Hoe Creek, Wyoming. The program was developed to meet two major requirements: (1) storage of selected field data on magnetic tape, and (2) real-time analysis of the data. The data analysis consists primarily of the calculation of gas flows and material balances relevant to the process. Operating personnel require this analysis to assist them in successfully operating the gasification experiment.

The program is written in BASIC for use on a Computer Automation Corporation ALPHA-16 minicomputer.

INTRODUCTION

This report describes a computer program designed for on-site use during the *in situ* coal-gasification stage of the Hoe Creek Experiment No. 1. The program is written in BASIC and designed specifically for use on a Computer Automation Corporation ALPHA-16 computer. The program fulfills two major objectives: (1) storing of field data on magnetic tape; and (2) carrying on continuing initial analysis of the data. Storage on magnetic tape will allow the data to be processed later by a large computer system. The initial analysis will assist in real-time interpretation of the test.

The mini computer system for which the program was designed consists of the ALPHA-16 computer, a nine-track read/write magnetic tape unit, a paper tape unit, and a teletype. The program is designed so that field data are input through the teletype unit by using the appropriate letter codes describing the type of data. The computer then stores these raw data on magnetic tape. It also does some simple calculations to update the analysis of the data and stores these results on tape. Also, newly computed information is outputted to the teletype for use by the test operators.

The following discussion first describes the type of data recorded and the simple calculations performed, and then describes the use of the actual computer program. A complete listing of the BASIC program is provided in the Appendixes.

DESCRIPTIONS OF DATA AND CALCULATIONS

Data

The field test at Hoe Creek is described in detail elsewhere.¹ Of concern here is the gasification phase of the test that consists of the injection of air through an injection well into the coal seam and the production of gases at a production well. The data required to monitor the progress of the test (from a material-balance standpoint) consist of gas-flow rates, water-flow rates, gas compositions, gas temperatures, and gas pressures,

Figure 1 is a schematic representation of the experiment, with points of data collection noted by the circles. The letters adjacent to the circles correspond to the computer instructions for entering each type of data (see Operation of Program, p. 9).

Gas-flow rates at the injection and production wells, data I and P, are determined from four pieces of data at each well: gas temperature, gas pressure, orifice-plate pressure drop, and orifice-plate size. These data, along with the time the data are collected, are entered into the computer.

Analysis of a sample stream provides data describing the composition of the produced gas. A condenser unit removes tars and liquid water. A flow meter records total gas flow and analysis of the dry gas by a chromatograph provides the composition data. Determination of the rate of water and tar production in the gas requires the information denoted by the letter W on Fig. 1. This consists of the total gas flow in the sample line over a time interval, the gas temperature, the gas pressure, and the weight of water collected during the interval. The weight of tar is also recorded.

1. R. W. Hill, Lawrence Livermore Laboratory, private communication (March 25, 1976).

Fig. 1. Schematic of field test.

The final set of data used is denoted by the letter L and consists of water-production rates from the coal seam (in the form of liquid water) from all wells. The data consist of time and total flow measurements provided by an integrating flow meter.

Table 1 summarizes the five types of data input to the system.

Field Calculations

The calculations described here are intended as an initial workup of the field data. Their primary aims are to:

- 1) estimate *in situ* gas losses,
- 2) estimate coal consumption,
- 3) estimate water intrusion into the system.

Table 1. Input Data.

Code	Description	Data
I	Injection well gas-flow rate	t Time
		ΔP Orifice pressure drop (psi)
		P Gas pressure (psia)
		T Gas temperature ($^{\circ}\text{C}$)
P	Production well gas-flow rate	t Time
		ΔP Orifice pressure drop (psi)
		P Gas pressure (psia)
		T Gas temperature ($^{\circ}\text{C}$)
L	Liquid water production	t Time
		L_1 Produce volume meter 1 (gal)
		L_2 Produce volume meter 2 (gal)
W	Water production in the gas	t_i Initial time
		Q_i Initial volume through meter (ft^3)
		T_i Temperature ($^{\circ}\text{C}$)
		P Pressure (psia)
		t_f Final time
		Q_f Final volume (ft^3)
		T_f Temperature ($^{\circ}\text{C}$)
		P Pressure (psia)
M	Dry gas composition	t Time
		y_i Gas mole fractions

The complexity of the required calculations increases as one proceeds down this list, as does the uncertainty of the results. In order to address the last two calculations a model framework must be developed. The simplest possible assumption — a single effective *in situ* reaction of wet coal with air and water — is made for this model. This assumption allows estimates of coal consumption and water influx to be derived from produced gas composition and rates.

Injection Well - Calculations performed for the injection well include total air injection as well as total oxygen and nitrogen input. The data from the injection well are used to calculate a gas-flow rate using standard orifice-plate calibrations (see ENR-76-6 for details). The total flow into the injection well is simply

$$F_I = \int_0^t f_I dt ,$$

where F_I is the total flow into the well. A simple numerical integration procedure in which the last recorded value of f_I is employed in the integrand to provide current values of F_I at each new time. The integration is updated each time new data are recorded.

Species inputs of O_2 and N_2 are calculated using

$$I_1 = 0.932 F_I$$

for N_2 , and

$$I_2 = 0.251 F_I$$

for O_2 . Here, as elsewhere, F_I is assumed to be given in standard cubic feet and I_I in gram-moles. The standard conditions are assumed to be 60°F and 14.7 psia.

Production Well - The calculations performed for the production well include total gas flow and total production of N_2 , O_2 , $H_2O(g)$, H_2 , CH_4 , CO , and CO_2 . These numbers are used to compute coal consumption, water influx, and gas losses.

The flow rate is calculated in a manner identical to that of the injection well, except a modification is made in order to use the actual

specific gravity of the gas produced in the orifice-plate correlation. The total flow is again the integral of this rate. Old values of composition temperature are used to update the integral. An update occurs when any new data are entered.

The mole fraction of the actual produced gas, x_i , is calculated from the dry mole fraction, y_i , and the rate of water accumulation and gas rate in the sample line. The gas ion components are numbered as follows:

1-N₂, 2-O₂, 3-H₂O, 4-H₂, 5-CH₄, 6-CO, and 7-CO₂.

For $i = 1$ to 7 , $i \neq 3$,

$$x_i = y_i \left(1 + 0.046 \frac{\Delta W_s}{\Delta Q} \right)^{-1}.$$

For $i = 3$,

$$x_3 = \left(y_3 + 0.046 \frac{\Delta W_s}{\Delta Q} \right) \left(1 + 0.046 \frac{\Delta W_s}{\Delta Q} \right)^{-1}.$$

Here, ΔW_s is the water accumulation from the condenser in grams, and ΔQ is the sample line flow over the same period in standard cubic feet. y_3 is included to account for any humidity remaining in the supposedly dry gas.

Produced molecular species P_i are then simply given by

$$P_i = 1.195 X_i F_p,$$

where P_i is given in gram-moles and F_p is the total produced gas in standard cubic feet. The total atomic species produced in the gas are calculated by using

$$A_c = P_5 + P_6 + P_7,$$

$$A_H = 2P_3 + 2P_4 + 4P_5,$$

$$A_O = 2P_2 + P_3 + P_6 + 2P_7.$$

These atomic production numbers do not include hydrogen and oxygen produced in the form of liquid water. Also, carbon, hydrogen, and oxygen present in produced species other than N₂, O₂, H₂O(g), H₂, CH₄, CO, and CO₂ are not included.

Coal Consumption - To estimate coal consumption we assume that the *in situ* reaction of interest can be given by

The effective stoichiometric coefficients, a_i s, can be determined from the dry gas composition:

$$i = 4 \text{ to } 7, a_i = \frac{y_i}{y_5 + y_6 + y_7 + y_4},$$

$$a_2 = \frac{a_6 + 2a_7 - a_3 - \beta}{2},$$

$$a_3 = 2a_5 + a_4 - \frac{\alpha}{2}.$$

Since a single overall reaction involving carbon is assumed, the consumption of coal in gram-moles of a pseudo coal molecule $\text{CH}_{\alpha}\text{O}_{\beta}$ is equivalent to A_c . The volume of wet coal is:

$$V_c = (3.53 \times 10^{-5}) \frac{A_c M_c}{\rho_c (1 - w_w - w_a)},$$

where V_c is the volume of wet coal in cubic feet, M_c is the molecular weight of the pseudo coal molecules, ρ_c is the effective *in situ* specific gravity of wet coal, w_w is the weight fraction of water in the coal, and w_a is the weight fraction of ash in the coal. Also, R_1 , the moles of coal consumed per mole of O_2 , and R_2 , the moles of coal consumed per mole of H_2O entering the reaction, are calculated and are given simply by:

$$R_1 = 1/a_2$$

and

$$R_2 = 1/a_3.$$

Water Influx - The water influx into the gasification system is given by a balance around the seam that assumes no accumulation of water in any open pore. The influx of water, W_I , is given by:

$$W_I = W_A + A_c \left[a_3 - \frac{w_w}{18(1 - w_w - w_a)} \right].$$

Here, W_I is the water influx in gram-moles, and W_A is the total produced water in gram-moles given by

$$W_A = P_3 + 3.02 (W_L).$$

W_L is the produced water volume given in gallons and obtained from meter readings.

Gas Losses - The loss of gas underground can be easily estimated by using a nitrogen balance. The fractional gas loss, G_L , as estimated from a nitrogen balance, is given simply by:

$$G_L = \frac{I_2 - P_2}{I_2}.$$

We assume here that all the nitrogen in the incoming air passes through the system unchanged and that no molecular nitrogen is produced from the coal or ash.

Constants - A number of the parameters used in the calculations are constants that do not change during the course of the experiment, or they change in a prescribed manner. These constants are built into the body of the program, and a simple program modification is generally required to change them.

A group of these parameters is related to the coal system. They include α , β , ρ_c , M_c , w_w , and w_a . Values characteristic of the coal of interest at Hoe Creek are found in the version of the program listed in Appendixes B and C.

Another group of constants are those related to the orifice meters that are used to measure rates of gas flow. They include orifice coefficients related to orifice-plate diameters. Provisions have been built into the code so that the use of a limited number of orifice-plate sizes can be accounted for without reprogramming. These sizes and the manner in which they can be changed are described in Operation of Program, page 9.

Finally, there are a number of constants describing molecular weights of species, unit conversions, and standard conditions, which should not require modification as long as the units prescribed by the code are used.

OPERATION OF PROGRAM

Start Up

When reading in the program tape, the computer sometimes returns an error message with the statement in error. If this occurs, type:

TAPE,*

and the remainder of the program will be read into the computer. Have a current listing of the program handy, and retype the statements in error.

Whenever the program is started, either because one stopped it or recently loaded it, the computer responds with the question:

START OR RESTART?

One then types S if the experiment is just beginning; or he types R if the experiment is already running and this program has been previously used to calculate data.

Start - To initialize the calculations in this program, we need to input a few things that are only done once during the entire experiment. The program first asks for the actual time at the start of the experiment. The operator then inputs the number of the day from the beginning of the year, the hour of the day, and the minute, separating them by commas. Also, all types of data need to be entered now.

Since there are six orifice plates used to measure the rates of gas flow, we must initially tell the computer the flange-tap sizes to be used. There are two different sizes for the injection well and four different sizes for the production well. Designation of these sizes will be explained later.

Restart - When the program is restarted, it scans the tape and finds the last data that have been stored. (Note: There also may be data coming into the program automatically.) The computer prints out this last record number and its corresponding entry time. Sometimes the last entry is lost, since entry times are stored in pairs.

* Commands or answers to questions need to be followed by a carriage return.

Action

When this question is asked:

ACTION WANTED?,

the user may respond in three ways:

F - flange-tap size,

D - data input,

S - stop.

The computer will then ask the appropriate questions.

Flange-tap size - For injection flange-tap, one inputs 1 or 2 corresponding to the tap size being used:

1 - 1.7177 in. diameter,

2 - 3.028 in. diameter.

For production flange-tap, one inputs 1, 2, 3, or 4, corresponding to the tap size being used:

1 - 0.82339 in. diameter,

2 - 1.6288 in. diameter,

3 - 3.0023 in. diameter,

4 - 4.500 in. diameter.

Data Input - First the actual time of the data entry is inputted. This time must be later than the previous time, or the program will ask the question again. It need not be the same as the time one actually types on the teletype. Keep in mind, that the data must be entered in chronological order since there is an ongoing integration in this program.

Now, the program will ask for the type of data. This will be explained later.

