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Charles D. Bonham
Sverdrup Technology, Inc.
NASA Lewis Research Center Group
Cleveland, Ohio

and

Christopher DellaCorte
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

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THE APPLICATION OF A COMPUTER DATA ACQUISITION SYSTEM FOR A NEW HIGH TEMPERATURE TRIBOMETER

Charles D. Bonham
Sverdrup Technology, Inc.
NASA Lewis Research Center Group
Cleveland, Ohio 44135

and

Christopher DellaCorte
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

Abstract

This report describes two data acquisition computer programs which were developed for a high temperature tribometer, a friction and wear test apparatus. The raw data produced by the tribometer and the methods used to sample that data are explained. In addition, the instrumentation and computer hardware and software are presented. This report also shows how computer data acquisition was applied to increase convenience and productivity on a high temperature tribometer.

INTRODUCTION

Ceramics and composites are increasingly being applied in the industrial and research communities. There is a great need to determine the properties of these materials such as strength and thermal stability. The tribological characteristics of these materials are also important. Friction and wear data are critically important for material selection in rubbing or sliding applications. Since new composites and ceramics are typically applied under extreme conditions, such as high temperatures and loads, tribological evaluation must be done under similar use conditions. Therefore, specialized friction and wear test machines (tribometers) have been developed to acquire this data.

Extreme testing conditions, however, present a number of problems which must be overcome in order to evaluate a proposed material. The tribometer design must allow for various configurations of sliding contact in temperatures up to 1200 °C. In addition to the obvious mechanical difficulties associated with testing materials under extreme conditions, instrumentation and control concerns are also present. Reference 1 describes a tribometer at NASA Lewis Research Center designed to test metals and ceramic materials up to 1200 °C.

Computer data acquisition is well suited to acquire and store data from tribological tests, but has its own disadvantages. Although computer data acquisition allows the reduction of data prior to its being stored and enables the data to be plotted or examined directly from the test apparatus, software is not generally available for specific applications and must be developed along with the application instrumentation and hardware. In addition to the software problems, computer data acquisition is not a substitute for analog instrumentation. Since digital computers sample signals discretely rather than continuously, they are best used to acquire data averages. In this application, the computer is used to obtain the average values and scatter that is normally read manually from analog devices such as strip chart recorders and oscilloscopes. Analog devices are used in conjunction with the computer to corroborate the accuracy of the computer acquired data.

Tribometer tests are generally one of two types: unidirectional sliding, where the outputs are fairly constant with time, or oscillating (reciprocating) sliding, where direction is periodically reversed. Examples of the output signals may be seen in Fig. 1. The two testing types, due to the differences in the form the data takes, require different acquisition methods, although the data of interest is the same. Unidirectional sliding is relatively easy to sample because the signals have constant polarity. Oscillating sliding tests must consider specimen rotation direction as well as signal magnitude.

Typical values which are monitored and stored are: friction coefficient, friction force, load force, specimen speed, specimen temperature, and time. Relevant parameters also frequently monitored, but not stored, are spindle support bearing oil flow and temperature and furnace temperatures. This paper describes the development and implementation of two computer data acquisition programs which read, manipulate, and present data from a high temperature tribometer.

PROCEDURE: TYPICAL TEST CONDITIONS AND PARAMETERS

The friction and wear properties of materials are determined using a pin-on-disk tribometer. With this apparatus, a disk is rotated unidirectionally or oscillated and a hemispherically tipped pin is loaded against it. The pin wears a track in the disk which has a radius of 25.4 mm. Friction and load forces are measured electronically, using load cells, during the test runs. The specimens are removed periodically to make wear measurements. The tribometer is illustrated in Fig. 2.

For a unidirectional test, the sliding velocity ranges from 0.2 to 22 m/sec. For oscillating tests, the specimen frequency is between 0.1 and 5 Hz at amplitudes of near 0 to ±60°. Because of the crank and rocker drive system used for oscillating tests, the specimen speed is sinusoidal. In both cases, the load can vary from 0.1 to 100 kg. The temperature can be controlled from 25 to 1200 °C. A typical test may last for 1 hr, but test durations up to many hours can be obtained in a variety of purge atmospheres.

Because the tribometer instrumented here is capable of such a wide range of testing conditions, the data acquisition system must, in this case, be flexible enough to handle a wide range of inputs and test parameters.

HARDWARE: INSTRUMENTATION AND COMPUTER

Instrumentation for the tribometer is conventional. The data of interest consists of: friction force, load force, specimen speed, temperature and time.

The friction coefficient which is calculated by dividing friction force by load force is also stored. Figure 3 shows, schematically, the instrumentation layout for the tribometer.

Friction force and load force are measured by using calibrated strain gauge load cells. In compression, the load cells produce a negative output voltage and when in tension the output is positive. Signal conditioners and amplifiers are used to modify the load cell outputs and produce a calibrated output of 1 V/kg to the analog input board of a data interface and to the analog instrumentation.

Analog meters are used to monitor the polarities of the friction force and load force signals. The polarity of the friction force signal is used to determine the direction of disk rotation. Although the polarity of both signals is useful for tribometer operation, it is not retained on acquired data. The analog signals are also monitored by an oscilloscope and chart recorder in order to double check the accuracy of the computer acquired data and establish the data scatter band.

The oscilloscope is used to verify that disk run-out (TIR) is minimal. Although during assembly, disk run-out is measured to ensure that it is within tolerances (<0.025 mm), run-out as small as 0.006 mm can be detected electronically. Disk run-out causes both the friction force and load force signals to become sinusoidal. Figure 4 shows examples of the oscilloscope traces of the load and friction force signals with a run-out condition. As shown, both signals become sinusoidal and remain in phase, indicating that the increase in load corresponds to the increase in friction force.

If run-out is suspected as the cause of data fluctuations, then the amplitude of the friction force scatter will be approximately equal to the average friction coefficient multiplied by amplitude of the load force scatter. If a periodic data scatter in the friction force is detected without a corresponding scatter in the loading force, then it can be inferred that the variation friction coefficient is a function of disk track location. Thus, in this case, it is a material characteristic rather than a testing artifact. Since the friction coefficient is a ratio of friction force to load force the computer automatically calculates the value and compensates for run-out induced fluctuations.

Specimen speed is measured by using a proximity probe and a toothed wheel pickup. The probe, stimulated by the pickup wheel on the rig drive, produces a sine wave with a frequency directly related to the motor speed. This frequency is converted to a dc voltage and calibrated to 1 V/1000 rpm.

Specimen temperature is measured using four platinum-rhodium proximity thermocouples. In order to compensate for any thermal gradients within the furnace the four temperature readings are averaged. The average, which has an estimated external error of ±5 percent, is stored as the specimen temperature.

Elapsed time is stored directly from within the acquisition programming. The elapsed time is calculated by using the number of the current data point and the time interval for sampling or by accessing the computer clock. The time is then stored as data.

Support bearing oil flow in and out are monitored using flow meters. The flow meters, having a dimensionless calibration, are used to verify oil flow only. The oil temperature is monitored using iron-constantan thermocouples. Room temperature and relative humidity are also monitored and documented on the screen display.

A personal computer is used for data acquisition. The computer has 1024 K of RAM and an expanded graphics adapter. A Keithley 570 data acquisition module and I-EEE computer interface are also used. The interface is equipped with a thermocouple board, capable of reading up to 16 inputs, an analog input module, which can monitor 32 single-ended or 16 differential inputs, and isolated digital input and output modules, both having 16 channels. Resolution of analog signals is to 1 mV with a -10 to 10 V range. The digital boards are configured for 5 V inputs. Data sampling or acquisition time varies from ~1 μsec for digital inputs up to 3 msec for temperature readings. The system multiplexer samples the interface module signals and a single analog to digital (A to D) converter with 12 bit resolution, communicates the multiplexed data to the computer.

For this application 11 data inputs are used. The inputs consist of five thermocouple, five analog and one digital input. The thermocouple inputs consist of four proximity furnace thermocouples and a thermocouple monitoring return oil temperature. The analog inputs are support bearing oil flow in and out, friction force, load force, and specimen speed. The digital input is used as the data sampling trigger for oscillating tests. The hardware configuration allows friction force and load force resolution to 1 g and temperature resolution to 6 °C.

SOFTWARE

The system software used for the data acquisition programs is specifically designed for data acquisition and control functions and allows two computer modes, foreground and background. These are controlled by a user selected interrupt rate which toggles the computer between the two modes. The foreground mode allows the user to examine and manipulate data on a real time basis, while sampling and storing the data in the background mode at essentially the same time. The software is also capable of configuring the input/output (I/O) ports of the data interface by using a configuration table. (See Appendix A, for an example of the table.) The configuration table, seen as a user file by the computer, allows inputs and outputs to be identified outside the actual acquisition program. This greatly increases the speed in which the program is able to run and allows more than one program to be used without renaming the I/O channels.

The programs, which are written in BASIC, are enhanced by the use of callable machine language library subroutines which are installed as part of the Keithley system software. These subroutines enable internal data arrays to be created and single line commands to be used instead of intensive program routines which would normally be too time consuming to be performed while the program is running. For example, the mean and standard deviation may be calculated for a group of values simply by using a software command and identifying the array name in which the data is stored. Use of this software has made it possible to conveniently acquire data from the tribometer. (See Ref. 2 for more information regarding the software.)

PROGRAMS: DEVELOPMENT AND USE

The programs for both the unidirectional and oscillating sliding use an introduction and information input section and similar real time displays and data summaries. (See Appendix B for examples of the data summaries and screen displays.) This allows the user to input test run identifiers, specimen materials, test conditions and the number of data points for the test. Input verification is required for all information entered. This permits correction of errors without restarting the program. In addition, both programs include a monitor mode which enables all test rig parameters to be verified prior to the test run and during preheating. The programs also use similar screen displays. The displays are used for test rig operation only and are not intended to render data to be examined. After the data input and monitor stage, the two programs are different.

Unidirectional Sliding Program

The program for unidirectional sliding functions as follows: every 30 sec, 10 friction force and load force pairs are sampled, typically at 1 sec intervals. These values are stored in a temporary data array. After the 10 sec acquisition period, the other test parameters such as speed and temperature are read and stored. The friction force and load force pairs are ratioed to calculate 10 local friction coefficients. The 10 local friction coefficients are averaged and this average friction coefficient, in addition to the load force and friction force are stored in the permanent data file. Because each local friction coefficient is a ratio of individual friction force and load force pairs, the overall friction coefficient calculation compensates for any run-out induced errors in the friction force and load force magnitudes.

When sampling data at preselected times, rather than randomly, it is conceivable that if the disk speed was exactly synchronized with the data acquisition rate then the 10 data points would consistently be taken at the same disk location and perhaps not be representative of a true average. However, due to small fluctuations in motor speed (~1 percent) and, to a lesser extent, computer speed fluctuations, undesired synchronized data acquisition has not occurred. Appendix C describes other timing considerations concerning data acquisition accuracy such as acquisition and settling times.

It is important to keep in mind that the purpose of the computer is not to replace analog devices such as chart recorders and oscilloscopes. The computer is used to acquire an average sampling of the data over a particular time interval. During the implementation of this program, it was found that sampling the data as just described yields an average and a standard deviation data which agree very well with averages and scatter bands measured with analog equipment. The advantage of using a computer is that the stored data is already entered into the computer memory and is already reduced to a form which can be easily manipulated and plotted.

The program also includes calculation lines to allow for different calibrations for the load cells in addition to other data and rig parameters.

This makes the program easily adapted to any changes in the instrumentation. (See Appendix D for a listing of the program.)

Oscillating Sliding Program

The oscillating sliding program uses a digital signal to trigger data sampling. It is necessary to use the trigger to prevent data acquisition at the reversal points of travel where the friction output may be irregular and not truly representative of average values. The triggering is accomplished by using a cam on the test rig drive which closes a microswitch at the midpoint of disk travel. The microswitch applies a 5 V signal to the computer data acquisition interface which triggers the computer to begin sampling for each cycle. At the sampling position, as seen in Fig. 1(b), the disk is near maximum velocity and the friction force is typically stable. When the trigger signal is received, the computer acquires 25 friction and load data points at 1 msec intervals and stores them in a temporary array. The data, after eliminating the polarities, are averaged and stored in a second temporary array. The trigger is reset and the first temporary array is cleared making the system ready for another trigger signal. The program will perform this procedure 14 more times on subsequent disk oscillations. After the second temporary array is filled with the 15 averaged data points, the values are again averaged and the friction coefficient and standard deviation are calculated. The final values are stored in the data file along with rotations per minute, specimen temperature and time. All arrays, except the permanent data file, are then erased and the program prepares for the acquisition cycle to repeat.

As with the unidirectional program, the oscillating program samples data points at prescribed intervals; however, due to the large number of points, the short period of time in which the points are acquired and the rapid interrupt rate, it was necessary to make modifications to the software and some changes in the program.

