

AD-A128 713

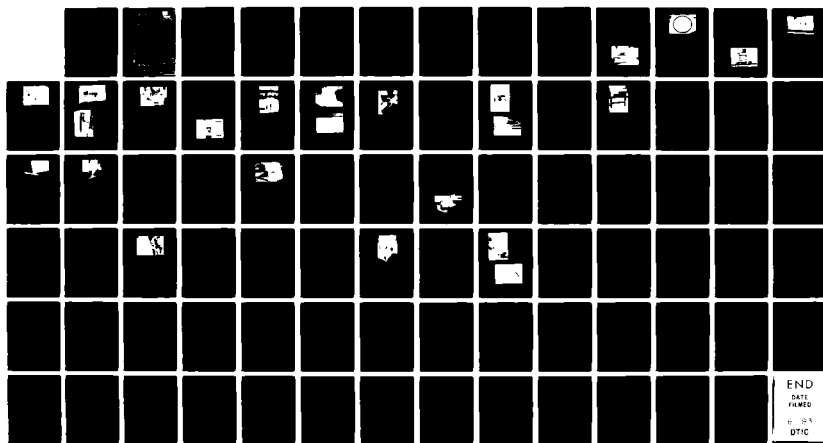
THE CRREL INSTRUMENTED VEHICLE: HARDWARE AND SOFTWARE
(U) COLD REGIONS RESEARCH AND ENGINEERING LAB HANOVER
NH G L BLAISDELL JAN 83 CRREL-SR-83-3

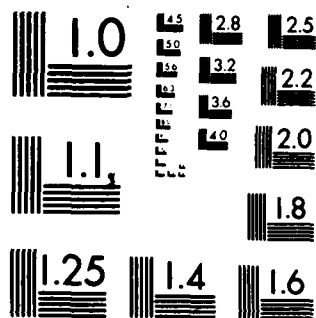
1/1

UNCLASSIFIED

F/G 13/6

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A 128 713

Special Report 83-3

January 1983

The CRREL Instrumented Vehicle Hardware and software

George L. Blaisdell

AD A 128 713

DTIC FILE COPY

Not available in DTIC form and
must be requested separately

DTIC
ELECTRIC
JUN 1 1983
A

For conversion of SI metric units to U.S. Customary
customary units of measurement consult ASTM
Standard E482, Metric Practice Guide, published
by the American Society for Testing and Materi-
als, 1916 Race St., Philadelphia, Pa. 19103.

DISCLAIMER NOTICE

**THIS DOCUMENT IS BEST QUALITY
PRACTICABLE. THE COPY FURNISHED
TO DTIC CONTAINED A SIGNIFICANT
NUMBER OF PAGES WHICH DO NOT
REPRODUCE LEGIBLY.**

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Special Report 83-3	2. GOVT ACCESSION NO. A128713	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE CRREL INSTRUMENTED VEHICLE: HARDWARE AND SOFTWARE		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s) George L. Blaisdell		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Cold Regions Research and Engineering Laboratory Hanover, New Hampshire 03755		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Office of the Chief of Engineers Washington, D.C. 20314		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA Project 4A762730AT42, Technical Area A, Work Unit 003
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE January 1983
		13. NUMBER OF PAGES 80
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Tires Vehicle forces Vehicle testing		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report gives a detailed description of the CRREL Instrumented Vehicle (CIV). The CIV is equipped with instrumentation to measure three mutually perpendicular forces acting at the interface between the front tires and any surface material. In addition, accurate wheel and vehicle speeds and rear axle torque are measured. The vehicle is equipped for front-wheel, rear-wheel or four-wheel drive. A dual brake system allows front-, rear- or four-wheel braking. A minicomputer-based data acquisition system is installed in the vehicle to control data gathering and to process the data. The software for data acquisition and manipulation and the interfacing techniques required are described.		

DD FORM 1473

1 JAN 73

EDITION OF 1 NOV 65 IS OBSOLETE

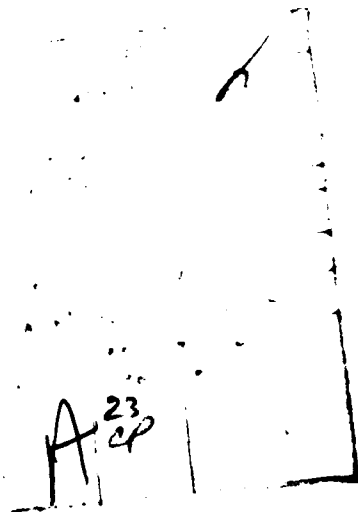
Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This report was prepared by George L. Blaisdell, Research Civil Engineer, of the Applied Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory. Funding was provided by DA Project 4A762730AT42, Design, Construction, and Operations Technology for Cold Regions; Technical Area A, Combat Operations Support; Work Unit 003, Battlefield Mobility in Cold Regions. The author expresses gratitude to Dr. William Harrison and Ronald Atkins for their careful technical reviews of this report.

The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of such commercial products.



CONTENTS

	<u>Page</u>
Abstract	1
Preface	11
Introduction	1
Vehicle hardware	2
Mechanical hardware	3
Electronic measuring equipment	8
Driver readout	13
Data acquisition and manipulation equipment	15
Load-cell signal conditioner	16
Velocity signal conditioner	19
Multiplexer and analog-digital converter	19
Minicomputer	23
Software	24
Interfacing	27
Operation	35
Basic functioning	35
Calibration procedures	36
Maintenance	43
Conclusion	43
Appendix A: Operating manuals	45
Appendix B: Schematic and wiring diagrams.....	47
Appendix C: Computer programs.....	55

ILLUSTRATIONS

Figure

1.	CRREL instrumented vehicle	2
2.	Warn lock-out axle	3
3.	Emergency drive lock control	4
4.	Dual brake system control valves	5
5.	Schematic of modified brake system	5
6.	Air-shock-absorber regulator panels	6
7.	Twelve-V d.c. to 115-V a.c. static inverter and battery	7
8.	Power strip in the instrumentation section of the vehicle	7
9.	Moment-compensated triaxial load cell	8
10.	Axes convention used with the triaxial load cells.	9
11.	Pulse pickup proximity detector and steel nodes on the brake disc	9
12.	Rear propeller-shaft-mounted torque cell and pulse pickup proximity detector	10
13.	Fifth-wheel assembly	11
14.	Fifth-wheel tire with a chain installed for operating on materials with low coefficients of friction	12
15.	Driver readout unit	14

	Page
16. Block diagram of the instrumentation installed in the CIV	15
17. Data acquisition equipment	16
18. Series 300 strain-gage mode card	17
19. Series 300 reference supply, relay driver card ...	18
20. Series 400 last-channel switches	20
21. Series 400 throughput-rate switches	21
22. Hewlett-Packard 9845 minicomputer	24
23. Sixteen-bit-parallel interface and cable	27
24. Bit assignments for the R5-out interface register	28
25. Bit assignments for the R5-in interface register	29
26. Cable connections between the Series 300 and 400 peripherals and the bit-parallel interface ...	30
27. Sample sequence timing	33
28. External power receptacle and switch	36
29. Shunt-resistor calibration wheel	40
30. Lubrication of the axle shaft	42
B1. Wiring convention to and from the triaxial load cells	47
B2. Wiring convention to and from the pulse pickups ..	47
B3. Wiring convention to and from the torque cell	48
B4. Wiring convention to and from the fifth-wheel assembly	48
B5. Input and output wiring to the Series 300 card edge connector	49
B6. Schematic of the velocity signal conditioner	50
B7. Input wiring to the Series 400 card edge connector	51
B8. Input wiring to the fifth-wheel readout	51
B9. Input wiring to the pulse counters	52
B10. Input wiring to the digital panel meters	52
B11. Selector switch wiring	53
B12. Typical channel from the eight channel differential amplifier	53
B13. Input and output wiring to the driver readout differential amplifier	54
B14. Wiring diagram for additional cables	54

TABLES

Table

1. Shunt-resistor load equivalent values	18
2. Gain code - full scale sensitivity values	23
3. Jumper wires installed on the 98032A interface ...	31

THE CRREL INSTRUMENTED VEHICLE:

HARDWARE AND SOFTWARE

George L. Blaisdell

INTRODUCTION

Since the advent of the pneumatic tire, a sophisticated system of transportation has developed to the point where nearly all of our functions are in some way affected by vehicular transportation. For nearly a century continued efforts have been directed towards making faster, safer and more efficient vehicles. With this has come great refinements in tire technology and our understanding of vehicle mobility. However, tire design, evaluation and testing methods are still the subjects of a large number of studies and will remain so in the foreseeable future. Likewise, prediction of vehicle mobility is still in its developmental stages.

The quantities of traction and motion resistance have characteristically been used to establish how mobile (or immobile) a vehicle is, especially on deformable surface materials. It is reasonable to conclude that these quantities are really measures of tire performance, provided the vehicle is adequately powered. In the past, tests to evaluate traction involved using a dynamometer (hold-back) vehicle equipped with a load-cell drawbar. Traction was then calculated from the measured drawbar pull, the motion resistance and appropriate correction factors. Motion resistance was determined from vehicle deceleration and by towing or pushing the vehicle.

Traction and motion resistance as quantities are really just measures of the forces between the vehicle's tires and their supporting surface. However, past testing measured quantities that are physically removed from the vehicle/material interface. With the development of a sophisticated

load cell and a specially equipped vehicle, direct measurement of these forces is now possible.

This report will describe in detail the equipment and operation of the CRREL Instrumented Vehicle (CIV), which is equipped with these load cells. This information is meant to supplement the operation manuals provided by the manufacturers of the individual pieces of equipment (Appendix A). Points that are either omitted or not clear in these manuals and the techniques involved with operating all of the equipment together are emphasized in this report.

VEHICLE HARDWARE

The CRREL Instrumented Vehicle was originally constructed by the Nevada Automotive Test Center (NATC) in Carson City, Nevada, and is based on a 1977 AMC Jeep Cherokee frame and chassis (Fig. 1). The stock vehicle was modified by NATC in May of 1978 under contract with the San Dimas Equipment Development Center of the U.S. Forest Service, San Dimas, California. Further mechanical modifications were made to the vehicle by NATC in February of 1980 under the direction of CRREL. Subsequently, electronic modifications have been made by CRREL.



Figure 1. CRREL instrumented vehicle.

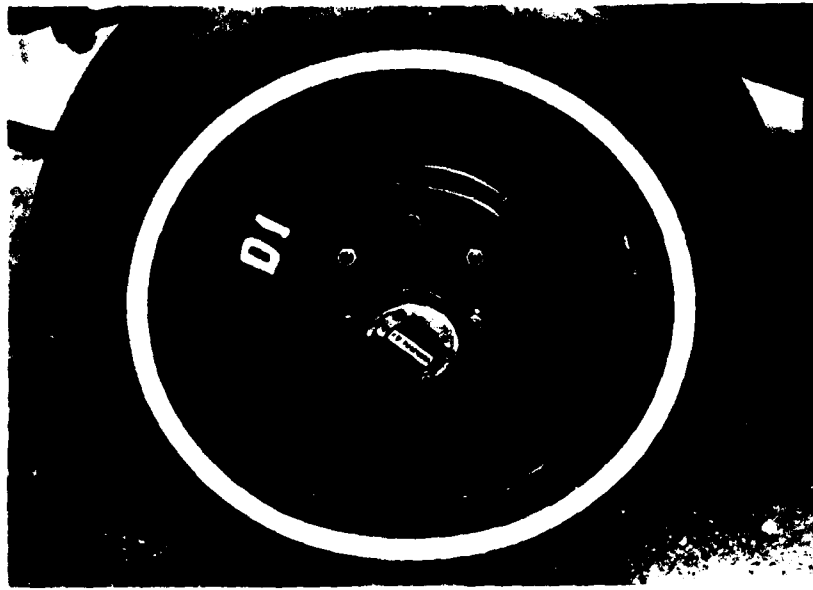


Figure 2. Warn lock-out axle.

Mechanical hardware

Special equipment was added to the vehicle to facilitate specific test configurations and to provide support for the data acquisition instrumentation. This included changes to the hubs, the transfer case, the brakes, the shock absorbers, the electrical system and the seats.

The instrumented vehicle is equipped with Warn locking hubs on all four axles (Fig. 2). This allows the vehicle to be operated as a four-wheel-drive, rear-wheel-drive or front-wheel-drive unit. This versatility is made possible by the Quadra-Trac full-time four-wheel-drive system, which was stock equipment on the vehicle before its modification. With the Quadra-Trac system, engine torque is delivered from the transmission to a controlled-slip third differential (or transfer case), which is located directly behind the transmission. The transfer case, in turn, transmits torque along front and rear propeller shafts to the differentials located between the front and rear sets of wheels. The transfer case ensures that some torque is sent to both front and rear propeller shafts. This results in drive to at least one front and one rear wheel (due to breakdown of torque at the front and rear differentials).

With all four Warn hubs locked, the vehicle operates as a normal full-time four-wheel-drive unit. It can be driven at highway speeds or

used with Jeep's low-range reduction unit (gear reduction) for greater engine braking, control and torque at low vehicle speeds.

Two-wheel drive (front or rear) is not as straightforward. Since the Quadra-Trac transfer case sends torque to both propellor shafts in proportion to their needs, having two hubs (both front or both rear) in the free position causes them to appear to be most in need of torque. The transfer case thus sends all of the torque to the differential of the free axles, which produces no vehicle movement. However, the vehicle is equipped with an emergency drive system (Fig. 3), a stock item controlled by a switch in the glove box. When engaged, the system nullifies the differential action of the transfer case. An equivalent amount of torque is then sent to each propellor shaft, and two-wheel drive is achieved.

A dual-brake system has also been built into the CIV. This system allows hydraulic pressure to be applied (through the standard brake pedal) to all four disc brakes or only to the front brakes or rear brakes. The valves for changing the brake configuration are located on the floor at the left side of the driver's seat (Fig. 4). To actuate a set of brakes, the appropriate pressure valve is opened (counterclockwise rotation) and its corresponding bleed valve is closed. Caution should be exercised to ensure that the vehicle is not totally without brakes (both pressure valves closed). A schematic of the brake system is provided in Figure 5.

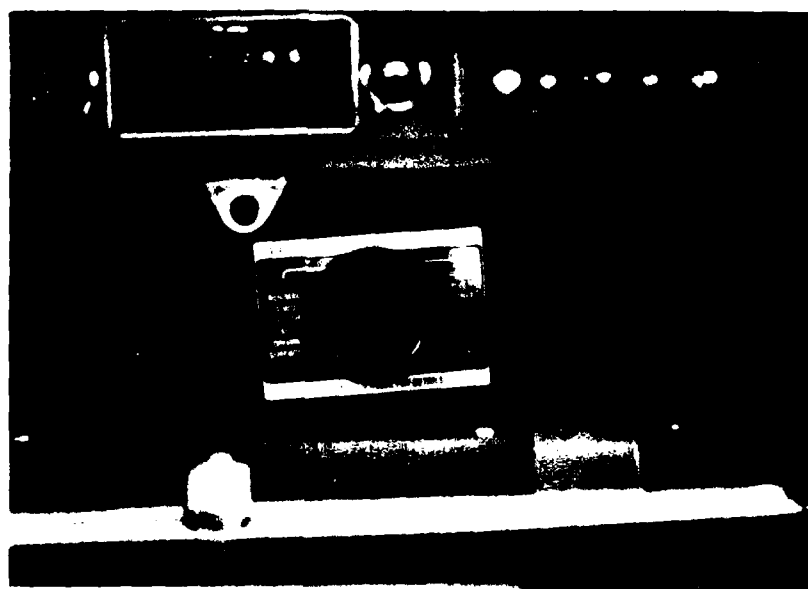


Figure 3. Emergency drive lock control.

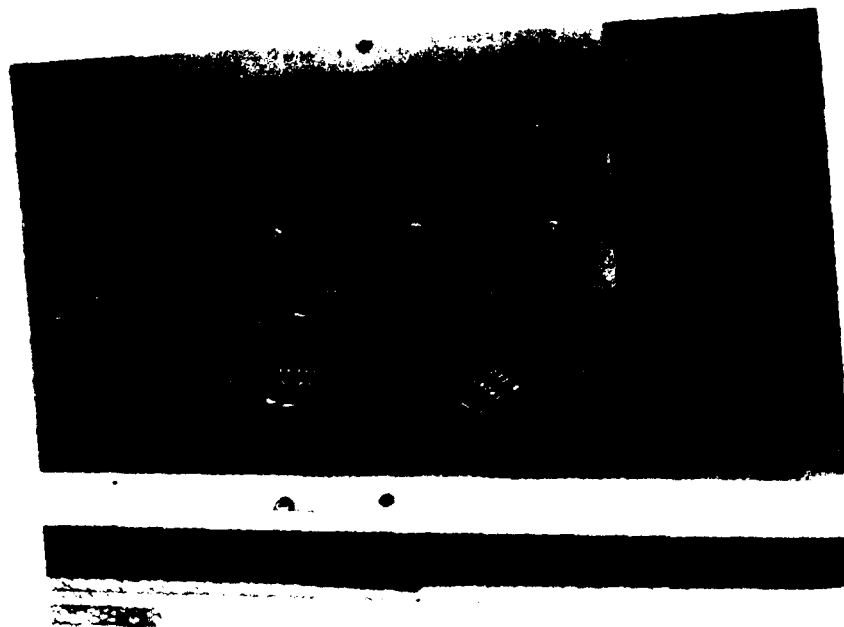


Figure 4. Dual brake system control valves.

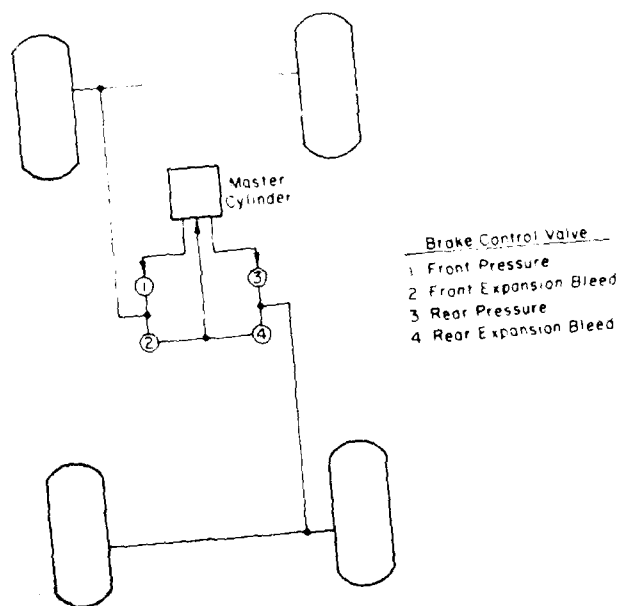


Figure 5. Schematic of modified brake system.

Four air-adjustable shock absorbers take the place of the standard shocks. These are connected in pairs (front two and rear two) to a vacuum-actuated air compressor, which is controlled by two regulator panels (Fig. 6). This system allows the vertical force on the front or rear

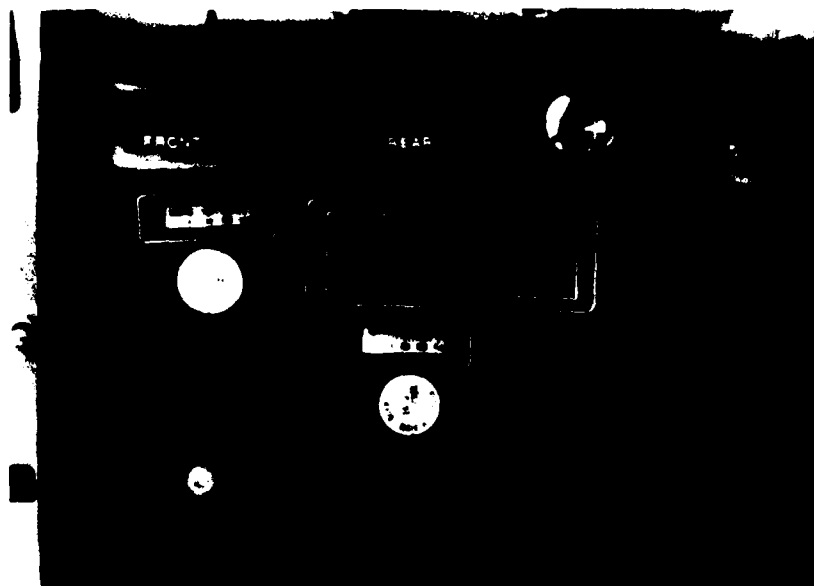


Figure 6. Air-shock-absorber regulator panels.

wheels to be varied by up to 20 lbs through inflation of one set of shocks and deflation of the other set. In addition, greater wheel-well clearance for certain oversize tires can be obtained by inflating the shock absorbers. Vehicle trim is also controlled by appropriate inflation and deflation of the shocks. This is important for aligning the load-cell axes properly for the tire size being tested.

