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A MICROCOMPUTER BASED DATA ACQUISITION/CONTROL SYSTEM FOR ENDURANCE TESTING WITH VEGETABLE OIL FUELS

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SUMMARY:

Three hydraulic load stands equipped with Wisconsin 1.0 L air cooled, direct injection engines have been constructed and are being operated with a Hewlett-Packard 85F microcomputer and 3054 Data Logger. The computer will control both the test cycle, according to the Engine Manufacturers Association Guidelines, and analyze and collect the data on-line.

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A Microcomputer Based Data Acquisition/Control System for Endurance Testing with Vegetable Oil Fuels

Charles L. Peterson and Gary L. Wagner*

Introduction

Investigation into the use of alternative fuels, such as safflower, sunflower, or winter rape vegetable oils, for diesel engines necessitates both short and long term testing programs. Facilities for short term testing on a bench dynamometer were available but long term testing is a new endeavor requiring equipment previously unavailable at the University of Idaho. The Northern Agricultural Energy Center, in cooperation with the Engine Manufacturers Association (EMA), have developed a suggested 200 hour test procedure for screening alternative fuels. The test schedule is intended to allow early assessment of the potential impacts of these fuels on engine durability. It is designed to initiate durability problems with a reasonable amount of test time. A copy of the latest test procedure available to the authors is included as appendix A. The test cycle specifies a four step procedure where different levels of speed and torque are specified, requiring 3 hours to complete each cycle.

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Previous endurance testing with two small engines has shown the desirability of replicating the data, since when only one engine was used per treatment it was virtually impossible to separate problems which develop as a result of the fuel from more ordinary engine malfunctions which may occur as a result of chance. Thus, six engines were purchased with the intent of operating three engines on each fuel in each test. Only three test stands were constructed as the time required for tear down and assembly is at least as long as the time required for completing 200 hours of the test cycle. Therefore, three engines would be undergoing test continuously while the other three would be undergoing tear down and evaluation. Automated control and collection of data on these test stands was desirable to minimize the need for a technician, freeing him for other work. Also, automation allows data collection to be on a more regular basis. Several systems were studied, but a microcomputer which would do all tasks seemed most desirable. Since the staff was familiar with programming in BASIC and also since start-up time was critical, the Hewlett-Packard[1] (HP) 85 system with a 3054DL data logger was selected. The unit can be purchased as a package, minimizing interfacing problems and since it is programmable in BASIC a minimum of learning was required to put the machine on-line. The total cost of (about $14,000 plus transducers) is higher than some other systems, but the savings in software and interfacing time makes the system comparable. This paper will give a brief description of the engines with their hydraulic load stands, and

[1]To simplify information, trade names have been used in this publication. No endorsement of named products is intended nor is criticism of similar products, not mentioned, implied.

will describe the HP/85/3054DL control/data acquisition system. It will also provide some program segments which should aid first time users to operate the system quickly. Hewlett-Packard has provided considerable software and a profusion of manuals which will provide help in meeting needs for particular applications.

Engines and Hydraulic Load Units

Six Wisconsin WD2-1000, 1.0L, direct injection, air cooled, twin cylinder diesel engines rated 15.7 KW at 3000 rpm were selected as test engines. Engines of this size were required in order to keep the fuel bill within manageable levels for continuous testing and also to keep the test cells as small as possible. Three test cells were constructed which will allow for one-half the engines to be under test and the other half to be undergoing tear down and inspection at all times.

The engines are connected to cradled Hydreco gear pumps. The oil flow is directed through a Sperry-Vickers dual pressure, pilot operated relief valve which serves to load the pump. An electric solenoid valve is used to select the high or low pressure setting of the relief valve or when in neutral to vent the pump at no load. Thus three load settings can be selected. The high and low setting are manually adjustable. After the relief valve, the oil is directed through a heat exchanger and back to the reservoir. The heat exchanger has a hydraulically driven fan which is operated whenever the oil temperature exceeds a pre-set value. A hydraulic schematic of the load units is shown as Figure 1. A photograph of the units in place is shown as Figure 2.

Each unit has a strain gage load cell for measuring engine torque and weight of fuel in supply tank, an rpm pick-up for engine speed, a