The software modification involved disabling the internal clock in the computer and using only software generated interrupts for program timing. Disabling the computer clock and software timer functions was necessary in order to prevent internal and software interrupts from occurring at the same time. Two interrupts received simultaneously causes the operating software to fail, data loss and possible hard drive corruption.

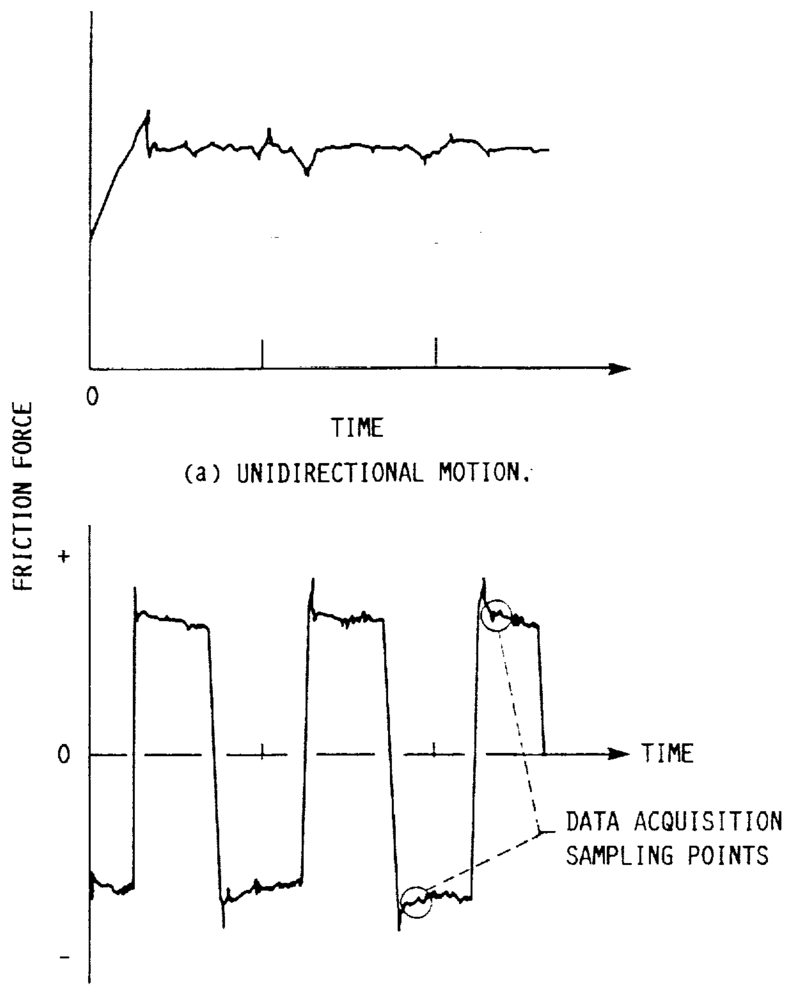
The program changes involved using a BASIC array to store the final data values. This allows the data to be stored in the foreground, as opposed to being stored in the background when using a software generated array. This was done to isolate the final data values from data processing commands in the program. Finally, a "stall" loop was used to replace the disabled timer function. The "stall" loop acts as timing delay which uses a counting function in order to adjust the period of time between acquisition cycles. (See Appendix E for a listing of the program.)

SUMMARY

Computerized data acquisition, for high temperature tribometer experiments, has been proven very effective. The computer acquired data agrees well when compared to analog recordings performed simultaneously. By using a computer, the acquired data is automatically compensated for run-out induced variations and is stored as averaged values which are ready to be plotted, further manipulated and presented. This increases convenience and productivity of the tribometer. It was found that a thorough understanding of the capabilities and limitations of the system software and the nature of the data signals from a test rig are essential to ensure successful data acquisition.

REFERENCES

1. Sliney, H.E. and DellaCorte, C., "A New Test Machine for Measuring Friction and Wear in Controlled Atmospheres to 1200 °C," NASA TM-102405 (1990).
2. "SOFT500 Software System Manual," Rev. F., Keithley Data Acquisition and Control, May 1988.



(b) OSCILLATING MOTION.

FIGURE 1. - TYPICAL FRICTION FORCE OUTPUTS FOR UNIDIRECTIONAL AND OSCILLATING TESTS.

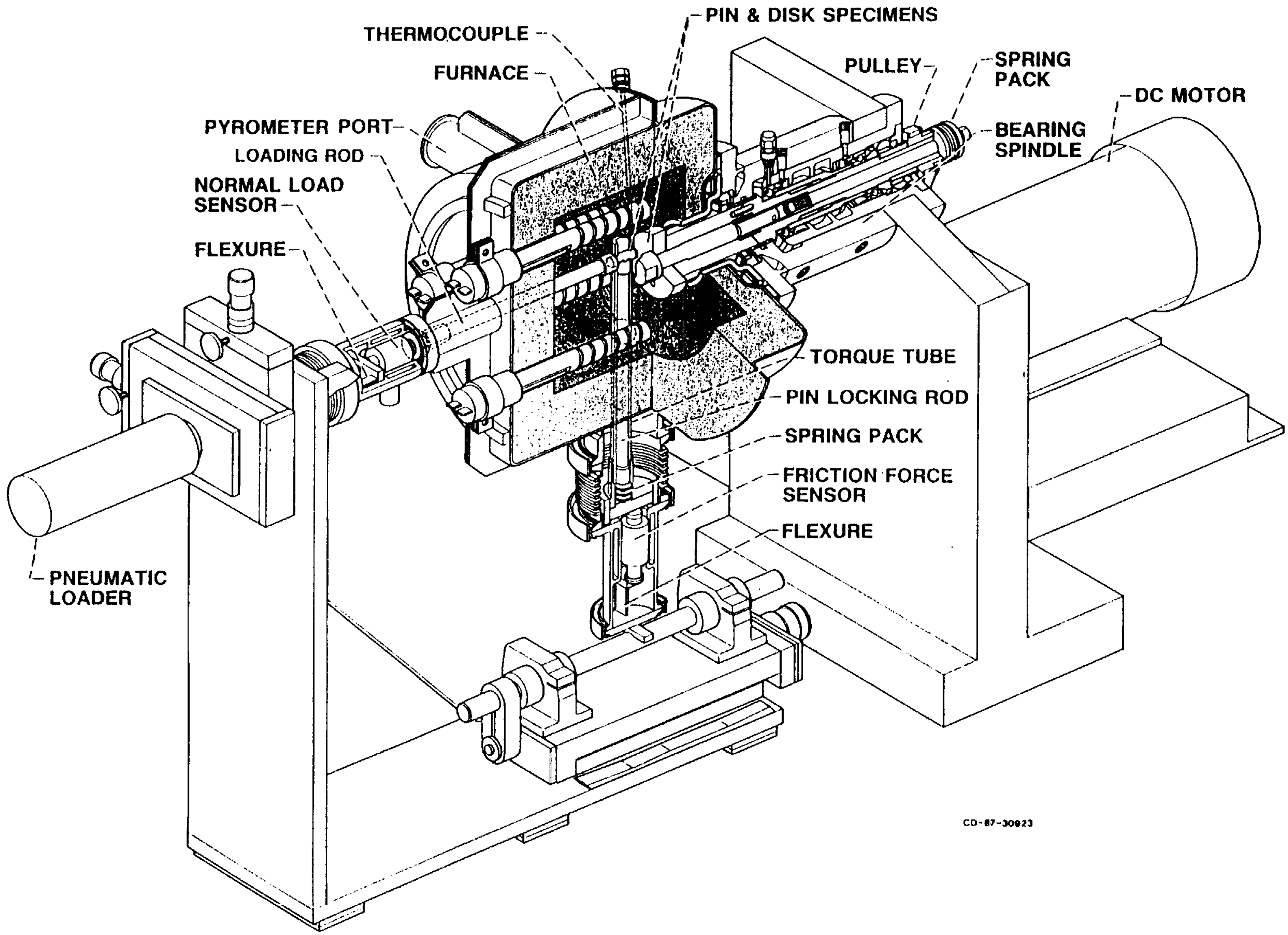


FIG. 2. - HIGH-TEMPERATURE PIN ON DISK TRIBOMETER.

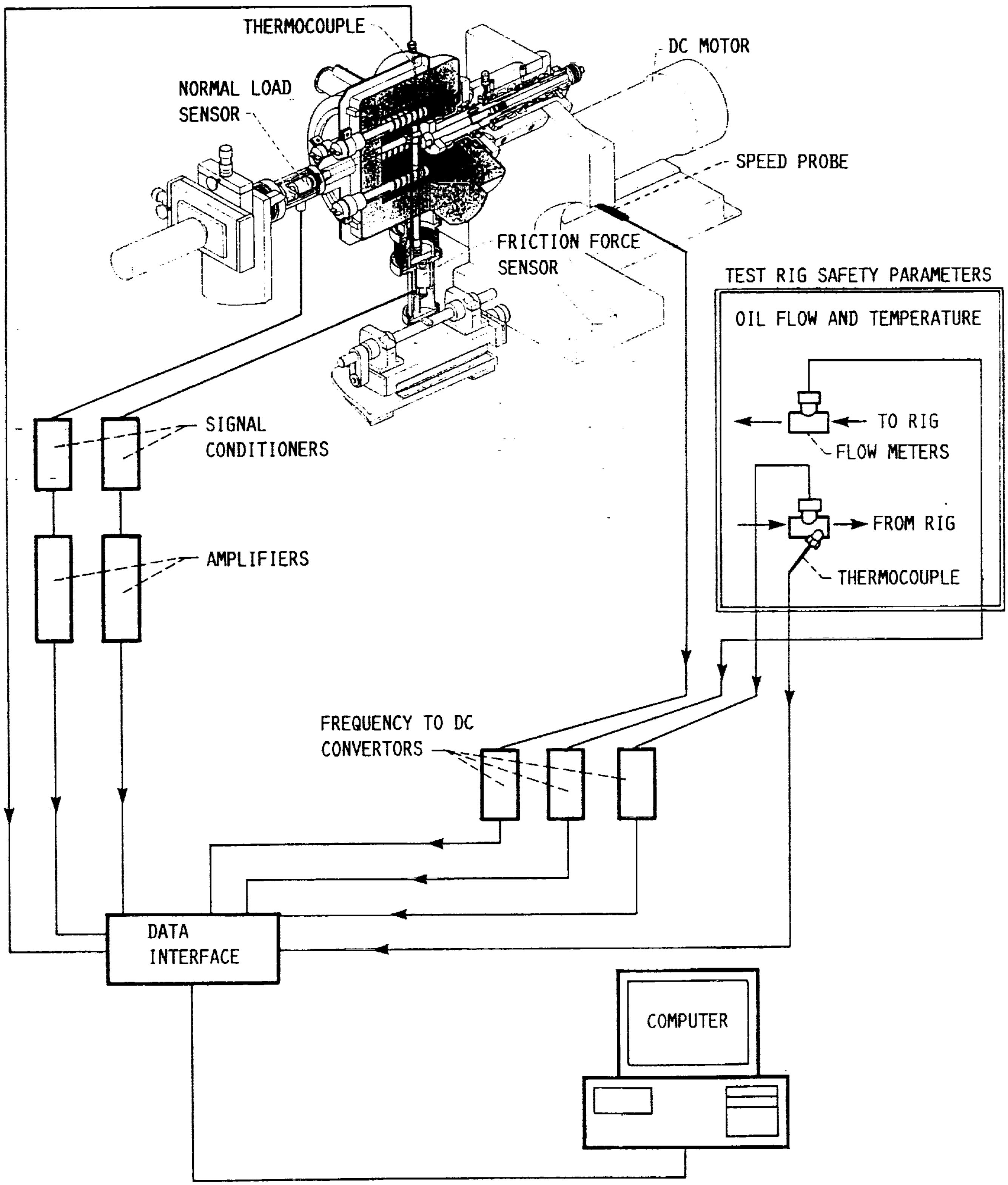


FIGURE 3. - INSTRUMENTATION SCHEMATIC BLOCK DIAGRAM INDICATES ALL MONITORED SIGNALS; TEST RIG PARAMETERS AND DATA INPUTS.