Electrical power (500 W) is supplied for most of the instrumentation from a 12-V d.c. to 115-V a.c. sine-wave static inverter (Topaz type GZ, Fig. 7). The inverter is mounted in the cargo area of the CIV next to a 12-V battery that provides its input. The battery is charged by an auxiliary oversize alternator in the vehicle, and the battery's charge is monitored with a meter located in the instrumentation section of the vehicle. Output from the inverter is sent to an outlet block located in the instrumentation section of the vehicle (Fig. 8).

The vehicle is also equipped with swivel seats for both the driver and passenger to allow them to operate the vehicle and the instrumentation. An overhead 110-V a.c. light has been installed for use during overcast or night conditions. Shock-mounted tables are provided for all of the instrumentation.



Figure 7. Twelve-V d.c. to 115-V a.c. static inverter and battery.



Figure 8. Power strip in the instrumentation section of the vehicle.



Figure 9. Moment-compensated triaxial load cell.

Electronic measuring equipment

Instrumentation has been added to the vehicle to obtain measurements of pertinent parameters during operation. Descriptions of this equipment and their locations are detailed in this section. Wiring diagrams for this instrumentation are contained in Appendix B.

Central to the CIV are the moment-compensated, triaxial load cells mounted in the two front-wheel assemblies.¹ The load cells are mounted so that they become a vertical section of the cantilevered rod that supports the wheel (Fig. 9). Since the load cells add 10 inches (5 inches each) to the overall wheelbase width, each of the front two axles from the steering universal out were replaced with longer ones. Each load cell is annular to allow the axle to pass through it.

The load cells each contain three, complete, strain-gage Wheatstone bridges that measure forces acting in three, mutually perpendicular directions. These directions are oriented as shown in Figure 10 and will be referred to as vertical, longitudinal and side directions. Moment

¹ Shoberg, R.S. and Wallace, B. (1975) A triaxial automotive wheel force and moment transducer. Society of Automotive Engineers, Paper No. 750049, 25 p.

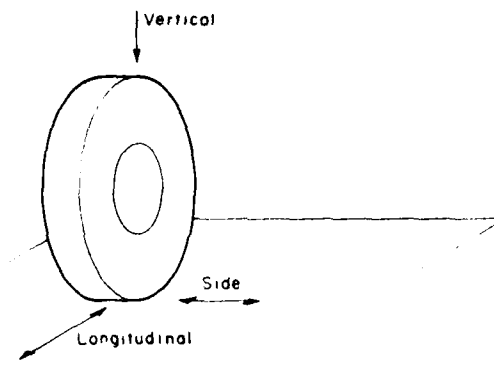


Figure 10. Axes convention used with the triaxial load cells.

compensation is performed by the strain-gage bridges so that the forces read by the bridges represent the forces acting at the tire contact patch. The compensation is such that a torque or a couple applied to the tire registers no force on the load cell.

Each front brake disc is equipped with 100 equally spaced steel nodes on an 8-inch-diameter circle. A counting proximity detector (Red Lion

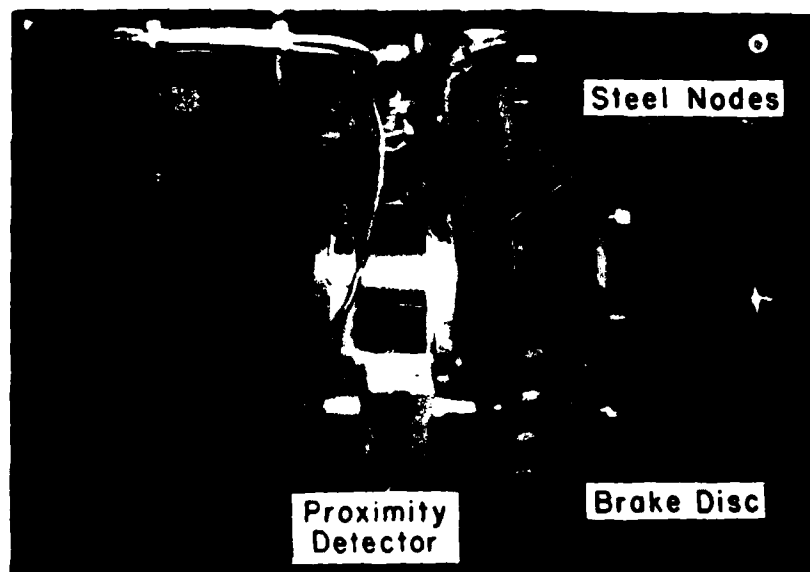


Figure 11. Pulse pickup proximity detector and steel nodes on the brake disc.

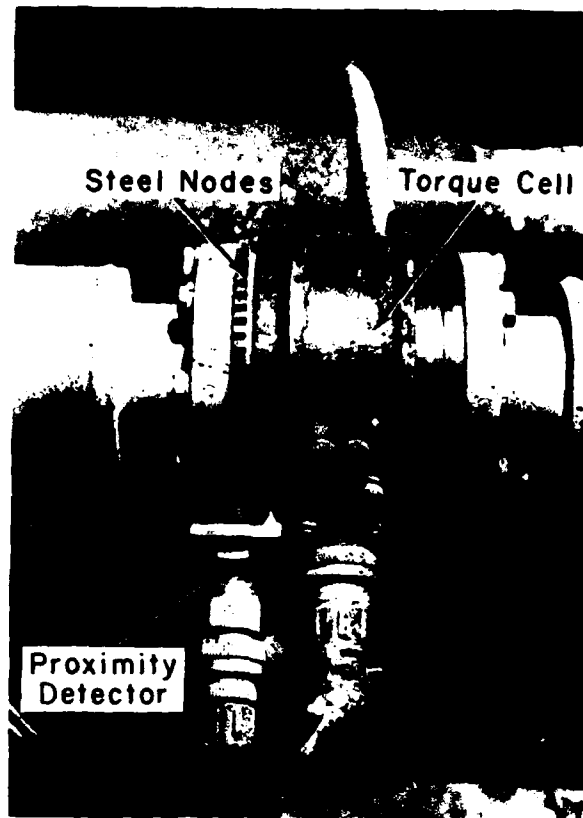
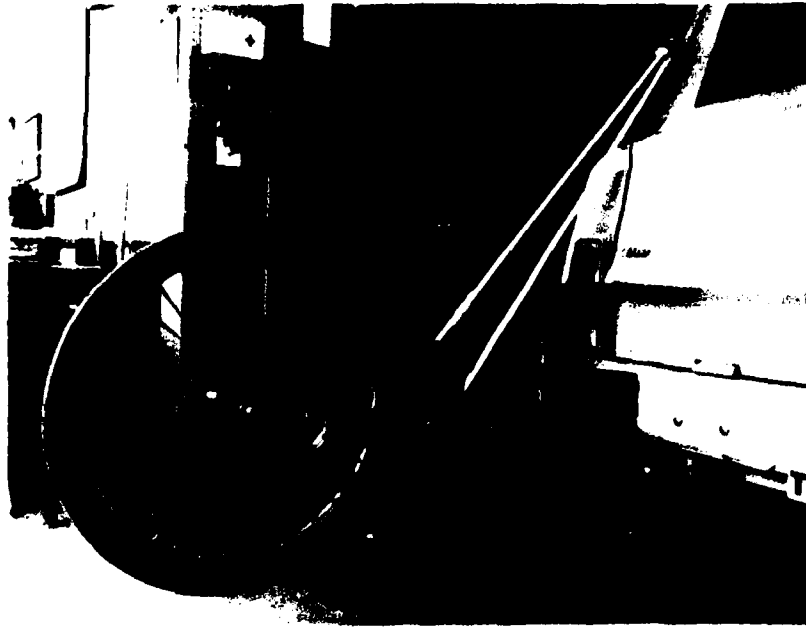


Figure 12. Rear propellor-shaft-mounted torque cell and pulse pickup proximity detector.

Controls Prox-Stik Model PSA-EF) is mounted within 0.05 inches of the ends of the nodes (Fig. 11). This signal yields exact individual wheel distance and velocity values. A similar arrangement (using an Airpax 300 Series control tachometer) on the rear propeller shaft measures the average rear-wheel speed (Fig. 12).

A strain-gage torque sensor (Lebow model 1228) is also mounted on the rear propeller shaft (Fig. 12). Its signal can be used to measure the energy input to the rear wheels during both driving and braking.

To the rear bumper is attached a fifth-wheel assembly for measuring vehicle speed and distance traveled (Fig. 13). The unit consists of a 26-inch by 2.125-inch pneumatic tire mounted on a heavy-duty rim and secured in a mounting frame. Attached to the wheel axle is a tachometer generator (for recording speed) and a transmitter with an etched metal



a. Electric winch pickup.



b. Control switch.

Figure 13. Fifth-wheel assembly.

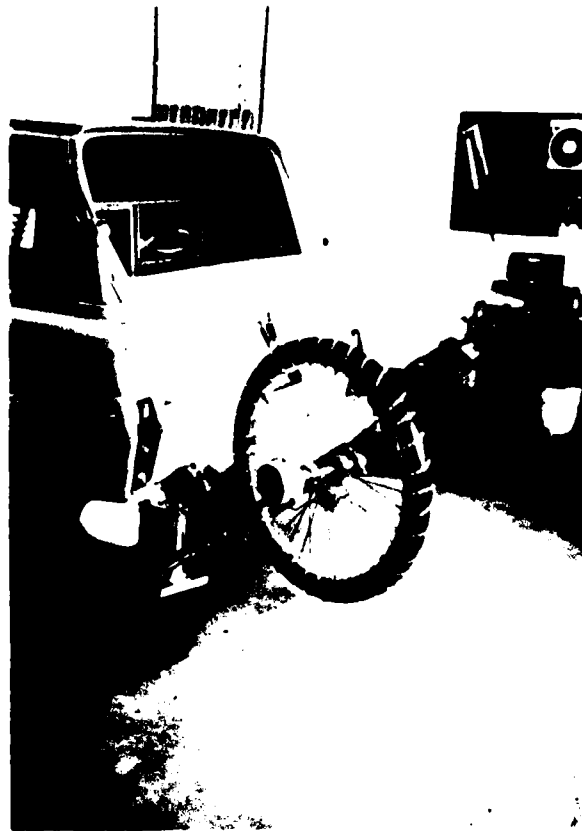


Figure 14. Fifth-wheel tire with a chain installed for operating on materials with low coefficients of friction.

optical encoder for a 50-pulse-per-foot output (for measuring distance). A tire pressure of 34 psi is required for an accurate distance measurement, and a tire change is required when the tire has worn to within 1/32 inch of the bottom of the tread grooves. The fifth-wheel assembly must not be left in its operating position (down) when the vehicle is backed up; the wheel assembly will jackknife and become damaged.

For operating on ice and other materials with low coefficients of friction, a chain has been installed on the tire to eliminate slippage (Fig. 14). This increases the wheel circumference, and the system must be recalibrated to yield accurate speed and distance measurements.

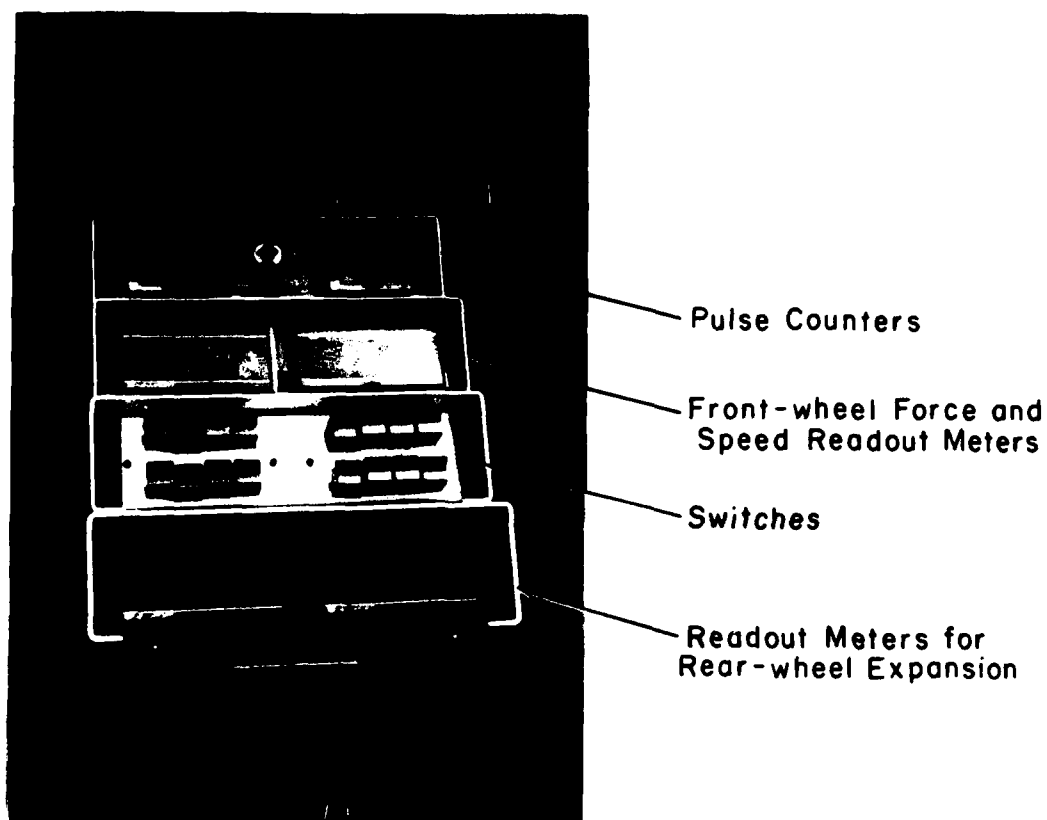
Driver readout

To allow immediate feedback of force and velocity values and to allow the use of a particular measured quantity as a control parameter, a driver readout display unit has been installed (Fig. 15). The main unit consists of three pulse counters (for the front two wheels and the fifth wheel), a right- and left-side digital panel meter (DPM), and two sets of switches (right and left side). Each switch set contains four push-button, double-pole, double-throw switches, which select wheel speed or vertical, longitudinal, or side force. A second set of switches and DPMs are present to accommodate future instrumentation of the rear wheels. The driver readout unit is mounted on the floor between the driver and passenger seats and can be easily read by the vehicle operator. Fifth-wheel speed is read on a digital meter, which is mounted on the top of the dash directly in front of the driver (Fig. 15b, Fig. B8). This allows the operator to maintain a particular vehicle speed without diverting his eyesight from the test course.

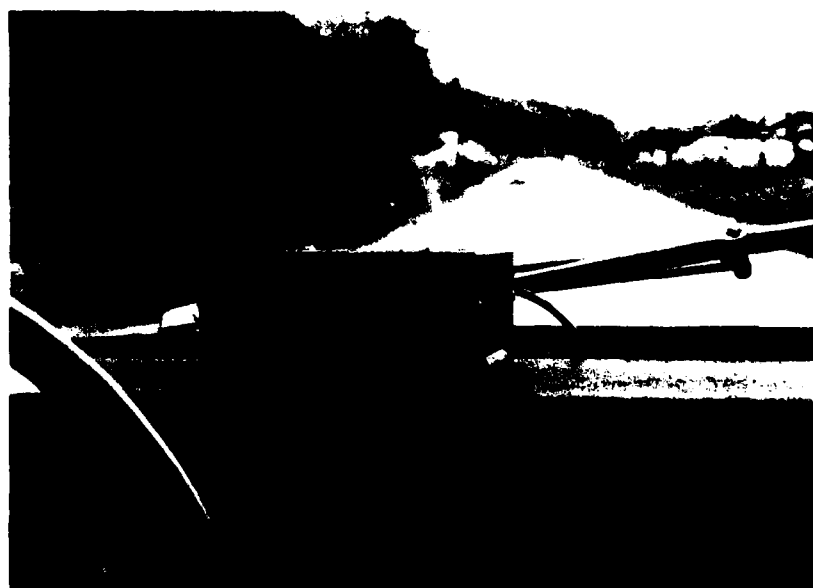
The pulse counters require a 12 V d.c. signal while the DPMs need 110 V a.c. Both are supplied from the velocity signal conditioner unit (described later) and can be switched with the master switch on the front of the conditioner. The fifth-wheel unit operates on 12 V d.c., which is supplied by a hard-wire connection to the vehicle's main battery. A switch on the readout display unit activates the whole fifth-wheel assembly. A switch on the pulse counter box (Fig. B9) is used to interrupt the input pulse train to allow pulse count recording for a discrete interval. The total distance can be calculated from the pulse count; the fifth-wheel outputs 50 pulses per foot of travel (the pulse counter reads every other pulse on the fifth-wheel). Thus the total count divided by 25 yields the distance traveled in feet. The front wheels output 100 pulses per revolution, so the rolling circumference of the tires is necessary to convert the number of front wheel pulses to distance.

The DPMs receive their input signal (Fig. B10) by way of the selector switches (Fig. B11). When displaying load-cell readings the DPMs read in hundredths of millivolts and represent the actual force in pounds. A decimal point is added to the DPM display when a velocity channel is displayed; the readout is in miles per hour.

To facilitate driver readout in actual pounds of force and speed, the input signal, piggybacked from the input leads to the Series 400



a. Equipment mounted on the floor.



b. Fifth-wheel speed readout mounted on the dash.

Figure 15. Driver readout unit.

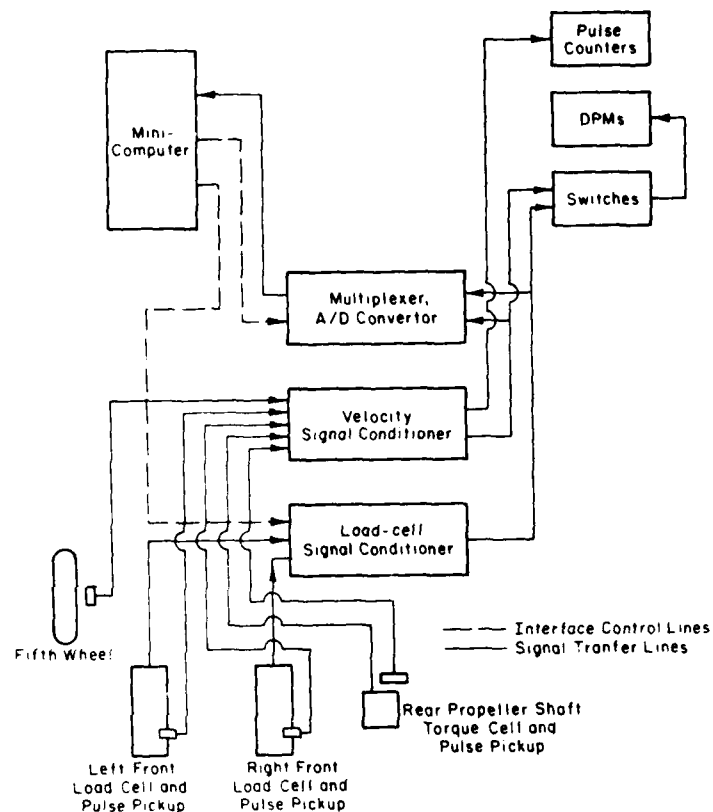


Figure 16. Block diagram of the instrumentation installed in the CIV.

multiplexer (described later), must be zero-adjusted and scaled. This is accomplished by a differential amplifier, which, for space and convenience considerations, was constructed on a blank Series 400 card and is housed in the multiplexer box. A schematic and connector instructions are supplied in Figures B12 and B13.