Stop - The operator will be asked if he really wants to stop. This avoids inadvertantly stopping the program and possibly losing some data. One responds with:

Y - yes,

N - no.

Detailed Data Input

Type of Data - When asked what type of data one wishes to input, he responds:

- I - injection rates,
- P - production rates,
- M - mole fractions,
- W - water production rate in gas,
- L - liquid water production.

The operator then proceeds to answer the questions. After each type of data has been entered, the user is asked if he wishes to enter more data. Also, if a particular type of data is not entered, it will stay the same as the last entry.

Restrictions - When the program is started for the first time, all types of data must be input. Remember that times must be entered in chronological order.

When injection and production rates are input, the current flange-tap sizes are first printed out. If one finds that the wrong size is being used, the operator may input a number less than or equal to -100 for the temperature. This will abort all action for this time slot, and the question:

ACTION WANTED?

will then be asked. The flange-tap size may be changed at this point. All the data for that particular time must be reentered.

Also, the initial time for the water-production rate in the tap line to the gas chromatograph is assumed to be the entry time. Hence, when the final time is entered for calculating the rate, it must be greater than the data entry time.

Data Correction - Data correction may be accomplished in two ways: by using a backarrow or by reentering the data. When one mistypes a number, he can correct it by using a backarrow (←) before hitting the carriage return. Striking the backarrow once deletes the last character; striking it twice deletes the last two characters, etc. The remainder of the correct number may then be typed. (A space is considered a character.) Caution: If a letter is typed when the program is asking for a number, an error message will be given

and the program will stop execution. The computer will then jump into BASIC command mode. The program can be restarted by first typing RUN and then using the restart provisions. However, in most cases the program can be successfully restarted by using the command GO TO N, where N is the statement number where the error occurred. The appropriate statement number can be found by consulting the program listing. This type of action can also be used to correct numerically incorrect data by using the AUTO key on the computer console to interrupt the program when an incorrect number has been inputted.

Printout

After one enters all the data, he responds with an N to the question:
MORE DATA?

The computations then take place, and the computer responds with:
LONG OR SHORT FORM?

Answering with an L will result in having both the raw data and the calculated data printed out. Responding with an S will produce only the changed data. The program will then ask you to turn to the bottom of the page and input any character. This will result in having all of the output on one page.

Next to the heading of the five types of raw input data will be either a 0 or a 1. The 0 will mean that there was no input of that type of data for this entry and that these values were left unchanged. A 1 will signify that this type of data was changed.

Data Storage

When the computer has finished the printout, it will ask if this data is to be stored or not. If the user responds negatively, the data input is completely aborted and the entries must be made again. This feature was added so that the values the operator thought he inputted are indeed in the computer.

If the operator says that he wants to store this data, the computer will respond in one of two ways. First, it may ask:

ACTION WANTED?

meaning that the data will be stored in the first half of a record.

(Caution: This data is not physically stored on tape. It would be lost if execution somehow terminated.) Second, it would type:

DATA STORED

and then give the record number that it is stored under. In other words, the

last two times were just stored on tape. The program will then respond with:
ACTION WANTED?

The user then continues.

If at any time the computer types:
DATA STORAGE ERROR,
an error occurred while the operator was trying to write on tape. Consult someone familiar with the ALPHA-16 software to correct the problem.

If at any time the computer types:
DATA STORAGE ERROR NO. (number),
an error occurred while the operator was trying to read from tape. Check Appendix E for the type of error that occurred. Then consult someone familiar with the ALPHA-16 system.

Program Explanation

There are two programs, one named FIELD, the other, FLONG. FIELD is the shorter version, which is used for the experiment. FLONG is the slightly longer version, which contains more commentary but requires more memory than the ALPHA-16 has. This version explains the program in more detail.

To understand this program, one should first have a good grasp of the BASIC language used on the ALPHA-16. One should also become familiar with the list of program variables provided in Appendix D. After one understands these, the program itself should be fairly easy to follow.

Sample Run

A sample run is provided in Appendix A. It starts with the beginning of the experiment on page 1 of the run. Note that the start time and the initial gas rates are asked for. Then the flange-tap size is initialized. All types of data are initially input into the program.

On page 2, no more data are wanted and the long form is requested. Hence, page 3 contains the raw data in the calculated data. At the top of page 4 these data are requested to be stored and filed in the first half of the record.

Only two types of data are changed on the next time entry with the short form requested. On page 5, the printout for the short form is given. Note the flags signifying the changed data. The calculated variables were not listed. These data were requested to be stored. Since there have been two

entries now, the data are actually stored on tape. Then the file number under which it is stored is given. This number could be written at the top of the printout as shown for the next record.

Execution of this program was then stopped by the user and restarted on the following page. The last record stored and the corresponding time is printed out. Note the first time input. Only the day was given. The computer responded with another question mark, expecting the next two values.

A bad request was then given for the type of data, and the input was requested again. The production flow-rate data were requested, and it was noticed that the flange-tap size was wrong. Thus, -100 was entered for the temperature, and the data input was aborted. A flange-tap size change was then requested, but, when asked, the operator changed his mind and still inputted 1, keeping the size the same.

On page 7, an E was used to correct mistyped data. On page 8, the liquid-water production rate was entered twice for corrections. The results were then printed out. On page 10, a mistake was made typing the time. An O was used instead of a Ø. There is a difference! Hence, an error message^{*} was given and the program stopped execution. The last entry was lost, and the program was restarted. The data that were wiped out were then reentered. Note that the data need not be the same this time. The run continued normally then.

On page 15, the printout did not start on a new page. That does not affect anything, however. After the operator observed that the printout did not include the desired values, he aborted data input and stopped the program. (Note: answers to questions may be spelled out since only the first character is recognized to allow for misspelling.)

* BASIC error messages are given in Appendix F.

APPENDIX A; PRINTOUT OF EXAMPLE RUN

On the following pages is given a printout of a sample run described in the text. Page numbers for reference purposes are given in boxes at the upper right corner. These are not part of a normal printout.

START OR RESTART ? S

ACTUAL TIME AT START OF RUN , DAY,HR,MIN ? 200,10,0

INITIAL GAS INJECTION RATE , SCFM ? 1.805

INITIAL GAS PRODUCTION RATE , SCFM ? 1.5

ACTION WANTED ? F

INJECTION FLANGE TAP SIZE ? 1

PRODUCTION FLANGE TAP SIZE ? 1

ACTION WANTED ? D

ACTUAL TIME , DAY,HR,MIN ? 200,12,0

TYPE OF DATA ? I

INJECTION FLOW RATE

FLANGE TAP SIZE = 1.7177 IN.

TEMPERATURE , C ? 37.78

PRESSURE , PSIA ? 75

PRESS. DROP , PSI ? .0000163

MORE DATA , YES OR NO ? Y

TYPE OF DATA ? P

PRODUCTION FLOW RATE

FLANGE TAP SIZE = 0.82338 IN.

TEMPERATURE , C ? 148.9

PRESSURE , PSIA ? 30

PRESS. DROP , PSI ? .000064

MORE DATA , YES OR NO ? Y

TYPE OF DATA ? M

MOLE FRACTIONS (DRY BASIS)

Y (1) ? .11

Y (2) ? .03

Y (4) ? .38

Y (5) ? .05

Y (6) ? .15

Y (7) ? .28

MORE DATA , YES OR NO ? Y

TYPE OF DATA ? W

WATER PROD. RATE IN TAP LINE TO G. C.

INITIAL TIME

TOTAL FLOW THRU G. C. , CF ?0

TEMPERATURE , C ?25

PRESSURE , PSIA ?14

FINAL TIME , DAY,HR,MIN ?200,12,30

TOTAL FLOW THRU G. C. , CF ?100

TEMPERATURE , C ?25

PRESSURE , PSIA ?14

WEIGHT OF WATER , GM ?100

WEIGHT OF TARS , GM ?5

MORE DATA , YES OR NO ?Y

TYPE OF DATA ?L

LIQUID WATER PRODUCTION

CLEAN RATE , GAL/MIN ?.83

DIRTY RATE , GAL/MIN ?.63

CLEAN TOTAL , GAL ?100

DIRTY TOTAL , GAL ?75

MORE DATA , YES OR NO ?N

LONG OR SHORT FORM ?L

TURN PAPER TO BOTTOM OF OLD PAGE .

INPUT ANY CHARACTER FOR OUTPUT OF RESULTS ..

?R

RECORD NO. =

ACTUAL TIME : 200 DAY 12 HOUR 0 MINUTE
ELAPSED TIME : 0 DAY 2 HOUR 0 MINUTE

INJECTION WELL - 1		PRODUCTION WELL - 1		
TAP SIZE ,S3 = 1.7177		TAP SIZE ,S4 = 0.82338		IN.
TEMPERATURE,R1 = 37.7		TEMPERATURE,R2 = 148.9		DEG. C
PRESSURE ,G1 = 75		PRESSURE ,G2 = 30		PSIA
PRESS. DROP,H1 = 1.63E-05		PRESS. DROP,H2 = 6.4E-24		PSI

MOLE FRACTIONS (DRY BASIS) - 1

Y (1) = 0.11	Y (5) = 5.E-02
Y (2) = 3.E-02	Y (6) = 0.15
Y (4) = 0.38	Y (7) = 0.25

SUM OF Y'S = 1 HEAT OF COMBUSTION = 46.7459 KCAL/MOLE

LIQUID WATER PRODUCTION - 1

CLEAN RATE , R5 = 0.83	DIRTY RATE , R8 = 0.63	GPM
CLEAN TOTAL , W2 = 100	DIRTY TOTAL , W8 = 75	GAL

TAP LINE TO G. C. - 1

INIT. TIME = 200	12	0	FINAL TIME = 200	12	30	DAY HR MIN
TOT. FLOW,F3 = 0			TOT. FLOW,F4 = 100			CF
TEMP. ,C3 = 25			TEMP. ,C4 = 25			DEG. C
PRESS. ,P3 = 14			PRESS. ,P4 = 14			PSIA
WATER WGT,W0 = 100			TAR WGT ,T0 = 5			GM

INJ. RATE,N1 = 1.80245	PROD. RATE,O1 = 1.57641	SCFM
TOT. INJ.,F1 = 216.447	TOT. PROD.,P1 = 184.585	SCF

MOLE FRACTIONS (WET BASIS)

X (1) = 0.104474	X (5) = 4.74883E-02
X (2) = 2.6493E-02	X (6) = 0.142465
X (3) = 5.02343E-02	X (7) = 0.265934
X (4) = 0.360911	

TOTAL INJECTED NITROGEN , I1 = 201.729	MOLES
TOTAL INJECTED OXYGEN , I2 = 54.3282	MOLES

TOTAL PRODUCED SPECIES

P (1) = 23.0448	P (5) = 10.4749	MOLES
P (2) = 6.23494	P (6) = 31.4247	MOLES
P (3) = 11.0606	P (7) = 58.6594	MOLES
P (4) = 79.6092		MOLES

WATER PRODUCTION RATE IN GAS = 3.33333	GM/MIN
APPROX. NET WATER INFUX RATE = 1.2521	GPM
TOTAL WATER PRODUCTION , W3 = 36797.1	MOLES
TOTAL NET WATER INFUX , W4 = 36754.5	MOLES

CARBON PRODUCTION , A1 = 100.559	ATOMS
HYDROGEN PRODUCTION , A2 = 73795.4	ATOMS
OXYGEN PRODUCTION , A3 = 36958.4	ATOMS

DIFF. FRACTIONAL AIR LOSS , L1 = 0.885764
TOTAL FRACTIONAL AIR LOSS , L = 0.885763

TOTAL VOLUME OF COAL BURNED , V = 6.94343E-02 CF
MOLES OF COAL / MOLE OF OXYGEN , C1 = 2.69845
MOLES OF COAL / MOLE OF WATER , C2 = 1.83824