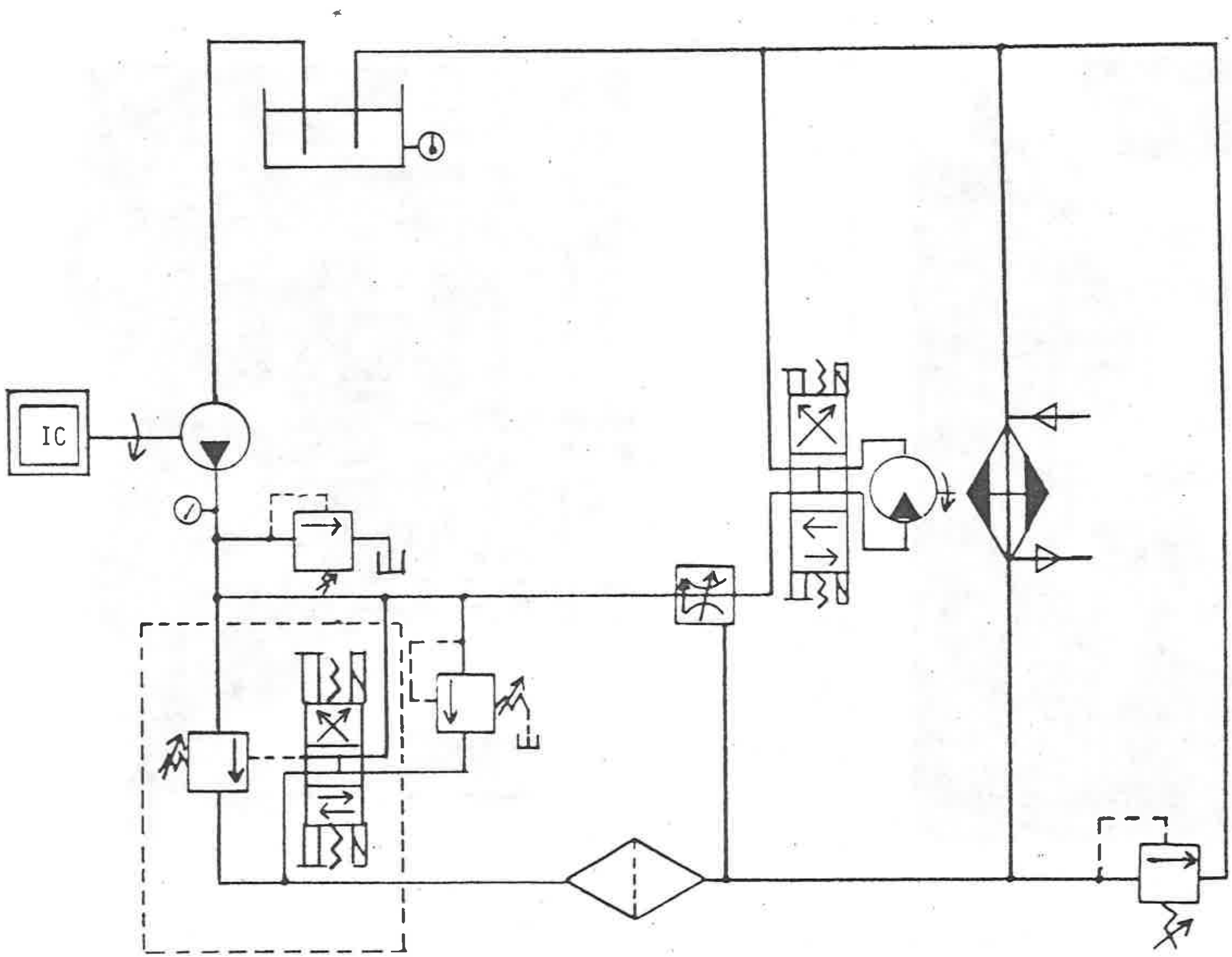


Figure 1. Test Unit Hydraulic Schematic

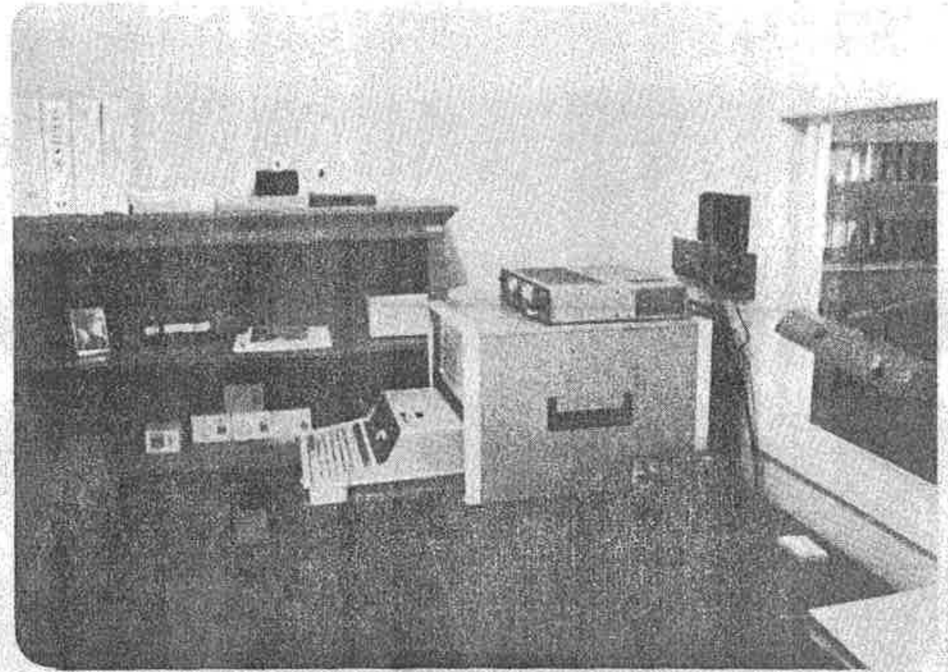
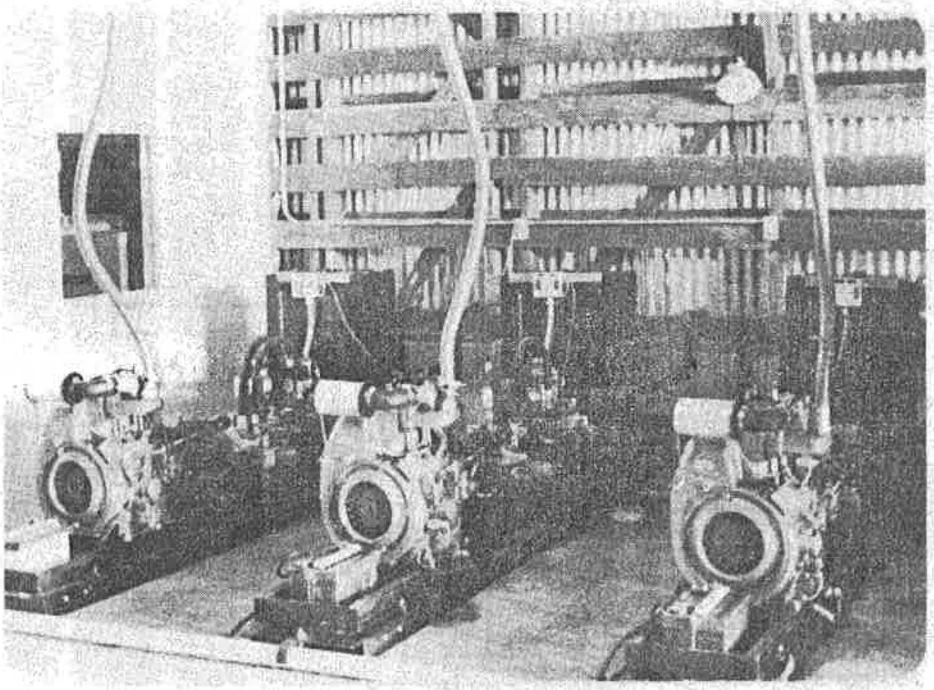