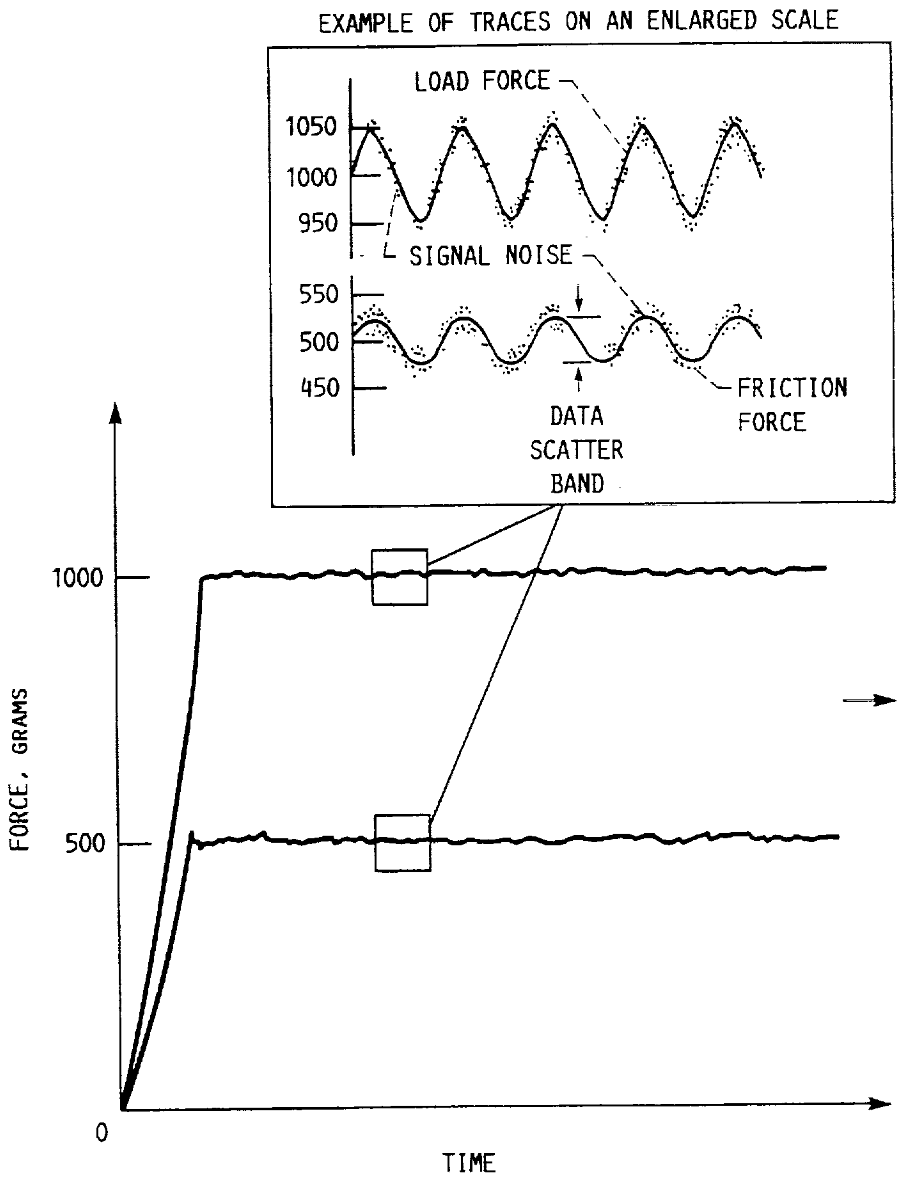


FIGURE 4. - EXAMPLE OF FRICTION FORCE AND LOAD FORCE SIGNALS IN A RUN-OUT CONDITION FOR A $\mu \cong .50$.

APPENDIX A

CONFIGURATION TABLE 1. - INPUT/OUTPUT CONFIGURATION

Denotes type, location and modes of input modules (ex: aim → analog input module).

```
CONFIGURATION TABLE

SLOT TABLE-
    SLOT 1: AIM1
    SLOT 2: ADM1, Range: -10. to 10.V
    SLOT 3: AOM1, Range:0)-10.B 1)10.B 2)10.B 3)10.B 4)10.B
    SLOT 4: DIM1
    SLOT 5: DOM1
    SLOT 6: AIM3, Gain: x1, SINGLE-ENDED
    SLOT 7: PCM2
    SLOT 8: AIM7
```

Denotes I/O name, channel number resolution and gain of module inputs.

```
CHANNEL NAMES-
    SLOT 6-
        FRCTNF   : AIM3, SL 6, CH 0, 12 BIT, LOCx1, GLOx1
                   , A FP 7.2
        LOAD     : AIM3, SL 6, CH 1, 12 BIT, LOCx1, GLOx1
                   , A FP 7.2
        MTRSPD   : AIM3, SL 6, CH 2, 12 BIT, LOCx1, GLOx1
                   , A FP 7.2
        FLOWIN   : AIM3, SL 6, CH 3, 12 BIT, LOCx1, GLOx1
                   , A FP 7.2
        FLOWOUT  : AIM3, SL 6, CH 4, 12 BIT, LOCx1, GLOx1
                   , A FP 7.2
        RMTMP    : AIM3, SL 6, CH 8, 12 BIT, LOCx1, GLOx1
                   , A FP 7.2
        RELH     : AIM3, SL 6, CH 9, 12 BIT, LOCx1, GLOx1
                   , A FP 7.2
    SLOT 8-
        TFURNAC3: AIM7, SL 8, CH 1, 12 BIT, LOCx100, GLOx1
                   , A FP 7.2
        TFURNAC1: AIM7, SL 8, CH 2, 12 BIT, LOCx100, GLOx1
                   , A FP 7.2
        TFURNAC2: AIM7, SL 8, CH 3, 12 BIT, LOCx100, GLOx1
                   , A FP 7.2
        OILTEMP : AIM7, SL 8, CH 5, 12 BIT, LOCx100, GLOx1
                   , A FP 7.2
        FCTRL1  : AIM7, SL 8, CH 6, 12 BIT, LOCx100, GLOx1
                   , A FP 7.2
        COLDJUNC: AIM7, SL 8, COLD JUNCTION REFERENCE
                   , A FP 7.2
```

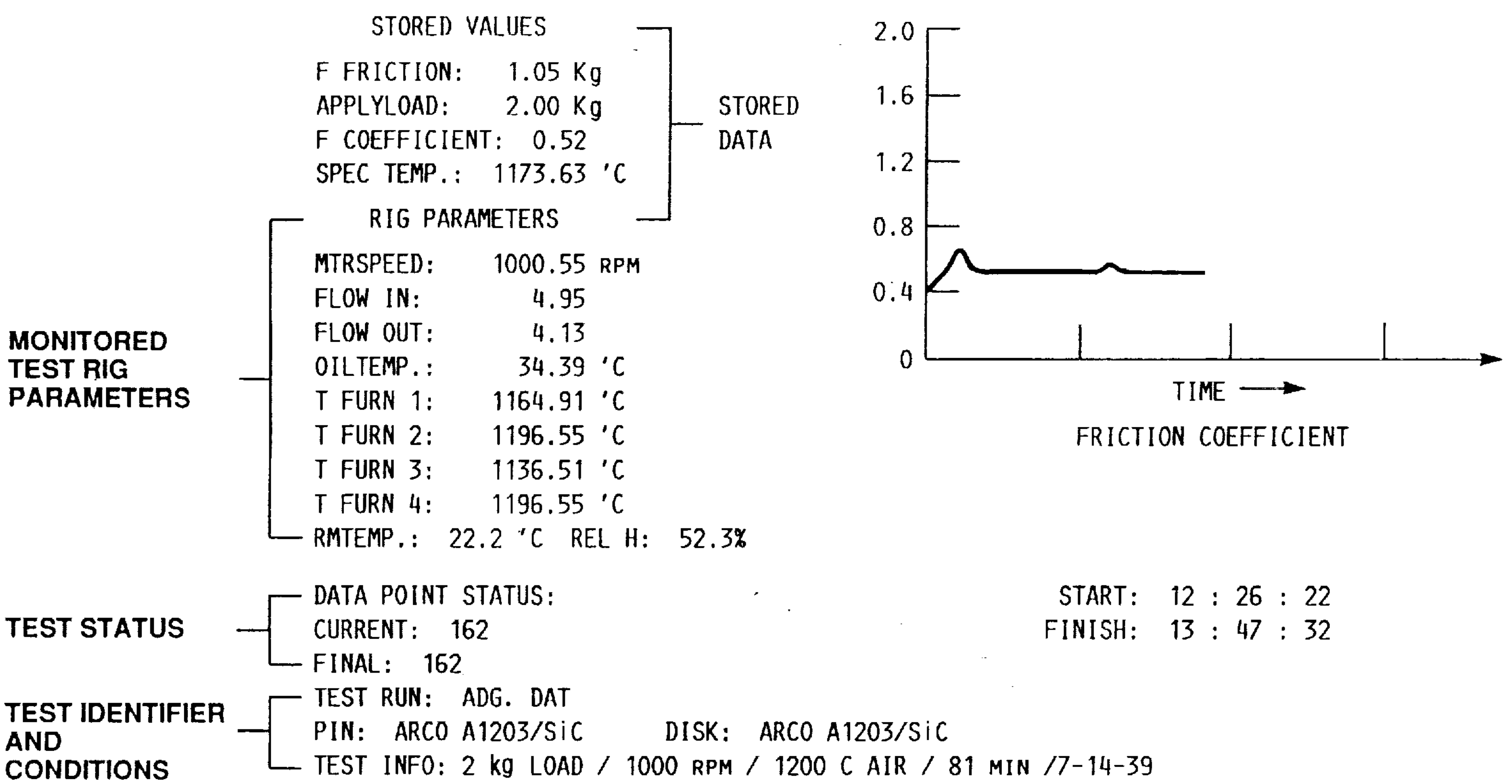


FIGURE A-1. - UNIDIRECTIONAL MODE: SCREEN DISPLAY.

APPENDIX B

SCREEN DISPLAYS AND DATA SUMMARIES

Unidirectional Summary

FFRCTN	LOAD	FCOEFF	SPEED	SPECTEMP	TIME	POINT
0.01	0.03	0.23	1003.66	1183.13	0.00	0.00
1.03	2.36	0.44	984.13	1181.43	0.50	1.00
1.06	2.30	0.46	1003.66	1176.07	1.00	2.00
1.17	2.06-	0.57	998.73	1176.14	1.50	3.00
1.15	2.12	0.54	1003.66	1173.41	2.00	4.00
1.09	2.21	0.49	989.01	1172.53	2.50	5.00
1.08	2.21	0.49	998.78	1175.26	3.00	6.00
1.12	2.09	0.53	1023.20	1172.53	3.50	7.00
1.20	2.01	0.60	998.78	1175.26	4.00	8.00
1.11	2.33	0.48	993.90	1173.43	4.50	9.00
0.99	2.23	0.44	1023.20	1171.69	5.00	10.00
1.32	1.96	0.67	979.24	1177.02	5.50	11.00
1.13	1.30	0.56	998.78	1172.60	6.00	12.00
1.21	2.06	0.59	993.90	1175.26	6.50	13.00
1.09	2.17	0.50	1008.55	1171.71	7.00	14.00
1.18	1.83	0.64	1008.55	1174.37	7.50	15.00
1.20	1.94	0.62	993.90	1176.15	8.00	16.00
1.32	1.73	0.76	1003.66	1172.60	8.50	17.00
1.13	2.36	0.43	979.24	1173.43	9.00	18.00
1.03	2.22	0.46	1003.66	1172.60	9.50	19.00
1.05	2.19	0.43	1008.55	1172.60	10.00	20.00
1.00	2.35	0.43	999.01	1176.15	10.50	21.00
1.24	1.75	0.71	1003.65	1173.49	11.00	22.00
1.03	2.24	0.46	998.73	1175.25	11.50	23.00
0.02	0.01	3.00	1042.74	1172.60	12.00	24.00
0.02	0.01	1.40	1003.66	1173.43	12.50	25.00
0.02	0.01	2.33	1003.66	1177.02	13.00	26.00
1.12	2.06	0.54	979.24	1172.60	13.50	27.00
1.08	2.04	0.53	1008.55	1175.24	14.00	28.00
1.13	2.03	0.58	979.24	1171.71	14.50	29.00
1.06	2.03	0.52	1003.66	1172.60	15.00	30.00
1.13	2.04	0.55	993.90	1175.25	15.50	31.00
1.00	2.06	0.49	1018.32	1172.60	16.00	32.00
1.03	2.05	0.50	998.78	1174.36	16.50	33.00
1.08	2.03	0.53	993.90	1170.82	17.00	34.00
1.05	2.06	0.51	1003.66	1172.60	17.50	35.00
1.02	2.07	0.49	1003.66	1175.26	18.00	36.00
1.07	1.99	0.54	1008.55	1172.60	18.50	37.00
1.10	2.00	0.55	989.01	1176.16	19.00	38.00
1.02	2.02	0.50	1018.32	1174.37	19.50	39.00
0.98	2.02	0.48	1008.55	1173.48	20.00	40.00
1.10	2.00	0.55	1003.66	1176.22	20.50	41.00
1.10	2.02	0.55	998.78	1173.49	21.00	42.00
1.00	2.01	0.50	993.90	1176.19	21.50	43.00
1.11	1.99	0.56	1018.32	1172.60	22.00	44.00
1.07	2.00	0.53	1008.55	1172.60	22.50	45.00
1.01	2.01	0.50	993.90	1173.55	23.00	46.00
1.04	2.02	0.51	998.78	1172.60	23.50	47.00
1.06	1.98	0.54	989.01	1174.44	24.00	48.00
1.02	2.00	0.51	993.90	1172.60	24.50	49.00
1.14	1.99	0.57	1023.20	1172.50	25.00	50.00
1.02	2.00	0.51	989.01	1176.21	25.50	51.00
1.00	1.99	0.50	998.79	1172.60	26.00	52.00
1.10	2.00	0.55	1003.66	1174.44	26.50	53.00
1.04	2.00	0.52	1003.66	1171.71	27.00	54.00
1.09	1.98	0.55	1003.66	1172.60	27.50	55.00
1.11	1.99	0.56	1003.66	1175.32	28.00	56.00
1.01	1.99	0.51	1037.85	1172.62	28.50	57.00
1.02	1.99	0.51	993.90	1175.32	29.00	58.00
1.11	1.99	0.56	979.24	1172.67	29.50	59.00

Unidirectional Mode: Data Summary

Print-out of stored data: friction force, load force, friction coefficient, specimen rotations per minute, specimen temperature elapsed time and data point number.