DO YOU WISH TO STORE THIS DATA , YES OR NO?Y

ACTION WANTED ?D

ACTUAL TIME , DAY,HR,MIN ?200,14,0

TYPE OF DATA ?P

PRODUCTION FLOW RATE

FLANGE TAP SIZE = 0.82338 IN.
TEMPERATURE , C ?148.9
PRESSURE , PSIA ?30
PRESS. DROP , PSI ?.00066

MORE DATA , YES OR NO ?Y

TYPE OF DATA ?L

LIQUID WATER PRODUCTION

CLEAN RATE , GAL/MIN ?.83
DIRTY RATE , GAL/MIN ?1.25
CLEAN TOTAL , GAL ?200
DIRTY TOTAL , GAL ?225

MORE DATA , YES OR NO ?N

LONG OR SHORT FORM ?L

TURN PAPER TO BOTTOM OF OLD PAGE .
INPUT ANY CHARACTER FOR OUTPUT OF RESULTS .
?R

RECORD NO. =

ACTUAL TIME : 200 DAY 14 HOUR 0 MINUTE
ELAPSED TIME : 0 DAY 4 HOUR 0 MINUTE

INJECTION WELL - 0	PRODUCTION WELL - 1	
TAP SIZE , S3 = 1.7177	TAP SIZE , S4 = 0.82338	IN.
TEMPERATURE, R1 = 37.78	TEMPERATURE, R2 = 148.9	DEG. C
PRESSURE , G1 = 75	PRESSURE , G2 = 30	PSIA
PRESS. DROP, H1 = 1.63E-05	PRESS. DROP, H2 = 6.6E-04	PSI

MOLE FRACTIONS (DRY BASIS) - 0

Y (1) = 0.11	Y (5) = 5.E-02
Y (2) = 3.E-02	Y (6) = 0.15
Y (4) = 0.38	Y (7) = 0.28

SUM OF Y'S = 1 HEAT OF COMBUSTION = 46.7459 KCAL/MOLE

LIQUID WATER PRODUCTION - 1

CLEAN RATE , R5 = 0.83	DIRTY RATE , R8 = 1.25	GPM
CLEAN TOTAL , W2 = 200	DIRTY TOTAL , W8 = 225	GAL

TAP LINE TO G. C. - 0

INIT. TIME = 200 12 0	FINAL TIME = 200 12 30	DAY HR MIN
OT. FLOW, F3 = 0	TOT. FLOW, F4 = 100	CF
TEMP. , C3 = 25	TEMP. , C4 = 25	DEG. C
PRESS. , P3 = 14	PRESS. , P4 = 14	PSIA
WATER WGT, W0 = 100	TAR WGT , T0 = 5	GM

INJ. RATE, N1 = 1.80245	PROD. RATE, O1 = 1.60085	SCFM
TOT. INJ., F1 = 432.741	TOT. PROD., P1 = 375.22	SCF

MOLE FRACTIONS (WET BASIS)

X (1) = 0.104474	X (5) = 4.74883E-02
X (2) = 2.8493E-02	X (6) = 0.142465
X (3) = 5.02343E-02	X (7) = 0.265934
X (4) = 0.360911	

TOTAL INJECTED NITROGEN , I1 = 403.315	MOLES
TOTAL INJECTED OXYGEN , I2 = 108.618	MOLES

TOTAL PRODUCED SPECIES

P (1) = 46.845	P (5) = 21.2932	MOLES
P (2) = 12.7759	P (6) = 63.8795	MOLES
P (3) = 22.5245	P (7) = 119.242	MOLES
P (4) = 161.828		MOLES

WATER PRODUCTION RATE IN GAS = 3.33333	GM/MIN
APPROX. NET WATER INFUX RATE = 1.78914	GPM
TOTAL WATER PRODUCTION , W3 = 89360.1	MOLES
TOTAL NET WATER INFUX , W4 = 89273.4	MOLES

CARBON PRODUCTION , A1 = 204.415	ATOMS
HYDROGEN PRODUCTION , A2 = 179129	ATOMS
OXYGEN PRODUCTION , A3 = 89688	ATOMS

DIFF. FRACTIONAL AIR LOSS , L1 = 0.881935
TOTAL FRACTIONAL AIR LOSS , L = 0.88385

TOTAL VOLUME OF COAL BURNED , V = 0.141145
MOLES OF COAL / MOLE OF OXYGEN , C1 = 2.69845
MOLES OF COAL / MOLE OF WATER , C2 = 1.83824

CF

DO YOU WISH TO STORE THIS DATA , YES OR NO?Y

----- DATA STORED -----

RECORDED NO. = 223

ACTION WANTED ? S

DO YOU REALLY WANT TO STOP , YES OR NO ?Y

*RUN

START OR RESTART ?R

LAST RECORD STORED = 223

LAST TIME ENTERED = 200 DAY 14 HOUR 0 MINUTE

ACTION WANTED ? D

ACTUAL TIME , DAY,HR,MIN ?200,16,0

TYPE OF DATA ?P

PRODUCTION FLOW RATE

FLANGE TAP SIZE = 0.82338 IN.

TEMPERATURE , C ?148.9

PRESSURE , PSIA ?30

PRESS. DROP , PSI ?0.00068

MORE DATA , YES OR NO ?Y

TYPE OF DATA ?L

LIQUID WATER PRODUCTION

CLEAN RATE , GAL/MIN ?.83

DIRTY RATE , GAL/MIN ?.67

CLEAN TOTAL , GAL ?300

DIRTY TOTAL , GAL ?305

MORE DATA , YES OR NO ?N

LONG OR SHORT FORM ?L

TURN PAPER TO BOTTOM OF OLD PAGE .

INPUT ANY CHARACTER FOR OUTPUT OF RESULTS .

?R

RECORD NO. =

ACTUAL TIME : 200 DAY 16 HOUR 0 MINUTE
ELAPSED TIME : 0 DAY 6 HOUR 0 MINUTE

INJECTION WELL - 0		PRODUCTION WELL - 1		
TAP SIZE ,S3 =	1.7177	TAP SIZE ,S4 =	0.82338	IN.
TEMPERATURE,R1 =	37.78	TEMPERATURE,R2 =	148.9	DEG. C
PRESSURE ,G1 =	75	PRESSURE ,G2 =	30	PSIA
PRESS. DROP,H1 =	1.63E-05	PRESS. DROP,H2 =	6.8E-04	PSI

MOLE FRACTIONS (DRY BASIS) - 0	
Y (1) =	0.11
Y (2) =	3.E-02
Y (4) =	0.38
Y (5) =	5.E-02
Y (6) =	0.15
Y (7) =	0.28

SUM OF Y'S = 1 HEAT OF COMBUSTION = 46.7459 KCAL/MOLE

LIQUID WATER PRODUCTION - 1		
CLEAN RATE , R5 =	0.83	DIRTY RATE , R8 = 0.67 GPM
CLEAN TOTAL , W2 =	300	DIRTY TOTAL , W8 = 305 GAL

TAP LINE TO G. C. - 0		
INIT. TIME = 200	12 0	FINAL TIME = 200 12 30 DAY HR MIN
TOT. FLOW,F3 =	0	TOT. FLOW,F4 = 100 CF
TEMP. ,C3 =	25	TEMP. ,C4 = 25 DEG. C
PRESS. ,P3 =	14	PRESS. ,P4 = 14 PSIA
WATER WGT,W0 =	100	TAR WGT ,T0 = 5 GM

INJ. RATE,N1 =	1.80245	PROD. RATE,O1 = 1.62492 SCFM
TOT. INJ.,F1 =	649.035	TOT. PROD.,P1 = 568.767 SCF

MOLE FRACTIONS (WET BASIS)	
X (1) =	0.104474
X (2) =	2.8493E-02
X (3) =	5.02343E-02
X (4) =	0.360911
X (5) =	4.74883E-02
X (6) =	0.142465
X (7) =	0.265934

TOTAL INJECTED NITROGEN , I1 =	604.901	MOLES
TOTAL INJECTED OXYGEN , I2 =	162.908	MOLES

TOTAL PRODUCED SPECIES			
P (1) =	71.0086	P (5) = 32.2767 MOLES	
P (2) =	19.366	P (6) = 96.83 MOLES	
P (3) =	34.143	P (7) = 180.749 MOLES	
P (4) =	245.303		MOLES

WATER PRODUCTION RATE IN GAS =	3.33333	GM/MIN
APPROX. NET WATER INFLUX RATE =	1.28786	GPM
TOTAL WATER PRODUCTION , W3 =	127209	MOLES
TOTAL NET WATER INFLUX , W4 =	127077	MOLES

CARBON PRODUCTION , A1 =	309.856	ATOMS
HYDROGEN PRODUCTION , A2 =	255037	ATOMS
OXYGEN PRODUCTION , A3 =	127706	ATOMS

DIFF. FRACTIONAL AIR LOSS , LI = 0.880132
TOTAL FRACTIONAL AIR LOSS , L = 0.882611

TOTAL VOLUME OF COAL BURNED , V = 0.21395
MOLES OF COAL / MOLE OF OXYGEN , C1 = 2.69845
MOLES OF COAL / MOLE OF WATER , C2 = 1.83824

CF

DO YOU WISH TO STORE THIS DATA , YES OR NO?Y

ACTION WANTED ?D

ACTUAL TIME , DAY,HR,MIN ?200,18,0

TYPE OF DATA ?P

PRODUCTION FLOW RATE

FLANGE TAP SIZE = 0.82338 IN.
TEMPERATURE , C ?148.9
PRESSURE , PSIA ?25-30
PRESS. DROP , PSI ?0.0060

MORE DATA , YES OR NO ?Y

TYPE OF DATA ?L

LIQUID WATER PRODUCTION

CLEAN RATE , GAL/MIN ?83
DIRTY RATE , GAL/MIN ?-1.2
CLEAN TOTAL , GAL ?400
DIRTY TOTAL , GAL ?450

MORE DATA , YES OR NO ?N

LONG OR SHORT FORM ?L

TURN PAPER TO BOTTOM OF OLD PAGE .
INPUT ANY CHARACTER FOR OUTPUT OF RESULTS .
?R

RECORD NO. =

ACTUAL TIME : 200 DAY 18 HOUR 0 MINUTE
ELAPSED TIME : 0 DAY 8 HOUR 0 MINUTE

INJECTION WELL - 0 PRODUCTION WELL - 1
TAP SIZE , S3 = 1.7177 TAP SIZE , S4 = 0.82338 IN.
TEMPERATURE, R1 = 37.78 TEMPERATURE, R2 = 148.9 DEG. C
PRESSURE , G1 = 75 PRESSURE , G2 = 30 PSIA
PRESS. DROP, R1 = 1.63E-05 PRESS. DROP, R2 = 6.8E-04 PSI

MOLE FRACTIONS (DRY BASIS) - 0
Y (1) = 0.11 Y (5) = 5.E-02
Y (2) = 3.E-02 Y (6) = 0.15
Y (4) = 0.38 Y (7) = 0.28

SUM OF Y'S = 1 HEAT OF COMBUSTION = 46.7459 KCAL/MOLE

LIQUID WATER PRODUCTION - 1
CLEAN RATE , R5 = 0.83 DIRTY RATE , R8 = 1.2 GPM
CLEAN TOTAL , W2 = 400 DIRTY TOTAL , W8 = 450 GAL

TAP LINE TO G. C. - 0
INIT. TIME = 200 12 0 FINAL TIME = 200 12 30 DAY HR MIN
OT. FLOW, F3 = 0 TOT. FLOW, F4 = 100 CF
TEMP. , C3 = 25 TEMP. , C4 = 25 DEG. C
PRESS. , P3 = 14 PRESS. , P4 = 14 PSIA
WATER WGT, W6 = 100 TAB WGT , T8 = 5 GM

INJ. RATE, N1 = 1.80245 PROD. RATE, O1 = 1.62492 SCFM
TOT. INJ., F1 = 865.329 TOT. PROD., P1 = 763.758 SCF

MOLE FRACTIONS (WET BASIS)
X (1) = 0.104474 X (5) = 4.74883E-02
X (2) = 2.8493E-02 X (6) = 0.142465
X (3) = 5.02343E-02 X (7) = 0.265934
X (4) = 0.360911

TOTAL INJECTED NITROGEN , I1 = 806.487 MOLES
TOTAL INJECTED OXYGEN , I2 = 217.198 MOLES

TOTAL PRODUCED SPECIES
P (1) = 95.3526 P (5) = 43.3421 MOLES
P (2) = 26.0053 P (6) = 130.026 MOLES
P (3) = 45.8484 P (7) = 242.716 MOLES
P (4) = 329.4 MOLES

WATER PRODUCTION RATE IN GAS = 3.33333 GM/MIN
APPROX. NET WATER INFLUX RATE = 1.75331 GPM
TOTAL WATER PRODUCTION , W3 = 178721 MOLES
TOTAL NET WATER INFLUX , W4 = 178545 MOLES