Figure 2. The completed hydraulic load units with the Wisconsin 1.0L engines (below) and the controller/data logger (above).



pulse-type flow meter which gives a pulse in proportion to flow volume,a dc reversible gear head motor for throttle control, thermocouple transducers for fuel, oil, air, exhaust and load unit oil temperature and two solenoid valves, one for load control and one to control the cooling fans on the heat exchanger. The next section will describe the computer used to operate the system.

Description of Control/Data Acquisition System

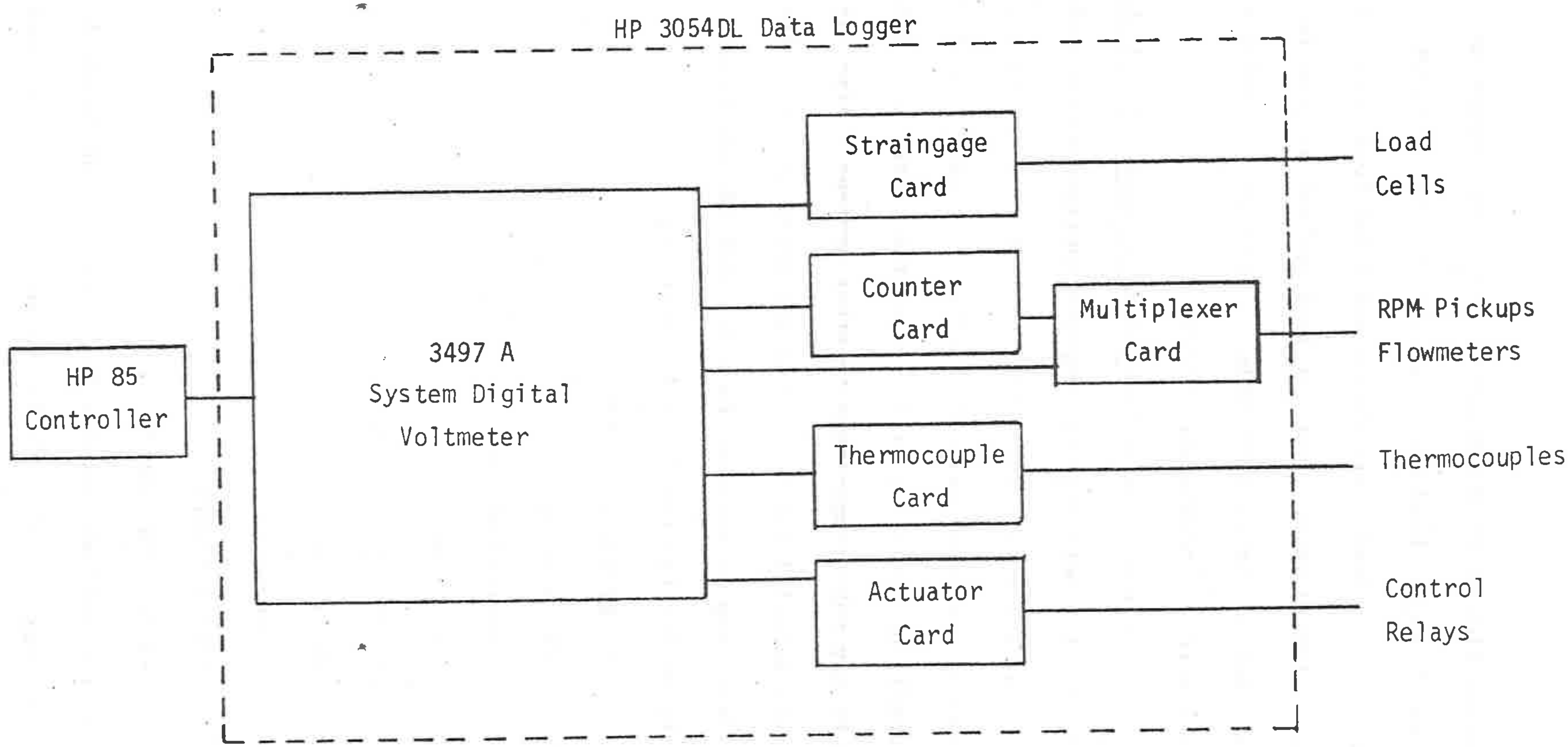
Many different types of computer configurations could be used for the control and data acquisition required. No effort will be made to justify the equipment selected, rather a description of the equipment and details of operation will provide the reader with information on which he may make comparisons to other systems. Also, it is anticipated that this material may be used by new users of the HP/85F/3054DL systems as a first step in becoming familiar with the equipment.