DATA ACQUISITION AND MANIPULATION EQUIPMENT

Up to this point the description of the CIV has involved basically nonremovable or integral parts of the vehicle (the external fifth-wheel assembly is removable). If the proper inputs to and outputs from the measuring devices are satisfied, any system for readout and recording could be attached. This section contains a description of the present data acquisition equipment and its operation. Figure 16 is a general block diagram of this equipment.

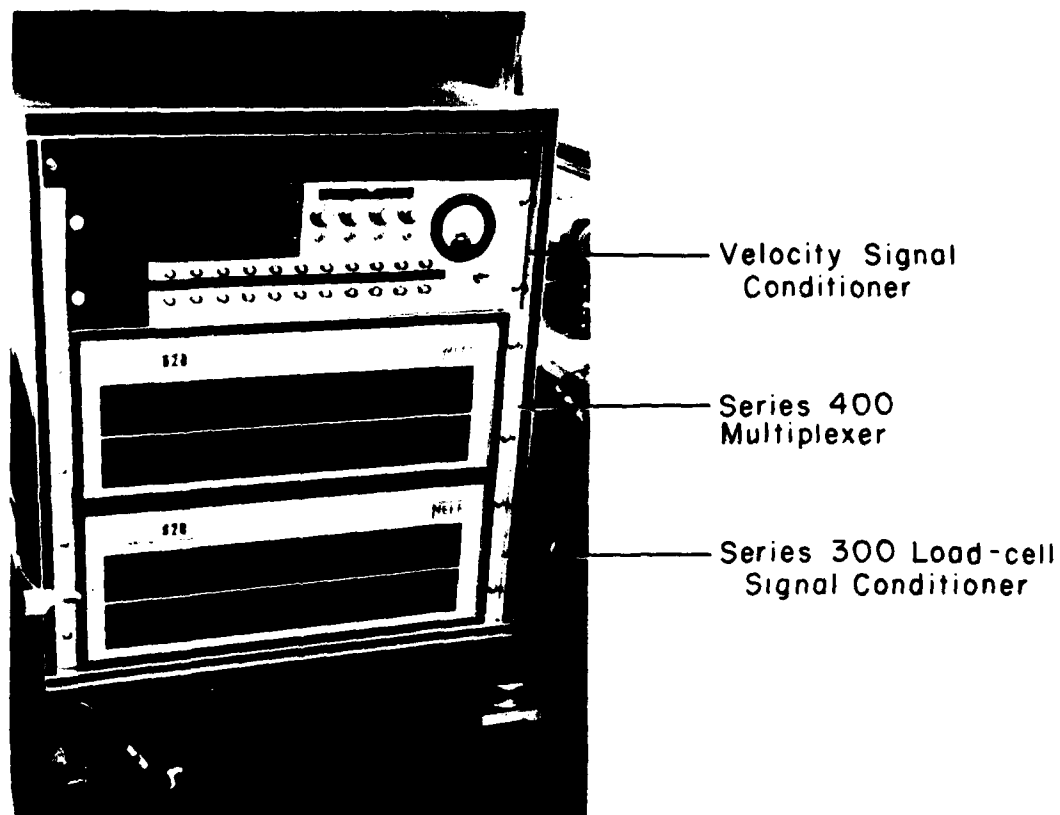


Figure 17. Data acquisition equipment.

Eleven channels of information have been identified; seven are force measurements from load cells (strain-gage bridges) and four are velocity measurements from a tachometer generator or pulse pickups. Each load-cell and pulse-pickup channel requires an excitation or power source in order to function. This power is supplied by two signal conditioners, one for the load cells and the other to configure the velocity channels.

Load-cell signal conditioner

The load-cell signal conditioner is a Neff Series 300 model (Fig. 17) and allows each channel to be separately configured for a particular transducer type. The signal conditioner provides a constant-voltage (2-10 V d.c.) or a constant current (2-50 mA) excitation. It also furnishes circuitry for bridge completion and remote-control calibration.

Connections to the Series 300 from the load cells are hard-wired in groups of four channels to a screw terminal p-c card edge connector

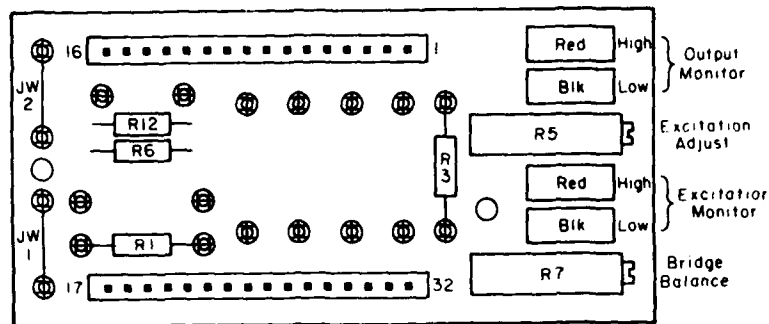


Figure 18. Series 300 strain-gage mode card.

accessible from the rear of the unit. A typical connector and the key to attachment is illustrated in Figure B5.

The Series 300 is equipped with four-channel input conditioning plug-in circuit cards. Each of these cards contains an excitation power supply, relays and calibration circuits for each of the four channels it conditions. Four mode cards may be attached to each input conditioning card. The mode cards provide circuitry for bridge completion and balance, and positions for mounting shunt resistors. Figure 18 shows the strain-gage mode card as it is configured for each of the load-cell channels. Excitation is monitored from the front of the card and adjusted with resistor R5. Likewise, transducer output can be monitored on the mode card and the bridge balanced with R7. The system is normally adjusted to provide a 10-V d.c. excitation to each of the seven load-cell channels.

Output from the Series 300 comes from the rear-mounted card-edge connectors and consists of high and low signal terminals and cable shield connections (Fig. B5).

The Series 300 can be operated in either a local or remote mode as chosen by switch SW5 on the reference supply, relay driver card (Fig. 19). In the local mode an LED indicator and switches SW1 - SW4 are activated. Relay K101 is activated by placing switch SW1 in position 1 (not position 0 as indicated in the Neff Series 300 manual). This enables voltage calibration of each channel when the optional voltage dividers are installed. The present system does not have these dividers. When K101 is activated, a short is placed across the output leads, allowing a system zero-point reference.

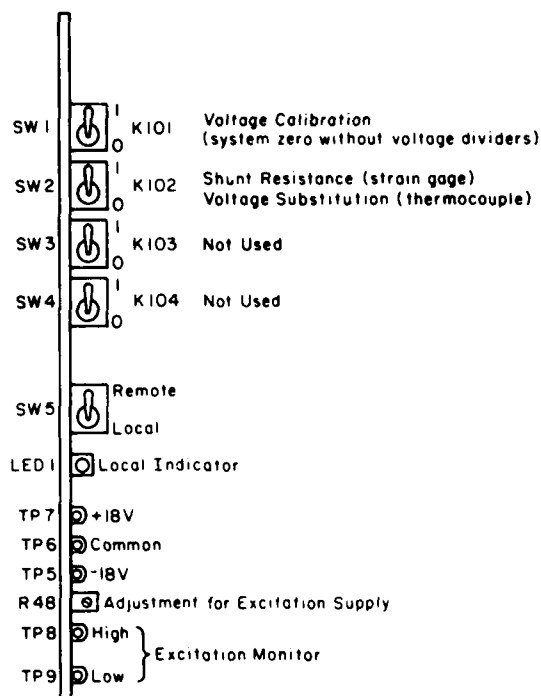


Figure 19. Series 300 reference supply, relay driver card (0 = off, 1 = on).

Table 1. Shunt-resistor load equivalent values.

Channel	Signal	Resistor Value (K Ω)	Load Equivalent (lbs)
1	R. Vertical	150	2124
2	R. Longitudinal	150	2001
3	R. Side	300	1992
5	L. Vertical	150	2184
6	L. Longitudinal	150	2011
7	L. Side	300	2108
9	Torque Cell	60	594 (in-lbs)

The activation of relay K102 puts resistor R1 (Fig. 18) into the bridge parallel with one arm of the bridge. This enables single-point shunt calibration, provided the load equivalent of the resistor has been calculated and the bridge has been balanced (zero output) before K102 is activated. It is important to zero the bridge first to avoid the possibility of nonlinear calibration. Shunt values for each load-cell channel

on the CIV are listed in Table 1. Relays K103 and K104 are not used with the standard input conditioning cards in the CIV.

Switches SW1 - SW4 can also be operated remotely if SW5 is in the remote position. This is accomplished with instructions entered through an interface (discussed later) connected to port J15 (CAL ADDR in) located on the back of the Series 300.

Velocity signal conditioner

A second signal conditioner (Fig. 17) provides the necessary circuitry for the velocity channels. This unit was initially constructed by NATC and has subsequently been modified by CRRFL to function properly with the new instrumentation. The velocity signal conditioner converts the incoming pulse frequencies (from the proximity detectors) to a d.c. voltage, which represents speed. Three of these converters are present, one for each front wheel and one for the rear propeller shaft. Conversion from frequency to d.c. for the fifth wheel is not necessary since an analog signal is output from the assembly's tachometer generator. Circuitry is provided for making scaling adjustments (located on the front face) and for filtering (switches on the back panel). Input and output from the velocity signal conditioner is via connectors located on the back of the unit (Fig. B6).

Multiplexer and analog-digital converter

Conditioned analog (d.c. voltage) signals from each of the 11 data channels are output from the two signal conditioners into a Neff Series 400 multiplexer (Fig. 17). The Series 400 contains a high-speed analog-signal multiplexer, programmable gain amplifiers, a sample-and-hold amplifier, an analog-to-digital converter and logic for interface control. The unit houses differential multiplexer plug-in circuit cards containing 10-Hz low-pass filters and remote-controlled channel switches for 16 channels. The output from the multiplexer card is applied to a two-stage programmable gain amplifier, which allows full-scale input sensitivities from 5 mV to 10.24 V. The signal is then passed through a sampling-rate filter and a sample-and-hold amplifier before analog-to-digital conversion and output.

Input to the Series 400 from the Series 300 and velocity signal conditioners is hard-wired in groups of 16 channels to a screw terminal p-c card edge connector located in the rear of the unit. Attachment instructions are illustrated in Fig. B7.

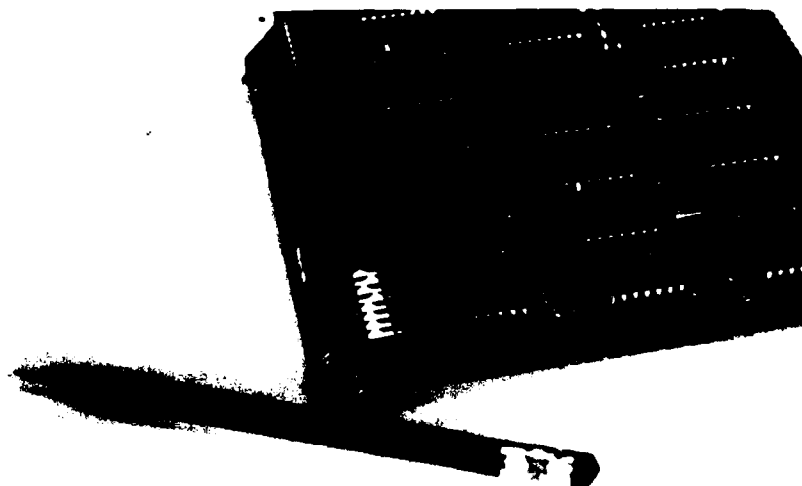


Figure 20. Series 400 last-channel switches.

Unlike the Series 300, the Series 400 can only be operated in remote mode. An optional control panel (not present in the CIV) would allow some local control.

The Series 400 can be operated in one of two channel addressing modes, sequential or random. During sequential operation, data sampling begins at channel 0 and continues until the last channel is sampled. The channel address pointer is automatically advanced by one each time a channel is sampled until the last channel is converted, at which point the address pointer is reset to channel 0. The number of the last channel to be sampled is set on the last-channel switches (Fig. 20) located on the logic control card in slot 2 of the card cage. The switches consist of a miniature eight-toggle assembly. Each switch, when set to the open position, generates a logic one while the closed position produces a logic zero. The last channel to be sampled is then chosen by producing a base two number (ones and zeros), which represents the last-channel address. For convenience, base ten numbers are listed beside each toggle. The last-channel address can be easily set by adding the appropriate combination of base ten numbers and putting each of their toggles to the open position, with all others closed. Channel addresses begin with 0, so that for a system with

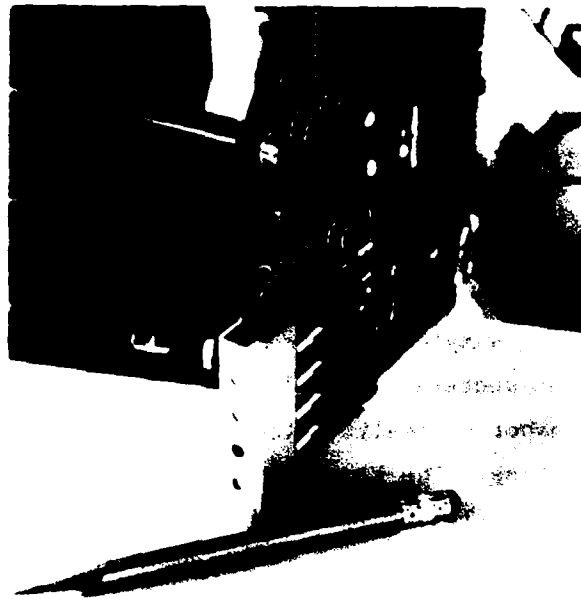


Figure 21. Series 400 throughput-rate switches.

52 input signals the last channel address is 51. (Last-channel switches for this example would have toggles set open for the base ten numbers 1, 2, 16 and 32, while all the remaining toggles would be in the closed position.)

Random mode addressing requires that the system be fed a channel address each time a request-for-conversion is initiated. When set to random mode the Series 400 deactivates the last-channel switches.

The actual time required to sample a channel is governed by the throughput-rate switches (Fig. 21), which are mounted on the filter, sample-and-hold card in slot 4 of the card cage. These push-button switches represent (from top to bottom) 1.25-, 2.5-, 5.0- and 10-kHz conversion rates. Selection of a throughput rate not only sets the per channel sampling time but automatically adjusts a sampling-rate filter to an appropriate bandwidth for that conversion rate.

The Series 400, as mentioned previously, is operated remotely through an interface. Details of operation via the interface are covered in a separate section; however, the operation of the Series 400 is briefly covered here to avoid confusion with interfacing instructions and functioning.

Before actual sampling, the correct throughput-rate and last-channel switches must be set. To select the proper conversion rate, the total number of channels to be sampled must be multiplied by the desired scan rate (time between successive samples on one channel). This number indicates the total number of readings (conversion cycles) that must be performed per unit of time. The throughput-rate switch must be set so that conversions are accomplished at this speed or faster. The last-channel switches should indicate a number that is one less than the total number of channels to be scanned.

Operating the multiplexer in a sequential addressing mode requires that the SEQ/RAN line be set to a positive-true level (binary 1). This instruction resets the address pointer to channel 0 and activates the last-channel switches. A gain code is then read, which represents the magnitude of the expected full-scale analog input. Gain codes and their corresponding maximum sensitivity levels are shown in Table 2. Sampling may now begin by issuing a positive-true level on the STEP/STROBE line. When the STEP/STROBE line is set, the Series 400 begins the conversion cycle and may not be interrupted again until the system has output a data word and has issued an EOC (end of conversion) pulse. On the trailing edge of the EOC pulse, the channel address pointer is advanced by one, and the system can again accept a STEP/STROBE input. Data may be read on the trailing edge of the EOC pulse, even if a new conversion cycle has been initiated.

Random mode sampling is accomplished by not setting the SEQ/RAN line (binary 0). The gain code and channel address must be specified for each conversion request and may be issued before or with each STEP/STROBE pulse. As with sequential operation, an EOC pulse follows output of a data word and a new conversion cycle may be initiated.

The minimum time required to complete a scan (one sample taken for each channel in the system) is found by multiplying the number of channels by the selected throughput sampling time. This assumes that STEP/STROBE pulses are issued immediately after an EOC pulse is received. Sampling

Table 2. Gain code - full scale sensitivity values

Gain code		Gain	Sensitivity
Base 10	Binary		
11	1011	2048	5 mV
10	1010	1024	10 mV
9	1001	512	20 mV
8	1000	256	40 mV
7	0111	128	80 mV
6	0110	64	160 mV
5	0101	32	320 mV
4	0100	16	640 mV
3	0011	8	1.28 V
2	0010	4	2.56 V
1	0001	2	5.12 V
0	0000	1	10.24 V

rates (channel-to-channel delay) can then be governed by the time between consecutive STEP/STROBE pulses. The scan rate is a function of the time used to sample all the channels plus any delay inserted between the EOC pulse received from the last channel and the STEP/STROBE pulse for the first channel.

Output from the Series 400 consists of a digitized two's-complement 12-bit word. The output word is available to the interface on the output register during the channel period following analog-to-digital conversion. The output interface is connected through port J6 on the rear of the Series 400. Input instructions during remote operation of the multiplexer are transferred via the interface through port I8.

Minicomputer

The Series 300 and 400 are operated in the remote mode by a Hewlett-Packard 9845B minicomputer (Fig. 22). The computer, through a 16-bit parallel interface, sends instructions that set appropriate switches, furnish sequential or random sampling, gain and channel address information, and initiate conversion cycles. Data words sent back by the Series 400 are read and stored for later manipulation.

The 9845 has two 217K-byte tape cartridge drives, which are used for mass storage of data and programs. A 187K-byte read-write memory is available for working semiconductor memory. Data and programs can be displayed with the computer's 20-line, 80-column CRT or the 80-column internal



Figure 22. Hewlett-Packard 9845 minicomputer.

thermal printer. A graphics read-only-memory (ROM) allows data plots to be generated and outputs in video or hard copy form. The 9845 also has a real-time clock, which is used to measure time intervals accurately and to generate interrupts for initiating a scan or conversion cycle. The entire data acquisition system is operated through the software instructions used by the computer.

SOFTWARE

The HP9845 computer programs for use with the CIV are written in BASIC programming language. Two primary programs are present, one which controls and acquires data during operation of the vehicle (DATAQ) and one for reading and manipulating stored data (READ-2). These programs are listed in Appendix C.

The programs are written in an interactive mode and prompt the user for the required input. Where convenient, a menu is provided to allow the user to choose the desired routine.

The data acquisition program (DATAQ) is divided into a main program, which gathers documentary information about the locality and conditions present in the test area, and several subprograms. The main program begins

by checking to see that the data storage cartridge (tape drive T14 on the 9845) is not full (42 files). If full the program directs the user through a cartridge-changing procedure.

The user must next choose whether to proceed into the main program or to run the calibration subprogram (Calibration) (line 360). The purpose of the calibration subprogram is to take zero-load, zero-speed readings and shunt-resistance, fixed-speed readings and to calculate the appropriate scale factors for each channel. The subprogram stores the zeros and scale factors in a file which always begins with the letter C. A new calibration file should be created each time the data acquisition system is turned on, the front tires are changed, or the air pressure in the shock absorbers is changed.

Following input and printout of the documentary data (lines 400-1250), a channel sampling subprogram (Scan) is called (line 1260), which performs the actual data conversion and transfer. Subprogram Scan is set up with a series of two interrupts. The 9845 real-time clock is used to generate interrupts at a user-chosen rate. This rate represents the frequency with which a call is made to the subroutine Sample, which sequentially collects a data word from each channel in the system. The clock interrupts a meaningless infinite loop (lines 1890 and 1900), which allows the Sample routine to be addressed as quickly as possible following the clock signal.

Data acquisition may be terminated in two ways. The program is set up to hold a maximum of 1400 data points per channel. The clock interrupts and the Sample routine are automatically disabled when 1400 data scans have been completed. Should the test be finished before the maximum number of scans is completed, data acquisition can be terminated by the user by pressing the special function key K0, which is defined in an ON KEY statement (line 1730). This user-generated interrupt has a higher priority than the clock-generated interrupt, so it is always serviced when called. Details of the coding used in the Scan subprogram to control the data acquisition equipment will be covered in the interfacing section.