CARBON PRODUCTION , A1 = 416.084 ATOMS
HYDROGEN PRODUCTION , A2 = 358274 ATOMS
OXYGEN PRODUCTION , A3 = 179388 ATOMS

DIFF. FRACTIONAL AIR LOSS , L1 = 0.879238
TOTAL FRACTIONAL AIR LOSS , L = 0.881768

TOTAL VOLUME OF COAL BURNED , V = 0.287299
MOLES OF COAL / MOLE OF OXYGEN , C1 = 2.69845
MOLES OF COAL / MOLE OF WATER , C2 = 1.83824

CF

DO YOU WISH TO STORE THIS DATA , YES OR NO?Y

----- DATA STORED -----

RECORDED NO. = 227

ACTION WANTED ?S

DO YOU REALLY WANT TO STOP , YES OR NO ?Y

*

APPENDIX B: PROGRAM TO USE ON THE COMPUTER

On the following pages is given a listing of the FIELD computer program,


```

1000 REM FIELD DATA WORKUP
1010 DIM A(7),AS(1),BS(1),P(7),X(7),Y(7)
1020 REM DEFINE PROPERTIES OF COAL MOLECULE
1030 LET M=16.02
1040 LET A9=.912
1050 LET B9=0.194
1060 REM DEFINE WEIGHT FRACTION OF COAL WHICH IS WATER
1070 LET F5=.3
1080 REM DEFINE WEIGHT FRACTION OF COAL WHICH IS ASH
1090 LET F6=.07
1100 REM DEFINE DENSITY OF NATIVE COAL
1110 LET PS=1.3
1120 REM BRANCH FOR START UP
1130 PRINT "START OR RESTART ";
1140 INPUT AS
1150 ON (AS="S")+2*(AS="R") GO TO 1180,4960
1160 PRINT "BAD INPUT"
1170 GO TO 1130
1180 PRINT
1190 PRINT "ACTUAL TIME AT START OF RUN , DAY,HR,MIN ";
1200 INPUT D8,H8,M8
1210 LET D0=D8
1220 LET H0=H8
1230 LET M0=M8
1240 PRINT
1250 PRINT
1260 PRINT "INITIAL GAS INJECTION RATE , SCFM ";
1270 INPUT N1
1280 PRINT "INITIAL GAS PRODUCTION RATE , SCFM ";
1290 INPUT O1
1300 REM ZERO ACCUMULATING VARIABLES
1310 LET F1=P1=I1=R=W4=0
1320 FOR I=1 TO 7
1330 LET P(I)=0
1340 NEXT I
1350 REM F - FLANGE TAP SIZE
1360 REM D - DATA INPUT
1370 REM S - STOP
1380 PRINT
1390 PRINT "ACTION WANTED ";
1400 INPUT AS
1410 ON (AS="D")+2*(AS="F")+3*(AS="S") GO TO 1570,2930,4900
1420 PRINT "BAD INPUT"
1430 GO TO 1380
1440 REM REINITIALIZE VARIABLES DUE TO ABORTED ACTION
1450 LET D0=D9
1460 LET H0=H9
1470 LET M0=M9
1480 LET N1=N0
1490 LET F1=F0
1500 LET O1=O0
1510 LET P1=P0
1520 LET P(1)=P9
1530 LET I1=I0
1540 PRINT

```

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1550 PRINT "DATA INPUT ABORTED"
1560 GO TO 1330
1570 REM WHAT KIND OF DATA ?
1580 REM I - INJECTION RATES
1590 REM P - PRODUCTION RATES
1600 REM M - MOLE FRACTIONS
1610 REM W - WATER PRODUCTION RATE IN GAS
1620 REM L - LIQUID WATER PRODUCTION
1630 LET Z1=Z2=Z3=Z4=Z5=0
1640 REM SAVE NECESSARY VALUES FROM PREVIOUS TIME
1650 LET D9=D0
1660 LET H9=H0
1670 LET M9=M0
1680 LET N0=N1
1690 LET F0=F1
1700 LET O0=O1
1710 LET P0=P1
1720 LET P9=P(1)
1730 LET I0=I1
1740 PRINT
1750 PRINT "INPUT RAW DATA"
1760 PRINT "-----"
1770 PRINT
1780 PRINT "ACTUAL TIME , DAY,HR,MIN ";
1790 INPUT D0,H0,M0
1800 LET D=1440*(D0-D9)+60*(H0-H9)+M0-M9
1810 IF D>0 GO TO 1850
1820 PRINT "BAD INPUT"
1830 PRINT "THIS TIME MUST BE GREATER THAN PREVIOUS TIME"
1840 GO TO 1770
1850 PRINT
1860 PRINT "TYPE OF DATA ";
1870 INPUT AS
1880 ON (AS="I")+2*(AS="P")+3*(AS="M") GO TO 1920,2040,2160
1890 ON (AS="W")+2*(AS="L") GO TO 2370,2700
1900 PRINT "BAD INPUT"
1910 GO TO 1850
1920 PRINT
1930 PRINT "INJECTION FLOW RATE"
1940 PRINT
1950 PRINT "FLANGE TAP SIZE = ";S3;" IN."
1960 PRINT "TEMPERATURE , C ";
1970 INPUT R1
1975 IF R1<=-100 GO TO 1450
1980 PRINT "PRESSURE , PSIA ";
1990 INPUT G1
2000 PRINT "PRESS. DROP , PSI ";
2010 INPUT H1
2020 LET Z1=1
2030 GO TO 2820
2040 PRINT
2050 PRINT "PRODUCTION FLOW RATE "
2060 PRINT
2070 PRINT "FLANGE TAP SIZE = ";S4;" IN."
2080 PRINT "TEMPERATURE , C ";

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```

2090 INPUT R2
2095 IF R2<=-100 GO TO 1450
2100 PRINT "PRESSURE , PSIA ";
2110 INPUT G2
2120 PRINT "PRESS. DROP , PSI ";
2130 INPUT H2
2140 LET Z2=1
2150 GO TO 2320
2160 PRINT
2170 PRINT "MOLE FRACTIONS (DRY BASIS)"
2180 FOR I=1 TO 7
2190 IF I=3 THEN 2220
2200 PRINT "Y (";I;") ";
2210 INPUT Y(I)
2220 NEXT I
2230 LET S=0
2240 FOR I=1 TO 7
2250 LET S=S+Y(I)
2260 NEXT I
2270 IF (S<.95)+(S>1.05)=1 GO TO 2300
2280 LET Z3=1
2290 GO TO 2320
2300 PRINT
2310 PRINT "SUM OF Y(I)'S =";S
2320 PRINT "DO YOU WISH TO CHANGE THEM , YES OR NO ";
2330 INPUT A$
2340 ON (A$="Y")+2*(A$="N") GO TO 2160,2280
2350 PRINT "BAD INPUT"
2360 GO TO 2320
2370 PRINT
2380 PRINT "WATER PROD. RATE IN TAP LINE TO G. C. "
2390 PRINT
2400 PRINT "INITIAL TIME , DAY HR MIN ";D0;H0;M0
2410 PRINT "TOTAL FLOW THRU G. C. , CF ";
2420 INPUT F3
2430 PRINT "TEMPERATURE , C ";
2440 INPUT C3
2450 PRINT "PRESSURE , PSIA ";
2460 INPUT P3
2470 PRINT
2480 PRINT "FINAL TIME , DAY,HR,MIN ";
2490 INPUT D4,H4,M4
2500 PRINT "TOTAL FLOW THRU G. C. , CF ";
2510 INPUT F4
2520 PRINT "TEMPERATURE , C ";
2530 INPUT C4
2540 PRINT "PRESSURE , PSIA ";
2550 INPUT P4
2560 PRINT
2570 PRINT "WEIGHT OF WATER , GM ";
2580 INPUT W0
2590 PRINT "WEIGHT OF TARS , GM ";
2600 INPUT T0
2610 LET Z5=1
2620 REM WATER PROD. RATE IN GAS

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2630 LET T3=1440*D0+60*H0+M0
2640 LET T4=1440*D4+60*H4+M4
2645 IF T4>T3 GO TO 2650
2646 PRINT "FINAL TIME MUST BE > INITIAL TIME"
2647 GO TO 2370
2650 LET R4=W0/(T4-T3)
2660 LET D3=D0
2670 LET H3=H0
2680 LET M3=M0
2690 GO TO 2820
2700 PRINT
2710 PRINT "LIQUID WATER PRODUCTION"
2720 PRINT
2730 PRINT "CLEAN RATE , GAL/MIN ";
2740 INPUT R5
2750 PRINT "DIRTY RATE , GAL/MIN ";
2760 INPUT R8
2770 PRINT "CLEAN TOTAL , GAL      ";
2780 INPUT W2
2790 PRINT "DIRTY TOTAL , GAL      ";
2800 INPUT W8
2810 LET Z4=1
2820 PRINT
2830 PRINT "MORE DATA , YES OR NO ";
2840 INPUT A$
2850 IF A$="Y" GO TO 1850
2860 IF A$="N" GO TO 3260
2870 PRINT "BAD INPUT"
2880 GO TO 2820
2890 REM FLANGE TAP SIZE
2900 REM INJECTION WELL
2910 REM S1=1 FOR 1.7177 IN. DIA.
2920 REM S1=2 FOR 3.028 IN. DIA.
2930 PRINT
2940 PRINT "INJECTION FLANGE TAP SIZE ";
2950 INPUT S1
2960 ON S1 GO TO 2990,3020
2970 PRINT "BAD INPUT"
2980 GO TO 2940
2990 LET K1=84.856
3000 LET S3=1.7177
3010 GO TO 3090
3020 LET K1=311.03
3030 LET S3=3.028
3040 REM PRODUCTION WELL
3050 REM S2=1 FOR 0.82338 IN. DIA.
3060 REM S2=2 FOR 1.6288 IN. DIA.
3070 REM S2=3 FOR 3.0023 IN. DIA.
3080 REM S2=4 FOR 4.500 IN. DIA.
3090 PRINT "PRODUCTION FLANGE TAP SIZE ";
3100 INPUT S2
3110 ON S2 GO TO 3140,3170,3200,3230
3120 PRINT "BAD INPUT"
3130 GO TO 3090
3140 LET K2=10.305

```

```

3150 LET S4=0.82338
3160 GO TO 1330
3170 LET K2=41.243
3180 LET S4=1.6288
3190 GO TO 1330
3200 LET K2=164.922
3210 LET S4=3.0023
3220 GO TO 1330
3230 LET K2=370.067
3240 LET S4=4.5
3250 GO TO 1330
3260 REM INJECTION FLOW RATE
3270 LET N1=K1*SQR(27.6807*H1*(560/(1.8*R1+492))*(G1/75))
3280 REM MOLE FRACTIONS (WET BASIS)
3282 K(3)=2.36E-3*W0*(C3+C4+546)/(F4-F3)/(P3+P4)
3290 FOR I=1 TO 7
3300 IF I=3 GO TO 3320
3310 LET K(I)=Y(I)/(1+K(3))
3320 NEXT I
3330 LET K(3)=(Y(3)+K(3))/(1+K(3))
3340 REM SPECIFIC GRAVITY OF GAS
3350 LET G=X(1)*28.0184+X(2)*31.998+X(3)*18.0153+X(4)*2.0159
3360 LET G=(G+X(5)*16.043+X(6)*28.011+X(7)*44.01)/28.966
3370 REM PRODUCTION FLOW RATE
3380 LET O1=K2*SQR(27.6807*H2*(760/(1.8*R2+492))*(G2/30)/G)
3390 REM TOTAL INJECTED FLOW
3400 LET F1=F0+(N0+N1)*D/2
3410 REM TOTAL INJECTED SPECIES
3420 LET I1=.932*F1
3430 LET I2=.251*F1
3440 REM TOTAL PRODUCTION FLOW
3450 LET P1=P0+(O0+O1)*D/2
3460 REM TOTAL PRODUCED SPECIES
3470 FOR I=1 TO 7
3480 LET P(I)=P(I)+X(I)*(P1-P0)*1.195
3490 NEXT I
3500 REM TOTAL WATER PRODUCTION
3510 LET W3=210.206*(W2+W8)+P(3)
3520 REM ATOMIC SPECIES
3530 LET A1=P(5)+P(6)+P(7)
3540 LET A2=2*W3+2*P(4)+4*P(5)
3550 LET A3=2*P(2)+W3+P(6)+2*P(7)
3560 REM AIR LOSSES
3570 LET L=1-P(1)/I1
3580 LET L1=(I1-I0-P(1)+P9)/(I1-I0)
3590 REM ATOMIC BALANCES
3600 LET Y0=Y(5)+Y(6)+Y(7)
3610 FOR I=4 TO 7
3620 LET A(I)=Y(I)/Y0
3630 NEXT I
3640 LET A(3)=2*A(5)+A(4)-A9/2
3650 LET A(2)=(A(6)+2*A(7)-A(3)-B9)/2
3660 REM COAL CONSUMPTION
3670 LET V=A1*M*3.53E-5/P5/(1-F5-F6)
3680 LET C1=1/A(2)