Oscillating Summary

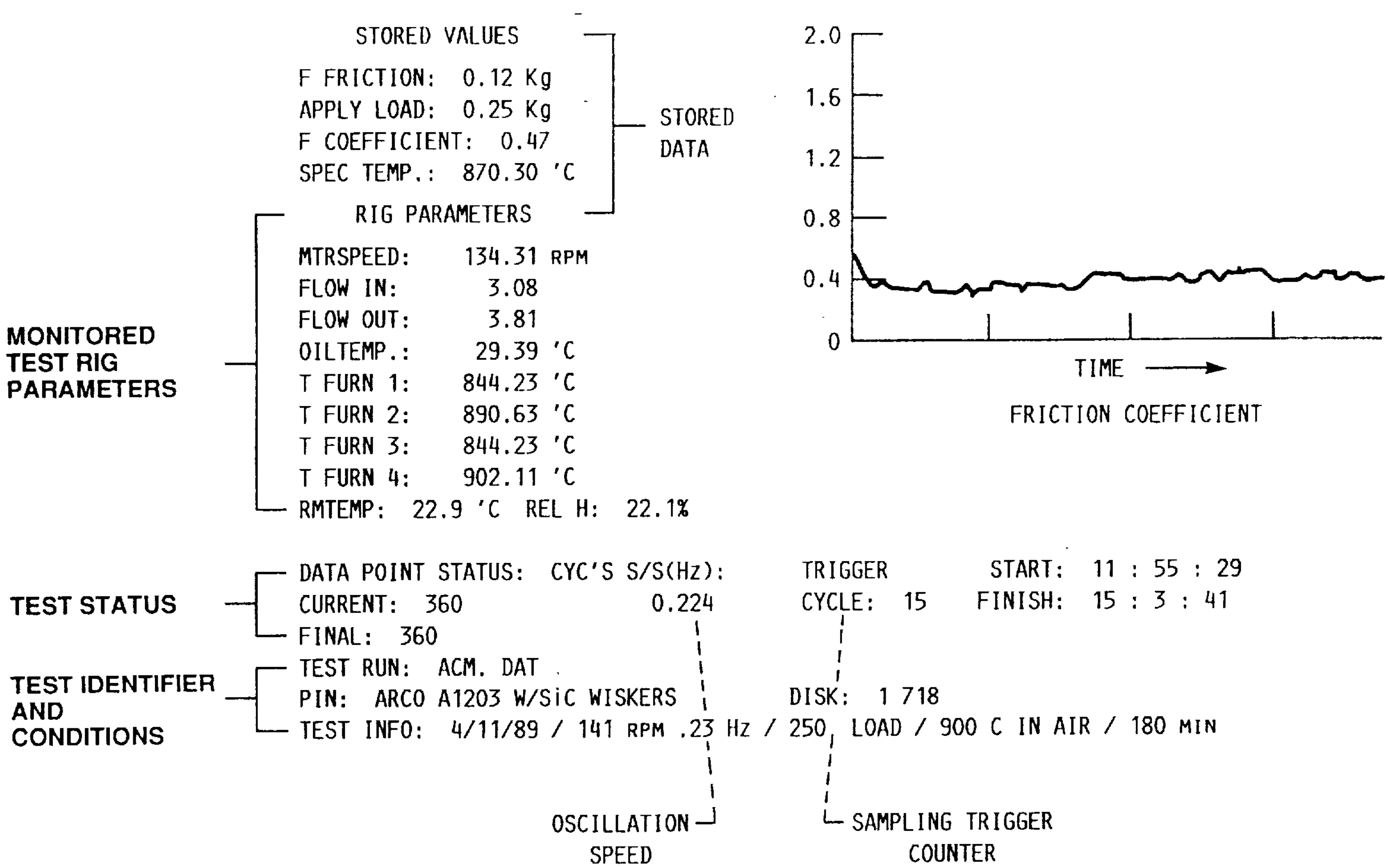


FIGURE B-1. - OSCILLATING MODE: SCREEN DISPLAY.

FFRCTN	LOAD	FCOEFF	SPEED	SPECTEMP	TIME	POINT
0.09	0.25	0.38	168.50	0.00	0.50	1.00
0.05	0.07	0.75	129.43	871.92	1.00	2.00
0.06	0.11	0.53	163.61	867.05	1.50	3.00
0.04	0.08	0.47	134.31	869.97	2.00	4.00
0.10	0.25	0.38	139.19	870.95	2.50	5.00
0.10	0.25	0.39	134.31	871.92	3.00	6.00
0.10	0.23	0.42	129.43	870.95	3.50	7.00
0.10	0.23	0.43	134.31	871.92	4.00	8.00
0.10	0.24	0.42	148.96	870.95	4.50	9.00
0.10	0.24	0.41	173.38	870.95	5.00	10.00
0.10	0.25	0.39	129.43	870.95	5.50	11.00
0.10	0.26	0.38	148.96	870.95	6.00	12.00
0.10	0.26	0.37	129.43	870.95	6.50	13.00
0.10	0.26	0.38	134.31	869.97	7.00	14.00
0.09	0.25	0.37	168.50	870.95	7.50	15.00
0.09	0.25	0.35	158.73	870.95	8.00	16.00
0.09	0.23	0.37	134.31	870.93	8.50	17.00
0.07	0.18	0.39	134.31	870.95	9.00	18.00
0.09	0.24	0.39	178.27	870.91	9.50	19.00
0.10	0.24	0.41	153.85	869.91	10.00	20.00
0.10	0.25	0.39	173.38	870.89	10.50	21.00
0.09	0.24	0.38	134.31	870.87	11.00	22.00
0.10	0.25	0.40	124.54	870.87	11.50	23.00
0.09	0.25	0.38	129.43	870.87	12.00	24.00
0.08	0.25	0.33	139.19	870.87	12.50	25.00
0.08	0.25	0.34	124.54	870.87	13.00	26.00
0.09	0.25	0.36	134.31	870.87	13.50	27.00
0.09	0.25	0.36	129.43	870.87	14.00	28.00
0.08	0.25	0.33	134.31	870.87	14.50	29.00
0.09	0.25	0.34	139.19	870.87	15.00	30.00
0.08	0.25	0.34	163.61	870.87	15.50	31.00
0.09	0.25	0.36	134.31	870.87	16.00	32.00
0.09	0.25	0.35	129.43	870.87	16.50	33.00
0.09	0.25	0.34	139.19	870.87	17.00	34.00
0.09	0.26	0.35	153.85	870.87	17.50	35.00
0.08	0.26	0.32	148.96	870.87	18.00	36.00
0.09	0.25	0.34	144.08	870.87	18.50	37.00
0.09	0.25	0.36	129.43	870.87	19.00	38.00
0.09	0.25	0.37	134.31	870.87	19.50	39.00
0.09	0.25	0.35	129.43	870.87	20.00	40.00
0.09	0.25	0.37	163.61	870.87	20.50	41.00
0.09	0.26	0.35	129.43	870.93	21.00	42.00
0.08	0.25	0.33	144.08	870.95	21.50	43.00
0.08	0.25	0.34	153.85	870.95	22.00	44.00
0.08	0.25	0.33	134.31	870.95	22.50	45.00
0.09	0.25	0.36	124.54	870.95	23.00	46.00
0.09	0.25	0.37	129.43	870.95	23.50	47.00
0.09	0.25	0.37	178.27	870.95	24.00	48.00
0.09	0.25	0.37	134.31	870.95	24.50	49.00
0.09	0.26	0.36	134.31	870.95	25.00	50.00
0.09	0.25	0.36	144.08	869.98	25.50	51.00
0.09	0.25	0.36	173.38	870.95	26.00	52.00
0.09	0.25	0.36	129.43	870.95	26.50	53.00
0.08	0.26	0.32	139.19	870.95	27.00	54.00
0.08	0.25	0.32	144.08	871.92	27.50	55.00
0.08	0.25	0.33	144.08	870.95	28.00	56.00
0.09	0.25	0.34	129.43	871.92	28.50	57.00
0.09	0.26	0.34	173.38	871.92	29.00	58.00
0.08	0.26	0.33	134.31	871.92	29.50	59.00

Oscillating Mode: Data Summary

Print-out of stored data: friction force, load force, friction coefficient, motor rotations per minute, specimen temperature elapsed time and data point number.

APPENDIX C

When employing any data acquisition system to dynamic signals, such as those produced by a tribometer, timing considerations can become very important. For example, consider the case of measuring the friction coefficient from a pin-on-disk apparatus. To do this, the acquisition system must measure both a friction force and load force, the ratio of the two being the desired result. Since computer data acquisition systems, such as the one referred to in this paper, sample data sequentially rather than simultaneously the friction coefficient calculated is an average value rather than the exact value. Timing calculations are needed to ascertain whether the measured value is meaningful and whether it is likely to be close to the value measured by an analog device such as an oscilloscope.

For our system, it takes ~28 μsec to sample an analog signal and an additional 10 μsec before the computer is ready to acquire the next signal. Therefore, the acquisition of the friction and load force signals, needed to calculate a friction coefficient, requires 66 μsec. Under typical test conditions of 1000 rpm disk speed, the disk will rotate less than 1° between sampling the friction force and sampling the load. Since a typical wear scar diameter on the pin is at least 1 mm, or 2.24° of the wear track, the load force is sampled at approximately the same wear area on the disk specimen as the friction force (see Fig. C-2 in this appendix). Therefore, the friction coefficient calculated from the measured forces yields a meaningful result and does in fact coincide with values measured by an oscilloscope.

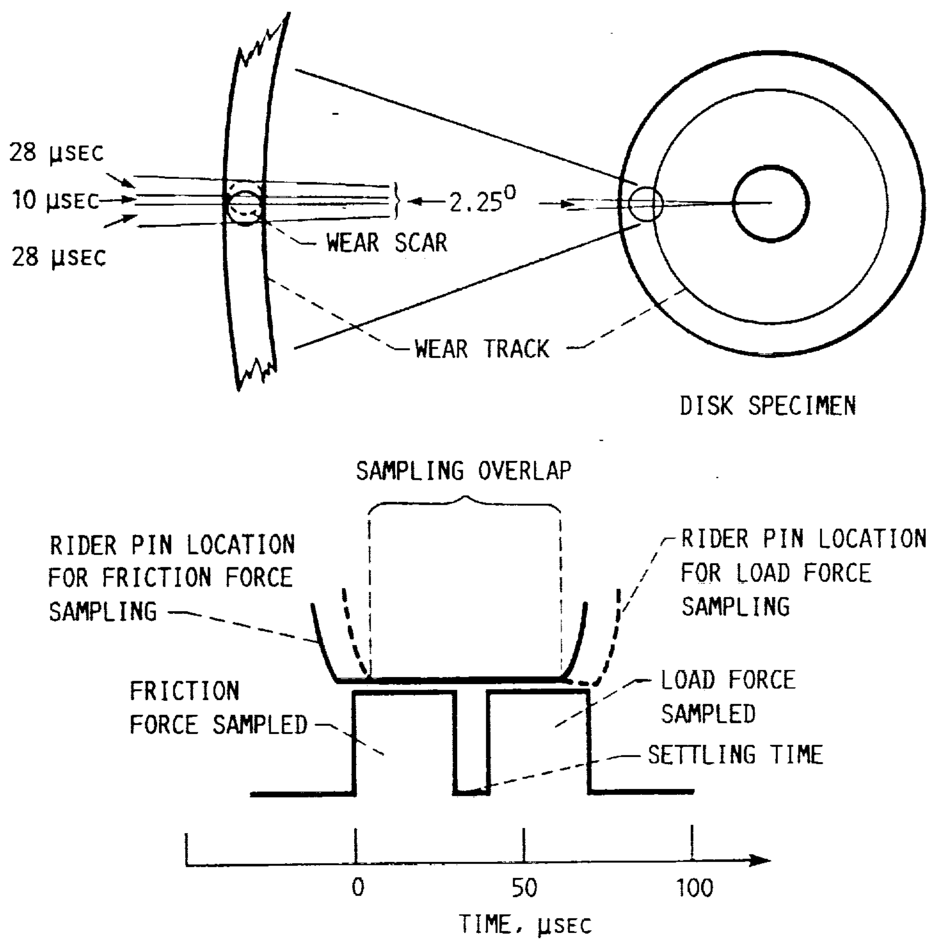


FIGURE C-1. - TYPICAL RIDER PIN LOCATION DURING DATA SAMPLING.