When data acquisition is complete, a menu is offered the user (lines 1310-1420). Included are subprograms for storing data, viewing the raw data, plotting the data, stopping the program, rerunning the program, calibrating the system, and generating several calculated values. The Store subprogram saves the documentary data gathered in the main program and all of the data acquired by Scan. The data taken in Scan are stored in

their internal, unformatted binary form. This greatly conserves storage space on the tape cartridge. Any subprogram that requires viewing or calculation of meaningful numbers requires conversion of the data acquired in Scan. The Convert subprogram is automatically accessed when a subprogram requiring meaningful values is chosen from the menu. Using a variable-to-variable transfer and the appropriate calibration file, the binary data are converted to numbers in units of pounds and miles per hour. As part of the Convert routine, the binary data must be inverted (zeros changed to ones and ones changed to zeros). This is accomplished with the BINCMP function (line 3950) and is necessary because the Series 400 uses positive-true logic, while the 9845 interface and computer use negative-true logic.

Data plots can be created with the Plots subprogram. Any of the measured quantities may be chosen for the ordinate, while time, distance or differential interface velocity are the choices for the *abscissa*. Both the right- and left-wheel data (for the chosen quantity) are plotted on a single graph. Distance, although not measured directly, is found by integration of the speed vs time data. Since both wheel and vehicle (fifth-wheel) speeds are being measured, plots can be with wheel or vehicle distance.

Several value-generating subprograms are included in DATA0. The Average subprogram gives the user the choice of which data channels he wants average force or speed values for. The value returned can be the average for any percent (chosen by the user) of the data points taken. Subprogram Average sorts the data into an ascending order array and then averages the upper percent chosen by the user. If a 100% average is requested, the array-sorting routine is omitted and all the data points are averaged.

Subprogram Slip-energy is an integration routine that calculates the area under the longitudinal force vs distance curve. The energy term generated by the subprogram can be relative to wheel or vehicle distance.

Program READ-2 is designed to access data files which were acquired and stored by DATA0. This program is also structured with a main program and several subprograms. The main program requests the file name of the data file to be viewed (line 140) and reads the documentary and test data from the file. The documentary data may or may not be viewed. Test data are then converted with subroutine Convert, just as in DATA0. Access to

the subprograms is through a menu item selection (lines 420-520). The READ-2 menu contains the same routines as DATACQ, except Store and Calibration.

Programs DATACQ and READ-2 are stored on the tape cartridge labeled "master cartridge." This cartridge must be run from tape drive T15 on the 9845 computer. Data cartridges, either for writing data to or reading data from, are operated in tape drive T14. The master cartridge contains a program AUTOST, which is designed to load and run DATACQ or READ-2, depending on the user's choice. If the AUTOST key on the computer is latched in the down position before the power is turned on to the computer, program AUTOST is automatically loaded and run. Thus, by depressing the AUTOST key before turning the power on, the user need only to respond to self-directed questions posed by the computer; no previous knowledge of the 9845 computer or its operation is necessary for running programs DATACQ or READ-2.

INTERFACING

Interfacing, the process of intercommunication between the 9845 computer and the programmable peripherals, is performed in subprograms Scan and Calibration. The interface card used to implement communication with the Neff instrumentation is a 16-bit-parallel interface and cable (Fig.

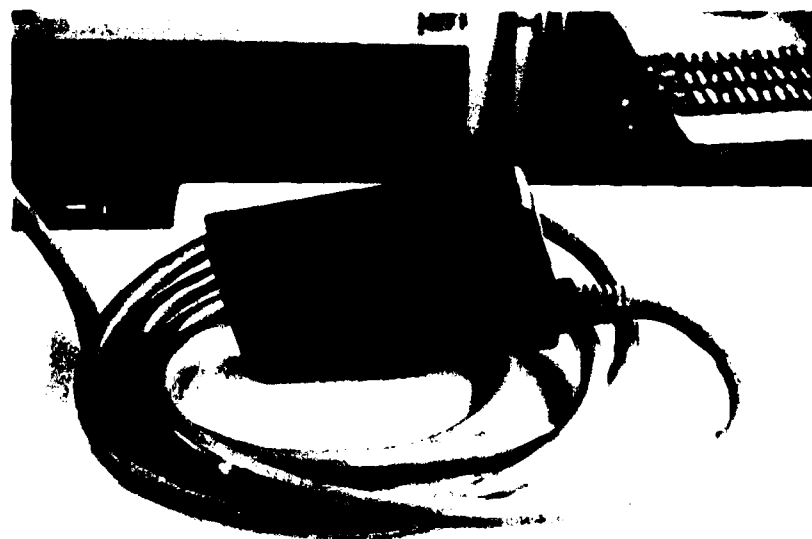


Figure 23. Sixteen-bit-parallel interface and cable.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
INT	DMA	RESET	AH	—	—	CTL1	CTL0

INT: Interrupt Enable on FLG = Ready
DMA: Direct Memory Access Enable
RESET: Reset the Card to Its Power-on State
AH: Auto Handshake Enable
X: These bits are not used and may be a 1 or a 0
CTL1,0: General User-definable Control Bits

Figure 24. Bit assignments for the R5-out interface register.

23). This interface allows 16 bits of binary data to be transferred simultaneously either for input or output. Several other peripheral control and status lines are also present.

All communication with the 98032A interface is addressed to the R5 interface register. The specific bit arrangement which is sent to the register dictates the interface's mode of operation. Figure 24 illustrates the bit assignments for the R5-out register (information sent by the computer). Input of a binary 1 to any bit constitutes "setting" a particular bit.

Bit 7, when set, instructs the interface to request an interrupt of the input-output (I/O) processor whenever the peripheral indicates (to the interface) it is ready. Bit 6 enables a direct memory access (DMA) transfer each time the peripheral indicates it is ready. A normal DMA transfer is handled automatically by the I/O read-only-memory (ROM), and thus program set and clear of bit 6 is unnecessary. Bit 5, the reset bit, is used to return the interface to its power-on state (bits 4, 6 and 7 cleared). Bit 4 of the R5 out register is used to operate in an "auto-handshake" mode, and like bit 6, it is normally operated automatically with the I/O ROM. No meaning is placed on bits 3 and 2; their values are ignored. Register bit 0 is used with the CIV system to direct instructions to the two programmable peripherals (Series 300 and 400). When the bit is set, subsequent I/O instructions are directed to the multiplexer (Series 400). A binary zero in bit 0 causes remote instructions to be sent to the Series 300 signal conditioner. Bit 1 is not used with the CIV system.

The control byte (the bit pattern sent to the R5-out register) is set up in the CONTROL MASK programming statement. This statement defines the bit configuration for ENTER and OUTPUT transfers. The mask value is the

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
INT	DMA	1	0	IID	IOD	STI1	STI0

INT: Interrupt Enabled Indicator
 DMA: DMA Enabled Indicator
 IID: Invert Input Data Jumper Installed
 IOD: Invert Output Data Jumper Installed
 STI1,0: General User-definable Status Bits

Figure 25. Bit assignments for the R5-in interface register.

base 10 equivalent of the binary sequence of ones and zeros that set or clear the R5 register bits. The CARD ENABLE statement is then used to actually write the current mask value to the R5 register.

Operational information (nondata) is sent back to the computer (through the interface) through the R5-in register. This eight-bit register is interrogated by the computer to gain information about the status of the interface. The bit assignments for the R5-in register are shown in Figure 25.

Bits 6 and 7 indicate (when their value is binary one) whether or not the interface card has been made available for DMA or interrupts, respectively. Bits 4 and 5 are set at the factory. Bits 2 and 3 indicate the presence or absence of hardwire jumpers on the interface card. The two jumpers tested for by bits 2 and 3 have been installed on the 98032A interface card and indicate that the incoming and outgoing binary data need to be inverted (complemented). This allows meaningful communication between the negative-true-logic computer and the positive-true-logic Neff peripherals.

The final two bits, 1 and 0, are defined by the user and may be connected to any peripheral output lines. Line connections between the interface and peripherals are shown in Figure 26. The standard Hewlett Packard nomenclature is shown beside each interface connection. The signals carried by these lines to and from the Series 300 and 400 and their meanings to the peripherals are also shown in Figure 26. Several standard jumpers are installed on the interface, allowing the computer-interface-peripheral system to operate efficiently (Table 3).

To fully explain the interfacing technique and how it fits in with the information presented in the sections covering data acquisition equipment

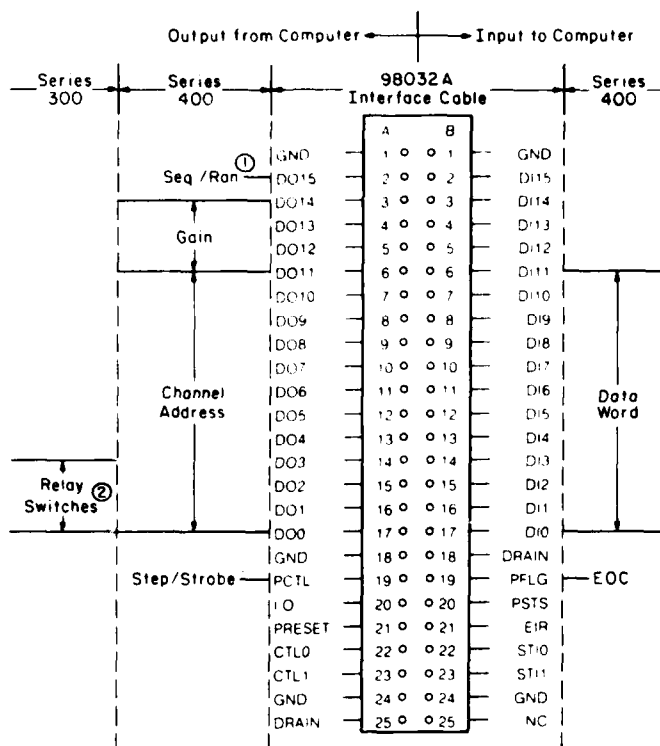


Figure 26. Cable connections between the Series 300 and 400 peripherals and the bit-parallel interface.

1. Random mode: 0; sequential mode: 1.
2. Switches activates: 0; off or normal operation: 1.

and software, portions of the Calibration and Scan subprograms will be described line by line. In the Calibration subprogram (program DATA0), line 2420 issues the first interfacing-related instruction. As previously mentioned, the CONTROL MASK statement sets the bit pattern for the R5-out register. The bit pattern in line 2420 is defined by a base 10 zero (which converts to a binary zero) and is meant only for the interface with its select code set to 6 (thus the 6 before the semicolon). Line 2430 writes this bit pattern to the R5 register of the interface with select code 6. Figure 24 shows that the function of lines 2420 and 2430 is to clear all seven of the control byte bits. Bit 0 being cleared, subsequent instructions will be directed to the Series 300. Line 2440 writes a data word to the Series 300 through the interface on select code 6 using the work handshake (WHS) mode of data transfer. Handshake is a term that describes the sequence of operations which occur when a data unit is transferred. The

Table 3. Jumper wires installed on the 98032A interface.

Jumper	
9	Clocks the high input byte when PFLG goes ready from busy.
D	Clocks the low input byte when PFLG goes ready from busy.
1	Sets bit 3 in the status register, changes the input data lines to positive true logic.
2	Sets bit 2 in the status register, changes the output data lines to positive true logic.
3	Complements the logic sense of PCTL; high = control set and low = control clear.
B	Selects the words input mode.
F	Selects the words output mode.
7	Allows the calculator to activate the DMA (Direct Memory Access) mode of operation.

handshake's basic purpose is to ensure proper timing during the transfer process. The data word sent by line 2440 is the binary equivalent of (base 10) 15, which is 1111. Figure 26 shows that this bit pattern clears (i.e. normal operation) all of the relay switches in the Series 300. Thus the peripheral unit is readied for normal data gathering. The format used to send this bit pattern is indicated by the USING "#, W" portion of the statement. The # specifier suppresses both the carriage-return and the line-feed normally output at the end of an output list. The W specifies that two bytes of two's complement binary data is to be output.

Lines 2450 and 2460 set the R5-out register bit pattern so that all bits are cleared except bit 0. This pattern directs future instructions to the Series 400. The OUTPUT statement in line 2490 is again directed to the 98032A interface (set to select code 6) and uses the same transfer and formatting types. The data word sent to the Series 400 is the binary equivalent of the base 10 result of the expression to the right of the semicolon. The gain code (represented by variable Gain) is defined in line 2350 and sets the system sensitivity as shown in Table 2. Gain is multiplied by 2048 so that the gain code will be placed in bits 11 - 14 of the output (from the computer) word (Fig. 26). Since bit 15 has not been set, the Series 400 is prepared to run in a random channel-sampling mode, and

thus requires a channel address for each call to the peripheral. The channel address is given by the (J-1) expression, which is defined by the loop set up in line 2480. Since it is handy to think of the channels as being numbered 1 - 11, the channel address (for the Series 400) must be decreased by one since the peripheral channel addresses begin with zero. (With Gain = 10 and J = 5 the output word equals 20484, which translates to 010100000000100 in binary. This bit pattern is sent to the Series 400 on the interface cable lines D00 - D015.)

The ENTER command (line 2500) reads the data word on cable lines D10 - D115. Since the Series 400 employs a 12-bit A/D convertor, only the first 11 lines contain the data word. The same interface select code is referenced by the ENTER statement. The format for input cancels the line-feed terminator (#, data entry terminates with the last item in the enter list), and requests input of one 16-bit word from an interface (W).

Lines 2530 - 2630 repeat this sequence; however, a 13 (binary 1101) is output to the Series 300 (line 2550), which activates switch K102 for shunt-resistance substitution.

The next series of instructions in the subprogram Calibration that involve interfacing are lines 2720 - 3050. The Series 300 is switched back to normal operation in line 2740. The output word sent to the Series 400 (line 2770) includes the gain code (multiplied by 2048 to move it into bits 11 - 14). The -32768 value converts to a binary number, which has a one in bit 15 and zeros in all others. This sets the Series 400 for sequential mode sampling, and thus no channel addresses are necessary. The call to sequential mode sampling in line 2770 also resets the channel address pointer to channel 0. Upon each successive conversion the pointer is advanced by one until the last channel (set by the last-channel switch) is reached.

Lines 2890 - 3050 repeat the sequence in lines 2720-2880, except with the Series 300 operating with switch K102 activated. The data acquisition sequence in lines 3060-3260 is performed in the random sampling mode (line 3230) and with the Series 300 in normal operating mode (line 3080).

The Scan subprogram involves interfacing to both the 98032A interface (select code 6) and the real-time clock interface (select code 9). Lines 1660 - 1680 ensure that the switches in the Series 300 are set for normal operation. Instructions in lines 1690 and 1700 set up the real-time clock for operation as a counter and as an interrupt producer. The ON INT #9

statement (line 1740) instructs the program where to branch when an interrupt request is received from the clock. This interrupt is given a priority of 8 so as to be overridden by any user-produced interrupt produced by key K0 (defined with priority 15 in line 1730).

The mask value of 128 (line 1750), which is defined for the clock, enables the clock to request interrupts (sets bit 7 of the R5 out register). Interrupts from the clock are generated at an interval (scan rate) that is defined in line 1760. The CARD ENABLE 9 statement enables the clock to request an interrupt of the processor for the purpose of transferring program control (since it is being used with an ON LIT statement). Lines 1780 - 1800 set up the Series 400 for sequential mode sampling and set the system gain.

The CONTROL MASK statement in line 1810 sets bit 5 (and bit 0) of the 98032A R5-out register. Bit 5 is used to return the interface to its power-on state, which causes the PCTL handshake line to return to high. Normally this would indicate that control is not set; however, with jumper 3 installed, PCTL high indicates that control is set.

The PCTL line is paired with the PFLG line. The peripheral sets control (low-to-high transition) on the PCTL line by a low-to-high transition on the PFLG line. Figure 27 illustrates how these features accomplish the data handshake process. The CONTROL MASK statement (line 1810) then defines a bit arrangement which gives control over the state of the PCTL (STEP/STROBE) line. When the CARD ENABLE 6 statement is executed, the mask bit arrangement is sent to the interface and the STEP/STROBE pulse is issued.

Line 1850 causes a 20-ms delay to be completed by the interrupt unit of the clock before any interrupts are issued. This is to allow the beginning time reading (lines 1870 and 1880) to be completed before any interrupts are requested. Line 1860 actually starts the clock and begins

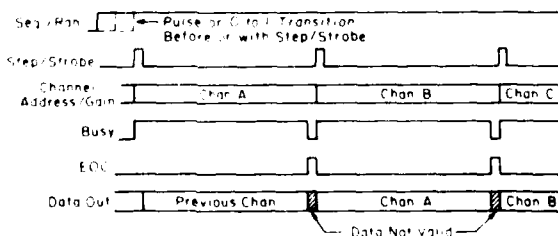


Figure 27. Sample sequence timing.

the data acquisition process. Program flow then continues into an endless loop. The ON INT #9, CONTROL MASK 128, CARD ENABLE 9 sequence produces clock interrupts that branch program flow to the subroutine Sample. When an interrupt request is received, the processor first completes execution of the current line before interrupt branching is taken. Thus, the rapidly executed meaningless statements in lines 1890 and 1900 are inserted in the program.

Upon receiving the request for an interrupt, the processor branches to subroutine Sample. The clock is made available for interrupts (line 1910) so that the scan rate can be maintained as closely as possible.

A special form of data input is utilized in line 1940 in order to gather the digitized Series 400 output as rapidly as possible. This transfer is an unformatted (NOFORMAT) word direct memory access (WDMA) input. By specifying NOFORMAT the data are sent and received in their internal binary form. Using NOFORMAT the number of words to be transferred must be specified; this is represented by the variable N. When the ENTER statement is called, the PCTL line is still in the high state and constitutes the issuance of a STEP/STROBE pulse. The Series 400 then converts one channel of data, the channel indicated by the channel address pointer. Channel 0 will be converted on the first STEP/STROBE pulse since the address pointer was reset to channel 0 when the Series 400 was set up for sequential sampling mode (line 1800). Following analog-to-digital conversion and placement of the data word on the interface cable lines DI0 - DI11, the Series 400 issues an EOC signal (low to high on the PFLG line). Since jumper 3 is installed in the interface, the incoming EOC signal causes the PCTL line to return to its high state (control set). This issues another STEP/STROBE pulse, which initiates another conversion cycle. The data word read at the end of each conversion cycle satisfies one count toward the count parameter N (line 1940). The self-triggering conversion cycles will continue until the number of data words read equals N. At this point the enter list (variable Dt\$) is satisfied and the ENTER NOFORMAT statement is terminated.

Line-by-line execution proceeds to line 1950, which returns the program to the line following the one that was being executed when the interrupt request was received. This will be either line 1890 or 1900, and the endless loop execution will continue until another clock-generated interrupt request is received. The endless loop is automatically exited

if 1400 data scans have been completed (array Dt\$ is full, line 1930). If a test is completed before 1400 scans have been executed, the loop may be exited by pressing special function key K0, which was defined in line 1730. Immediately after data acquisition is complete, an end time reading is taken (lines 1960 and 1970). The actual time between scans is then calculated from the beginning and end times and the number of scans completed (line 2020).

The data in array Dt\$ are still in an internal binary form and are not suitable for display or calculation. Each member of the character array Dt\$ is a single binary character string that represents the readings taken from all the channels during a scan. Subprogram Convert uses a variable-to-variable transfer to convert the character strings into separate numeric data items. Data are stored, however, just as they are in array Dt\$.

OPERATION

Basic Functioning

Instrumentation in the CIV may be used with or without the vehicle's engine running. For inside use or for performing system checks where running the engine is impractical, an extension cord can be used to provide the 110-V power requirements of the instrumentation. A receptacle is located on the far right side of the back of the vehicle, and a switch, located in the vehicle's rear compartment on the right side, is used for selecting inverter or shore (external) electrical supply. Receptacle and switch positions are shown in Figure 28. When operating from an external electrical supply, the instruments which require 12-V d.c. power are running off the vehicle's battery.

When using the inverter to supply electricity, the vehicle must be running before the inverter is switched on. The selector switch should then be moved from the center (off) to the inverter position.

Once the electrical supply for the vehicle has been established, power for any instrumentation is available at the power strip located inside the vehicle cab (Fig. 8). This outlet block contains an on-off switch, an indicator light and a circuit breaker. Switching the barrier strip on automatically turns on the Series 300 and 400 units. The computer has its own on-off switch located on its right side. The velocity signal conditioner switch is used to turn on the driver readout unit, both signal



Figure 28. External power receptacle and switch.

conditioners and the multiplexer. The fifth-wheel system is activated from the display unit's on-off switch (Fig. 13b).