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```

3690 LET C2=1/A(3)
3700 REM NET WATER INFLUX
3710 LET U5=U4
3720 LET W4=W3-A1*F5*M/18/(1-F5-F6)+A1*A(3)
3730 LET R7=4.088E-3*(W4-U5)/D
3740 PRINT
3750 PRINT "LONG OR SHORT FORM ";
3760 INPUT A$
3770 IF (A$="L")+(A$="S")=1 GO TO 3800
3780 PRINT "BAD INPUT"
3790 GO TO 3740
3800 PRINT
3810 PRINT "TURN PAPER TO BOTTOM OF OLD PAGE ."
3820 PRINT "INPUT ANY CHARACTER FOR OUTPUT OF RESULTS . "
3830 INPUT B$
3840 PRINT
3850 PRINT TAB(16);"RECORD NO. ="
3860 PRINT
3870 PRINT "ACTUAL TIME :";TAB(16);D0;TAB(22);"DAY";
3880 PRINT TAB(30);H0;TAB(37);"HOUR";TAB(45);M0;TAB(52);"MINUTE"
3890 PRINT "ELAPSED TIME :";TAB(16);D0-D8;TAB(22);"DAY";TAB(30);
3900 PRINT H0-H8;TAB(37);"HOUR";TAB(45);M0-M8;TAB(52);"MINUTE"
3910 PRINT "-----";
3920 PRINT "-----"
3930 IF (A$="S")+(Z1=0)+(Z2=0)=3 GO TO 4040
3940 PRINT
3950 PRINT " INJECTION WELL -";Z1;TAB(32);"PRODUCTION WELL -";Z2
3960 PRINT "TAP SIZE ,S3 =";S3;TAB(30);
3970 PRINT "TAP SIZE ,S4 =";S4;TAB(60);"IN."
3980 PRINT "TEMPERATURE,R1 =";R1;TAB(30);
3990 PRINT "TEMPERATURE,R2 =";R2;TAB(60);"DEG. C"
4000 PRINT "PRESSURE ,G1 =";G1;TAB(30);
4010 PRINT "PRESSURE ,G2 =";G2;TAB(60);"PSIA"
4020 PRINT "PRESS. DROP,H1 =";H1;TAB(30);
4030 PRINT "PRESS. DROP,H2 =";H2;TAB(60);"PSI"
4040 IF (A$="S")+(Z3=0)=2 GO TO 4150
4050 PRINT
4060 PRINT TAB(18);"MOLE FRACTIONS (DRY BASIS) -";Z3
4070 FOR I=1 TO 2
4080 PRINT "Y (";I;") =";Y(I);TAB(30);"Y (";I+4;") =";Y(I+4)
4090 NEXT I
4100 PRINT "Y (";4;") =";Y(4);TAB(30);"Y (";7;") =";Y(7)
4110 PRINT
4120 PRINT "SUM OF Y'S =";S;TAB(25);
4130 PRINT "HEAT OF COMBUSTION =";Y(4)*68.317+Y(5)*212.8+Y(6)*67.636;
4140 PRINT TAB(60);"KCAL/MOLE"
4150 IF (A$="S")+(Z4=0)=2 GO TO 4220
4160 PRINT
4170 PRINT TAB(19);"LIQUID WATER PRODUCTION -";Z4
4180 PRINT "CLEAN RATE , R5 =";R5;TAB(30);
4190 PRINT "DIRTY RATE , R6 =";R6;TAB(60);"GPM"
4200 PRINT "CLEAN TOTAL , W2 =";W2;TAB(30);
4210 PRINT "DIRTY TOTAL , W6 =";W6;TAB(60);"GAL"
4220 IF (A$="S")+(Z5=0)=2 GO TO 4730
4230 PRINT

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4240 PRINT TAB(22);"TAP LINE TO G. C. -";Z5
4250 PRINT " INIT. TIME =";D3;H3;M3;TAB(32);
4260 PRINT "FINAL TIME =";D4;H4;M4;TAB(60);"DAY HR MIN"
4270 PRINT "TOT. FLOW,F3 =";F3;TAB(30);
4280 PRINT "TOT. FLOW,F4 =";F4;TAB(60);"CF"
4290 PRINT "TEMP. ,C3 =";C3;TAB(30);
4300 PRINT "TEMP. ,C4 =";C4;TAB(60);"DEG. C"
4310 PRINT "PRESS. ,P3 =";P3;TAB(30);
4320 PRINT "PRESS. ,P4 =";P4;TAB(60);"PSIA"
4330 PRINT "WATER WGT,W0 =";W0;TAB(30);
4340 PRINT "TAR WGT ,T0 =";T0;TAB(60);"GM"
4350 IF A$="S" GO TO 4780
4360 PRINT
4370 PRINT "INJ. RATE,N1 =";N1;TAB(30);
4380 PRINT "PROD. RATE,O1 =";O1;TAB(60);"SCFM"
4390 PRINT "TOT. INJ.,F1 =";F1;TAB(30);
4400 PRINT "TOT. PROD.,P1 =";P1;TAB(60);"SCF"
4410 PRINT
4420 PRINT TAB(20);"MOLE FRACTIONS (WET BASIS)"
4430 FOR I=1 TO 3
4440 PRINT "X (";I;") =";X(I);TAB(30);"X (";I+4;") =";X(I+4)
4450 NEXT I
4460 PRINT "X (";4;") =";X(4)
4470 PRINT
4480 PRINT "TOTAL INJECTED NITROGEN , I1 =";I1;TAB(60);"MOLES"
4490 PRINT "TOTAL INJECTED OXYGEN , I2 =";I2;TAB(60);"MOLES"
4500 PRINT
4510 PRINT TAB(21);"TOTAL PRODUCED SPECIES"
4520 FOR I=1 TO 3
4530 PRINT "P (";I;") =";P(I);TAB(30)
4540 PRINT "P (";I+4;") =";P(I+4);TAB(60);"MOLES"
4550 NEXT I
4560 PRINT "P (";4;") =";P(4);TAB(60);"MOLES"
4570 PRINT
4580 PRINT "WATER PRODUCTION RATE IN GAS =";R4;TAB(60);"GM/MIN"
4590 PRINT "APPROX. NET WATER INFLUX RATE =";R7;TAB(60);"GPM"
4600 PRINT "TOTAL WATER PRODUCTION , W3 =";W3;TAB(60);"MOLES"
4610 PRINT "TOTAL NET WATER INFLUX , W4 =";W4;TAB(60);"MOLES"
4620 PRINT
4630 PRINT "CARBON PRODUCTION , A1 =";A1;TAB(60);"ATOMS"
4640 PRINT "HYDROGEN PRODUCTION , A2 =";A2;TAB(60);"ATOMS"
4650 PRINT "OXYGEN PRODUCTION , A3 =";A3;TAB(60);"ATOMS"
4660 PRINT
4670 PRINT "DIFF. FRACTIONAL AIR LOSS , L1 =";L1
4680 PRINT "TOTAL FRACTIONAL AIR LOSS , L =";L
4690 PRINT
4700 PRINT "TOTAL VOLUME OF COAL BURNED , V =";V;TAB(60);"CF"
4710 PRINT "MOLES OF COAL / MOLE OF OXYGEN , C1 =";C1
4720 PRINT "MOLES OF COAL / MOLE OF WATER , C2 =";C2
4730 PRINT
4740 PRINT
4750 PRINT
4760 PRINT
4770 GO TO 4310
4780 FOR I=1 TO 60

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4790 PRINT
4800 NEXT I
4810 PRINT "DO YOU WISH TO STORE THIS DATA , YES OR NO ";
4820 INPUT AS
4830 ON (AS="Y")+2*(AS="N") GO TO 4860,1450
4840 PRINT "BAD INPUT"
4850 GO TO 4810
4860 REM STORE DATA
4870 GOSUB 4990
4880 PRINT
4890 GO TO 1330
4900 PRINT "DO YOU REALLY WANT TO STOP , YES OR NO ";
4910 INPUT AS
4920 IF AS="Y" GO TO 4980
4930 IF AS="N" THEN 1330
4940 PRINT "BAD INPUT"
4950 GO TO 4900
4960 GOSUB 5340
4970 GO TO 1330
4980 END
4990 REM STORE DATA ON TAPE
5000 LET R0=R*100
5010 CALL(7,E,Z5,Z4,Z3,Z2,Z1,M0,H0,D0,M3,H3,D3,R0+1,11)
5020 IF E=1 GO TO 5280
5030 CALL(7,E,H2,G2,R2,S2,H1,G1,R1,S1,R0+12,8)
5040 IF E=1 GO TO 5280
5050 CALL(7,E,W3,W2,R3,R5,Y(7),Y(6),Y(5),Y(4),Y(2),Y(1),R0+20,10)
5060 IF E=1 GO TO 5280
5070 CALL(7,E,T0,W0,P4,C4,F4,M4,H4,D4,P3,C3,F3,R0+30,11)
5080 IF E=1 GO TO 5280
5090 CALL(7,E,X(7),X(6),X(5),X(4),X(3),X(2),X(1),P1,F1,O1,N1,R0+41,11)
5100 IF E=1 GO TO 5280
5110 CALL(7,E,P(7),P(6),P(5),P(4),P(3),P(2),P(1),I2,I1,R0+52,9)
5120 IF E=1 GO TO 5280
5130 CALL(7,E,C2,C1,V,L,L1,A3,A2,A1,W4,W3,R7,R4,R0+61,12)
5140 IF E=1 GO TO 5280
5150 CALL(7,E,M3,H3,D3,K2,K1,S4,S3,S,R0+73,8)
5160 IF E=0 GO TO 5280
5170 IF R=0 GO TO 5310
5180 CALL(7,E,2,90,1)
5190 IF E>0 GO TO 5280
5200 CALL(3,F,E)
5210 IF E=1 GO TO 5280
5220 PRINT
5230 PRINT "----- DATA STORED -----"
5240 PRINT
5250 PRINT "RECORDED NO. ="JF
5260 LET R=0
5270 GO TO 5320
5280 PRINT
5290 PRINT "DATA STORAGE ERROR"
5300 STOP
5310 LET R=1
5320 RETURN
5330 END

```



```

5340 REM RESTART PROGRAM
5350 CALL(11,L0)
5360 CALL(9,E,C,0,L0,1,1)
5370 IF E>0 GO TO 5640
5380 IF C=0 GO TO 5620
5390 REM RECALL DATA
5400 CALL(9,E,Z5,Z4,Z3,Z2,Z1,M0,H0,D0,M8,H8,D8,101,L0,1,11)
5410 IF E>0 GO TO 5640
5420 CALL(9,E,H2,G2,R2,S2,H1,G1,R1,S1,112,L0,1,8)
5430 IF E>0 GO TO 5640
5440 CALL(9,E,W8,W2,R8,R5,Y(7),Y(6),Y(5),Y(4),Y(2),Y(1),120,L0,1,10)
5450 IF E>0 GO TO 5640
5460 CALL(9,E,T0,W0,P4,C4,F4,M4,H4,D4,P3,C3,F3,130,L0,1,11)
5470 IF E>0 GO TO 5640
5480 CALL(9,E,X(7),X(6),X(5),X(4),X(3),X(2),X(1),137,L0,1,7)
5490 IF E>0 GO TO 5640
5500 CALL(9,E,P1,F1,O1,N1,141,L0,1,4)
5510 IF E>0 GO TO 5640
5520 CALL(9,E,P(7),P(6),P(5),P(4),P(3),P(2),P(1),12,11,152,L0,1,9)
5530 IF E>0 GO TO 5640
5540 CALL(9,E,C2,C1,V,L,L1,A3,A2,A1,W4,W3,R7,R4,161,L0,1,12)
5550 IF E>0 GO TO 5640
5560 CALL(9,E,M3,H3,D3,K2,K1,S4,S3,S,173,L0,1,8)
5570 IF E>0 GO TO 5640
5580 PRINT
5590 PRINT "LAST RECORD STORED =";L0
5600 PRINT "LAST TIME ENTERED  =";D0;"DAY  ";H0;"HOUR  ";M0;"MINUTE"
5605 LET R=0
5610 RETURN
5620 LET L0=L0-1
5630 GO TO 5360
5640 PRINT
5650 PRINT "DATA STORAGE ERROR NO. ";E
5645 IF E=11 GO TO 5360
5660 RETURN
5670 END