APPENDIX D

UNIDIRECTIONAL PROGRAM LISTING

```
10 COLOR 11,0,0
20 CLS
30 GOSUB 3620
40 REM:PIN-ON-DISK UNIDIRECTIONAL    <POD.UNI>
50 CLS
60 LOCATE 10,30:PRINT"WELCOME TO   POD.UNI"
70 LOCATE 12,31:PRINT"WRITTEN CDB 881711":LOCATE 5,70:PRINT"UNIDIRECTIONAL"
80 LOCATE 25,2:PRINT"PLEASE WAIT"
90 FOR X=1 TO 5000
100 NEXT X
110 CLS
120 LOCATE 5,34:PRINT "DIRECTIONS"
130 LOCATE 7,5:PRINT"THIS PROGRAM IS DESIGNED TO GATHER TEST DATA FROM THE HIGH
TEMPERATURE"
140 LOCATE 8,5:PRINT"TRIBOMETER. IT WILL MONITOR THE TEST RIG DURING HEATING AND
 BEGIN"
150 LOCATE 9,5:PRINT"DATA ACQUISITION UPON COMMAND. IT WILL RECORD FRICTION"
160 LOCATE 10,5:PRINT"FORCE AND LOAD IN KG'S, MOTOR SPEED, SPECIMEN AND FURNACE
TEMPERATURES."
170 LOCATE 11,5:PRINT"THIS PROGRAM WILL ALSO PROVIDE TEST RIG STATUS: OIL FLOW,
OIL TEMPERATURE,"
180 LOCATE 12,5:PRINT"CURRENT DATA POINT AND ROOM TEMPERATURE AND HUMIDITY."
190 LOCATE 19,5:PRINT"ENTER TEST INFORMATION AS REQUESTED; (NOTE: TO IDENTIFY A
TEST FILE"
200 LOCATE 20,5:PRINT"A FILE NAME MUST EXIST-EX.:FOR TEST ***; THE FILE IS ***.D
AT;"
210 LOCATE 25,2:INPUT"ARE YOU READY TO CONTINUE (Y OR N):";A$
220 IF A$="Y" THEN 240
230 GOTO 210
240 CLS
250 LOCATE 5,2:INPUT"ENTER THE TEST RUN DATA FILE NAME (***.DAT): ";TPF$
260 CLS
270 LOCATE 5,5:PRINT"TEST RUN:  ";TPF$
280 LOCATE 10,2:INPUT"IS THE FILE NAME CORRECT(Y OR N): ";B$
290 IF B$="Y" THEN 360
300 IF B$="N" THEN 320
310 GOTO 280
320 CLS:TPF$=" "
330 LOCATE 3,2:PRINT"FILE NAME HAS BEEN DELETED. PLEASE RE-ENTER:"
340 BEEP
350 GOTO 250
360 CLS
370 LOCATE 5,2:PRINT"ENTER ANY TEST INFORMATION YOU WANT RECORDED."
380 LOCATE 7,10:INPUT"PIN MATERIAL & I.D.#: ";PM$
390 LOCATE 9,10:INPUT"DISK MATERIAL & I.D.#: ";DM$
400 LOCATE 11,10:INPUT"TEST INFORMATION(IE: TEMP., LOAD., ETC.): ";INFO$
410 LOCATE 25,2:INPUT"IS THE TEST INFORMATION CORRECT (Y OR N): ";C$
420 IF C$="Y" THEN 500
430 IF C$="N" THEN 450
440 GOTO 410
450 DM$=" ":PM$=" ":INFO$=" "
460 CLS
470 LOCATE 3,2:PRINT"TEST INFORMATION HAS BEEN DELETED. PLEASE RE-ENTER."
480 BEEP
490 GOTO 370
500 CLS
510 LOCATE 5,2:INPUT"ENTER THE NUMBER OF DATA POINTS FOR THE TEST: ";N
520 DIM POINTS(N,7)
530 LOCATE 7,2:INPUT"ENTER THE TIME INTERVAL IN SECONDS: ";T%
540 LOCATE 25,2:INPUT"IS THE NUMBER OF DATA POINTS CORRECT (Y OR N): ";D$
550 IF D$="Y" THEN 640
560 IF D$="N" THEN 580
570 GOTO 540
580 N=0
```

```
590 DIM POINTS (0,0)
600 CLS
610 LOCATE 3,2:PRINT"THE NUMBER OF DATA POINTS HAS BEEN DELETED PLEASE RE-ENTER.
"
620 BEEP
630 GOTO 510
640 CLS
650 LOCATE 3,5:PRINT"TEST RUN: ";TPF$
660 LOCATE 6,5:PRINT"DATA FILE: ";TPF$
670 LOCATE 10,5:PRINT"PIN MATERIAL: ";PM$
680 LOCATE 11,5:PRINT"DISK MATERIAL: ";DM$
690 LOCATE 13,5:PRINT"TEST INFORMATION: ";INFO$
700 LOCATE 16,5:PRINT"NUMBER OF DATA POINTS: ";N
710 LOCATE 17,5:PRINT"TIME INTERVAL: ";T%
720 LOCATE 25,2:INPUT"ARE THE VALUES AND INFORMATION CORRECT (Y OR N): ";E$
730 IF E$="Y" THEN 970
740 IF E$="N" THEN 760
750 GOTO 720
760 CLS
770 GOSUB 3180
780 CLS
790 LOCATE 1,20:PRINT"ALL TEST DATA HAS BEEN DELETED."
800 BEEP
810 LOCATE 9,2:INPUT"DO YOU WANT TO RE-ENTER NEW DATA (Y OR N): ";F$
820 IF F$="Y" THEN 240
830 IF F$="N" THEN 850
840 GOTO 810
850 CLS
860 LOCATE 5,12:PRINT"ENTER THE NUMBER OF THE FUNCTION YOU WANT TO PERFORM."
870 LOCATE 8,15:PRINT"1. GO TO DIRECTIONS"
880 LOCATE 10,15:PRINT"2. RE-ENTER TEST DATA"
890 LOCATE 12,15:PRINT"3. MONITOR MODE"
900 LOCATE 14,15:PRINT"4. QUIT"
910 LOCATE 16,2:INPUT"ENTER NUMBER: ";G
920 IF G=1 THEN 40
930 IF G=2 THEN 240
940 IF G=3 THEN 970
950 IF G=4 THEN 3580
960 GOTO 910
970 CLS
980 CALL INIT
990 REM:INITIATES MONITOR FUNCTIONS AND DATA TIME INTERVAL
1000 LOCATE 23,2:PRINT"PRESS <SPACEBAR> TO START MONITOR FUNCTION."
1010 I$=INKEY$:IF I$=" " THEN 1020 ELSE 1000
1020 CP=CP+1
1030 IF CP = 1000 THEN 1460
1040 I$=INKEY$:IF I$=" " THEN 1560
1050 IF I$=CHR$(64) THEN 3580
1060 REM:ACCESS TO MONITOR VALUES
1070 CALL ANREAD'("FLOWIN",FIN,0)
1080 CALL ANREAD'("FLOWOUT",FOT,0)
1090 CALL ANREAD'("OILTEMP",OTP,10)
1100 CALL ANREAD'("TFURNAC1",TFURN1,16)
1110 CALL ANREAD'("TFURNAC2",TFURN2,16)
1120 CALL ANREAD'("TFURNAC3",TFURN3,16)
1130 CALL ANREAD'("FCTRL1",TFURN4,16)
1140 CALL ANREAD'("MTRSPD",SPD,0)
1150 CALL ANREAD'("RMTMP",RTP,0)
1160 CALL ANREAD'("RELH",RH,0)
1170 FOR X=1 TO 5000:NEXT X
1180 REM:SCREEN DISPLAY
1190 CLS
1200 LOCATE 10,50:PRINT"MONITOR MODE"
1210 LOCATE 1,4:PRINT"***STORED VALUES***"
1220 LOCATE 2,3:PRINT"F FRICTION: ":LOCATE 2,22:PRINT"Kg"
1230 LOCATE 3,3:PRINT"APPLYLOAD: ":LOCATE 3,22:PRINT"Kg"
```

```
1240 LOCATE 4,3:PRINT"F COEFFICIENT: "
1250 LOCATE 5,3:PRINT"SPEC TEMP: ":LOCATE 5,22:PRINT"'C"
1260 TSPEC=(TFURN1+TFURN2+TFURN3+TFURN4)/4
1270 LOCATE 5,14:PRINT USING"####.##";TSPEC
1280 LOCATE 6,4:PRINT"***RIG PARAMETERS***"
1290 LOCATE 7,3:PRINT"MTRSPEED:  ";"        RPM"
1300 SPD=SPD*1000
1310 LOCATE 7,14:PRINT USING "####.##";SPD
1320 LOCATE 8,3:PRINT"FLOW IN :  ":LOCATE 8,17:PRINT USING "#.##";FIN
1330 LOCATE 9,3:PRINT"FLOW OUT: ":LOCATE 9,17:PRINT USING "#.##":FOT
1340 LOCATE 10,3:PRINT"OILTEMP :   ";OTP;" 'C"
1350 LOCATE 11,3:PRINT"T FURN 1:           'C":LOCATE 11,14:PRINT USING"####.##"
;TFURN1
1360 LOCATE 12,3:PRINT"T FURN 2:           'C":LOCATE 12,14:PRINT USING"####.##"
;TFURN2
1370 LOCATE 13,3:PRINT"T FURN 3:           'C":LOCATE 13,14:PRINT USING"####.##"
;TFURN3
1380 LOCATE 14,3:PRINT"T FURN 4:           'C":LOCATE 14,14:PRINT USING"####.##"
;TFURN4
1390 RTP=RTP*10
1400 LOCATE 15,3:PRINT"RMTEMP:":LOCATE 15,11:PRINT USING"###.#":RTP:LOCATE 15,17
:PRINT"'C"
1410 RH=RH*10
1420 LOCATE 15,21:PRINT"REL H: ":LOCATE 15,28:PRINT USING "##.#":RH:LOCATE 15,33
:PRINT "%"
1430 LOCATE 22,2:PRINT"PRESS <SPACEBAR> FOR DATA ACQUISTION."
1440 LOCATE 23,10:PRINT"PRESS <@> TO ABORT FUNCTION."
1450 GOTO 1020
1460 REM:PROGRAM CROSSROAD
1470 CLS
1480 LOCATE 10,5:PRINT"*** PRESS ***"
1490 LOCATE 12,5:PRINT"R TO RETURN TO MONITOR MODE."
1500 LOCATE 14,5:PRINT"A FOR DATA ACQUISITION MODE."
1510 LOCATE 16,5:PRINT"Q TO QUIT."
1520 I$=INKEY$:IF I$="Q" THEN 3580
1530 IF I$="A" THEN 1570
1540 IF I$="R" THEN 1550
1550 GOTO 1010
1560 REM:DATA ACQUISITION
1570 CLS
1580 CLS:KEY OFF:SCREEN 2:WIDTH 80: GOSUB 3660
1590 GOSUB 3270
1600 LOCATE 23,2:PRINT"PRESS <SPACEBAR> TO START DATA ACQUISITION."
1610 I$=INKEY$:IF I$=" " THEN 1620 ELSE 1600
1620 CALL CLOCKREAD'(HR1%,MIN1%,SEC1%)
1630 LPRINT "TEST RUN: ";TPF$
1640 LPRINT"      FFRCTN      LOAD      FCOEFF    SPEED     SPECTEMP      TIME       POI
NT"
1650 LOCATE 23,2:PRINT"                                                       "
1660 X!=0
1670 X!=TIMER
1680 CALL INIT
1690 CALL INTON'(1,"SEC")
1700 LOCATE 17,48:PRINT"DATA BEING SAMPLED!"
1710 CALL ANIN'("SAMPTS%",10.,"LOAD,FRCTNF",1,"CLOCK")
1720 STAT%=0
1730 CALL STATUS'("CLOCK",STAT%)
1740 IF STAT% <> 0 GOTO 1730
1750 CALL INTOFF
1760 LOCATE 17,48:PRINT"                    "
1770 MLOAD=0:SLOAD=0:MFRCTNF=0:SFRCTNF=0
1780 CALL MEANDEV'("SAMPTS%",1,MLOAD,SLOAD,1.,10.,0)
1790 CALL MEANDEV'("SAMPTS%",2,MFRCTNF,SFRCTNF,1.,10.,0)
1800 MU=0
1810 FOR AVG = 1 TO 10
1820 L=0:F=0:MUL=0
```

```
1830 CALL ARGETVAL'("SAMPTS%",AVG,1,L,0)
1840 CALL ARGETVAL'("SAMPTS%",AVG,2,F,0)
1850 L=ABS(L):F=ABS(F)
1860 MUL=F/L