The HP/85F has the following features:

- -Programmable in BASIC
- -CRT display
- -internal printer
- -live keybourd
- -priority interrupt
- -buffered I/O
- -auto-start
- -error trapping
- -3 internal timers

The control/data acquisition system, shown in block diagram form as Figure 3, consists of an HP/85F microcomputer, programmable in HP-BASIC,

Figure 3. Block Diagram of HP85/3054DL Data Logger Connections



and a 5½ digit precision scanning voltmeter. The 3054DL comes standard with a digital voltmeter and a programmable current source. Optional capability is provided via up to 5 plug-in assemblies (additional plug-ins can be added with an optional expander) which include:

1. A 20-channel relay multiplexer assembly. The multiplexer is useful for 20 channels of dcV, 2-wire ohm measurement or 10 channels of 4-wire measurement. It is also used with the counter assembly to provide up to 20 inputs to the single channel counter. The multiplexer has a maximum of ±170V peak and 50 MA.

2. A 19-channel relay multiplexer with thermocouple compensation. It can multiplex up to 19 thermocouples or 19 dc voltages. Channel 20 on this cards provides a reference junction voltage. The card can be used with all thermocouple types through software compensation or a single thermocouple type through hardware compensation.

3. A Reciprocal Counter Assembly. Frequency mode 1 Hz -100 kHz or totalize mode 0 to 999,999 events. The device will count up, count down or measure pulse width down to 18 μs. It can be used with the multiplexer as described earlier for multiple channels.

4. A 16-channel actuator/digital output assembly. The actuator contains 16 mercury-wetted relays with a maximum rating of 100 V peak at 1 amp rms and 100 VA. The relays are opened and closed on program command.

5. A 350 ohm strain gage/bridge assembly. Ten bridges per card for any mixture of ¼, ½ or full bridge circuits. No minimal adjustment, software is used to measure bridge output, compute strain, and for calibration.

Other options are available. The ones described above are those used to operate the engine test stand.

The computer controls:

- -engine load
- -engine speed
- -load unit oil temperature

The computer measures:

- -fuel consumption
- -engine load
- -engine speed
- -oil, air, fuel, and exhaust temperatures

The computer continuously scans all three load units, one at a time. Data can be stored, printed, and graphed on-line.

The control/data acquisition system as purchased was installed in a cabinet. All connections to the option cards were through screw terminals located on the cards. To simplify connections a terminal panel was constructed and attached to the back of the cabinet. The terminal panel has thermocouple jacks for both iron constantan and copper constantan, jacks for the strain gage bridge and screw terminal blocks for the multiplexer and actuator boards. This panel reduces the need to remove and install the plug-in cards and is useful for speeding connection of the transducers to the 3054DL.

Operation of the Engine Test

To run an engine test cycle, the program ENTEST is called into the computer and run. It tells when to start the engines and asks for the