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APPENDIX C: PROGRAM - EXPLANATION ONLY

On the following pages is given a listing of the FLONG computer program.

```

1000 REM FIELD DATA WORKUP - EXPLANATION ONLY
1005 REM CAUTION - ALL INPUT DATA MUST BE ENTERED AT START OF RUN
1010 DIM A(7),AS(1),BS(1),P(7),X(7),Y(7)
1020 REM DEFINE PROPERTIES OF COAL MOLECULE
1030 LET M=16.02
1040 LET A9=.912
1050 LET B9=0.194
1060 REM DEFINE WEIGHT FRACTION OF COAL WHICH IS WATER
1070 LET F5=.3
1080 REM DEFINE WEIGHT FRACTION OF COAL WHICH IS ASH
1090 LET F6=.07
1100 REM DEFINE DENSITY OF NATIVE COAL
1110 LET P5=1.3
1120 REM BRANCH FOR START UP
1130 PRINT "START OR RESTART ";
1140 INPUT AS
1150 ON (AS="S")+2*(AS="R") GO TO 1130,4960
1160 PRINT "BAD INPUT"
1170 GO TO 1130
1180 PRINT
1190 PRINT "ACTUAL TIME AT START OF RUN , DAY,HR,MIN ";
1200 INPUT D8,H8,M8
1205 REM INITIALIZE TIME FOR NUMERICAL INTEGRATION
1210 LET D0=D8
1220 LET H0=H8
1230 LET M0=M8
1240 PRINT
1250 PRINT
1260 PRINT "INITIAL GAS INJECTION RATE , SCFM ";
1270 INPUT N1
1280 PRINT "INITIAL GAS PRODUCTION RATE , SCFM ";
1290 INPUT O1
1300 REM ZERO ACCUMULATING VARIABLES
1310 LET F1=P1=I1=R=W4=0
1320 FOR I=1 TO 7
1330 LET P(I)=0
1340 NEXT I
1350 REM F - FLANGE TAP SIZE
1360 REM D - DATA INPUT
1370 REM S - STOP
1380 PRINT
1390 PRINT "ACTION WANTED ";
1400 INPUT AS
1410 ON (AS="D")+2*(AS="F")+3*(AS="S") GO TO 1570,2930,4900
1420 PRINT "BAD INPUT"
1430 GO TO 1380
1440 REM REINITIALIZE VARIABLES DUE TO ABORTED ACTION
1445 REM TIME
1450 LET D0=D9
1460 LET H0=H9
1470 LET M0=M9
1475 REM FLOW RATES AND TOTALS
1480 LET N1=N0
1490 LET F1=F0
1500 LET O1=O0

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1510 LET P1=P0
1515 REM VALUES NECESSARY FOR AIR LOSS CALCULATION
1520 LET P(1)=P9
1530 LET I1=I0
1540 PRINT
1550 PRINT "DATA INPUT ABORTED"
1560 GO TO 1330
1570 REM WHAT KIND OF DATA ?
1580 REM I - INJECTION RATES
1590 REM P - PRODUCTION RATES
1600 REM M - MOLE FRACTIONS
1610 REM V - WATER PRODUCTION RATE IN GAS
1620 REM L - LIQUID WATER PRODUCTION
1625 REM ZERO FLAGS WHICH SIGNIFIES CHANGE OF INPUT DATA
1630 LET Z1=Z2=Z3=Z4=Z5=0
1640 REM SAVE NECESSARY VALUES FROM PREVIOUS TIME
1645 REM TIME
1650 LET D9=D0
1660 LET H9=H0
1670 LET M9=M0
1675 REM FLOW RATES AND TOTALS
1680 LET N0=N1
1690 LET F0=F1
1700 LET O0=O1
1710 LET P0=P1
1715 REM VALUES NECESSARY FOR AIR LOSS CALCULATION
1720 LET P9=P(1)
1730 LET I0=I1
1740 PRINT
1750 PRINT "INPUT RAW DATA"
1760 PRINT "-----"
1770 PRINT
1780 PRINT "ACTUAL TIME , DAY,HR,MIN ";
1790 INPUT D0,H0,M0
1800 LET D=1440*(D0-D9)+60*(H0-H9)+M0-M9
1810 IF D>0 GO TO 1350
1820 PRINT "BAD INPUT"
1830 PRINT "THIS TIME MUST BE GREATER THAN PREVIOUS TIME"
1840 GO TO 1770
1850 PRINT
1860 PRINT "TYPE OF DATA ";
1870 INPUT A$
1880 ON (A$="I")+2*(A$="P")+3*(A$="M") GO TO 1920,2040,2160
1890 ON (A$="V")+2*(A$="L") GO TO 2370,2700
1900 PRINT "BAD INPUT"
1910 GO TO 1350
1920 PRINT
1930 PRINT "INJECTION FLOW RATE"
1940 PRINT
1945 REM INPUT -100 OR < FOR TEMP. IF FLANGE TAP SIZE IS WRONG
1950 PRINT "FLANGE TAP SIZE = ";S3;" IN."
1960 PRINT "TEMPERATURE , C ";
1970 INPUT R1
1973 REM ABORT IF FLANGE TAP SIZE IS WRONG
1975 IF R1<=-100 GO TO 1450

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1980 PRINT "PRESSURE , PSIA ";
1990 INPUT G1
2000 PRINT "PRESS. DROP , PSI ";
2010 INPUT H1
2015 REM SET FLAG
2020 LET Z1=1
2030 GO TO 2820
2040 PRINT
2050 PRINT "PRODUCTION FLOW RATE "
2060 PRINT
2065 REM INPUT -100 OR < FOR TEMP. IF FLANGE TAP SIZE IS WRONG
2070 PRINT "FLANGE TAP SIZE = ";S4;" IN."
2080 PRINT "TEMPERATURE , C ";
2090 INPUT R2
2093 REM ABORT IF FLANGE TAP SIZE IS WRONG
2095 IF R2<=-100 GO TO 1450
2100 PRINT "PRESSURE , PSIA ";
2110 INPUT G2
2120 PRINT "PRESS. DROP , PSI ";
2130 INPUT H2
2135 REM SET FLAG
2140 LET Z2=1
2150 GO TO 2820
2160 PRINT
2170 PRINT "MOLE FRACTIONS (DRY BASIS)"
2180 FOR I=1 TO 7
2190 IF I=3 THEN 2220
2200 PRINT "Y (";I;") ";
2210 INPUT Y(I)
2220 NEXT I
2225 REM-CHECK SUM OF Y(I)'S
2230 LET S=0
2240 FOR I=1 TO 7
2250 LET S=S+Y(I)
2260 NEXT I
2270 IF (S<.95)+(S>1.05)=1 GO TO 2300
2275 REM SET FLAG
2280 LET Z3=1
2290 GO TO 2820
2300 PRINT
2310 PRINT "SUM OF Y(I)'S =";S
2320 PRINT "DO YOU WISH TO CHANGE THEM , YES OR NO ";
2330 INPUT A$
2340 ON (A$="Y")+2*(A$="N") GO TO 2160,2280
2350 PRINT "BAD INPUT"
2360 GO TO 2320
2370 PRINT
2380 PRINT "WATER PROD. RATE IN TAP LINE TO G. C. "
2390 PRINT
2400 PRINT "INITIAL TIME , DAY HR MIN   ";D0;H0;M0
2410 PRINT "TOTAL FLOW THRU G. C. , CF ";
2420 INPUT F3
2430 PRINT "TEMPERATURE , C ";
2440 INPUT C3
2450 PRINT "PRESSURE , PSIA ";

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2460 INPUT P3
2470 PRINT
2480 PRINT "FINAL TIME , DAY,HR,MIN ";
2490 INPUT D4,H4,M4
2500 PRINT "TOTAL FLOW THRU G. C. , CF ";
2510 INPUT F4
2520 PRINT "TEMPERATURE , C ";
2530 INPUT C4
2540 PRINT "PRESSURE , PSIA ";
2550 INPUT P4
2560 PRINT
2570 PRINT "WEIGHT OF WATER , GM ";
2580 INPUT W0
2590 PRINT "WEIGHT OF TARS , GM ";
2600 INPUT T0
2605 REM SET FLAG
2610 LET Z5=1
2620 REM WATER PROD. RATE IN GAS
2625 REM CALCULATE TOTAL TIMES
2630 LET T3=1440*D0+60*H0+M0
2640 LET T4=1440*D4+60*H4+M4
2645 IF T4>T3 GO TO 2650
2646 PRINT "FINAL TIME MUST BE > INITIAL TIME"
2647 GO TO 2370
2650 LET R4=W0/(T4-T3)
2655 REM SAVE INITIAL TIME FOR THIS DATA CHANGE
2660 LET D3=D0
2670 LET H3=H0
2680 LET M3=M0
2690 GO TO 2320
2700 PRINT
2710 PRINT "LIQUID WATER PRODUCTION"
2720 PRINT
2730 PRINT "CLEAN RATE , GAL/MIN ";
2740 INPUT R5
2750 PRINT "DIRTY RATE , GAL/MIN ";
2760 INPUT R8
2770 PRINT "CLEAN TOTAL , GAL ";
2780 INPUT W2
2790 PRINT "DIRTY TOTAL , GAL ";
2800 INPUT W8
2805 REM SET FLAG
2810 LET Z4=1
2820 PRINT
2830 PRINT "MORE DATA , YES OR NO ";
2840 INPUT A$
2850 IF A$="Y" GO TO 1350
2860 IF A$="N" GO TO 3260
2870 PRINT "BAD INPUT"
2880 GO TO 2320
2890 REM FLANGE TAP SIZE
2900 REM INJECTION WELL
2910 REM S1=1 FOR 1.7177 IN. DIA.
2920 REM S1=2 FOR 3.028 IN. DIA.
2930 PRINT

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2940 PRINT "INJECTION FLANGE TAP SIZE ";
2950 INPUT S1
2960 ON S1 GO TO 2990,3020
2970 PRINT "BAD INPUT"
2980 GO TO 2940
2990 LET K1=34.856
3000 LET S3=1.7177
3010 GO TO 3090
3020 LET K1=311.03
3030 LET S3=3.023
3040 REM PRODUCTION WELL
3050 REM S2=1 FOR 0.82338 IN. DIA.
3060 REM S2=2 FOR 1.6288 IN. DIA.
3070 REM S2=3 FOR 3.0023 IN. DIA.
3080 REM S2=4 FOR 4.500 IN. DIA.
3090 PRINT "PRODUCTION FLANGE TAP SIZE ";
3100 INPUT S2
3110 ON S2 GO TO 3140,3170,3200,3230
3120 PRINT "BAD INPUT"
3130 GO TO 3090
3140 LET K2=10.305
3150 LET S4=0.82338
3160 GO TO 1330
3170 LET K2=41.243
3180 LET S4=1.6288
3190 GO TO 1380
3200 LET K2=164.922
3210 LET S4=3.0023
3220 GO TO 1380
3230 LET K2=370.067
3240 LET S4=4.5
3250 GO TO 1380
3260 REM INJECTION FLOW RATE
3270 LET N1=K1*SQR(27.6807*H1*(560/(1.3*R1+492)))*(G1/75))
3280 REM MOLE FRACTIONS (WET BASIS)
3282 X(3)=2.36E-3*W0*(C3+C4+546)/(F4-F3)/(P3+P4)
3290 FOR I=1 TO 7
3300 IF I=3 GO TO 3320
3310 LET X(I)=Y(I)/(1+X(3))
3320 NEXT I
3330 LET X(3)=(Y(3)+X(3))/(1+X(3))
3340 REM SPECIFIC GRAVITY OF GAS
3350 LET G=X(1)*28.0184+X(2)*31.993+X(3)*18.0153+X(4)*2.0159
3360 LET G=(G+X(5)*16.043+X(6)*28.011+X(7)*44.01)/28.966
3370 REM PRODUCTION FLOW RATE
3380 LET O1=K2*SQR(27.6807*H2*(760/(1.3*R2+492)))*(G2/30)/G)
3390 REM TOTAL INJECTED FLOW
3400 LET F1=F0+(N0+N1)*D/2
3410 REM TOTAL INJECTED SPECIES
3420 LET I1=.932*F1
3430 LET I2=.251*F1
3440 REM TOTAL PRODUCTION FLOW
3450 LET P1=P0+(O0+O1)*D/2
3460 REM TOTAL PRODUCED SPECIES
3470 FOR I=1 TO 7

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3480 LET P(1)=P(1)+X(1)*(P1-P2)*1.195
3490 NEXT I
3500 REM TOTAL WATER PRODUCTION
3510 LET W3=210.206*(W2+W3)+P(3)
3520 REM ATOMIC SPECIES
3530 LET A1=P(5)+P(6)+P(7)
3540 LET A2=2*W3+2*P(4)+4*P(5)
3550 LET A3=2*P(2)+W3+P(6)+2*P(7)
3560 REM AIR LOSSES
3570 LET L=1-P(1)/I1
3580 LET L1=(I1-I0-P(1)+P9)/(I1-I0)
3590 REM ATOMIC BALANCES
3600 LET Y0=Y(5)+Y(6)+Y(7)
3610 FOR I=4 TO 7
3620 LET A(I)=Y(I)/Y0
3630 NEXT I
3640 LET A(3)=2*A(5)+A(4)-A9/2
3650 LET A(2)=(A(6)+2*A(7)-A(3)-B9)/2
3660 REM COAL CONSUMPTION
3670 LET V=A1*M*3.53E-5/P5/(1-F5-F6)
3680 LET C1=1/A(2)
3690 LET C2=1/A(3)
3700 REM NET WATER INFLUX
3710 LET W5=W4
3720 LET W4=W3-A1*F5*M/18/(1-F5-F6)
3730 LET R7=4.038E-3*(W4-W5)/D
3740 PRINT
3750 PRINT "LONG OR SHORT FORM ";
3760 INPUT AS
3770 IF (AS="L")+(AS="S")=1 GO TO 3800
3780 PRINT "BAD INPUT"
3790 GO TO 3740
3800 PRINT
3810 PRINT "TURN PAPER TO BOTTOM OF OLD PAGE ."
3820 PRINT "INPUT ANY CHARACTER FOR OUTPUT OF RESULTS . "
3830 INPUT BS
3840 PRINT
3850 PRINT TAB(13);"RECORD NO. ="
3860 PRINT
3870 PRINT "ACTUAL TIME :";TAB(16);D0;TAB(22);"DAY";
3880 PRINT TAB(30);H0;TAB(37);"HOUR";TAB(45);M0;TAB(52);"MINUTE"
3890 PRINT "ELAPSED TIME :";TAB(16);D0-D8;TAB(22);"DAY";TAB(30);
3900 PRINT H0-H3;TAB(37);"HOUR";TAB(45);M0-M3;TAB(52);"MINUTE"
3910 PRINT "-----";
3920 PRINT "-----"
3925 REM SKIP FOR SHORT FORM
3930 IF (AS="S")+(Z1=0)+(Z2=0)=3 GO TO 4040
3940 PRINT
3950 PRINT " INJECTION WELL -";Z1;TAB(32);"PRODUCTION WELL -";Z2
3960 PRINT "TAP SIZE ,S3 =";S3;TAB(30);
3970 PRINT "TAP SIZE ,S4 =";S4;TAB(60);"IN."
3980 PRINT "TEMPERATURE,R1 =";R1;TAB(30);
3990 PRINT "TEMPERATURE,R2 =";R2;TAB(60);"DEG. C"
4000 PRINT "PRESSURE ,G1 =";G1;TAB(30);
4010 PRINT "PRESSURE ,G2 =";G2;TAB(60);"PSIA"

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4020 PRINT "PRESS. DROP,H1 =" ; H1 ; TAB(30) ;
4030 PRINT "PRESS. DROP,H2 =" ; H2 ; TAB(60) ; "PSI"
4035 REM SKIP FOR SHORT FORM
4040 IF (AS="S")+(Z3=0)=2 GO TO 4150
4050 PRINT
4060 PRINT TAB(18) ; "MOLE FRACTIONS (DRY BASIS) -" ; Z3
4070 FOR I=1 TO 2
4080 PRINT "Y (" ; I ; " ) =" ; Y(I) ; TAB(30) ; "Y (" ; I+4 ; " ) =" ; Y(I+4)
4090 NEXT I
4100 PRINT "Y (" ; 4 ; " ) =" ; Y(4) ; TAB(30) ; "Y (" ; 7 ; " ) =" ; Y(7)
4110 PRINT
4120 PRINT "SUM OF Y'S =" ; S ; TAB(25) ;
4130 PRINT "HEAT OF COMBUSTION =" ; Y(4)*68.317+Y(5)*212.3+Y(6)*67.636 ;
4140 PRINT TAB(60) ; "KCAL/MOLE"
4145 REM SKIP FOR SHORT FORM
4150 IF (AS="S")+(Z4=0)=2 GO TO 4220
4160 PRINT
4170 PRINT TAB(19) ; "LIQUID WATER PRODUCTION -" ; Z4
4180 PRINT "CLEAN RATE , R5 =" ; R5 ; TAB(30) ;
4190 PRINT "DIRTY RATE , R6 =" ; R6 ; TAB(60) ; "GPM"
4200 PRINT "CLEAN TOTAL , W2 =" ; W2 ; TAB(30) ;
4210 PRINT "DIRTY TOTAL , W3 =" ; W3 ; TAB(60) ; "GAL"
4215 REM SKIP FOR SHORT FORM
4220 IF (AS="S")+(Z5=0)=2 GO TO 4730
4230 PRINT
4240 PRINT TAB(22) ; "TAP LINE TO G. C. -" ; Z5
4250 PRINT " INIT. TIME =" ; D3 ; H3 ; M3 ; TAB(32) ;
4260 PRINT "FINAL TIME =" ; D4 ; H4 ; M4 ; TAB(60) ; "DAY HR MIN"
4270 PRINT "TOT. FLOW,F3 =" ; F3 ; TAB(30) ;
4280 PRINT "TOT. FLOW,F4 =" ; F4 ; TAB(60) ; "CF"
4290 PRINT "TEMP. ,C3 =" ; C3 ; TAB(30) ;
4300 PRINT "TEMP. ,C4 =" ; C4 ; TAB(60) ; "DEG. C"
4310 PRINT "PRESS. ,P3 =" ; P3 ; TAB(30) ;
4320 PRINT "PRESS. ,P4 =" ; P4 ; TAB(60) ; "PSIA"
4330 PRINT "WATER WGT,W0 =" ; W0 ; TAB(30) ;
4340 PRINT "TAR WGT ,T0 =" ; T0 ; TAB(60) ; "GM"
4345 REM SKIP FOR SHORT FORM
4350 IF AS="S" GO TO 4730
4360 PRINT
4370 PRINT "INJ. RATE,N1 =" ; N1 ; TAB(30) ;
4380 PRINT "PROD. RATE,O1 =" ; O1 ; TAB(60) ; "SCFM"
4390 PRINT "TOT. INJ.,F1 =" ; F1 ; TAB(30) ;
4400 PRINT "TOT. PROD.,P1 =" ; P1 ; TAB(60) ; "SCF"
4410 PRINT
4420 PRINT TAB(20) ; "MOLE FRACTIONS (WET BASIS)"
4430 FOR I=1 TO 3
4440 PRINT "X (" ; I ; " ) =" ; X(I) ; TAB(30) ; "X (" ; I+4 ; " ) =" ; X(I+4)
4450 NEXT I
4460 PRINT "X (" ; 4 ; " ) =" ; X(4)
4470 PRINT
4480 PRINT "TOTAL INJECTED NITROGEN , I1 =" ; I1 ; TAB(60) ; "MOLES"
4490 PRINT "TOTAL INJECTED OXYGEN , I2 =" ; I2 ; TAB(60) ; "MOLES"
4500 PRINT
4510 PRINT TAB(21) ; "TOTAL PRODUCED SPECIES"

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4520 FOR I=1 TO 3
4530 PRINT "P (";I;") =";P(I);TAB(30)
4540 PRINT "P (";I+4;") =";P(I+4);TAB(60);"MOLES"
4550 NEXT I
4560 PRINT "P (";4;") =";P(4);TAB(60);"MOLES"
4570 PRINT
4580 PRINT "WATER PRODUCTION RATE IN GAS =";R4;TAB(60);"GM/MIN"
4590 PRINT "APPROX. NET WATER INFLUX RATE =";R7;TAB(60);"GPM"
4600 PRINT "TOTAL WATER PRODUCTION , W3 =";W3;TAB(60);"MOLES"
4610 PRINT "TOTAL NET WATER INFLUX , W4 =";W4;TAB(60);"MOLES"
4620 PRINT
4630 PRINT "CARBON PRODUCTION , A1 =";A1;TAB(60);"ATOMS"
4640 PRINT "HYDROGEN PRODUCTION , A2 =";A2;TAB(60);"ATOMS"
4650 PRINT "OXYGEN PRODUCTION , A3 =";A3;TAB(60);"ATOMS"
4660 PRINT
4670 PRINT "DIFF. FRACTIONAL AIR LOSS , L1 =";L1
4680 PRINT "TOTAL FRACTIONAL AIR LOSS , L =";L
4690 PRINT
4700 PRINT "TOTAL VOLUME OF COAL BURNED , V =";V;TAB(60);"CF"
4710 PRINT "MOLES OF COAL / MOLE OF OXYGEN , C1 =";C1
4720 PRINT "MOLES OF COAL / MOLE OF WATER , C2 =";C2
4730 PRINT
4740 PRINT
4750 PRINT
4760 PRINT
4770 GO TO 4810
4775 REM SKIP LINES TO PUT SHORT FORM ON SEPARATE PAGE
4780 FOR I=1 TO 60
4790 PRINT
4800 NEXT I
4810 PRINT "DO YOU WISH TO STORE THIS DATA , YES OR NO ";
4820 INPUT A$
4830 ON (A$="Y")+2*(A$="N") GO TO 4860,1450
4840 PRINT "BAD INPUT"
4850 GO TO 4810
4860 REM STORE DATA
4870 GOSUB 4990
4880 PRINT
4890 GO TO 1380
4900 PRINT "DO YOU REALLY WANT TO STOP , YES OR NO ";
4910 INPUT A$
4920 IF A$="Y" GO TO 4980
4930 IF A$="N" THEN 1380
4940 PRINT "BAD INPUT"
4950 GO TO 4900
4955 REM RESTART PROGRAM
4960 GOSUB 5340
4970 GO TO 1380
4980 END
4990 REM STORE DATA ON TAPE
4995 REM SET INDEX FOR 1 ST OR 2 ND HALF OF RECORD
5000 LET R0=R*100
5005 REM LOAD VARIABLES INTO BUFFER
5010 CALL(7,E,Z5,Z4,Z3,Z2,Z1,M0,H0,D0,M3,H3,D3,R0+1,11)
5020 IF E=1 GO TO 5280