1870 MU=MU+MUL
1880 NEXT AVG
1890 LD=ABS(MLOAD):VA=ABS(MFRCTNF)
1900 MU=MU/10
1910 CALL ARDEL'("SAMPTS%")
1920 I$=INKEY$:IF I$="@" THEN 2670
1930 REM: DATA VALUE ACCESS
1940 CALL ANREAD'("MTRSPD",SPD,0)
1950 CALL ANREAD'("FLOWIN",FIN,0)
1960 CALL ANREAD'("FLOWOUT",FOT,0)
1970 CALL ANREAD'("OILTEMP",OTP,10)
1980 CALL ANREAD'("TFURNAC1",TFURN1,16)
1990 CALL ANREAD'("TFURNAC2",TFURN2,16)
2000 CALL ANREAD'("TFURNAC3",TFURN3,16)
2010 CALL ANREAD'("FCTRL1",TFURN4,16)
2020 CALL ANREAD'("RMTMP",RTP,0)
2030 CALL ANREAD'("RELH",RH,0)
2040 TSPEC=(TFURN1+TFURN2+TFURN3+TFURN4)/4
2050 SPD=SPD*1000
2060 POINTS(LPOLD,0)=MU
2070 POINTS(LPOLD,1)=VA
2080 POINTS(LPOLD,2)=LD
2090 POINTS(LPOLD,3)=SPD
2100 POINTS(LPOLD,4)=TSPEC
2110 POINTS(LPOLD,6)=TFURN2
2120 POINTS(LPOLD,7)=TFURN4
2130 POINTS(LPOLD,5)=TIME
2140 REM: SCREEN DISPLAY  ACQUISITION
2150 LOCATE 1,4:PRINT"***STORED VALUES***"
2160 LOCATE 2,3:PRINT"F FRICTION: ":LOCATE 2,22:PRINT"Kg"
2170 LOCATE 2,15:PRINT USING"###.##";VA
2180 LOCATE 3,3:PRINT"APPLYLOAD: ":LOCATE 3,22:PRINT"Kg"
2190 LOCATE 3,15:PRINT USING"###.##";LD
2200 LOCATE 4,3:PRINT"F COEFFICIENT: "
2210 LOCATE 4,18:PRINT USING"##.##";MU
2220 LOCATE 5,3:PRINT"SPEC TEMP: ":LOCATE 5,22:PRINT"'C"
2230 LOCATE 5,14:PRINT USING"####.##";TSPEC
2240 LOCATE 6,4:PRINT"***RIG PARAMETERS***"
2250 LOCATE 7,3:PRINT"MTRSPEED:   ";"         RPM"
2260 LOCATE 7,14:PRINT USING"####.##";SPD
2270 LOCATE 8,3:PRINT"FLOW IN:   ":LOCATE 8,17:PRINT USING"#.##";FIN
2280 LOCATE 9,3:PRINT"FLOW OUT: ":LOCATE 9.17:PRINT USING"#.##";FOT
2290 LOCATE 10,3:PRINT"OILTEMP :    ";OTP;" 'C"
2300 LOCATE 11,3:PRINT"T FURN 1:              'C":LOCATE 11,14:PRINT USING"####.##"
;TFURN1
2310 LOCATE 12,3:PRINT"T FURN 2:              'C":LOCATE 12,14:PRINT USING"####.##"
;TFURN2
2320 LOCATE 13,3:PRINT"T FURN 3:              'C":LOCATE 13,14:PRINT USING"####.##"
;TFURN3
2330 LOCATE 14,3:PRINT"T FURN 4:              'C":LOCATE 14,14:PRINT USING"####.##"
;TFURN4
2340 RTP=RTP*10
2350 LOCATE 15,3:PRINT"RMTEMP:":LOCATE 15,11:PRINT USING"###.#";RTP:LOCATE 15,17
:PRINT"'C"
2360 RH=RH*10
2370 LOCATE 15,21:PRINT"REL H: ":LOCATE 15,28:PRINT USING "##.#";RH:LOCATE 15,33
:PRINT "%"
2380 LOCATE 19,50:PRINT"PRESS <@> TO ABORT TEST RUN."
2390 LOCATE 17,3:PRINT"DATA POINT STATUS:"
2400 LOCATE 18,3:PRINT"CURRENT: ";LPOLD
2410 LOCATE 19,3:PRINT"FINAL: ";N
2420 LOCATE 20,3:PRINT"TEST RUN: ";TPF$
```

```
2430 LOCATE 21,3:PRINT"PIN: ";PM$;"       DISK: ";DM$
2440 LOCATE 22,3:PRINT"TEST INFO: ";INFO$
2450 LOCATE 14,56:PRINT"TIME ----->"
2460 LOCATE 1,50:PRINT"FRICTION COEFFICIENT"
2470 LOCATE 3,35:PRINT"2.0"
2480 LOCATE 5,35:PRINT"1.6"
2490 LOCATE 7,35:PRINT"1.2"
2500 LOCATE 9,35:PRINT"0.8"
2510 LOCATE 11,35:PRINT"0.4"
2520 LOCATE 13,35:PRINT"0.0"
2530 LPRINT USING"#######.##";VA;LD;MU;SPD;TSPEC;TIME;LP
2540 GOSUB 3480
2550 IF LP=N THEN 2670
2560 TRP=N-LPOLD
2570 TRF=60/T%
2580 TTRM=TRP/TRF
2590 LOCATE 17,30:PRINT"TIME REMAINING"
2600 LOCATE 18,30:PRINT USING"###.#";TTRM:LOCATE 18,37:PRINT"MINUTES"
2610 WHILE TIMER < X!+T% : WEND
2620 TTXP=TTXP+T%
2630 TIME=TTXP/60
2640 LP=LP+1
2650 LPOLD=LP
2660 GOTO 1660
2670 REM:DATA COMPLETETION AND SHUTDOWN
2680 CALL CLOCKREAD'(HR2%,MIN2%,SEC2%)
2690 LOCATE 19,50:PRINT"                              "
2700 LOCATE 23,2:PRINT"DATA ACQUISITION COMPLETE. SHUT RIG DOWN. PRESS <R> TO CO
NTINUE.          "
2710 I$=INKEY$:IF I$="R" THEN 2740
2720 BEEP
2730 GOTO 2700
2740 CALL INIT
2750 ARN$="DATAPTS!"
2760 SZ=N+1
2770 CALL ARMAKE'(ARN$,SZ,8)
2780 CALL ARLABEL'(ARN$,INFO$)
2790 LOCATE 16,60:PRINT"PRESS <P> TO PRINT"
2800 LOCATE 17,60:PRINT"<D> TO PRINT DATA"
2810 LOCATE 18,60:PRINT"OR <Q> TO QUIT."
2820 LOCATE 23,2:PRINT"
      "
2830 LPRINT CHR$(12)
2840 I$=INKEY$
2850 IF I$="P" THEN 2890:   REM:PRINT ALL
2860 IF I$="D" THEN  2950:     REM:PRINT DATA
2870 IF I$="Q" THEN  END:     REM:QUIT
2880 GOTO 2840
2890 LOCATE 16,60:PRINT"                    "
2900 LOCATE 17,60:PRINT"                   "
2910 LOCATE 18,60:PRINT"                 "
2920 LOCATE 17,55:PRINT"START: ";HR1%;":";MIN1%;":";SEC1%
2930 LOCATE 18,54:PRINT"FINISH: "HR2%;":";MIN2%;":";SEC2%
2940 GOSUB 3690
2950 LOCATE 16,60:PRINT"                    "
2960 LOCATE 17,60:PRINT"                   "
2970 LOCATE 18,60:PRINT"                 "
2980 LOCATE 17,55:PRINT"START: ";HR1%;":";MIN1%;":";SEC1%
2990 LOCATE 18,54:PRINT"FINISH: "HR2%;":";MIN2%;":";SEC2%
3000 LPRINT"      FFRCTN     LOAD      FCOEFF   SPEED     SPECTEMP      TIME       POI
NT"
3010 TP= 0:AP=1
3020   MU=POINTS(TP,0) :CALL ARPUTVAL'(ARN$,AP,1,MU)
3030   VA=POINTS(TP,1) :CALL ARPUTVAL'(ARN$,AP,2,VA)
3040   LD=POINTS(TP,2) :CALL ARPUTVAL'(ARN$,AP,3,LD)
3050   SP=POINTS(TP,3) :CALL ARPUTVAL'(ARN$,AP,4,SP)
```

```
3060   TS=POINTS(TP,4) :CALL ARPUTVAL'(ARN$,AP,5,TS)
3070 TIME=POINTS(TP,5) :CALL ARPUTVAL'(ARN$,AP,6,TIME)
3080   F1=POINTS(TP,6) :CALL ARPUTVAL'(ARN$,AP,7,F1)
3090   F2=POINTS(TP,7) :CALL ARPUTVAL'(ARN$,AP,8,F2)
3100 LPRINT USING"#######.##";VA;LD;MU;SP;TS;TIME:TP
3110 IF TP=N THEN 3150
3120 TP=TP+1
3130 AP=AP+1
3140 GOTO 3020
3150 CALL ARWRITE'(ARN$,TPF$)
3160 LPRINT CHR$(12)
3170 END
3180 REM:DATA DELETE SUBROUTINE
3190 LOCATE 25,2:PRINT"                                                        "
3200 FOR Y= 1 TO 100
3210 LOCATE 3,15:PRINT"ALL TEST INFORMATION IS BEING DELETED."
3220 LOCATE 23,2:PRINT"PLEASE WAIT                    ":Y
3230 NEXT Y
3240 TDF$=" ":TTF$=" ":TPF$=" ":PM$=" ":DM$=" ":INFO$=" ":N=0:T%=0
3250 RETURN
3260 END
3270 REM:REAL TIME GRAPH SUBROUTINE
3280 REM:SET UP GRAPH PARAMETERS
3290 LP=0:UP=2!:LX=300:RX=660:TY=20:BY=100:YG=5:XG=4
3300 SX=RX-LX
3310 SF=SX/(RX-LX):PY=(UP-LP)/(BY-TY):XX=LX
3320 GOSUB 3360
3330 GOSUB 3440
3340 RETURN
3350 END
3360 REM:FRAME AND PLOT
3370 LINE (LX-1,TY-1)-(RX+1,BY+1),1,B
3380 FOR GY=TY TO BY STEP (BY-TY)/YG:LINE(LX-1,GY)-(LX-9,GY):NEXT GY
3390 FOR GX=LX TO RX STEP (RX-LX)/XG:LINE (GX,BY+1)-(GX,BY+5):NEXT GX
3400 RETURN
3410 END
3420 REM:CLEAR ACTIVE WINDOW AND DRAW GRID
3430 LINE (LX,TY)-(RX,BY),0,BF
3440 FOR GY=TY TO BY STEP ((BY-TY)/YG):LINE(RX,GY)-(LX,GY):NEXT GY
3450 FOR GX=LX TO RX STEP ((RX-LX)/XG):LINE(GX,BY)-(GX,TY):NEXT GX
3460 RETURN
3470 END
3480 REM:PLOTTING DATA POINTS
3490 IF XX>RX THEN XX=LX:GOSUB 3420
3500 PL=UP-MU
3510 YY=(PL/PY)+TY
3520 IF YY<TY THEN YY=TY
3530 IF YY>BY THEN YY=BY
3540 PSET (XX,YY),1
3550 XX=XX+1/SF
3560 RETURN
3570 END
3580 REM:PROGRAM ABORT SUBROUTINE
3590 CALL INTOFF
3600 CLS
3610 SYSTEM
3620 REM:REINITILIZE VARIABLES AND CLEAR SCREEN
3630 CLS
3640 MMX=0:MSPD=0:SSPD=0:T%=0:N=0:TMX=0:LP=0:LPOLD=0:CP=0:HR%=0:HR1%=0:HR2%=0:MI
N%=0:MIN1%=0:MIN2%=0:SEC%=0:SEC1%=0:SEC2%=0:TADJ=0
3650 MU=0:VA=0:LD=0:TTXP=0:TRP=0:TRF=0:TTRM=0
3660 FIN=0:FOT=0:OTP=0:TSPEC=0:TFURN1=0:TFURN2=0:TFURN3=0:TFURN4=0:SPD=0:RTP=0:R
H=0:STAT%=0:SPCYC=0:MON%=0:MONITOR%=0:SP=0:TS=0:F1=0:F2=0
3670 RETURN
3680 END
```

```
3690 REM:PRINT SCREEN SUBROUTINE
3700 DEF SEG:P=0:I=0:J=0:DIM ARRAY(3)
3710 DATA &H55
3720 DATA &HCD, &H05
3730 DATA &H5D
3740 DATA &HCB
3750 P=VARPTR(ARRAY(1)):FOR I=0 TO 4:READ J:POKE(P+I),J:NEXT I
3760 SUBRT=VARPTR(ARRAY(1)):CALL SUBRT
3770 LPRINT CHR$(12)
3780 ERASE ARRAY:RESTORE:DEF SEG=20
3790 RETURN
3800 END
```