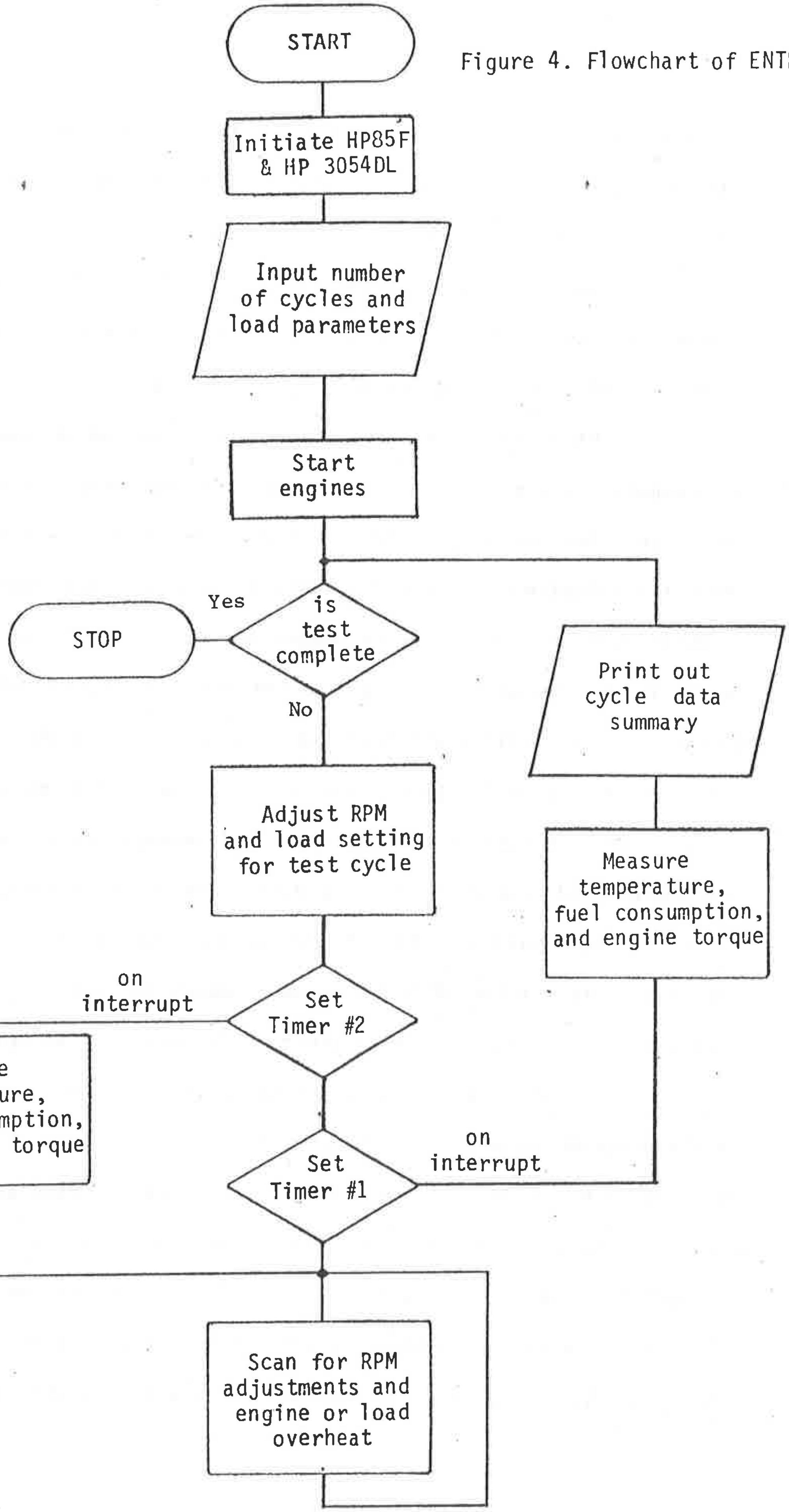


Figure 4. Flowchart of ENTEST Program

load cycle parameters, i.e. number of cycles, engine speed, load settings (0, 1 or 2) and cycle length. When the engines are started the computer will bring all three engines to the first cycle's test speed. The load is applied and the first test cycle starts. The engine speed is monitored frequently and adjustments made to attain ±20 rpm of the desired speed. This range of rpm was selected to prevent a "hunting" condition from occurring between the computer and the engine. Load unit oil temperature and crankcase oil temperature are measured frequently (10 or 20 times per minute) to insure that the engines and load units are not overheating. If the load unit temperature goes over 60°C the computer will start the heat exchanger cooling fan. If the engine oil overheats the computer will terminate the test and print out a warning to the operator telling which engine overheated and at what time. Three times during the cycle, power, fuel consumption, and temperature data are recorded. A summary printout of cycle average power, fuel consumption and temperatures along with cycle starting time, length of cycle, and load valve position is reported at the end of each cycle. The flow chart for the ENTEST program is shown in Figure 4. The program uses two of the HP85's internal timers. One timer is assigned the cycle length and the other the data collection interval. Some of the software in the program was written by HP for the data logger system. These are subprograms which measure thermocouple temperatures using software compensation, measure the strain gage bridge circuits, and help debug the system in case of failure or error. Several subprograms of the ENTEST program are shown below to help explain programming of the computer. The subprogram listings are located in Appendix B.

1. The "RCHECK" subprogram is used to adjust engine speed to the desired level. The computer reads the engine speed and compares it speed to the desired speed. If the RPM of the engine is too low, the computer activates the DC gear head motor connected to the throttle linkage to increase the fuel flow to the engine. If RPM of the engine is too high then the DC motor is reversed and the throttle is closed down a small amount. By repeating this procedure the engine speed is adjusted to within the acceptable ±20 rpm of the desired speed.

2. the "LOCHECK" subprogram monitors the load unit oil temperature on each of the 3 load units. If the temperature exceeds 60°C the hydraulically driven cooling fan is started using a computer operated solenoid hydraulic valve. When the temperature drops to below 60°C the fan is turned off. If the temperature continues to rise above 71°C the engine test is terminated and an operator warning message is displayed showing when the termination occurred and which load unit was responsible.

3. The "CCHECK" subprogram monitors crankcase oil temperatures and terminates the test when it exceeds 120°C. An operator message is also displayed on the computer printout describing the problem and when it happened.

4. The "FUMEAS" subprogram measures the fuel flow to and from the engines using calibrated pulse type flow meters. A flow meter is located in the incoming fuel line to the engine and another flow meter in the return line from the injectors. The difference between these is the fuel consumed by the engine. This data is summarized during the test and presented at the cycle termination.Since installation of this

system it was determined that the flow rates of fuel to the engine were at the low end of the capability of the flow meters. The flow meters proved unreliable in determining fuel consumption, even though two different types of flow meters were tested. Strain gage proving ring type transducers have been installed. These weigh the totla fueld in the tank and determined fuel consumption by weight loss per unit time.

5. The subprogram "SC_DEG" was supplied with the 3054DL system to do software compensation on thermocouple temperature measurements. The subprogram inputs are the thermocouple type and its channel connection. The thermocouple voltage is read using the 3497A. The reference junction voltage on the card must also be read and added to the thermocouple voltype.

Examples of Control/Data Acquisition Programming with the HP85F/3054DL

The HP85 and the 3054DL are linked via the HP-IB interface. The 3054DL has an address of 709 on the interface as both a data source and a destination. All instructions sent from the computer go through the 709 address, for example to set the real time clock on the data logger the program would look as follows: (These segments are intended to be examples, consult the HP manuals for complete instructions.)

```
10 OUTPUT 709; "TDMMDDHHmmss"
```

where:
- MM = month
- DD = day
- HH = hour
- mm = minute
- ss = second

To read the clock for data output

```
10 OUTPUT 709; "TD"
20 ENTER 709; A$
30 PRINT A$
```

The program segment reads the clock and prints the output on the line printer.

To use the data logger as a DVM, assume the unit is connected to a circuit via the external input jack and it is desired to read a voltage

```
10  OUTPUT 709; "VR5VTIVD5"
20  ENTER 709; X
30  DISP X
WHERE:

VR5 = auto range
VT1 = internal trigger
VD5 = specifies number of digits
DISP x; displays x on the CRT.
```

Each of the 5 slots in the data logger mainframe is allocated 20 channels for option card use. For example, slot 0 is accessed on channels 0 to 19, slot 1 is accessed through channels 20 to 39 and so on. The option cards can be accessed through the HP-IB interface from the HP85 controller or manually from the front panel of the 3054DL. In Remote mode only instructions from the controller will be accepted, however with the 3054DL in local mode, inputs from both the controller and front panel will be accepted.

After reviewing several statements we can begin to program the HP85 to operate the 3054DL and all the option cards for some simple operations. The statements and a brief description of each will be given below.