Set-up for a test should include adjusting the excitation supply (10 V) to each load-cell channel (variable resistor R5, Fig. 18) and placing the remote-local switch (Fig. 19) and switches K101 - K104 in the desired positions (for local operation only, Fig. 19). The throughput-rate switches (Fig. 21) should also be set. With the power off, the last-channel switches (Fig. 20) should be set and the 98032A interface card plugged into the 9845 computer.

The actual test may now be started by latching the AUTOST key on the computer in the down position and turning it on (with the master cartridge in tape drive T15 and a data tape in T14). If the AUTOST key is not used, the instruction GET "DATAQ:T15" followed by pressing the EXECUTE key will load the data acquisition program. When the program has been loaded, pressing the RUN key will begin the program. The same sequence can be used with GET "READ-2:T15" to load and run the read program.

Calibration procedures

To ensure that accurate force and speed readings are being obtained, several levels of system calibration must be regularly performed. These

range from the readings which zero out the weight of each test tire and measure their rolling circumference to a whole system calibration which determines the accuracy of the shunt resistors and the fifth-wheel measurements. Calibration of the data acquisition equipment itself is covered by the appropriate manufacturer's manual.

In-field or pretest calibration is essentially a self-directed process performed by the Calibration subprogram. The program collects zero and shunt resistance values for the vertical force channels with the front of the vehicle elevated. Upon being lowered the vehicle is rocked back and forth by switching the gearshift between forward and reverse. It is then allowed to roll to a stop (with the transmission in neutral) and zero and shunt resistance readings are taken for the longitudinal and side force channels; zero readings are also taken for the velocity channels. The rocking procedure is performed to remove any "unnatural" forces developed when the tires were lowered back onto the pavement following vertical force channel sampling. The velocity channels are scaled by driving at a constant speed of 10 mph while data sampling occurs on those channels.

During the program-directed calibration procedure, the driver readout unit may be adjusted if necessary. When elevated (vertical channels zero) and after rolling back and forth (longitudinal, side and velocity channels zero), the zero-adjust resistors on the driver readout amplifier can be adjusted to yield a zero reading on the DPMs. Likewise, when shunt resistance is substituted into the bridge, the gain resistor of the amplifier may be adjusted to display the shunt resistance load values on the DPMs. The velocity channel resistors can be adjusted during the 10-mph run.

The driver readout unit can also be adjusted by switching the Series 300 to local operating mode and manually switching the shunt resistors in and out (switch K102, Fig. 19). (The zero for vertical channels still requires jacking the front of the vehicle off the ground.)

The subprogram finally calculates scaling factors and stores these and the zero readings in a file that begins with a C and includes the date and tire code. As previously mentioned, a new calibration file should be collected each time the front tires are changed (to zero out the weight of the tire), the inflation pressure of the shock absorbers is changed, or the system is turned on.

The whole system should be calibrated periodically (approximately every 100 hours of use) or whenever concerns about the validity of the data arise. Two forms of whole system calibration will be discussed; the first is perhaps better identified as a system adjustment.

The system adjustment is performed to obtain maximum sensitivity from the instrumentation. The Series 400 returns digital values (counts) in the range from -2048 to +2047. The system adjustment zeros and scales the incoming signals so that the expected range of these signals is spread over the largest portion of the numbers from -2048 to +2047 but does not fall outside them.

Lines 3730 - 3790 of DATACQ are included in the Calibration subprogram as comment statements (non-executed). By removing the leading exclamation point from each of these lines, running of the subprogram will generate a hard copy of the digital zero values. Also output is the shunt (calibration) value and the scale factor, which represents the number of pounds (or miles per hour) per digital count. Ideally channels 1 and 5 (vertical force) should have zero values near -2048 (or well into the negative numbers), since the vertical force varies between zero and approximately 2000 pounds (it does not go negative). The longitudinal and side forces are both two-directional forces, yielding positive and negative values. The side forces are symmetric, and thus the zero load reading should yield a digital count near zero. Longitudinal forces are not symmetric; generally force magnitudes in traction (positive) can range up to twice as much as resistance (negative) forces. Thus, the zero load count for longitudinal forces should be about -700. Zero load count values can be adjusted with resistor R7 on the strain-gage mode card (Fig. 18). Rereading the digital counts after adjusting the resistor is then accomplished by rerunning the Calibration subprogram.

Scaling the load-cell channels can only be done in integer multiples by changing the gain code (line 2350 of DATACQ) in the Series 400. This increases or decreases the sensitivity with which the Series 400 reads the input data, as shown in Table 2. (Caution: whenever the gain code in subprogram Calibration is changed [line 2350], it must also be changed in Scan [line 1630] to acquire meaningful data.)

The velocity channels have no voltage output when the vehicle is at rest. Thus, the Series 400 returns a digital count near zero for the zero velocity value. Once scaling (gain) is set for the load-cell channels, the

velocity digital count can be checked for a speed of 10 mph from the matrix output of the shunt values for channels 4, 8, 10 and 11. The digital count for 10 mph can be adjusted with the knurled variable resistors (top row) on the front of the velocity signal conditioner. Since zero speed gives a count of zero, the maximum speed expected should be set equal to a count of 2047. The count which should be output from the calibration procedure (10 mph) can be found by multiplying the ratio of calibration speed to maximum expected speed by 2047.

The second form of whole system calibration is quite involved and should be performed annually. The procedure involves checking the accuracy of the shunt resistors and the fifth-wheel assembly. Since no variable scaling can be performed on the load-cell channels, the accuracy of the system depends entirely on the accuracy of the shunt resistance substitution. Table 1 lists the current values of the precision shunt resistors. This whole system calibration checks the accuracy of these values and changes them if necessary. The reason for including the fifth-wheel in the calibration is that it is used to scale all the other velocity channels. (The 10-mph speed maintained during subprogram Calibration is based on the fifth-wheel readout.)

Calibration of the fifth-wheel assembly involves operating it over an accurately measured course of at least one mile. The vehicle should be carefully aligned at the beginning and end course markers and the accumulated pulse counts read from the driver readout unit. Dividing the counts by 25 yields the distance in feet. If the measured and true distances vary by less than 0.2%, the fifth-wheel tire pressure can be varied to bring the two into agreement. Errors greater than 0.2% should be corrected by the manufacturer. The fifth-wheel speed is automatically calibrated when distance is calibrated, since a crystal clock is used for obtaining velocity.

To check the shunt resistor values, a special wheel has been constructed for calibrating the longitudinal and side forces (Fig. 29). When the calibration wheel is being used, the axle housing should be supported by a stable jack stand placed only slightly outside the centerline of the vehicle (toward the side with the calibration wheel). This allows the suspension system to be as uninhibited by the jack stand as possible. By pulling on the calibration wheel chain with an accurate load cell inserted in the force train, a known load can be applied along the longitudinal or



Figure 29. Shunt-resistor calibration wheel.

side directions. Care should be taken to ensure that the direction of pull is directly along the longitudinal or side axes. If the external load-cell reading differs from the value read out by the subprogram Rawdata of DATAC0, then the value of the shunt resistor for the channel needs to be changed (lines 3460 - 3560 of subprogram Calibration).

If there is a disparity between the load applied to the wheel and the force value output by the CIV system, a check should be made to see that the external force is being applied exactly along the longitudinal or side axes. If a difference in values still exists, the shunt resistor value must be changed. This is accomplished by monitoring the output from the bridge through the upper set of jacks on the strain-gage mode card (Fig. 18). A voltmeter with 1- μ V accuracy should be used to obtain 1-lb accuracy. With the Series 300 switched to local control, K102 activated (shunt

resistor in bridge), and no forces acting on the calibration wheel, the bridge output can be read with the precision voltmeter. With switch K102 then set for normal operation, the force on the calibration wheel should be increased until the same bridge output is read on the voltmeter. The external load-cell output will then indicate the true value of the shunt resistor. This sequence can be repeated for the longitudinal and side channels.

A similar sequence, using a flat load cell, can be performed for calibrating the vertical force channels. In this case the vehicle retains its normal front wheels and tires. To ensure loading along the vertical axis, it is best if the external load cell is placed in a recess that allows the vehicle to drive directly onto it. If the external load-cell reading differs from that registered by the triaxial load cell, the vertical channel shunt resistor values must be corrected. Again, with no load on the vertical channels (tires elevated), the shunt resistor is placed in the bridge and the bridge output is read with a precision voltmeter. Returning to normal operation, the vehicle is rolled back over the external load cell. The axle must now be tied to the floor in such a way that additional vertical force can be applied to the wheel.

While the bridge output is monitored with the precision voltmeter, the vertical load is increased with a take-up device until the shunt resistance voltage appears across the bridge. At this point the reading on the external load cell represents the new value of the shunt resistor.

Evaluating the torque cell shunt resistor involves the same basic procedure as outlined for the triaxial load cells. However, an accurate external torque measuring device must be used on the rear propellor shaft to read the torque when the bridge output is equal to the shunt resistance value.

The procedures for re-evaluating the shunt resistance values must be performed carefully. The accuracy of the external load and torque measuring devices should be within 1% or less. (The triaxial load cells have an accuracy of better than 1%.) Alignment when applying external forces must be as exact as possible. Several repetitions of each step are also recommended; significant differences in repetition results should be scrutinized.

For ultimate accuracy the shunt resistor calibration sequence should be performed on an air-bearing plate. These devices, however, are not in



a. Axle grease recess location.



b. Grease gun.

Figure 30. Lubrication of the axle shaft.

great abundance and take a significant amount of time to learn to use. Three-dimensional air-bearing plates are nonexistent, although development is in the process. A two-dimensional plate can be used, though, but care must be taken to ensure that no load is being imparted in the third direction.

Maintenance

In addition to normal vehicular maintenance, which should be followed closely, the CIV requires special attention in certain areas. Since the vehicle spends a lot of time with the engine running but without accumulating many miles, the carburetor should be cleaned regularly. Periodically the vehicle should be driven for several miles at normal highway speeds to ensure lubrication of the drive train.

Of primary importance is the lubrication (greasing) of the axle shaft where it passes through the load cell. A grease recess has been machined into the steering universal joint in the piece that extends through the load cell (Fig. 30a). This recess can be accessed by turning the wheels their full amount and rotating the universal until the recess comes into view. A special grease-gun tip is necessary for lubrication (Fig. 30b). These shafts must be greased no less than following each full day of operation. All cable connections located under the vehicle should be regularly checked for corrosion and snugness of fit.

The tape drives of the minicomputer require frequent cleaning (every 8 hours of use) with the cleaning solution supplied by the manufacturer and a cotton tip applicator. Also, the air filters located on the underside of the computer, near the front, should be removed and cleaned periodically.

CONCLUSION

The CIV has been used by CRREL for gathering mobility data during the past two winters. Aside from the obvious interest in the interaction of the three mutually perpendicular forces at the tire contact path, several areas of mobility research have received emphasis. Most attention has been devoted to tire traction, with several techniques being used to generate traction data for many varied tire types on ice, snow and thawing soils. Numerous evaluation schemes have been applied to the data and relative performance levels compared. Along with this, operator dependence on traction test output is being studied.

Resistance tests have been used to compare various tire types on several cold regions materials, including low temperature, clear pavement. Using a single tire type, resistance tests have also been used to compare the resistance to motion offered by varieties of cold regions materials. These values have formed the beginning of a cold regions materials mobility data bank.

Although the CIV is regularly undergoing modifications, the bulk of the information contained in this report will remain unchanged. Anticipated changes include the addition of an automatic throttle-control device and the replacement of the fifth wheel with a radar speed-and-distance metering device. Additionally, a random-access mass storage device will probably be added to the data acquisition equipment to increase storage capacity and I/O speed. Changes to the software will undoubtedly take place on a regular basis, primarily in the data analysis sections. Any changes in the data acquisition portions of the program will be directed at improving the speed and efficiency of data sampling.

APPENDIX A: OPERATING MANUALS

Advanced Programming ROM Manual. Hewlett Packard Co., Part No. 09845-92065, Feb. 1980, 108 p.

BASIC Language Interfacing Concepts. Hewlett Packard Co., Part No. 09835-90600, Sept. 1979, 189 p.

Data Book USFS 3296 System. Nevada Automotive Test Center Project No. 20-17-70, June 1978.

Graphics ROM Manual. Hewlett Packard Co., Part No. 09845-91050, May 1979, 203 p.

I/O ROM Manual. Hewlett Packard Co., Part No. 09845-92060, Aug. 1980, 192 p.

Mass Storage ROM Manual. Hewlett Packard Co., Part No. 09845-92070, Feb. 1980, 132 p.

98032A 16-Bit Interface Installation and Service Manual. Hewlett Packard Co., Part No. 98032-90000, May 1979, 47 p.

98035A Real Time Clock Installation and Operation Manual. Hewlett Packard Co., Part No. 98035-90000, Feb. 1979, 73 p.

System 620, Series 300 Operation and Maintenance Manual. Neff Instrument Corp., Publication No. 620953, Sept. 1980, 57 p.

System 620, Series 400 Operation and Maintenance Manual. Neff Instrument Corp., Publication No. 620954, Nov. 1978, 149 p.

System 620 to H-P 9825, Interface Cable Connection Manual. Neff Instrument Corp., Publication No. 620079, Apr. 1979, 8 p.

System 45 Operating and Programming Manual. Hewlett Packard Co., Part No. 09845-92000, Feb. 1980, 302 p.

APPENDIX B: SCHEMATIC AND WIRING DIAGRAMS

The diagrams and schematics that follow are meant, when used with the manufacturer's manuals, to provide complete electronic coverage of the CIV. Most of the figures are referenced in the text; however, some which are not are included here for completeness. Pin assignments, connector labels and wiring color codes are also included where appropriate.

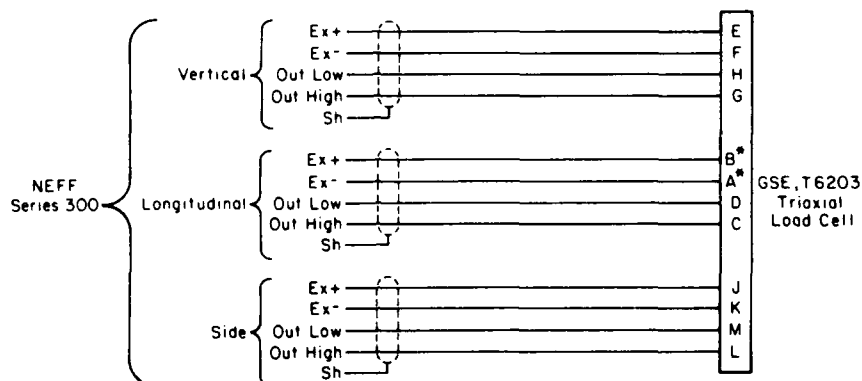


Figure B1. Wiring convention to and from the triaxial load cells. Color code: Ex+, red; Ex-, black; Out Low, white; Out High, green; Sh, stranded wire.

*The left-side load cell is depicted here; the right-side load cell is the same except that it has Ex- on pin B and Ex+ on pin A.

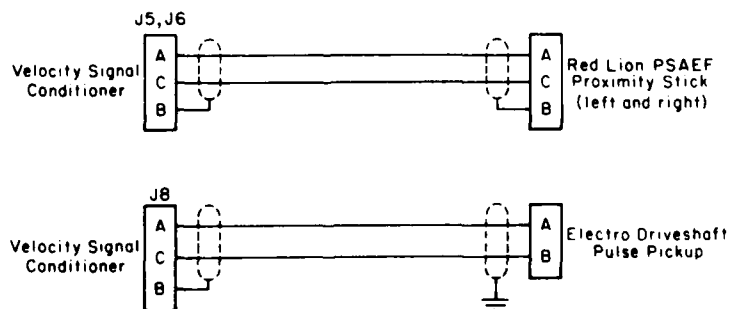


Figure B2. Wiring convention to and from the pulse pickups. Color code for J5, J6 and J8: A, red; B, stranded wire; C, black.

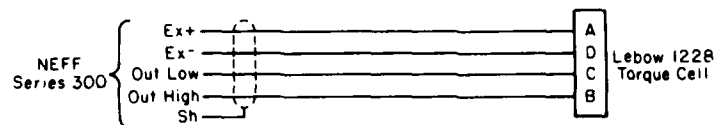


Figure B3. Wiring convention to and from the torque cell. Color code: Ex+, white; Ex-, green; Out Low, black; Out High, red; Sh, stranded wire.

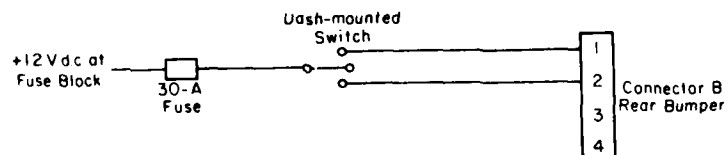
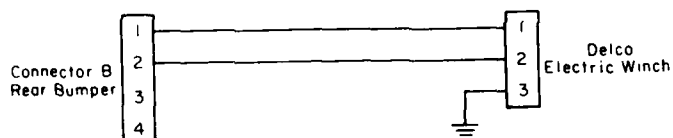
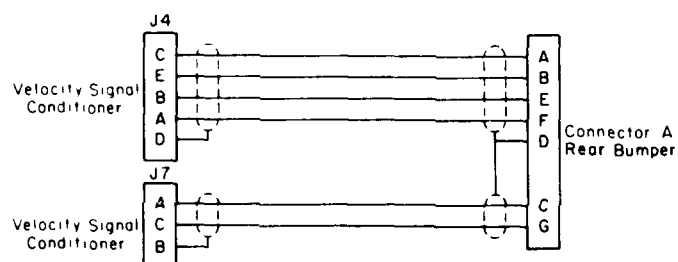
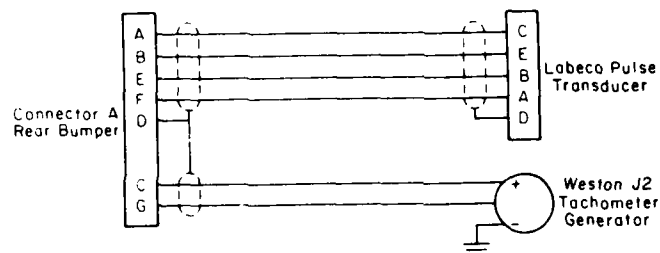
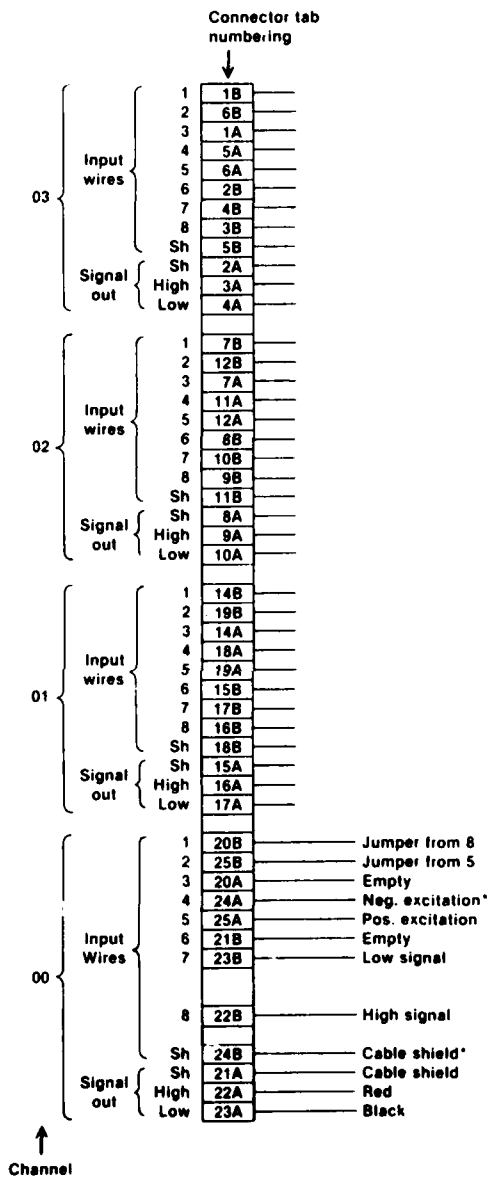


Figure B4. Wiring convention to and from the fifth-wheel assembly. Color code for connector A: A, white; B, green; C, red (large); D, stranded wire; E, black (small); F, red (small); G, black (large). Color code for J4: A, red; B, black; C, white; D, stranded wire; E, green. Color code for J7: A, red; B, stranded wire; C, black.