APPENDIX E

OSCILLATING PROGRAM LISTING

```
10 COLOR 11,0,0
20 CLS
30 GOSUB 3460
40 REM:PIN-ON-DISK OSILLATING  <POD.OSI>
50 CLS
60 LOCATE 10,30:PRINT"WELCOME TO   POD.OSI"
70 LOCATE 12,31:PRINT"WRITTEN CDB 881711"
80 LOCATE 25,2:PRINT"PLEASE WAIT"
90 FOR X=1 TO 5000
100 NEXT X
110 CLS
120 LOCATE 5,34:PRINT "DIRECTIONS"
130 LOCATE 7,5:PRINT"THIS PROGRAM IS DESIGNED TO GATHER TEST DATA FROM THE HIGH
TEMPERATURE"
140 LOCATE 8,5:PRINT"TRIBOMETER. IT WILL MONITOR THE TEST RIG DURING HEATING AND
 ESTABLISH"
150 LOCATE 9,5:PRINT"THE INTERUPT TIME INTERVAL FORM DATA SAMPLING. IT WILL RECO
RD FRICTION"
160 LOCATE 10,5:PRINT"FORCE AND LOAD IN KG'S, MOTOR SPEED, SPECIMEN AND FURNACE
TEMPERATURES."
170 LOCATE 11,5:PRINT"THIS PROGRAM WILL ALSO PROVIDE TEST RIG STATUS: OIL FLOW,
OIL TEMPERATURE,"
180 LOCATE 12,5:PRINT"CURRENT DATA POINT AND ROOM TEMPERATURE AND HUMIDITY."
190 LOCATE 19,5:PRINT"ENTER TEST INFORMATION AS REQUESTED; (NOTE: TO IDENTIFY A
TEST FILE"
200 LOCATE 20,5:PRINT"A FILE NAME MUST EXIST-EX.:FOR TEST ***; THE FILE IS ***.D
AT;"
210 LOCATE 25,2:INPUT"ARE YOU READY TO CONTINUE (Y OR N):";A$
220 IF A$="Y" THEN 240
230 GOTO 210
240 CLS
250 LOCATE 5,2:INPUT"ENTER THE TEST RUN DATA FILE NAME (***.DAT): ";TPF$
260 CLS
270 LOCATE 5,5:PRINT"TEST RUN:   ";TPF$
280 LOCATE 10,2:INPUT"IS THE FILE NAME CORRECT(Y OR N): ";B$
290 IF B$="Y" THEN 360
300 IF B$="N" THEN 320
310 GOTO 280
320 CLS:TPF$=" "
330 LOCATE 3,2:PRINT"FILE NAME HAS BEEN DELETED. PLEASE RE-ENTER:"
340 BEEP
350 GOTO 250
360 CLS
370 LOCATE 5,2:PRINT"ENTER ANY TEST INFORMATION YOU WANT RECORDED."
380 LOCATE 7,10:INPUT"PIN MATERIAL & I.D.#: ";PM$
390 LOCATE 9,10:INPUT"DISK MATERIAL & I.D.#: ";DM$
400 LOCATE 11,10:LINE INPUT"TEST INFORMATION(IE: TEMP., LOAD., ETC.): ";INFO$
410 LOCATE 25,2:INPUT"IS THE TEST INFORMATION CORRECT (Y OR N): ";C$
420 IF C$="Y" THEN 500
430 IF C$="N" THEN 450
440 GOTO 410
450 DM$=" ":PM$=" ":INFO$=" "
460 CLS
470 LOCATE 3,2:PRINT"TEST INFORMATION HAS BEEN DELETED. PLEASE RE-ENTER."
480 BEEP
490 GOTO 370
500 CLS
510 LOCATE 5,2:INPUT"ENTER THE NUMBER OF DATA POINTS FOR THE TEST: ";N
520 DIM POINTS(N,4)
530 LOCATE 7,2:PRINT"PLEASE NOTE THAT THE DATA POINT INTERVAL IS 5 MILLISECONDS.
"
540 LOCATE 8,2:PRINT"BE AWARE THAT THE LENGTH OF THE TEST WILL VARY BASED ON THE
 "
550 LOCATE 9,2:PRINT"OSCILLATION RATE OF THE SPECIMEN."
560 FOR STALL= 1 TO 3500
```

```
570 NEXT STALL
580 LOCATE 25,2:INPUT"IS THE NUMBER OF DATA POINTS CORRECT (Y OR N): ";D$
590 IF D$="Y" THEN 680
600 IF D$="N" THEN 620
610 GOTO 580
620 N=0
630 ERASE POINTS
640 CLS
650 LOCATE 3,2:PRINT"THE NUMBER OF DATA POINTS HAS BEEN DELETED PLEASE RE-ENTER.
"
660 BEEP
670 GOTO 510
680 CLS
690 LOCATE 3,5:PRINT"TEST RUN: ";TPF$
700 LOCATE 6,5:PRINT"DATA FILE: ";TPF$
710 LOCATE 10,5:PRINT"PIN MATERIAL: ";PM$
720 LOCATE 11,5:PRINT"DISK MATERIAL: ";DM$
730 LOCATE 13,5:PRINT"TEST INFORMATION: ";INFO$
740 LOCATE 16,5:PRINT"NUMBER OF DATA POINTS: ";N
750 LOCATE 25,2:INPUT"ARE THE VALUES AND INFORMATION CORRECT (Y OR N): ";E$
760 IF E$="Y" THEN 990
770 IF E$="N" THEN 790
780 GOTO 750
790 GOSUB 3020
800 CLS
810 LOCATE 1,20:PRINT"ALL TEST DATA HAS BEEN DELETED."
820 BEEP
830 LOCATE 9,2:INPUT"DO YOU WANT TO RE-ENTER NEW DATA (Y OR N): ";F$
840 IF F$="Y" THEN 240
850 IF F$="N" THEN 870
860 GOTO 830
870 CLS
880 LOCATE 5,12:PRINT"ENTER THE NUMBER OF THE FUNCTION YOU WANT TO PERFORM."
890 LOCATE 8,15:PRINT"1. GO TO DIRECTIONS"
900 LOCATE 10,15:PRINT"2. RE-ENTER TEST DATA"
910 LOCATE 12,15:PRINT"3. MONITOR MODE"
920 LOCATE 14,15:PRINT"4. QUIT"
930 LOCATE 16,2:INPUT"ENTER NUMBER: ";G
940 IF G=1 THEN 40
950 IF G=2 THEN 240
960 IF G=3 THEN 990
970 IF G=4 THEN 3420
980 GOTO 930
990 CLS
1000 CALL INIT
1010 REM:INITIATES MONITOR FUNCTIONS AND DATA TIME INTERVAL
1020 LOCATE 23,2:PRINT"PRESS <SPACEBAR> TO START MONITOR FUNCTION."
1030 I$=INKEY$:IF I$=" " THEN 1040 ELSE 1020
1040 CP=CP+1
1050 IF CP = 1000 THEN 1480
1060 I$=INKEY$:IF I$=" " THEN 1580
1070 IF I$=CHR$(64) THEN 3420
1080 REM:ACCESS TO MONITOR VALUES
1090 CALL ANREAD'("FLOWIN",FIN,0)
1100 CALL ANREAD'("FLOWOUT",FOT,0)
1110 CALL ANREAD'("OILTEMP",OTP,10)
1120 CALL ANREAD'("TFURNAC1",TFURN1,16)
1130 CALL ANREAD'("TFURNAC2",TFURN2,16)
1140 CALL ANREAD'("TFURNAC3",TFURN3,16)
1150 CALL ANREAD'("FCTRL1",TFURN4,16)
1160 CALL ANREAD'("MTRSPD",SPD,0)
1170 CALL ANREAD'("RMTMP",RTP,0)
1180 CALL ANREAD'("RELH",RH,0)
1190 FOR X=1 TO 10000:NEXT X
1200 REM:SCREEN DISPLAY
1210 CLS
```

```
1220 LOCATE 10,50:PRINT"MONITOR MODE"
1230 LOCATE 1,4:PRINT"***STORED VALUES***"
1240 LOCATE 2,3:PRINT"F FRICTION: ":LOCATE 2,22:PRINT"Kg"
1250 LOCATE 3,3:PRINT"APPLYLOAD: ":LOCATE 3,22:PRINT"Kg"
1260 LOCATE 4,3:PRINT"F COEFFICIENT: "
1270 LOCATE 5,3:PRINT"SPEC TEMP: ":LOCATE 5,22:PRINT"'C"
1280 TSPEC=(TFURN1+TFURN2+TFURN3+TFURN4)/4
1290 LOCATE 5,14:PRINT USING"####.##";TSPEC
1300 LOCATE 6,4:PRINT"***RIG PARAMETERS***"
1310 LOCATE 7,3:PRINT"MTRSPEED:  ";"         RPM"
1320 SPD=SPD*1000
1330 LOCATE 7,14:PRINT USING "####.##":SPD
1340 LOCATE 8,3:PRINT"FLOW IN :  ":LOCATE 8,17:PRINT USING "#.##":FIN
1350 LOCATE 9,3:PRINT"FLOW OUT: ":LOCATE 9,17:PRINT USING "#.##":FOT
1360 LOCATE 10,3:PRINT"OILTEMP :             'C":LOCATE 10,16:PRINT USING "##.##":
OTP
1370 LOCATE 11,3:PRINT"T FURN 1:             'C":LOCATE 11,14:PRINT USING"####.##"
;TFURN1
1380 LOCATE 12,3:PRINT"T FURN 2:             'C":LOCATE 12,14:PRINT USING"####.##"
;TFURN2
1390 LOCATE 13,3:PRINT"T FURN 3:             'C":LOCATE 13,14:PRINT USING"####.##"
;TFURN3
1400 LOCATE 14,3:PRINT"T FURN 4:             'C":LOCATE 14,14:PRINT USING"####.##"
;TFURN4
1410 RTP=RTP*10
1420 LOCATE 15,3:PRINT"RMTEMP:":LOCATE 15,11:PRINT USING"###.#";RTP:LOCATE 15,17
:PRINT"'C"
1430 RH=RH*10
1440 LOCATE 15,21:PRINT"REL H: ":LOCATE 15,28:PRINT USING "##.#";RH:LOCATE 15,33
:PRINT "%"
1450 LOCATE 22,2:PRINT"PRESS <SPACEBAR> FOR DATA ACQUISTION."
1460 LOCATE 23,10:PRINT"PRESS <@> TO ABORT FUNCTION."
1470 GOTO 1040
1480 REM:PROGRAM CROSSROAD
1490 CLS
1500 LOCATE 10,5:PRINT"*** PRESS ***"
1510 LOCATE 12,5:PRINT"R TO RETURN TO MONITOR MODE."
1520 LOCATE 14,5:PRINT"A FOR DATA ACQUISITION MODE."
1530 LOCATE 16,5:PRINT"Q TO QUIT."
1540 I$=INKEY$:IF I$="Q" THEN 3420
1550 IF I$="A" THEN 1590
1560 IF I$="R" THEN 1570
1570 GOTO 1030
1580 REM:DATA ACQUISITION
1590 CLS
1600 CLS:KEY OFF:SCREEN 2:WIDTH 80: GOSUB 3510
1610 GOSUB 3110
1620 LOCATE 23,2:PRINT"PRESS <SPACEBAR> TO START DATA ACQUISITION."
1630 I$=INKEY$:IF I$=" " THEN 1640 ELSE 1620
1640 CALL CLOCKREAD'(HR1%,MIN1%,SEC1%)
1650 LPRINT"      FFRCTN     LOAD      FCOEFF   SPEED    SPECTEMP    TIME     POIN
T"
1660 LOCATE 23,2:PRINT"                                                        "
1670 CALL INIT
1680 CALL ARMAKE'("STORE!",15.,2)
1690 REM:CYCLING MEMORY
1700 FOR TMX = 1 TO 15
1710 CALL DIGINTRIG'("DATRIG","ON","BT")
1720 CALL ANIN'("SAMPTS%",25.,"LOAD,FRCTNF",1,"WBT","CLOCK")
1730 CALL INTON'(5,"MIL")
1740 STAT%=0
1750 CALL STATUS'("CLOCK",STAT%)
1760 LOCATE 17,40:PRINT"TRIGGER"
1770 LOCATE 18,40:PRINT"CYCLE:";TMX
1780 IF STAT%<>0 GOTO 1750
1790 CALL INTOFF
```

```
1800 MLOAD=0:SLOAD=0:MFRCTNF=0:SFRCTNF=0
1801 LOCATE 18,50:PRINT"B41"
1810 CALL MEANDEV'("SAMPTS%",1,MLOAD,SLOAD,1.,25.,0)
1820 CALL MEANDEV'("SAMPTS%",2,MFRCTNF,SFRCTNF,1.,25.,0)
1821 LOCATE 18,50:PRINT"AF1"
1830 MLOAD=ABS(MLOAD)
1840 MFRCTNF=ABS(MFRCTNF)
1850 CALL ARPUTVAL'("STORE!",TMX,1,MLOAD)
1860 CALL ARPUTVAL'("STORE!",TMX,2,MFRCTNF)
1870 CALL ARDEL'("SAMPTS%")
1880 CALL BACKCLEAR