Multiplexer

To use the multiplexer located in slot 2 and to read a device connected to its 20th terminal, channel 59 must be closed. Use the statements:

```
10  OUTPUT 709; "AC59"

20  ENTER 709; A3
```

where "AC" means analog close. This command closes a relay connecting the input to the 20th channel of the multiplexer to the common bus. The value is stored in a location called A3.

Temperature Measurement

The temperature measurement described is software compensated. Since thermocouples are non-linear a best fit curve is used for software compensation. The HP software available with the 3054DL breaks the curve for each thermocouple type into 8 segments. An array of constants for their equation are provided. The steps for software compensation are:

1. Measure the temperature transducer voltage from the twentieth channel of the thermocouple card and compute the terminal junction's temperature in °C.

2. Convert the terminal junction temperature to a voltage for the type of thermocouple being measured.

3. Add this reference voltage to the voltage of the thermocouple.

4. Convert the total voltage to a temperature using the conversion coefficients.

The 20th channel of the thermocouple card is equipped with circuitry that provides a 100 mV/°C reference signal.

To read teamperatures from channel 10 of the thermocouple card which is in slot 3, we must access channel 69.

```
10  P1 = 3497
20  Go SUB 1000!  INIT
30  P1 = 69
40  P$ = "T"
50  GOSUB 2540 ! CALL SC_DEG
60  PRINT P
```

This program segment tells the subprogram SC DEG that we have a type T thermocouple in the variable P$. INIT pre-initializes the HP-IB interface so the proper data communication can take place in the system. P1=3497 tells INIT that a model 3497 DVM is used by the system.

SC_DEG is a driving routine that uses three other subprograms (DCV, SCTEMP, and TCOEF) to perform a software compensated temperature measurement. These programs are all available in the HP reference manual.

Counter

The counter card is located in slot 1. It is connected to the RPM pickup through the multiplexer card which uses channels 40-59. Therefore, to take an RPM reading using a magnetic pickup connected to channel 59 would require the following:

```
10  OUTPUT 709; "AC59"
20  OUTPUT 709; "CS1,0"
30  OUTPUT 709' "CF1,1"
40  OUTPUT 709; CR1,3"
50  WAIT 500
60  OUTPUT 709; "CR1,2"
70  ENTER 709; S
80  R = 5*6
```

Statement 10 closes a contact on channel 59 connecting the RPM pickup to the counter. Statement 20 initializes the counter located in slot 1 to a value of 0. Statement 30 instructs the counter to count up with overflow going past 999,999. Statement 40 is a counter read which sets the internal trigger to detect the pulse. Then statement 50 causes a wait period for 500 ms while counting is progressing. Statement 60 instructs the counter to read the instantaneous count. Statement 70 puts the count into the computer in a variable called S. The computer then converts counts per 500 ms to RPM.

Conclusions

The long term test facility has now been completed. The program "ENTEST" is operating, and calibration tests have been performed. Since no complete 200 hour test cycles have been completed, the long term use of the computer control/data acquisition system cannot yet be evaluated. Starting up the system was not difficult. Within a few hours of receipt of the equipment it was being used to measure and record temperatures from thermocouples. It became easier to use as the operators became more familiar with the commands and the software. The versatility of the equipment with the addition of the easily accessed terminal board, makes it easily moved from one location or project to another in a few minutes. The long term reliability of the equipment will be the ultimate measure of its suitability for this project.

LITERATURE CITED

Installation, Verification, Operation, and Programming 3054DL (85A) System Manual, Volume IA, Hewlett-Packard Company, 815 S.W. 14th Street, Loveland, Colorado 80537

APPENDIX A

AGRICULTURAL ENERGY CENTER
UNITED STATES DEPARTMENT OF AGRICULTURE
EXTENSION SERVICE

ENERGY NOTES

Northern Agricultural Energy Center
1815 N. University Street
Peoria, IL 61604

Telephone: 309-685-4011

Date: September 1, 1982

200-HOUR SCREENING TEST for ALTERNATE FUELS

Research on/or testing of renewable fuels (i.e. vegetable oils—neat, blended or modified) for diesel engines is in progress or being planned at many locations. Previous studies have limited value because conditions and procedures were unique to each test.

An advisory committee with representation from USDA, agricultural experiment stations, engine (tractor) manufacturers and fuel additive suppliers to advise on procedures for engine tests of renewable fuels has been organized and is coordinated from NAEC, Peoria.

The Engine Manufacturer's Association (EMA), a trade association of 21 international engine manufacturers, has proposed at the request of the United States Department of Agriculture, a 200-hour preliminary durability screening test to assess the potential impact of alternate fuels on diesel engine durability.

The test is intended for research and development purposes and is designed to try to initiate durability problems in a reasonable amount of test time. Successful completion of the test is no assurance that the fuel will be acceptable. However, the test will eliminate some candidate fuels, and patterns of performance and engine durability will be uniformly evaluated for all test fuels.

The advisory committee has adopted the EMA 200-hour screening test for farm tractor engine studies. Anyone contemplating engine testing of renewable fuels, or in an advisory or consultative role to such a project, is encouraged to follow this test procedure:

1. FUEL TEST SERIES:

A fuel test series shall include a 200-hr. baseline test of the engine, followed by one or more 200-hr. tests of alternate fuels for comparison under similar conditions.

2. FUELS TO BE TESTED:

a) Baseline test fuel: Phillips 2D Reference Fuel (P2D).

b) Vegetable oil/P2D blends and modified or hybridized fuels should be specified and tested, starting with the experimental fuel least likely to cause engine damage followed by tests with fuels in order of increasing likelihood of engine damage.