*Jumper pin 4 to cable shield in

Figure B5. Input and output wiring to the Series 300 card edge connector.

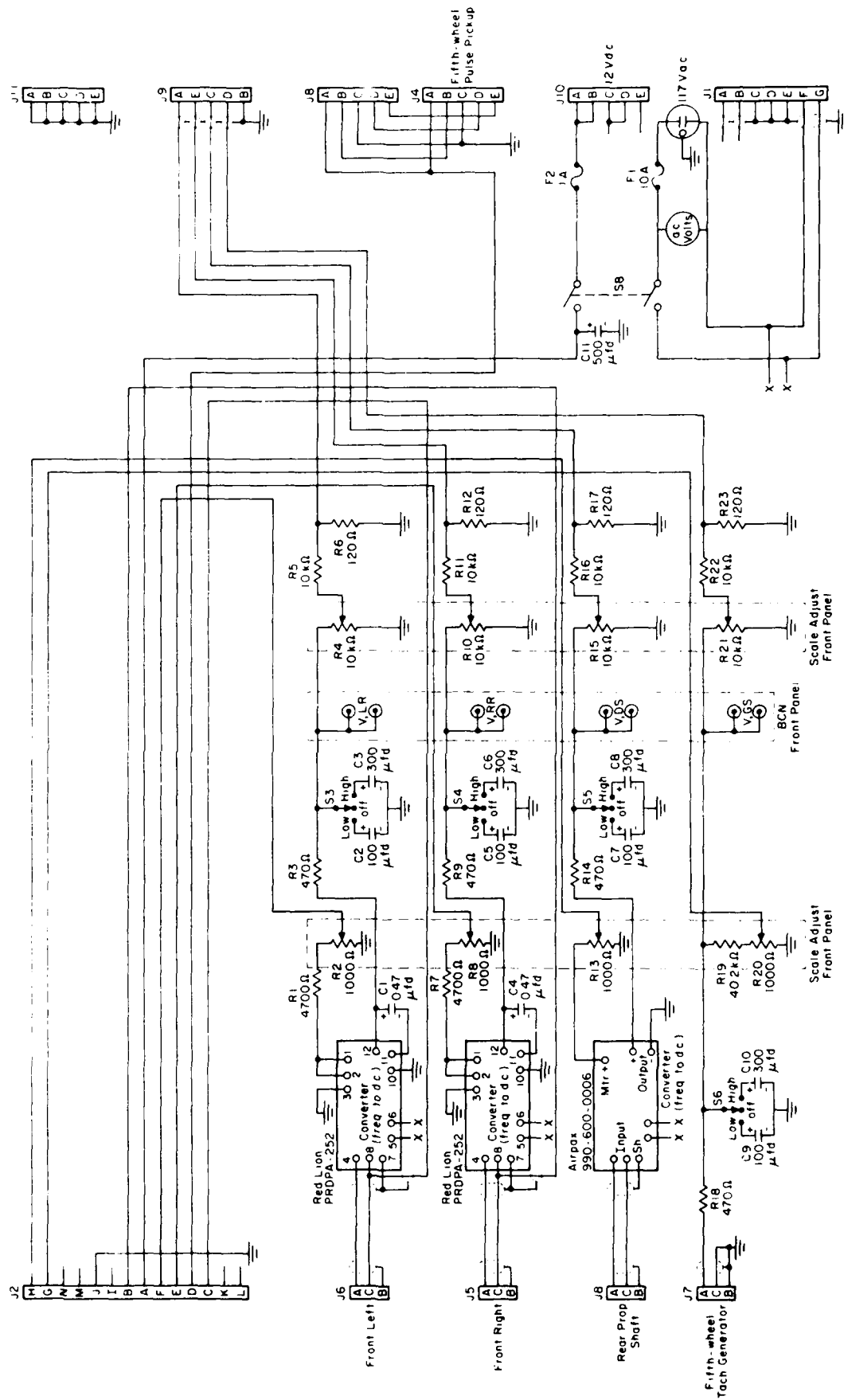


Figure 86. Schematic of the velocity signal conditioner.

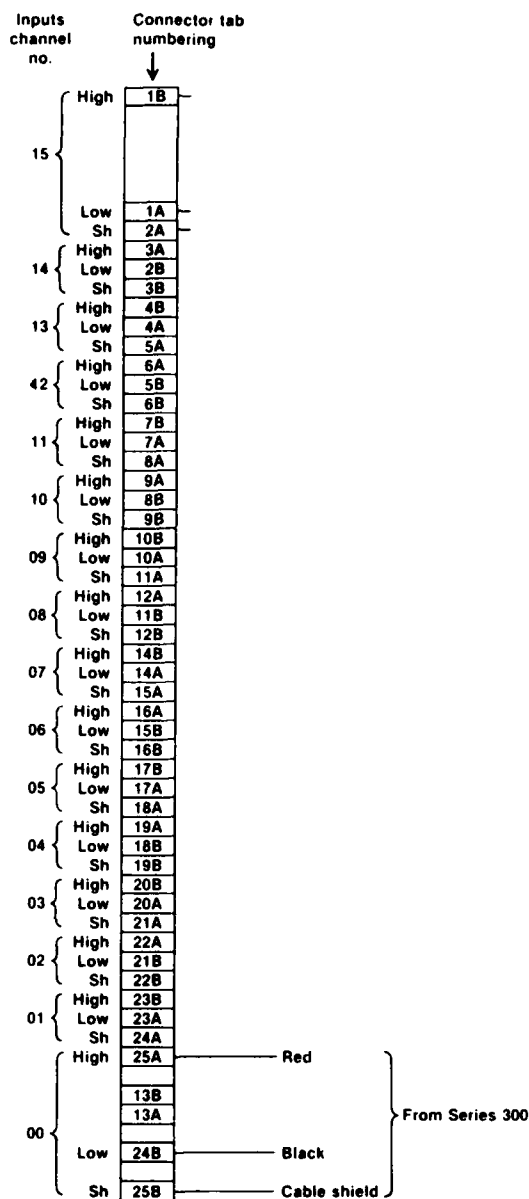


Figure B7. Input wiring to the Series 400 card edge connector.

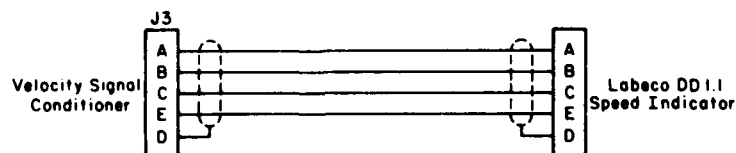


Figure B8. Input wiring to the fifth-wheel readout.
Color code: A, red; B, black; C, white; D, stranded wire; E, green.

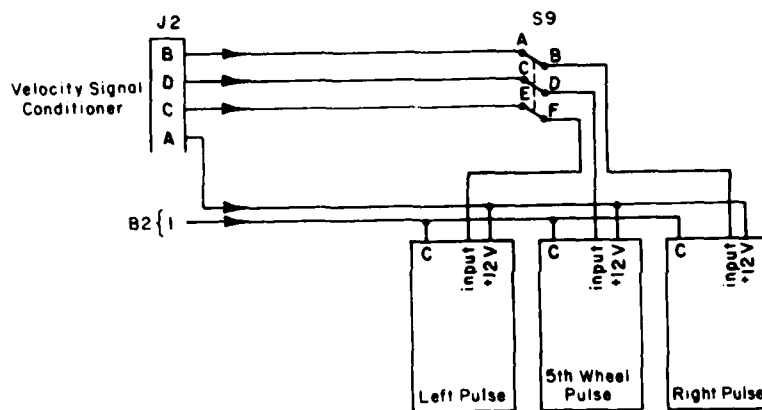


Figure B9. Input wiring to the pulse counters.

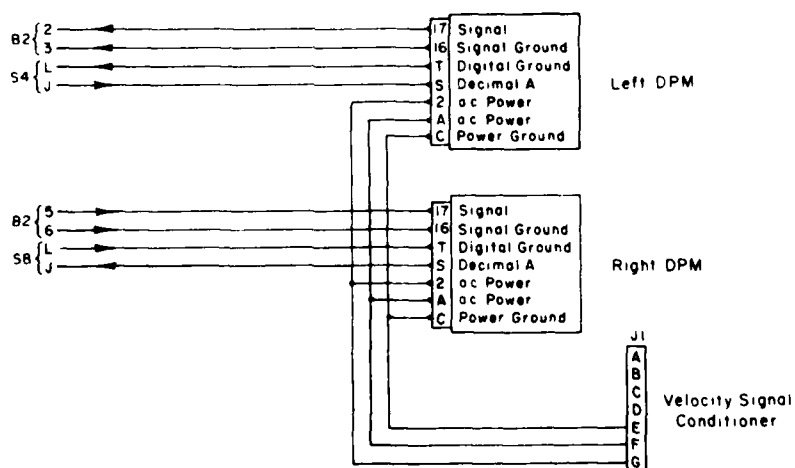


Figure B10. Input wiring to the digital panel meters.

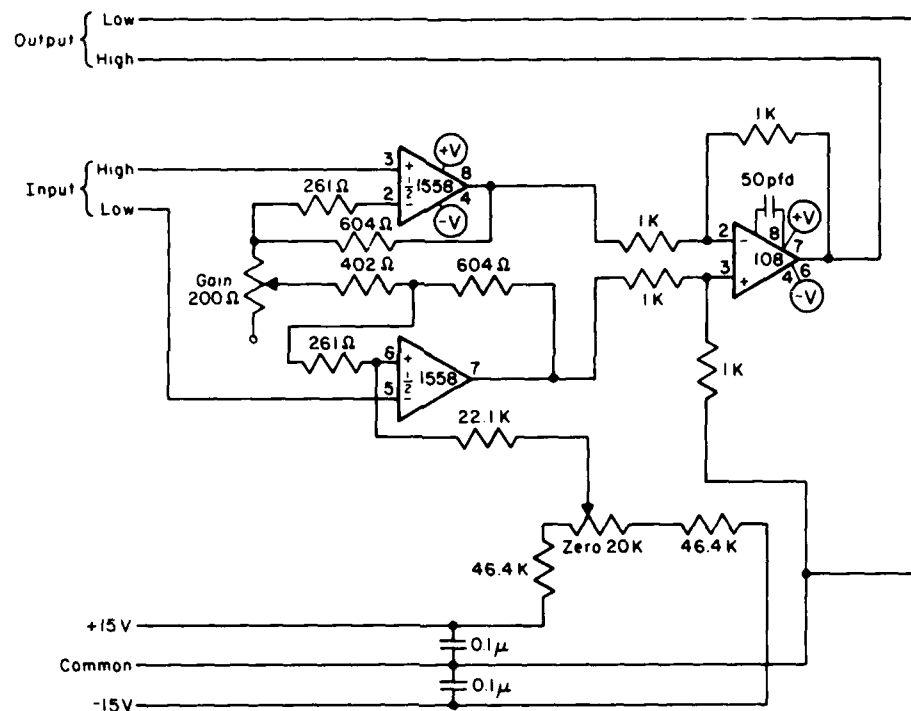


Figure B11. Selector switch wiring.

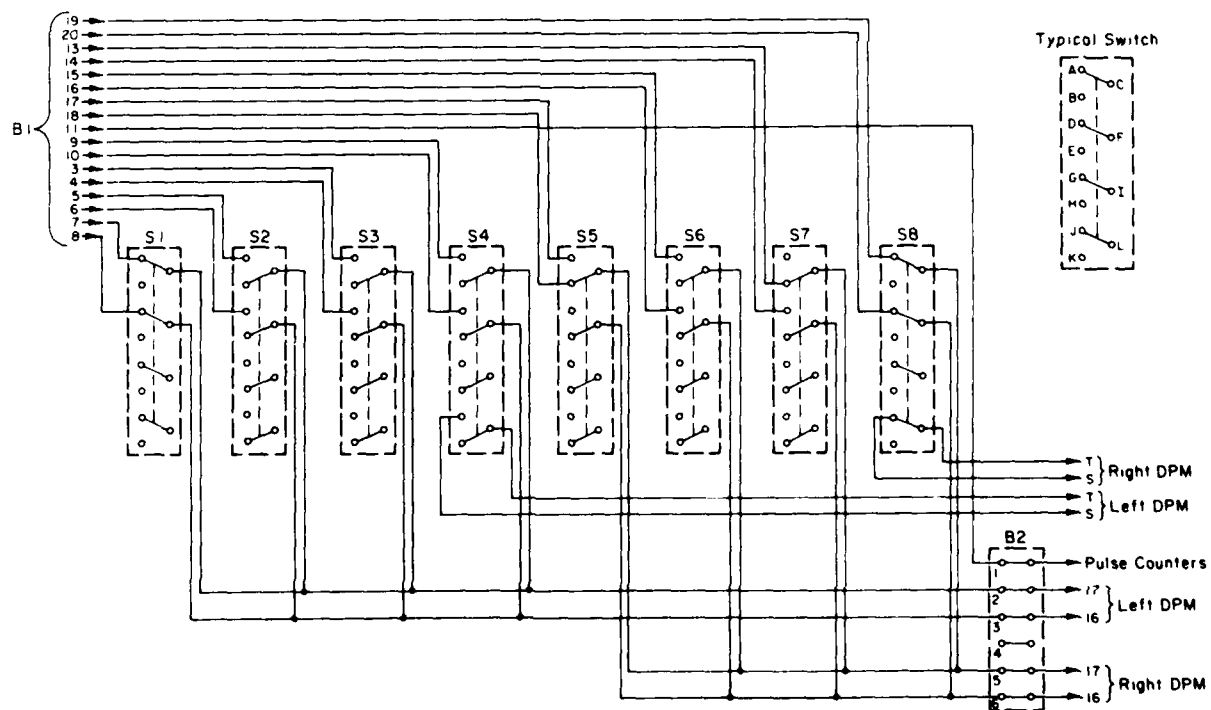


Figure B12. Typical channel from the eight-channel differential amplifier.

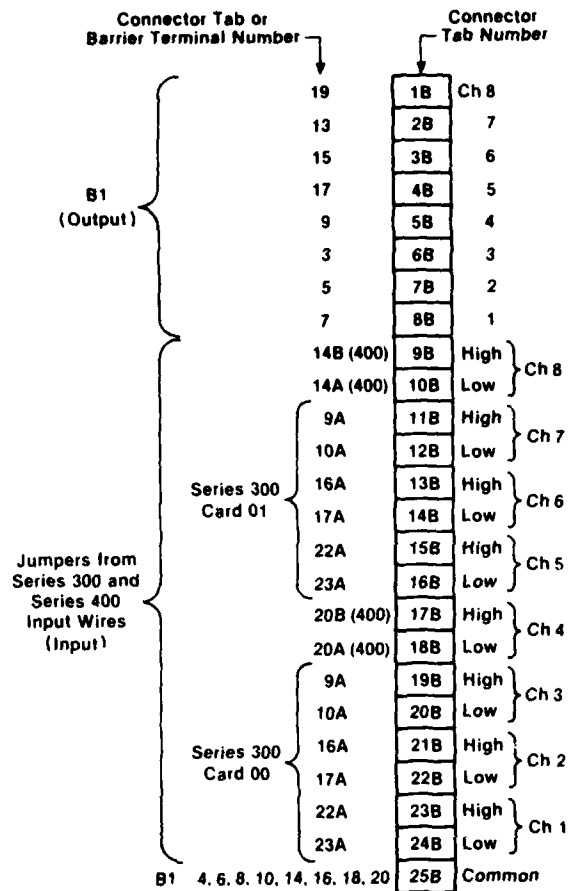


Figure B13. Input and output wiring to the driver readout differential amplifier.

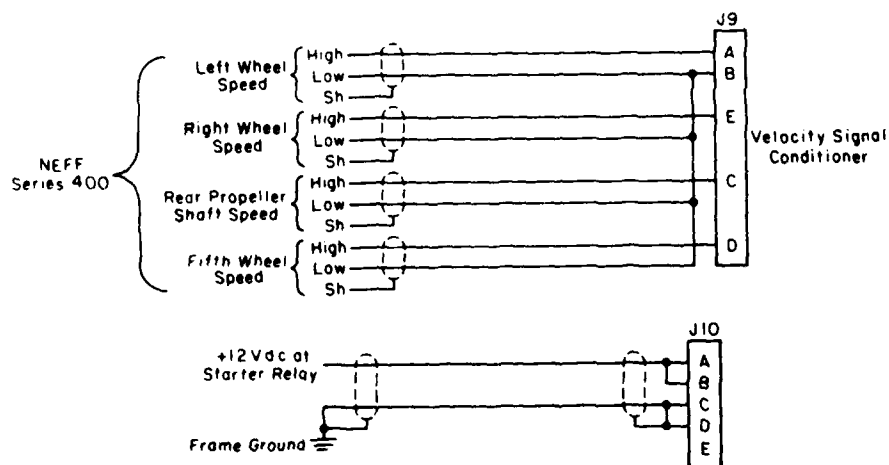


Figure B14. Wiring diagram for additional cables.
Color code: High, red; Low, black; Sh, stranded wire.

APPENDIX C: COMPUTER PROGRAMS.

The two computer programs used with the CIV system, DATACO and READ-2, are listed in full in the following pages. An explanation of the coding (beyond that given in the main text) will not be included here. The appropriate manuals (Appendix A) and the program documentation should provide the user with an adequate programming explanation.