```

```

5030 CALL(7,E,H2,G2,R2,S2,H1,G1,R1,S1,R0+12,8)
5040 IF E=1 GO TO 5280
5050 CALL(7,E,W8,W2,R8,R5,Y(7),Y(6),Y(5),Y(4),Y(2),Y(1),R0+20,10)
5060 IF E=1 GO TO 5280
5070 CALL(7,E,T0,W0,P4,C4,F4,M4,H4,D4,P3,C3,F3,R0+30,11)
5080 IF E=1 GO TO 5280
5090 CALL(7,E,X(7),X(6),X(5),X(4),X(3),X(2),X(1),P1,F1,O1,N1,R0+41,11)
5100 IF E=1 GO TO 5280
5110 CALL(7,E,P(7),P(6),P(5),P(4),P(3),P(2),P(1),I2,I1,R0+52,9)
5120 IF E=1 GO TO 5280
5130 CALL(7,E,C2,C1,V,L,L1,A3,A2,A1,W4,W3,R7,R4,R0+61,12)
5140 IF E=1 GO TO 5280
5150 CALL(7,E,M3,H3,D3,K2,X1,S4,S3,S,R0+73,8)
5160 IF E>0 GO TO 5230
5165 REM BRANCH IF ONLY 1 ST HALF OF RECORD IS IN BUFFER
5170 IF R=0 GO TO 5310
5175 REM ZERO 90 TH INDEX TO SIGNIFY NO DATA CORRECTION
5180 CALL(7,E,0,90,1)
5190 IF E>0 GO TO 5230
5195 REM ACTUALLY STORE DATA ON TAPE
5200 CALL(8,F,E)
5210 IF E=1 GO TO 5280
5220 PRINT
5230 PRINT "----- DATA STORED -----"
5240 PRINT
5250 PRINT "RECORDED NO. =";F
5255 REM RESET 1 ST HALF OF RECORD INDEX FLAG
5260 LET R=0
5270 GO TO 5320
5280 PRINT
5290 PRINT "DATA STORAGE ERROR"
5300 STOP
5305 REM SET 2 ND HALF OF RECORD INDEX FLAG
5310 LET R=1
5320 RETURN
5330 END
5340 REM RESTART PROGRAM
5345 REM RECALL LAST RECORD STORED
5350 CALL(11,L0)
5355 REM CHECK WHETHER INTEGER OR FLOATING POINT RECORD
5360 CALL(9,E,C,0,L0,1,1)
5365 REM BRANCH IF INTEGER RECORD
5370 IF E>0 GO TO 5640
5380 IF C=0 GO TO 5620
5390 REM RECALL DATA
5400 CALL(9,E,Z5,Z4,Z3,Z2,Z1,M0,H0,D0,M3,H8,D8,101,L0,1,11)
5410 IF E>0 GO TO 5640
5420 CALL(9,E,H2,G2,R2,S2,H1,G1,R1,S1,112,L0,1,8)
5430 IF E>0 GO TO 5640
5440 CALL(9,E,W8,W2,R8,R5,Y(7),Y(6),Y(5),Y(4),Y(2),Y(1),120,L0,1,10)
5450 IF E>0 GO TO 5640
5460 CALL(9,E,T0,W0,P4,C4,F4,M4,H4,D4,P3,C3,F3,130,L0,1,11)
5470 IF E>0 GO TO 5640
5480 CALL(9,E,X(7),X(6),X(5),X(4),X(3),X(2),X(1),137,L0,1,7)
5490 IF E>0 GO TO 5640