(NOTE: Commercial grade diesel fuels are not advised by the committee for the official 200-hr. screening test because of their variable properties. If commercial grade fuel must be used, its properties should be extensively tested and reported with the engine test results.)

c) Fuel additives: to be determined and specified.

3. FUEL CHARACTERIZATION AND DESCRIPTION TO INCLUDE:

a) Generic name, degree of refinement, source, percent of total mix for each energy component.

b) Gross caloric value; net caloric value. (May be specified as Btu/lb or Btu/gal.)

c) Viscosity at 100C and 40C.

d) Cetane number; Iodine Value; Wax Content; Phosphatide Content; Fatty acid profile by gas chromatography.

4. ENGINE WEAR OBSERVATIONS AND MEASUREMENTS:

a) Each 200-hr. fuel test to commence with new liners, rings, pistons, injector tips, valves, valve seat inserts and guides. (Other parts to be in good condition.)

b) Dimensions of liners and rings, and weight* of rings (and other parts as experience may indicate) to be measured before and after each 200-HOUR TEST.
*Weight to be determined after removal of any deposits.

c) All components of the engine that are likely to be affected by use of the fuel are to be observed, checked, and measured for proper function and for specification tolerances. Included are upper cylinder, cylinder head, induction and exhaust systems, turbo-charger, fuel injection system, and the entire lubrication system.

d) Components such as cylinder heads, injector bodies, valve lifters, cam shaft and bearings, and turbo charger can be cleaned and reused if within manufacturer's specifications.

e) Injectors (tips) will be inspected and performance checked after each test.

f) Parts that fail due to non-fuel related causes are to be replaced and the test continued.

g) There are to be no engine or parts modifications during a fuel test series.

5. CRITERIA FOR FUEL/ENGINE FAILURE:

a) Performance: A drop in power of 5% or more that cannot be corrected with minor adjustments (normal field adjustments) during the 200-hr. test. (Injector nozzles may be replaced to complete a test but this would constitute a failure.)

b) Durability:

1. Failure to complete 200 hours of EMA TEST CYCLE for any reason related to the test fuel.

*2. Measurement of blowby during testing is a convenient way of monitoring gross changes in engine performance which may be due to events such as ring sticking. Blowby measurement is optional and, if desired, need only be performed periodically (every 50 hours).

*c) Lubricating Oil (checked daily after warm-up):

1. Viscosity: A change of 50% from new oil value.

2. Dispersancy: Any indication of failure of dispersion. (Blotter spot test acceptable.)

**d) Engine Life (post inspection): Excessive wear that would extrapolate to a 50% or greater reduction in engine life based on the manufacturer's guidelines and experiences. Wear inspection should include, but is not limited to:

1. Piston, ring and liner wear or scuffing
2. Bearing wear
3. Cam and follower wear
4. Valve guttering.

*Category (b) 2 and (c) will allow termination of the test just prior to a total engine disaster.

**Category (d) will require knowledge of normal engine wear in that area of the world where the alternate fuel is being considered, recognizing geographic variability of diesel fuel quality and the kinds and amounts of impurities.

6. LUBRICATING OIL:

a) High detergent type CD to be used.

b) One lot of lube oil sufficient for the test series should be procured.

c) Physical properties and engine wear contaminants (by chemical analysis) to be recorded at 0, 50, 100, 200 hours.

d) Crankcase level to be checked before each cold start. If oil is low oil should be added. Records of oil consumption should be kept.

e) Oil and oil filter change interval to be as recommended by the engine manufacturer, but not less than 100 hours.

7. EMA BREAK-IN SCHEDULE (90 minutes). A new or re-built engine is to be broken in with P2D fuel before each test as follows:

STEP	SPEED	POWER	MINUTES
1	Low Idle	Idle	10
2	1/2 Rated	Idle	10
3	3/4 Rated	1/2 Rated	15
4	Rated	Rated	55
			90

8. POWER AND FUEL CONSUMPTION TESTS:

To be in accord with SAE test procedures.

9. EXHAUST EMISSIONS:

a) Emission measurements for HC, CO, NO_X, and Smoke are optional. If undertaken, measurements should be made before and after each 200-hour test.

b) The following engine operation modes should be used.

(1) low idle speed, zero load
(2) peak torque speed (*) at zero load
(3) peak torque speed (*) at 50% load
(4) peak torque speed (*) at 100% load
(5) rated speed at zero load
(6) rated speed at 50% load
(7) rated speed at 100% load

*Advertised peak torque speed or 60% of rated speed; whichever is higher.

10. FUEL PRESSURE:

To be monitored continuously and filters replaced as needed.

11. EMA TEST CYCLE (3-hours):

STEP	SPEED	TORQUE	POWER	DURATION-MIN
1	Rated	—	Rated*	60
2	85%	Max	~95%	60
3	90%	28%	25%	30
4	Low Idle	0	0	30
				180

Weighted averaged power = 69%

*Turbocharged engines should be tested at their highest power rating (use of derated engines is not advised).

12. PRELIMINARY DURABILITY SCREENING TEST (200 hours):

Five consecutive test cycles are to be run without stopping the engine, followed by a nine hour (or longer) cold shut down (normal interior ambient temperature). Test duration is 200 hours of EMA cycle operation.

NOTE: Engine Manufacturers Association (EMA) and its members disclaim liability from any cause whatsoever related to the use of this test procedure.

(The EMA 200-hour fuel screening test would be only preliminary to many more specific tests were an engine manufacturer to consider commercial applications of its equipment on non-specification fuels.)

Specific further information is available from Northern Agricultural Energy Center, 1815 N. University Street, Peoria, IL 61604.