FILE NAME: DATACO:T15

DATE : 09:17:13:41
MAIN PROGRAM

```

10      ' DATACO, DATA ACQUISITION PROGRAM FOR
20      ' INSTRUMENTED TEST VEHICLE.
30      ' WRITTEN BY G BLAISDELL
40      ' JANUARY 1981
50
60
70
80
90      MASS STORAGE IS "T14"
100     OPTION BASE 1
110     Ascii=65
120     DIM List$(41) (41)
130     COM Loc$(150),T$(14) (200),D$(1400) (22),D$(11),T$(,G$,SHORT D$(4,1400),M(1
140     (1400),D(1400,11),D(2,1400),INTEGER L,Flag3
150     Reply=3
160     GOTO 170
170     PEDIM D$(1400),M(11),1400,D(2,1400),D(1400,11),D(4,1400)
180     ENABLE
190     PRINTER IS 16
200     CAT TO List$(0),0,B
210     IF B=0 THEN GOTO 350
220     PRINT LIN(20)
230     PRINT CH$(133:1)
240     PRINT CH$(27:2)"E"
250     PRINT LIN(14) " REMOVE FULL DATA CARTRIDGE FROM T14 AND INSERT NEW DATA
260     CARTRIDGE."
270     PRINT LIN(14) " IF CARTRIDGE HAS BEEN USED BEFORE (ALREADY CONTAINS FIL
280     ES:"
290     PRINT LIN(14) " DO NOT RE-INITIALIZE). IF TAPE HAS NOT BEEN USED BEFOR
300     E OR"
310     PRINT LIN(14) " CONTAINS USELESS INFORMATION IT NEEDS TO BE INITIALIZED"
320     PRINT LIN(14) " TYPE 1 FOR INITIALIZATION, 0 TO JUST CONTINUE WITH
330     PROGRAM"
340     INPUT P
350     IF P = 1 THEN GOTO 350
360     INITIALIZE "T14"
370     PRINT LIN(20),CH$(133:1)
380     PRINT CH$(27:2)"E"
390     Flag3=0
400     IF Reply=0 THEN GOTO 400
410     INPUT "DO YOU WANT TO RUN CALIBRATION (0) OR A TEST (1)?:P
420     IF P=1 THEN GOTO 400
430     CALL Calibration
440     IF Flag3=1 THEN GOTO 210
450     PRINT LIN(20)
460     INPUT "IS DOCUMENTARY DATA SAME AS PREVIOUS TEST (Y OR N)?:Pp1$
470     IF Pp1$ = "Y" THEN GOTO 500
480     F$=T$(2:1,4)CH$(Ascii-1)
490     ON ERROR GOTO 460
500     GOTO 470
510     INPUT "ENTER PREVIOUS TEST FILE NAME (5 DIGITS)?:F$
520     ASSIGN #6 TO F$

```

Copy available to DTIC does not
permit fully legible reproduction

```

480 READ #6;LOC8,TS(1)
490 OFF EPROP
500 TS(1)="AA"
510 OUTPUT 9;"A"
520 OUTPUT 9;"R"

530 ENTER 9;TS(4)
540 TS(2)=TS(4)(1,2)&TS(4)(4,5)CHP$(ASC(1))
550 ASC(1)=ASC(1)+1
560 INPUT "ENTER NEW FILE NAME (MAX 5 CHAR, 4 DIGIT MONTH & DAY + LETTER FOR
TEST NO. 1)",TS(2)
570 INPUT "ENTER TIRE INFLATION PRESSURE",TS(6)
580 TS(5)=TS(5)
590 INPUT "ENTER TEST TYPE",TS(7)
600 TS(14)=GS
610 IF RPTS="Y" THEN GOTO 1010
620 INPUT "ENTER TEST LOCATION",LOC8
630 INPUT "AMBIENT TEMP( DEG C)",TS(3)
640 PRINT LIN(3),"SNOW - 1"
650 PRINT "ICE - 2"
660 PRINT "THAWING SOIL - 3"
670 PRINT "HARD SURFACE - 4",LIN(3)
680 ON ERROR GOTO 720
690 INPUT "SURFACE MATERIAL TYPE CODE",J
700 PRINT LIN(25)
710 ON J GOTO 740,810,880,950
720 PRINT ERRMS
730 GOTO 640
740 TS(3)="SNOW"
750 INPUT "SNOW TYPE",TS(9)
760 INPUT "NOMINAL SNOW DEPTH(CM)",TS(10)
770 INPUT "NOMINAL SNOW DENSITY(G/CC)",TS(12)
780 INPUT "NOMINAL SNOW TEMP( DEG C)",TS(11)
790 INPUT "SOLAR INPUT (% OF AREA OR SKY IN SUN)",TS(13)
800 GOTO 1010
810 TS(3)="ICE"
820 INPUT "SURFACE UNDERLYING ICE",TS(9)
830 INPUT "ICE THICKNESS(CM)",TS(10)
840 INPUT "ICE TEMP( DEG C)",TS(11)
850 INPUT "SOLAR INPUT (% OF AREA OR SKY IN SUN)",TS(13)
860 TS(12)="0"
870 GOTO 1010
880 TS(3)="THAWING SOIL"
890 INPUT "SOIL TYPE",TS(9)
900 INPUT "DEPTH OF THAWED LAYER(CM)",TS(10)
910 INPUT "THICKNESS OF FROZEN LAYER(CM)",TS(12)
920 INPUT "TEMP OF THAWED LAYER(CM)",TS(11)
930 INPUT "SOLAR INPUT (% OF AREA OR SKY IN SUN)",TS(13)
940 GOTO 1010
950 TS(3)="HARD SURFACE"
960 INPUT "SURFACE MATERIAL",TS(9)
970 INPUT "SURFACE TEMP( DEG C)",TS(11)
980 INPUT "SOLAR INPUT (% OF AREA OR SKY IN SUN)",TS(13)
990 TS(12)="0"
1000 TS(10)="NA"
1010
1020 PRINTER IS 0
1030 PRINT LIN(1),TS(2)
1040 PRINTER IS 16
1050 IMAGE 0,
1060 PRINT USING 1050
1070 PRINT LIN(1),"FILE NAME: ";TS(2)
1080 PRINT LIN(1),"LOCATION: ";LOC8
1090 PRINT LIN(1),"AMBIENT TEMP: ";TS(3);" DEG C"
1100 PRINT LIN(1),"DATE AND TIME: ";TS(4)
1110 PRINT LIN(1),"TIRE CODE: ";TS(5)
1120 PRINT LIN(1),"TIRE INFLATION PRESS: ";TS(6);" PSI"
1130 PRINT LIN(1),"TEST TYPE: ";TS(7)
1140 PRINT LIN(1),"CALIBRATION FILE NAME: ";TS(14)
1150 PRINT LIN(1),"TEST MATERIAL: ";TS(8)
1160 PRINT LIN(1),"TYPE(OR UNDERLYING SURFACE): ";TS(9)
1170 PRINT LIN(1),"DEPTH OR THICKNESS: ";TS(10);" CM"
1180 PRINT LIN(1),"MATERIAL TEMP: ";TS(11);" DEG C",LIN(1)
1190 IF TS(3)="SNOW" THEN PRINT "SNOW DENSITY: ";TS(12);" G/CC"
1200 IF TS(3)="THAWING SOIL" THEN PRINT "FROZEN LAYER THICK: ";TS(12);" CM"
1210 PRINT LIN(1),"SOLAR INPUT (CLOUD COVER, SHADE) ";TS(13);"%"
1220 INPUT "DO YOU WISH TO CHANGE DOCUMENTARY DATA (Y OR N)?",RPTS
1230 IF RPTS="Y" THEN GOTO 500
1240 PRINT LIN(5),"REMARKS:"
1250 PRINTER IS 16

```

```

1260 CALL Scan
1270 REDIM D$(L),DIO(4,L),MILLI(L),DIL(11),Dist(2,L)
1280 PRINT CHR$(27)+"E"
1290 Flag=0
1300 PRINTER IS 16
1310 PRINT LIN(20),"NUMBER OF SAMPLES TAKEN = ";L-1
1320 PRINT "          STORE DATA - 1"
1330 PRINT "          VIEW PWA DATA - 2"
1340 PRINT "          TO PLOT DATA - 3"
1350 PRINT "          STOP PROGRAM - 4"
1360 PRINT "          RUN ANOTHER TEST WITH SAME TYPE - 5"
1370 PRINT "          CALIBRATION PROGRAM (NEW TYPE) - 6"
1380 PRINT "          FIND AVE. MOTION RESIST. VALUES - 7"
1390 PRINT "          FIND TRACTION VALUE - 8"
1400 PRINT "          CALCULATE SLIP ENERGY - 9"
1410 PRINT LIN(3)
1420 INPUT "WHICH ROUTINE DO YOU WISH (TYPE IN NUMBER CODE) ",Reply
1430 IF Reply=1 THEN CALL Store
1440 IF Reply=4 THEN GOTO 1580
1450 IF Reply=5 THEN GOTO 160
1460 IF Reply=6 THEN CALL Calibration
1470 IF Flag=1 THEN GOTO 210
1480 IF (Reply=2) AND (Reply=3) AND (Reply=7) AND (Reply=8) AND (Reply=9)
THEN GOTO 1300
1490 Flag=Flag+1
1500 IF Flag=1 THEN GOTO 1520
1510 CALL Convert
1520 IF Reply=2 THEN CALL Paudata
1530 IF Reply=3 THEN CALL Plots
1540 IF Reply=7 THEN CALL Average
1550 IF Reply=8 THEN CALL Traction
1560 IF Reply=9 THEN CALL Slip_energy
1570 GOTO 1300
1580 END
1590 SUB Scan
1600 OVERLAP
1610 OPTION BASE 1
1620 DIM Loc$(50),T$(14)(30),D$(4),DIO(11),Tcs,Gs,SHORT DIO(4),MILLI(4),DIL(11),Dist(2)
1630 INTEGER L,Flag3
1630 Gain=10
1631 T=100
1632 GOTO 1650
1640 INPUT "SCAN INTERVAL IN MILLISECONDS (MINIMUM 15ms) (60 SAMPLES PER SECOND) ",T
1650 N=11
1660 CONTROL MASK 6;0
1670 CARD ENABLE 6
1680 OUTPUT 6 WMS USING "0,W";15
1690 OUTPUT 9;"A"
1700 OUTPUT 9;"U1=01,U2=12"
1710 L=0
1720 PRINT LIN(50),CHR$(133);"          ***** TO STOP DATA ACQUISITION PRESS A *****"
1730 ON KEY #0,15 GOTO 1960
1740 ON INT #9,8 GOSUB Sample
1750 CONTROL MASK 9;128
1760 OUTPUT 9;"B U1P",T
1770 CARD ENABLE 9
1780 CONTROL MASK 6;1
1790 CARD ENABLE 6
1800 OUTPUT 6 WMS USING "0,W";-32768+Gain*2048
1810 CONTROL MASK 6;33
1820 CARD ENABLE 6
1830 PRINT LIN(8)
1840 INPUT "          ***** TO START DATA ACQUISITION PRESS CONT *****"
1850 Cont
1860 OUTPUT 9;"U1D 20"
1870 OUTPUT 9;"U1G,U2G"
1880 OUTPUT 9;"U2V"
1890 ENTER 9;BeginTime
1900 REM
1910 GOTO 1890
1920 Sample: CARD ENABLE 9
1930 L=L+1
1940 IF L>1398 THEN GOTO 1960
1950 ENTER 6 WDMA N NOFORMAT;D$(L)
1960 RETURN
1970 OUTPUT 9;"U2V"
1980 ENTER 9;EndTime
1990 PRINT CHR$(27)+"E"

```

```

1990 PRINT LIN(50),TAB(16),CHR$(132):"DATA ACQUISITION COMPLETED"
2000 DISABLE
2010 REDIM D$(L),M11$(L),Dist(2,L),D(L,11)
2020 Scantime=(Endtime-Begintime)/L
2030 M11(1)=Scantime
2040 FOR I=2 TO L
2050 M11(I)=M11(I-1)+Scantime
2060 NEXT I
2070 WAIT 3000
2080 PRINT CHR$(27)@"E"
2090 SERIAL
2100 SUBEND
2110 SUB Store
2120 OPTION BASE 1
2130 COM Loc$(50),T$(14*(30)),D$(11),D1(11),Tcs,G$,SHORT Div(1),M11(11),D(1),D1
2140 INTEGER L,Flag3
2150 ON ERROR GOTO 2200
2160 Phnrec=1.3*(INT((L+24+L+2)*(256)*INT((L+24+L+2)/65536)+5)
2170 CREATE T$(2),Phnrec
2180 ASSIGN #4 TO T$(2)
2190 PRINT #4;Loc$,T$(1),L,D$(1),M11(1)
2200 GOTO 2250
2210 IF ERR%>54 THEN GOTO 2240
2220 DISP TAB(10),CHR$(129):"*** FILE HAS ALREADY BEEN STORED ***"
2230 WAIT 3500
2240 GOTO 2250
2250 PRINT ERR%
2260 SUBEND

```

SUBPROGRAM Calibration

```

2260 SUB Calibration
2270 OPTION BASE 1
2280 DIM Zer(30,11),Short(30,11),Zr(11),Scale(11),List$(27*(41)
2290 COM Loc$(50),T$(14*(30)),D$(11),D1(11),Tcs,G$,SHORT Div(1),M11(11),D(1),D1
2300 INTEGER L,Flag3
2310 CAT TO List$(1),0,B
2320 IF B=0 THEN GOTO 2330
2330 GOTO 3810
2340 MASS STORAGE IS ":T14"
2350 PRINTER IS 16
2360 Gain=10
2370 INPUT "ENTER TIRE CODE (ONE LETTER)",Tcs
2380 PRINT LIN(20)," TO BEGIN CALIBRATION SEQUENCE EQUIPMENT SHOULD BE"
2390 PRINT " TURNED ON FOR ABOUT 15 MINUTES. JACK FRONT END CLEAR"
2400 PRINT " OF GROUND. WHEN COMPLETE PRESS CONTINUE"
2410 INPUT R$
2420 PRINT LIN(20),TAB(12),CHR$(104):"*** DATA ACQUISITION IN PROGRESS ***"
2430 CONTROL MASK 6:0
2440 CARD ENABLE 6
2450 OUTPUT 6 WMS USING "#,W":15
2460 CONTROL MASK 6:1
2470 CARD ENABLE 6
2480 FOR I=1 TO 30
2490 FOR J=1 TO 5 STEP 4
2500 OUTPUT 6 WMS USING "#,W":Gain*2048+(J-1)
2510 ENTER 6 WMS USING "#,W":Zer(I,J)
2520 NEXT J
2530 NEXT I
2540 CONTROL MASK 6:0
2550 CARD ENABLE 6
2560 OUTPUT 6 WMS USING "#,W":13
2570 CONTROL MASK 6:1
2580 CARD ENABLE 6
2590 FOR I=1 TO 30
2600 FOR J=1 TO 5 STEP 4
2610 OUTPUT 6 WMS USING "#,W":Gain*2048+(J-1)
2620 ENTER 6 WMS USING "#,W":Short(I,J)
2630 NEXT J
2640 NEXT I
2650 PRINT CHR$(27)@"E"
2660 PRINT LIN(20)," LOWER FRONT END TO GROUND AND ROLL VEHICLE ALTERNATELY"
2670 PRINT " FORWARD AND BACK BY USING THE FORWARD AND REVERSE GEARS"
2680 PRINT " DO NOT USE ANY BRAKES IN BETWEEN AND ALLOW THE VEHICLE"
2690 PRINT " TO ROLL TO A STOP (VEHICLE IN NEUTRAL,5th WHEEL DOWN)"
2700 PRINT " PRESS CONT WHEN READY"
2710 INPUT R$

```

```

2710 PRINT LIN(20),TAB(13),CHR$(134); "+++ DATA ACQUISITION IN PROGRESS +++"
2720 CONTROL MASK 6;0
2730 CARD ENABLE 6
2740 OUTPUT 6 WMS USING "#,W";15
2750 CONTROL MASK 6;1
2760 CARD ENABLE 6
2770 OUTPUT 6 WMS USING "#,W";-32768+Gain+2048
2780 CONTROL MASK 6;33
2790 CARD ENABLE 6
2800 FOR I=1 TO 30
2810 FOR J=1 TO 11
2820 IF J=1 THEN GOTO 2860
2830 IF J=5 THEN GOTO 2860
2840 ENTER 6 WMS USING "#,W";Zer(I,J)
2850 GOTO 2870
2860 ENTER 6 WMS USING "#,W";Dum
2870 NEXT J
2880 NEXT I
2890 CONTROL MASK 6;0
2900 CARD ENABLE 6
2910 OUTPUT 6 WMS USING "#,W";13
2920 CONTROL MASK 6;1
2930 CARD ENABLE 6
2940 OUTPUT 6 WMS USING "#,W";-32768+Gain+2048
2950 CONTROL MASK 6;33
2960 CARD ENABLE 6
2970 FOR I=1 TO 30
2980 FOR J=1 TO 11
2990 IF J=1 THEN GOTO 3030
3000 IF J=5 THEN GOTO 3030
3010 ENTER 6 WMS USING "#,W";Shnt(I,J)
3020 GOTO 3040
3030 ENTER 6 WMS USING "#,W";Dum
3040 NEXT J
3050 NEXT I
3060 CONTROL MASK 6;0
3070 CARD ENABLE 6
3080 OUTPUT 6 WMS USING "#,W";15
3090 CONTROL MASK 6;1
3100 CARD ENABLE 6
3110 PRINT CHR$(27);"E"
3120 PRINT LIN(20); " FOR CALIBRATION OF VELOCITIES, LOWER 5th WHEEL AND"
3130 PRINT " DRIVE IN A STRAIGHT LINE ON A HARD SURFACE AT 10mph"
3140 PRINT " AS READ ON LABECO DD-1.1. IF VELOCITIES READ ON "
3150 PRINT " DPM ARE NOT ACCURATE, MAKE POT ADJUSTMENTS BEFORE "
3160 PRINT " PROCEEDING FURTHER IN PROGRAM, WHEN READY TO CAL-"
3170 PRINT " IBRATE (AT 10mph AS CLOSE AS POSSIBLE) PRESS CONT"
3180 INPUT R#
3190 PRINT LIN(20),TAB(13),CHR$(134); "+++ DATA ACQUISITION IN PROGRESS +++"
3200 FOR I=1 TO 30
3210 FOR J=4 TO 12 STEP 4
3220 IF J=12 THEN J=11
3230 OUTPUT 6 WMS USING "#,W";Gain+2048+(J-1)
3240 ENTER 6 WMS USING "#,W";Shnt(I,J)
3250 NEXT J
3260 NEXT I
3270 PRINT CHR$(27);"E"
3280 PRINT LIN(20); " *** VELOCITY RUN FINISHED ***"
3290 PRINT LIN(3); " IF YOU FEEL VELOCITY VARIED TOO MUCH DURING RUN AND WISH"
3300 PRINT " TO DO OVER, INPUT '1'. IF NOT INPUT '0'."
3310 INPUT R#1
3320 IF R#1=1 THEN GOTO 3110
3330 PRINT LIN(20)
3340 MAT Zt=ZER
3350 MAT St=ZER
3360 FOR J=1 TO 11
3370 FOR I=5 TO 30
3380 Zt(J)=Zt(J)+Zer(I,J)
3390 St(J)=St(J)+Shnt(I,J)
3400 NEXT I
3410 NEXT J
3420 FOR J=1 TO 11
3430 Zt(J)=Zt(J)/26
3440 St(J)=St(J)/26
3450 NEXT J
3460 Scale(1)=2124/(St(1)-Zt(1))
3470 Scale(2)=2001/(St(2)-Zt(2))
3480 Scale(3)=1992/(St(3)-Zt(3))
3490 Scale(4)=10/(St(4)-Zt(4))

```

```

3500 Scale(5)=2184/(St(5)-Zt(5))
3510 Scale(6)=2011/(St(6)-Zt(6))
3520 Scale(7)=2108/(St(7)-Zt(7))
3530 Scale(8)=10/(St(8)-Zt(8))
3540 Scale(9)=594/(St(9)-Zt(9))
3550 Scale(10)=10/(St(10)-Zt(10))
3560 Scale(11)=10/(St(11)-Zt(11))
3570 OUTPUT 3;"A"
3580 OUTPUT 3;"R"
3590 ENTER 3;T3
3600 DS=TS(1,2)ST(4,5)
3610 ON ERROR GOTO 3630
3620 GOTO 3690
3630 IF EPRN=54 THEN GOTO 3670
3640 PRINT ERRMS
3650 INPUT "PRESS CONT TO RESUME",Dumms
3660 GOTO 3690
3670 INPUT "ENTER 4 DIGIT DATE (MONTH : DAY) ",DS
3680 GS="C"&DS&T3
3690 CREATE GS,1
3700 ASSIGN #6 TO GS
3710 OFF ERROR
3720 PRINT #6;Zt(1),Scale(1)
3730 PRINTER IS 0
3740 PRINT LIN(4),GS
3750 PRINTER IS 16
3760 MAT PRINT Zt
3770 MAT PRINT St
3780 MAT PRINT Scale
3790 PRINTER IS 16
3800 GOTO 3820
3810 Flag3=1
3820 SUBEND

```

SUBPROGRAM Convert

```

3830 SUB Convert
3840 PRINT LIN(20)
3850 DISP TAB(10),CHR$(132);"DATA CONVERSION IN PROGRESS"
3860 OPTION BASE 1
3870 DIM Zt(11),Scale(11)
3880 COM Locs(50),TS(14),C301,D(14),D(11),T(3),GS,SHORT D(14),M(11),D(14),D(14)
3890 INTEGER L,Flag3
3900 PRINTER IS 16
3910 ASSIGN #7 TO TS(14)
3920 READ #7;Zt(1),Scale(1)
3930 FOR I=1 TO L-1
3940 ENTER D(14) USING "M,M(14)"
3950 FOR K=1 TO 11
3960 D(I,K)=(BINCMP(D(14,K))-Zt(K))*Scale(K)
3970 NEXT K
3980 NEXT I
3990 PRINT CHR$(27)"E"
3990 SUBEND