```

```

5500 CALL(9,E,P1,F1,O1,N1,141,L0,1,4)
5510 IF E>0 GO TO 5640
5520 CALL(9,E,P(7),P(6),P(5),P(4),P(3),P(2),P(1),I2,I1,152,L0,1,9)
5530 IF E>0 GO TO 5640
5540 CALL(9,E,C2,C1,V,L,L1,A3,A2,A1,W4,W3,R7,R4,161,L0,1,12)
5550 IF E>0 GO TO 5640
5560 CALL(9,E,M3,H3,D3,K2,K1,S4,S3,S,173,L0,1,8)
5570 IF E>0 GO TO 5640
5580 PRINT
5590 PRINT "LAST RECORD STORED =" ; L0
5600 PRINT "LAST TIME ENTERED =" ; D0 ; "DAY " ; H0 ; "HOUR " ; M0 ; "MINUTE"
5605 LET R=0
5610 RETURN
5615 REM LAST RECORD IS INTEGER - REDUCE BY 1
5620 LET L0=L0-1
5625 REM BRANCH TO CHECK NEXT RECORD
5630 GO TO 5360
5640 PRINT
5644 REM BRANCH IF SCAN IS NEAR
5645 IF E=11 GO TO 5360
5650 PRINT "DATA STORAGE ERROR NO. " ; E
5660 RETURN
5670 END

```

*

APPENDIX D: LIST OF VARIABLES USED IN COMPUTER CODE

Ai	Atomic balance coefficients (i = 1, 2, 3, 4, 5, 6, or 7)
A9	α subscript for coal
A\$	String variables for branching
B9	β subscript for coal
B\$	String variable for branching
C	$\emptyset$ -integer record, ≥ 1 - floating point record
C1	Coal/oxygen consumed
C2	Coal/water consumed
C3	Initial tap-line temperature
C4	Final tap-line temperature
D	Difference between last two entry times
D $\emptyset$	Data entry time - day
D3	Initial tap-line time
D4	Final tap-line time
D8	Start day
D9	Previous data entry-time - day
E	Data storage error if non-zero
F $\emptyset$	Total injected flow, current
F1	Total injected flow, previous
F3	Initial tap-line flow
F4	Final tap-line flow
F5	Weight fraction of coal that is water
F6	Weight fraction of coal that is ash
G	Specific gravity of gas
G1	Injection pressure
G2	Production pressure
H $\emptyset$	Data entry-time - hour
H1	Injection pressure-drop
H2	Production pressure-drop
H3	Initial tap-line hour
H4	Final tap-line hour
H8	Start hour
H9	Previous data entry-time - hour
I $\emptyset$	Previous injected nitrogen

I1	Current injected nitrogen
I2	Current injected oxygen
K1	Injection flow-rate constant
K2	Production flow-rate constant
L	Fractional air loss
L0	Last record number.
L1	Differential fractional air loss
M	Molecular weight of coal
M0	Minute - data entry-time
M3	Minute - initial tap-line time
M4	Minute - final tap-line time
M8	Minute - start tap-line time
M9	Minute - previous data-entry time
N0	Initial gas injection-rate - previous
N1	Initial gas injection-rate - current
O0	Initial gas production-rate - previous
O1	Initial gas production-rate - current
Pi	Produced species
P0	Total produced flow - previous
P1	Total produced flow - current
P3	Initial tap-line pressure
P4	Final tap-line pressure
P5	Density of coal
P9	Previous produced nitrogen
R	0-1st half record 1-Second half record
R0	0-1st half record, 100-Second half record
R1	Injection temperature
R2	Production temperature
R4	Water production-rate in gas
R5	Clean liquid water production
R7	Approximate net water influx-rate
R8	Dirty liquid water production
S1	Injection flange-tap flag
S2	Production flange-tap flag
S3	Injection flange-tap size
S4	Production flange-tap size

S	ΣY_{is}	
T	Tar weight	
T3	Total initial tap-line time	
T4	Total final tap-line time	
V	Volume of coal consumed	
W0	Condensed water weight	
W2	Clean liquid water production	
W3	Total water production	
W4	Total net water influx - current	
W5	Total net water influx - previous	
W8	Dirty liquid water production	
Xi	Wet mole fractions	
Yi	Dry mole fractions	
Z1	} Change of raw data flags	
Z2		
Z3		
Z4		
Z5		
*A1	Produced carbon	
A2	Produced oxygen	
A3	Produced hydrogen	

RECORD INDICES

1. D8	30. F3	59. P ₆	
2. H8	31. C3	60. P ₇	
3. M8	32. P3	61. R ₄	
4. DØ	33. D4	62. R ₇	90. Ø - OK
5. HØ	34. H4	63. W ₃	1 - correction
6. MØ	35. M4	64. W ₄	91. record no. corrected back to
7. Z1	36. F4	65. A ₁	
8. Z2	37. C4	66. A ₂	
9. Z3	38. P4	67. A ₃	
10. Z4	39. WØ	68. L1	
11. Z5	40. TØ	69. L	
12. S1	41. N1	70. V	
13. R1	42. O1	71. C1	
14. G1	43. F1	72. C2	
15. H1	44. P1	73. S	
16. S2	45. X ₁	74. S3	
17. R2	46. X ₂	75. S4	
18. G2	47. X ₃	76. K1	
19. H2	48. X ₄	77. K2	
20. Y1	49. X ₅	78. O3	
21. Y2	50. X ₆	79. H3	
22. Y4	51. X ₇		
23. Y5	52. I ₁		
24. Y6	53. I ₂		
25. Y7	54. P ₁		
26. R5	55. P ₂		
27. R8	56. P ₃		
28. W2	57. P ₄		
29. W8	58. P ₅		

APPENDIX E: TAPE-READING OF ERROR MESSAGES

The following is a list of errors returned from software controlling the operation of the tape unit.

1. Tape unit not ready
2. At beginning of tape
4. At end of tape
7. Record number requested is too high (has not been written yet).
8. File mark encountered
9. Negative record number requested
10. Record requested is beyond the area that can be accessed within scanning intervals
11. Not enough time available to reach record requested before next scan (can be reached after the scan).
16. Wrong record type (attempted to read integer rather than floating point record)
32. Parity error
If index position is returned, attempted to read beyond record limit
256. Invalid tape read request

APPENDIX F: BASIC ERROR MESSAGES FOR ALPHA-16 SYSTEM²

INTRODUCTION

When the BASIC system detects an error while scanning or processing a line of input from the user or while executing a BASIC statement, it prints an error message at the user's terminal (and reverts to the command mode of operation if it was in the execute mode).

ERROR MESSAGE FORMAT

An error message has the following format:

//aa dd

The aa field is a two-letter code identifying the error detected (as shown in the list below), and the dd field contains two decimal digits that locate the character position within the line at which the error was detected. The BASIC statement containing the error is printed on the next line following the error message. The list of possible error codes and their meanings is as follows:

- AR Arrays not conformable. A matrix operation has been specified and the dimensions of the matrix operands are such that the operation is not possible.
- CA No such CALL subroutine.
- CN Constant missing in data statement or input line.
- DA Doubly-defined array.
- DC List of DATA constants exhausted.
- DF Doubly-defined function. The same function name has appeared in more than one DEF statement.
- DZ Division by zero attempted.
- ER Syntax error. The statement or command does not have the proper structure.
- ET Program has reached end of text.

2. This is taken from the manual provided by Computer Automation Corporation.

EX Extraneous characters on line. The initial characters on the line are interpretable as a legal statement or command, but there are further unusable non-space characters.

FA Function argument error. The number of arguments in the function reference is not the same as in the function definition.

FO Improper FOR variable. The operand following FOR must be a simple variable.

IA Illegal assignment.

ID Illegal dimension specifier.

IM Square matrix required.

IN Improperly formed constant. Most likely cause of this error is missing digits in the exponent.

IO Illegal operator with string operand.

IS Illegal value for a statement number.

LG Negative or zero argument to LOG function.

LN Statement number not allowed.

LS LEN function requires a string argument.

M= No replacement operator in LET, DEF, or FOR statement.

M(Missing left parenthesis.

M) Missing right parenthesis.

MA Unrecognized MAT statement.

MM Mode mixing between string and numeric data.

MO No operand. The syntax of the statement requires an operand in this position.

MS Missing statement. A reference to a non-existent line number has been encountered in a GOTO, GOSUB, IF, ON, or PUNCH statements.

MT No program text. A LIST or PUNCH command has been given and there are no BASIC statements in the user's work area.

NL Statement number required on this statement.

NO Overflow on conversion to integer format.

NS Deletion of non-existent statement number.

NX NEXT statement encountered without having executed an associated FOR statement.

OV Numerical overflow. The value of a constant or an intermediate value of an expression has exceeded the maximum magnitude (approximately 9.23×10^{18}).

RT RETURN statement encountered while no GOSUB statement is active.

SA Illegal string argument.

SM Attempted inversion of a singular or nearly singular matrix.

SN Wrong number of subscripts in any array reference.

SO String overflow. The working length of a string has exceeded the maximum length.

SQ Negative argument to SQR function.

SR Subscript range error. A subscript has been encountered that refers to an array element outside the array.

SS Substring subscripts contradictory. The second argument of a substring reference is less than the first argument.

ST String operation not available.

TD Two-dimensional array required.

UF Undefined function. A reference has been made to a function that is not in the library and has not been defined in a DEF statement.

UM Undefined matrix in MAT statement.

UQ Unbalanced quotation marks.

US The input line is not recognizable as either a statement or command.

WA User's work area has been exhausted. If this error occurs while attempting to add a new line to a program, the only remedy is to reduce the size of the program. If the error occurs during program execution, it may be possible to avoid it by breaking up long expressions into two or more smaller expressions or by reducing the size of arrays.

XC Excess characters output by a TAB function.

XI Excess input characters.

XP Expression not permitted here.

APPENDIX G: BRIEF INSTRUCTIONS

Start or restart ?

- S - Start,
- R - Restart.

Action wanted ?

- F - Flange tap size,
- D - Data input,
- S - Stop.

Injection flange-tap size ?

- 1 - 1.7177-in. diam,
- 2 - 3.028-in. diam,

Production flange-tap size ?

- 1 - 0.82339-in. diam,
- 2 - 1.6288-in. diam,
- 3 - 3.0023-in. diam,
- 4 - 4.500-in. diam.

Type of data ?

- I - Injection rates,
- P - Production rates,
- M - Mole fractions,
- W - Water production rate in gas,
- L - Liquid water production.

Long or Short Form ?

- L - Long,
- S - Sort.

Corrections:

1. If flange-tap size wrong, input a temperature ≤ -100 .
2. Use backarrow ($\leftarrow$) to correct mistyped characters.
3. Reenter data before or after printout.

Caution: If character typed when expecting a number, execution terminates.

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