APPENDIX B

APPENDIX B

Subprogram RCHECK

```
1050 ! SUBPROGRAM RCHECK
1055 ON ERROR GOTO 5830
1060 FOR J=1 TO 15
1070 FOR J1=1 TO 3
1080 B1=40+(J1-1)*3
1090 OUTPUT 709;"AC",B1
1100 OUTPUT 709;"CS1,0"
1110 OUTPUT 709;"CF1,1"
1120 OUTPUT 709;"CR1,3"
1130 WAIT 500
1140 OUTPUT 709;"CR1,2"
1150 ENTER 709; R7
1160 N1=R7*5.05
1170 IF N1>R8(I)+20 THEN 1200
1180 IF N1<R8(I)-20 THEN 1230
1190 GOTO 1490
1200 IF J1=1 THEN 1260
1210 IF J1=2 THEN 1340
1220 GOTO 1420
1230 IF J1=1 THEN 1300
1240 IF J1=2 THEN 1380
1250 GOTO 1460
1260 OUTPUT 709;"DC4,0"
1270 WAIT 300
1280 OUTPUT 709;"DO4,0"
1290 GOTO 1490
1300 OUTPUT 709;"DC4,1"
1310 WAIT 300
1320 OUTPUT 709;"DO4,1"
1330 GOTO 1490
1340 OUTPUT 709;"DC4,5"
1350 WAIT 300
1360 OUTPUT 709;"DO4,5"
1370 GOTO 1490
1380 OUTPUT 709;"DC4,6"
1390 WAIT 300
1400 OUTPUT 709;"DO4,6"
1410 GOTO 1490
1420 OUTPUT 709;"DC4,10"
1430 WAIT 300
1440 OUTPUT 709;"DO4,10"
1450 GOTO 1490
1460 OUTPUT 709;"DC4,11"
1470 WAIT 300
1480 OUTPUT 709;"DO4,11"
1490 NEXT J1
1500 B1=0
1510 NEXT J
1520 RETURN
1530 !SUBEND
```

Subprogram RCHECK
(continued)

Where:
J1 and J are program loop counters
B1 is the channel number
R7 is the RPM value from counter(pulses/.5sec)
N1 is the corrected RPM value
R8 is the desired RPM value

Subprogram LOTEMP

```
5110 ! SUBPROGRAM LOTEMP
5115 ON ERROR GOTO 5830
5120 FOR Z2=60 TO 66 STEP 3
5140 P1=Z2 @ P$="T"
5150 GOSUB 2540 ! CALL Sc_deg
5160 IF P>60 THEN 5250
5165 IF P>80 THEN 5325
5170 IF Z2=60 THEN 5210
5180 IF Z2=63 THEN 5230
5190 OUTPUT 709;"DO4,14"
5200 GOTO 5320
5210 OUTPUT 709;"DO4,4"
5220 GOTO 5320
5230 OUTPUT 709;"DO4,9"
5240 GOTO 5320
5250 IF Z2=60 THEN 5290
5260 IF Z2=63 THEN 5310
5270 OUTPUT 709;"DC4,14"
5280 GOTO 5320
5290 OUTPUT 709;"DC4,4"
5300 GOTO 5320
5310 OUTPUT 709;"DC4,9"
5320 NEXT Z2
5321 GOTO 5330
5325 PRINT "OVERHEAT LOAD UNIT CHANNEL";Z2
5326 GOTO 5830
5330 RETURN
5340 !SUBEND
```

Where:
Z2 is the thermocouple channel from the load units
P1,P$,and P are varibles for subprogram Sc_deg

Subprogram FUMEAS

```
1540 ! SUBPROGRAM FUMEAS
1545 ON ERROR GOTO 5830
1550 I1=1
1560 FOR U=1 TO 8
1570 IF U=3 THEN 1690
1580 IF U=6 THEN 1690
1590 U1=40+U
1600 OUTPUT 709;"AC",U1
1610 OUTPUT 709;"CS1,0"
1620 OUTPUT 709;"CF1,1"
1630 OUTPUT 709;"CR1,3"
1640 WAIT 500
1650 OUTPUT 709;"CR1,2"
1660 ENTER 709; F1
1670 F(I1)=F1*720/X(I1)
1680 I1=I1+1
1690 NEXT U
1700 C1=C1+1
1710 RETURN
1720 !SUBEND
```

Where:

I1 and C1 are counters
F1 is the flow meter pulses per .5 sec.
X(I1) is the flow meter calibration const.
F(I1) is the fuel flow in gal/hr

Subprogram CCTEMP

```
5710 ! SUBPROGRAM CCTEMP
5715 ON ERROR GOTO 5830
5716 Z6=1
5720 FOR Z5=61 TO 67 STEP 3
5740 P1=Z5 @ P$="T"
5750 GOSUB 2540 ! CALL Sc_deg
5760 IF P>110 THEN 5780
5770 GOTO 5810
5780 OUTPUT 709;"TD"
5781 ENTER 709; D$
5785 PRINT "ENGINE",Z6,"OVERHEAT AT",D$
5786 PRINT "OVERHEAT TEMP IS";P;" C"
5805 Z6=Z6+1
5810 NEXT Z5
5820 RETURN
5825 ! SUBEND
```

Where:
Z5 is the thermocouple channels.
Z6 is the engine number counter.
D$ is the varible that is assigned the time.
P1,P$, and P are varibles used in the Sc_deg subprogram.

Subprogram SHUTDN

```
5830 ! SUBPROGRAM SHUTDN
5840 CLEAR 709
5850 OUTPUT 709;"DO4,0,5,10"
5880 PRINT "ENGINE SHUTDOWN EXECUTED"
5890 OUTPUT 709;"TD"
5900 ENTER 709; D$
5910 PRINT "AT TIME",D$
5920 PAUSE
5930 RETURN
5940 ! SUBEND
```

Where:
D$ is the varible assigned the time value