1890 NEXT TMX
1891 LOCATE 18,50:PRINT"B42"
1900 CALL MEANDEV'("STORE!",1,MLD1,SLD1,1.,15.)
1910 CALL MEANDEV'("STORE!",2,MVA1,SVA1,1.,15.)
1911 LOCATE 18,50:PRINT"AF2"
1920 MLD1=MLD1:REM:VOLTAGE CALIBRATION
1930 MVA1=MVA1
1940 LD=ABS(MLD1)
1950 VA=ABS(MVA1)
1960 MU=VA/LD
1970 I$=INKEY$:IF I$="@" THEN 2660
1980 LP=LP+1
1990 LPOLD=LP
2000 CALL ANREAD'("MTRSPD",SPD,0)
2010 CALL ANREAD'("FLOWIN",FIN,0)
2020 CALL ANREAD'("FLOWOUT",FOT,0)
2030 CALL ANREAD'("OILTEMP",OTP,10)
2040 CALL ANREAD'("TFURNAC1",TFURN1,16)
2050 CALL ANREAD'("TFURNAC2",TFURN2,16)
2060 CALL ANREAD'("TFURNAC3",TFURN3,16)
2070 CALL ANREAD'("FCTRL1",TFURN4,16)
2080 CALL ANREAD'("RMTMP",RTP,0)
2090 CALL ANREAD'("RELH",RH,0)
2100 SPD=SPD*1000
2110 CHZ=SPD/600
2120 POINTS(LPOLD,0)=VA
2130 POINTS(LPOLD,1)=LD
2140 POINTS(LPOLD,2)=SPD
2150 POINTS(LPOLD,3)=TSPEC
2160 REM: SCREEN DISPLAY  ACQUISITION
2170 LOCATE 1,4:PRINT"***STORED VALUES***"
2180 LOCATE 2,3:PRINT"F FRICTION: ":LOCATE 2,22:PRINT"Kg"
2190 LOCATE 2,15:PRINT USING"###.##":VA
2200 LOCATE 3,3:PRINT"APPLYLOAD: ":LOCATE 3,22:PRINT"Kg"
2210 LOCATE 3,15:PRINT USING"###.##";LD
2220 LOCATE 4,3:PRINT"F COEFFICIENT: "
2230 LOCATE 4,18:PRINT USING"##.##";MU
2240 LOCATE 5,3:PRINT"SPEC TEMP: ":LOCATE 5,22:PRINT"'C"
2250 TSPEC=(TFURN1+TFURN2+TFURN3+TFURN4)/4
2260 LOCATE 5,14:PRINT USING"####.##";TSPEC
2270 LOCATE 6,4:PRINT"***RIG PARAMETERS***"
2280 LOCATE 7,3:PRINT"MTRSPEED:  ";"          RPM"
2290 LOCATE 7,14:PRINT USING"####.##";SPD
2300 LOCATE 8,3:PRINT"FLOW IN:  ":LOCATE 8,17:PRINT USING"#.##":FIN
2310 LOCATE 9,3:PRINT"FLOW OUT: ":LOCATE 9,17:PRINT USING"#.##";FOT
2320 LOCATE 10,3:PRINT"OILTEMP :              'C":LOCATE 10,16:PRINT USING "##.##";
OTP
2330 LOCATE 11,3:PRINT"T FURN 1:              'C":LOCATE 11,14:PRINT USING"####.##"
;TFURN1
2340 LOCATE 12,3:PRINT"T FURN 2:              'C":LOCATE 12,14:PRINT USING"####.##"
;TFURN2
2350 LOCATE 13,3:PRINT"T FURN 3:              'C":LOCATE 13,14:PRINT USING"####.##"
;TFURN3
2360 LOCATE 14,3:PRINT"T FURN 4:              'C":LOCATE 14,14:PRINT USING"####.##"
;TFURN4
```

```
2370 RTP=RTP*10
2380 LOCATE 15,3:PRINT"RMTEMP:":LOCATE 15,11:PRINT USING"###.#";RTP:LOCATE 15,17
:PRINT"'C"
2390 RH=RH*10
2400 LOCATE 15,21:PRINT"REL H: ":LOCATE 15,28:PRINT USING "##.#";RH:LOCATE 15,33
:PRINT "%"
2410 LOCATE 19,50:PRINT"PRESS <@> TO ABORT TEST RUN."
2420 LOCATE 17,3:PRINT"DATA POINT STATUS:"
2430 LOCATE 18,3:PRINT"CURRENT: ";LPOLD
2440 LOCATE 19,3:PRINT"FINAL: ";N
2450 LOCATE 17,23:PRINT"CYC'S/S(Hz):"
2460 LOCATE 18,27:PRINT USING"##.###";CHZ
2470 LOCATE 20,3:PRINT"TEST RUN: ";TPF$
2480 LOCATE 21,3:PRINT"PIN: ";PM$;"       DISK: ";DM$
2490 LOCATE 22,3:PRINT"TEST INFO: ";INFO$
2500 LOCATE 14,56:PRINT"TIME ----->"
2510 LOCATE 1,50:PRINT"FRICTION COEFFICIENT"
2520 LOCATE 3,35:PRINT"2.0"
2530 LOCATE 5,35:PRINT"1.6"
2540 LOCATE 7,35:PRINT"1.2"
2550 LOCATE 9,35:PRINT"0.8"
2560 LOCATE 11,35:PRINT"0.4"
2570 LOCATE 13,35:PRINT"0.0"
2580 TIME=(LP*30)/60 'TIME CONSTANT FOR 141 RPM
2590 LPRINT USING"#######.##";VA;LD;MU;SPD;TSPEC;TIME;LP
2600 POINTS(LPOLD,4)=TIME
2610 GOSUB 3320
2620 CALL ARDEL'("STORE!")
2630 TMX = 0
2640 IF LP=N THEN 2660
2650 GOTO 1670
2660 REM:DATA COMPLETETION AND SHUTDOWN
2670 CALL CLOCKREAD'(HR2%,MIN2%,SEC2%)
2680 LOCATE 19,50:PRINT"                              "
2690 LOCATE 23,2:PRINT"DATA ACQUISITION COMPLETE. SHUT RIG DOWN. PRESS <R> TO CO
NTINUE.                  "
2700 I$=INKEY$:IF I$="R" THEN 2720
2710 GOTO 2690
2720 CALL INIT
2730 ARN$="DATAPTS!"
2740 CALL ARMAKE'(ARN$,N,5)
2750 CALL ARLABEL'(ARN$,INFO$)
2760 LOCATE 16,60:PRINT"PRESS <P> TO PRINT"
2770 LOCATE 17,60:PRINT"<D> TO PRINT DATA"
2780 LOCATE 18,60:PRINT"OR <Q> TO QUIT."
2790 LOCATE 23,2:PRINT"
     "
2800 LPRINT CHR$(12)
2810 I$=INKEY$
2820 IF I$="P" THEN 2860:   REM:PRINT ALL
2830 IF I$="D" THEN  2870:     REM:PRINT DATA
2840 IF I$="Q" THEN  END:     REM:QUIT
2850 GOTO 2810
2860 GOSUB 3540
2870 LPRINT"      FFRCTN      LOAD      FCOEFF    SPEED     SPECTEMP      TIME       POIN
T"
2880 FOR T= 1 TO LP
2890 VA=POINTS(T,0) :CALL ARPUTVAL'(ARN$,T,2,VA)
2900 LD=POINTS(T,1) :CALL ARPUTVAL'(ARN$,T,3,LD)
2910 SP=POINTS(T,2) :CALL ARPUTVAL'(ARN$,T,4,SP)
2920 TS=POINTS(T,3) :CALL ARPUTVAL'(ARN$,T,5,TS)
2930 VA=VA
2940 LD=ABS(LD)
2950 TIME=(T*30)/60 'TIME CONSTANT FOR 141 RPM
2960 MU=VA/LD :CALL ARPUTVAL'(ARN$,T,1,MU)
2970 LPRINT USING"#######.##";VA;LD;MU;SP;TS;TIME;T
```

```
2980 NEXT T
2990 CALL ARWRITE'(ARN$,TPF$)
3000 LPRINT CHR$(12)
3005 SCREEN 0,0,0:CLS
3010 END
3020 REM:DATA DELETE SUBROUTINE
3021 CLS
3030 LOCATE 25,2:PRINT"                                                                      "
3040 FOR Y= 1 TO 100
3050 LOCATE 3,15:PRINT"ALL TEST INFORMATION IS BEING DELETED."
3060 LOCATE 23,2:PRINT"PLEASE WAIT                  ";Y
3070 NEXT Y
3080 TDF$=" ":TTF$=" ":TPF$=" ":PM$=" ":DM$=" ":INFO$=" ":N=0:T%=0
3090 RETURN
3100 END
3110 REM:REAL TIME GRAPH SUBROUTINE
3120 REM:SET UP GRAPH PARAMETERS
3130 LP=0:UP=2!:LX=300:RX=660:TY=20:BY=100:YG=5:XG=4
3140 SX=RX-LX
3150 SF=SX/(RX-LX):PY=(UP-LP)/(BY-TY):XX=LX
3160 GOSUB 3200
3170 GOSUB 3280
3180 RETURN
3190 END
3200 REM:FRAME AND PLOT
3210 LINE (LX-1,TY-1)-(RX+1,BY+1),1,B
3220 FOR GY=TY TO BY STEP (BY-TY)/YG:LINE(LX-1,GY)-(LX-9,GY):NEXT GY
3230 FOR GX=LX TO RX STEP (RX-LX)/XG:LINE (GX,BY+1)-(GX,BY+5):NEXT GX
3240 RETURN
3250 END
3260 REM:CLEAR ACTIVE WINDOW AND DRAW GRID
3270 LINE (LX,TY)-(RX,BY),0,BF
3280 FOR GY=TY TO BY STEP ((BY-TY)/YG):LINE(RX,GY)-(LX,GY):NEXT GY
3290 FOR GX=LX TO RX STEP ((RX-LX)/XG):LINE(GX,BY)-(GX,TY):NEXT GX
3300 RETURN
3310 END
3320 REM:PLOTTING DATA POINTS
3330 IF XX>RX THEN XX=LX:GOSUB 3260
3340 PL=UP-MU
3350 YY=(PL/PY)+TY
3360 IF YY<TY THEN YY=TY
3370 IF YY>BY THEN YY=BY
3380 PSET (XX,YY),1
3390 XX=XX+1/SF
3400 RETURN
3410 END
3420 REM:PROGRAM ABORT SUBROUTINE
3430 CALL INTOFF
3440 CLS
3450 SYSTEM
3460 REM:REINITILIZE VARIABLES AND CLEAR SCREEN
3470 CLS
3480 MMX=0:MSPD=0:SSPD=0:T%=0:N=0:TMX=0:LP=0:LPOLD=0:CP=0:HR%=0:HR1%=0:HR2%=0:MI
N%=0:MIN1%=0:MIN2%=0:SEC%=0:SEC1%=0:SEC2%=0
3490 MLD1=0:SLD1=0:MVA1=0:SVA1=0
3500 MU=0:VA=0:LD=0:MLOAD=0:SLOAD=0:MFRCTNF=0:SFRCTNF=0:
3510 FIN=0:FOT=0:OTP=0:TSPEC=0:TFURN1=0:TFURN2=0:TFURN3=0:TFURN4=0:SPD=0:RTP=0:R
H=0:STAT%=0:SPCYC=0:MON%=0:MONITOR%=0:SP=0:TS=0
3520 RETURN
3530 END
3540 REM:PRINT SCREEN SUBROUTINE
3550 LOCATE 16,60:PRINT"                  "
3560 LOCATE 17,60:PRINT"                 "
3570 LOCATE 18,60:PRINT"               "
3580 LOCATE 17,55:PRINT"START: ";HR1%;":";MIN1%;":";SEC1%
```

```
3590 LOCATE 18,54:PRINT"FINISH: "HR2%;":";MIN2%;":";SEC2%
3600 DEF SEG:P=0:I=0:J=0:DIM ARRAY(3)
3610 DATA &H55
3620 DATA &HCD, &H05
3630 DATA &H5D
3640 DATA &HCB
3650 P=VARPTR(ARRAY(1)):FOR I=0 TO 4:READ J:POKE(P+I),J:NEXT I
3660 SUBRT=VARPTR(ARRAY(1)):CALL SUBRT
3670 LPRINT CHR$(12)
3680 ERASE ARRAY:RESTORE:DEF SEG=20
3690 RETURN
3700 END
```

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16. Abstract

This report describes two data acquisition computer programs which were developed for a high temperature friction and wear test apparatus, a tribometer. The raw data produced by the tribometer and the methods used to sample that data are explained. In addition, the instrumentation and computer hardware and software are presented. This report also shows how computer data acquisition was applied to increase convenience and productivity on a high temperature tribometer.

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