```

SUBPROGRAM Rawdata

```

4000 SUB Rawdata
4010 OPTION BASE 1
4020 COM Locs(50),TS(14),C301,D(14),D(11),T(3),GS,SHORT D(14),M(11),D(14),D(14)
4030 INTEGER L,Flag3
4040 INPUT "HARD COPY OR ON CRT (H OR C)",Rp1s
4050 PRINTER IS 16
4060 IF Rp1s="H" THEN PRINTER IS 0
4070 IMAGE 1X,"LV",5X,"LL",5X,"LS",5X,"LV",5X,"RV",5X,"PL",5X,"PE",5X,"PV",5X
4080 IMAGE 0,40,"M(11)"
4090 IMAGE 0,40,3X
4100 IMAGE 0,3X,40,3X
4110 IMAGE 0,DD,D,3X
4120 IMAGE 0,2X,DD,D,3X
4130 IMAGE 0,DDDDDD,D
4140 IMAGE 0,20X
4150 PRINT CHR$(27)"H"
4160 PRINT USING 4060
4170 PRINT CHR$(27)"I"
4180 FOR J=1 TO L-1
4190 PRINT USING 4120

```

```

4130 FOR K=1 TO 3
4190 IF K=5 THEN GOTO 4230
4200 IF (K=4) OR (K=9) THEN GOTO 4250
4210 PRINT USING 4070;D(J,K)
4220 GOTO 4260
4230 PRINT USING 4080;D(J,K)
4240 GOTO 4260
4250 PRINT USING 4090;D(J,K)
4260 NEXT K
4270 PRINT USING 4100;D(J,11)
4280 PRINT USING 4110;MILLI(J)
4290 NEXT J
4300 PRINT CHR$(27)&"m"
4310 PRINT LIN(3)
4320 SUBEND

```

SUBPROGRAM Average

```

4330 SUB Average
4340 OPTION BASE 1
4350 DIM Ave$(9),A$(L+1),Prnt$(8)
4360 COM LOC$(50),T$(14),C$(3),D$(11),T$(3),G$,SHORT D$(11),MILLI$(11),D$(11)
4370 INTEGER L,Flag$
4380 MAT Ave=ZER
4390 PRINTER IS 16
4400 PRINT LIN(20)
4410 PRINT LIN(20),"          VERTICAL - 1"
4420 PRINT "          LONGITUDINAL - 2"
4430 PRINT "          SIDE - 3"
4440 PRINT "          VELOCITY - 4"
4450 PRINT LIN(5)
4460 INPUT "CHOOSE CODE FOR CHANNEL TO BE AVERAGED ",Ch
4470 PRINT LIN(20)
4480 PRINT "          WHAT PERCENT OF THE DATA POINTS DO YOU WANT AVERAGED ?"
4490 PRINT LIN(20),"ANYTHING LESS THAN 100% WILL AVERAGE THE UPPER ABSOLUTE APL
4500 INPUT Prnt$(Ch)
4510 Prnt$(Ch+4)=Prnt$(Ch)
4520 PRINT LIN(20),"          I M WORKING"
4530 FOR G=Ch TO Ch+4 STEP 4
4540 FOR H=1 TO L-1
4550 A$(H)=D$(H,G)
4560 NEXT H
4570 IF Prnt=100 THEN GOTO 4630
4580 MAT SORT A
4590 Sum2=0
4600 FOR P=1 TO L-20
4610 Sum2=Sum2+A$(P)
4620 NEXT P
4630 Ave$(Sum2/(L-20))
4640 IF Ave$(0) THEN GOTO 4680
4650 FOR H2=1 TO L-1
4660 A$(H2)=ABS(D$(H2,G))
4670 NEXT H2
4680 MAT SORT A
4690 Sum1=0
4700 Count=INT(Prnt$(Ch)/100*(L-1))
4710 IF Count<1 THEN Count=1
4720 FOR P=L-Count TO L-1
4730 Sum1=Sum1+A$(P)
4740 NEXT P
4750 Ave$(G)=Sum1/Count
4760 PRINT LIN(20)
4770 INPUT "          DO YOU WANT TO CALCULATE ANY OTHER AVERAGES (Y OR N)?:Ques$
4780 IF Ques$="Y" THEN GOTO 4380
4790 INPUT "DO YOU WANT THE OUTPUT ON THE CRT OR A HARD COPY (C OR H)?:P$
4800 IF P$="H" THEN GOTO 4830
4810 PRINTER IS 0
4820 GOTO 4840
4830 PRINTER IS 16
4840 INPUT "DO YOU WANT TO SUPPRESS THE HEADING (DOCUMENTARY DATA) (Y OR N)?:Pp$
4850 IF Pp$="Y" THEN GOTO 4930
4860 PRINT LIN(5)

```

```

4870 PRINT USING 5050:Loc$
4880 PRINT USING 5060:"FILE ";T$(2);T$(7);" TEST"
4890 PRINT USING 5060:"TIRE ";T$(5);T$(6);" psi"
4900 PRINT USING 5070:"MATERIAL: ";T$(8)
4910 PRINT USING 5070:T$(10);" CM THICKNESS"
4920 PRINT USING 5060:T$(12);" g cc";T$(11);" DEG C AMBIENT"
4930 PRINT LIN(3)
4940 FOR I=1 TO 8
4950 IF Ave(I)=0 THEN GOTO 5090
4960 Sds="LEFT "
4970 IF I=4 THEN Sds="RIGHT "
4980 Units=" LBS"
4990 IF (I=4) OR (I=8) THEN Units=" MPH"
5000 IF (I=1) OR (I=5) THEN Chs="VERTICAL"
5010 IF (I=2) OR (I=6) THEN Chs="LONGITUDINAL"
5020 IF (I=3) OR (I=7) THEN Chs="SIDE"
5030 IF (I=4) OR (I=8) THEN Chs="VELOCITY"
5040 PRINT USING 5080:"AVERAGE OF UPPER ";Print(I);"% OF DATA = ";Sds;Chs;" = "
: Ave(I);Units
5050 IMAGE K
5060 IMAGE 2(K),4(K),2(K)
5070 IMAGE 3(K)
5080 IMAGE K,DDD.D,4(K),DDDD.D,K
5090 NEXT I
5100 IF Rs="H" THEN GOTO 5130
5110 PRINT LIN(5)
5120 INPUT " PRESS CONT TO RESUME",Dum
5130 SUBEND
5140 SUB Slip_energy
5150 OPTION BASE 1
5160 DIM Slipen(2,L)
5170 COM Loc$(50),T$(14);(30),D$(4);(D(I,1)),Tcs,G$,SHORT D$(4);(D(I,1)),D(I,1)
: st(4),INTEGER L,Flag3
5180 Flag1=0
5190 Flag2=0
5200 Cnt=0
5210 IF T$(7)="TRACTION" THEN GOTO 5280
5220 PRINT TAB(10);CHR$(132);"*** FILE INDICATES THIS IS NOT A TRACTION TEST **"
5230 PRINT CHR$(128)
5240 PRINT LIN(2);"DO YOU STILL WANT AN INTEGRATION OF THE LONGITUDINAL FORCE-D
:ISTANCE CURVE"
5250 PRINT TAB(30);"Y OR N?"
5260 INPUT Rs
5270 IF Rs="Y" THEN GOTO 5690
5280 INPUT "DO YOU WANT THE OUTPUT ON THE CRT (C) OR A HARD COPY (H)?",Rp1$
5290 PRINT LIN(20);TAB(30);"I'M WORKING"
5300 PRINT LIN(5)
5310 IF Rp1$(1)="H" THEN GOTO 5340
5320 PRINTER IS 0
5330 GOTO 5350
5340 PRINTER IS 16
5350 PRINT LIN(2)
5360 MAT Dist=ZER
5370 Cnt=Cnt+1
5380 IF Cnt=3 THEN GOTO 5670
5390 IF Cnt=2 THEN GOTO 5470
5400 FOR I=2 TO L-1
5410 Dist(1,I)=Dist(1,I-1)+5280/3600*(D(I,4)+D(I-1,4))/2+(M11(I)-M11(I-1)
:)/1000)
5420 Dist(2,I)=Dist(2,I-1)+5280/3600*(D(I,3)+D(I-1,3))/2+(M11(I)-M11(I-1)
:)/1000)
5430 NEXT I
5440 PRINT LIN(2);"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5450 PRINT LIN(1);"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
5460 GOTO 5540
5470 MAT Dist=ZER
5480 FOR I=2 TO L-1
5490 Dist(1,I)=Dist(1,I-1)+5280/3600*(D(I,11)+D(I-1,11))/2+(M11(I)-M11(I-1)
:)/1000)
5500 Dist(2,I)=Dist(2,I-1)
5510 NEXT I
5520 PRINT LIN(2);"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5530 INPUT "PRESS CONT TO RESUME",Dum
5540 MAT Slipen=ZER
5550 FOR I=2 TO L-1
5560 Slipen(1,I)=Slipen(1,I-1)+(D(I,2)+D(I-1,2))/2*(Dist(1,I)-Dist(1,I-1))
5570 Slipen(2,I)=Slipen(2,I-1)+(D(I,6)+D(I-1,6))/2*(Dist(2,I)-Dist(2,I-1))
5580 NEXT I
5590 IF Cnt=2 THEN GOTO 5640

```

```

5600 IMAGE =K,DDDDDD,D,K
5610 PRINT USING 5600;"LEFT WHEEL ENERGY INPUT = ";(Slipen-1,L-1);" FT-LBS"
5620 PRINT USING 5600;"RIGHT WHEEL ENERGY INPUT = ";(Slipen-2,L-1);" FT-LBS"
5630 GOTO 5660
5640 PRINT USING 5600;"VEHICLE DISTANCE BASED ENERGY LEFT SIDE = ";(Slipen-1,L-1);" FT-LBS"
5650 PRINT USING 5600;"VEHICLE DISTANCE BASED ENERGY RIGHT SIDE = ";(Slipen-2,L-1);" FT-LBS"
5660 GOTO 5370
5670 PRINTER IS 16
5680 INPUT "PRESS CONT TO RESUME",Dum
5690 SUBEND

```

SUBPROGRAM Traction

```

5700 SUB Traction
5710 OPTION BASE 1
5720 COM Loc$(501,T$(14),C$(30),D$(4),D$(11),T$(5),G$,SHORT Dime$,Mille$,Dime$,Dime$,
5730 ,INTEGER L,Flag3
5740 IF T$(7)="TRACTION" THEN GOTO 5810
5750 PRINT PAGE,CHR$(132),"++++ FILE INDICATES THIS IS NOT A TRACTION TEST ++++"
5760 PRINT CHR$(128)
5770 PRINT LIN(1)
5780 INPUT "DO YOU STILL WANT A TRACTION VALUE (Y OR N)?",Rpl$
5790 IF Rpl$="N" THEN GOTO 6510
5800 PRINT "
5810 MAT D10=ZER
5820 FOR I=1 TO L-1
5830 D10(1,I)=(D(I,4)-D(I,11))/88
5840 D10(2,I)=(D(I,3)-D(I,11))/88
5850 NEXT I
5860 FOR K=1 TO L-1
5870 D10(3,K)=D(K,2)
5880 D10(4,K)=D(K,6)
5890 NEXT K
5900 MAT SORT D10(1,*)
5910 Big1=D10(3,1)
5920 FOR J=2 TO L-1
5930 IF D10(3,J)>Big1 THEN GOTO 5960
5940 Big1=D10(3,J)
5950 Marker1=J
5960 NEXT J
5970 Count=0
5980 H=0
5990 Low=D10(1,Marker1)+44
6000 High=D10(1,Marker1)+44
6010 FOR I=1 TO L-1
6020 IF (D10(1,I)<Low) OR (D10(1,I)>High) THEN GOTO 6050
6030 Count=Count+1
6040 H=H+D10(3,I)
6050 NEXT I
6060 Hleft=H/Count
6070 MAT SORT D10(2,*)
6080 Big2=D10(4,1)
6090 FOR J=2 TO L-1
6100 IF D10(4,J)>Big2 THEN GOTO 6130
6110 Big2=D10(4,J)
6120 Marker2=J
6130 NEXT J
6140 Count=0
6150 H=0
6160 Low=D10(2,Marker2)+44
6170 High=D10(2,Marker2)+44
6180 FOR I=1 TO L-1
6190 IF (D10(2,I)<Low) OR (D10(2,I)>High) THEN GOTO 6220
6200 Count=Count+1
6210 H=H+D10(4,I)
6220 NEXT I
6230 Hright=H/Count
6240 PRINT PAGE
6250 INPUT "DO YOU WANT HARD COPY OR CPT OUTPUT (H OR C)?",Rpl$
6260 IF Rpl$="H" THEN GOTO 6290
6270 PRINTER IS 16
6280 GOTO 6300
6290 PRINTER IS 0
6300 INPUT "DO YOU WANT THE HEADING (DOCUMENTARY DATA SUPPRESSED (Y OR N)?",Rpl$

```

```

6310 IF Pp$="Y" THEN GOTO 6390
6320 PRINT LIN(5)
6330 PRINT USING 6470;Loc$
6340 PRINT USING 6480;"FILE "TS(2);TS(7);" TEST"
6350 PRINT USING 6480;"TIRE "TS(5);TS(6);" PSI"
6360 PRINT USING 6490;"MATERIAL: "TS(8)
6370 PRINT USING 6490;TS(10);" CM THICKNESS"
6380 PRINT USING 6480;TS(12);" g cc";TS(11);" DEG C (AMBIENT)"
6390 PRINT LIN(3)
6400 PRINT "TRACTION EFFORT (WITHOUT RESISTANCE ADDED IN)"
6410 PRINT USING 6500;" LEFT SIDE = ";Hleft
6420 PRINT USING 6500;" RIGHT SIDE = ";Hright
6430 PRINT LIN(2)
6440 PRINTER IS 16
6450 IF Pp$="H" THEN GOTO 6470
6460 INPUT "PRESS CONT TO RESUME",C0
6470 IMAGE K
6480 IMAGE 2(K),4X,2(K)
6490 IMAGE 3(K)
6500 IMAGE 6(K)
6510 SUBEND
6520 SUB Plots
6530 OPTION BASE 1
6540 DIM YLabel$(40),XLabel$(40)
6550 COM Loc$(50),TS(14) (30),Dts(11),Dts(11),Tos,Gr,SHORT Dts(11),Hleft(11),Dts(11),Dts(11)
6560 INTEGER L,Flag3
6570 Flag1=0
6580 Flag2=0
6590 PLOTTER IS 13,"GRAPHICS"
6600 PRINTER IS 16
6610 PRINT LIN(50)
6620 PRINT "          VERTICAL - 1"
6630 PRINT "          LONGITUDINAL - 2"
6640 PRINT "          SIDE - 3"
6650 PRINT "          VELOCITY - 4"
6660 PRINT "          LONG. VERTICAL - 5"
6670 PRINT LIN(3)
6680 INPUT "CHOOSE VERTICAL AXIS FORCE CODE ",Y
6690 PRINT LIN(3)
6700 PRINT "          DISTANCE - 1"
6710 PRINT "          TIME - 2"
6720 PRINT "          DIV - 3"
6730 PRINT LIN(3)
6740 INPUT "CHOOSE HORIZONTAL AXIS CODE ",X
6750 ON Y GOTO 6750,6840,6930,7020,7110
6750 Var1=1
6760 YLabel$="VERTICAL FORCE (LBS) "
6770 Var2=5
6780 Ymin=0
6790 Ymax=3000
6800 Ytic=50
6810 Yint=0
6820 Ymaj=10
6830 GOTO 7170
6840 Var1=2
6850 YLabel$="LONGITUDINAL FORCE (LBS) "
6860 Var2=5
6870 Ymin=-200
6880 Ymax=1000
6890 Ytic=25
6900 Yint=-200
6910 Ymaj=8
6920 GOTO 7170
6930 Var1=3
6940 YLabel$="SIDE FORCE (LBS)"
6950 Var2=7
6960 Ymin=-400
6970 Ymax=401
6980 Ytic=50
6990 Yint=-400
7000 Ymaj=4
7010 GOTO 7170
7020 Var1=4
7030 YLabel$="WHEEL SPEED (MPH)"
7040 Var2=8
7050 Ymin=0
7060 Ymax=30
7070 Ytic=.5
7080 Yint=0

```

```

7090 Ymaj=6
7100 GOTO 7170
7110 Ymin=0
7120 Ymax=.3001
7130 Xinc=.05
7140 Xint=0
7150 Xmaj=2
7160 Xlab=18:"LONGITUDINAL VERTICAL FORCE"
7170 IF X=2 THEN GOTO 7530
7180 IF X=3 THEN GOTO 7660
7190 PRINT LINK3)
7200 INPUT "DISTANCE TRAVELED BY VEHICLE (0) OR DISTANCE TRAVELED BY WHEEL (1) "
,P
7210 IF R=0 THEN GOTO 7340
7220 Flag1=Flag1+1
7230 IF Flag1=1 THEN GOTO 7450
7240 Dist(1,1)=0
7250 Dist(2,1)=0
7260 FOR I=2 TO L-1
7270 Dist(1,I)=Dist(1,I-1)+5280/3600*(D(I,4)+D(I-1,4))/2+(M111(I)-M111(I-1)
+1000)
7280 Dist(2,I)=Dist(2,I-1)+5280/3600*(D(I,8)+D(I-1,8))/2+(M111(I)-M111(I-1)
+1000)
7290 NEXT I
7300 PRINT LINK5), "TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1); " FT"
7310 PRINT LINK1), "TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1); " FT"
7320 INPUT "PRESS CONT TO RESUME",Dum
7330 GOTO 7450
7340 Flag2=Flag2+1
7350 IF Flag2=1 THEN GOTO 7440
7360 Dist(1,1)=0
7370 Dist(2,1)=0
7380 FOR I=2 TO L-1
7390 Dist(1,I)=Dist(1,I-1)+5280/3600*(D(I,11)+D(I-1,11))/2+(M111(I)-M111(I-1)
+1000)
7400 Dist(2,I)=Dist(1,I)
7410 NEXT I
7420 PRINT LINK5), "TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1); " FT"
7430 INPUT "PRESS CONT TO RESUME",Dum
7440 IF R=0 THEN GOTO 7470
7450 Xlab=18:"DISTANCE TRAVELED BY WHEEL (FT)"
7460 GOTO 7480
7470 Xlab=18:"DISTANCE TRAVELED BY VEHICLE (FT)"
7480 Xmin=0
7490 Xmax=Dist(1,L-1)+10
7500 IF Dist(2,L-1)>Dist(1,L-1) THEN Xmax=Dist(2,L-1)+10
7510 Xint=0
7520 Xmaj=5
7530 Xinc=2
7540 IF Xmax>110 THEN Xinc=4
7550 IF Xmax>210 THEN Xinc=8
7560 IF Xmax>800 THEN Xinc=24
7570 GOTO 7930
7580 Xlab=18:"TIME (SEC)"
7590 Xmin=0
7600 Xmax=INT((1000*(M111(5)-M111(4)))/+1
7610 Xinc=.5
7620 Xint=0
7630 Xmaj=2
7640 IF Xmax>16 THEN Xmaj=4
7650 GOTO 7930
7660 Xlab=18:"DIFFERENTIAL INTERFACE VELOCITY (FT/SEC)"
7670 MAT Div=ZER
7680 IF Y<5 THEN GOTO 7730
7690 Var1=1
7700 Var2=5
7710 Var3=2
7720 Var4=6
7730 FOR I=1 TO L-1
7740 Div(1,I)=D(I,4)-D(I,11)+5280/3600)
7750 IF Div(1,I)<0 THEN Div(1,I)=0
7760 Div(2,I)=(D(I,9)-D(I,11))+5280/3600)
7770 IF Div(2,I)<0 THEN Div(2,I)=0
7780 Div(3,I)=D(I,Var1)
7790 Div(4,I)=D(I,Var2)
7800 IF Y<5 THEN GOTO 7830
7810 Div(5,I)=D(I,Var3)
7820 Div(6,I)=D(I,Var4)
7830 NEXT I

```

```

7840 GOTO 7850
7850 Xmin=0
7860 MAT SORT Dloc(1,*)
7870 Xmax=Dloc(1,L-1)+5
7880 MAT SORT Dloc(2,*)
7890 IF Dloc(2,L-1)+5<Xmax THEN Xmax=Dloc(2,L-1)+5
7900 Xtic=.5
7910 Xmaj=10
7920 IF Xmax<50 THEN Xmaj=20
7930 Xr=ABS(Xmax-Xmin)
7940 Yr=ABS(Ymax-Ymin)
7950 PRINTER IS 16
7960 GRAPHICS
7970 SCALE Xmin-.3+Yr,Xmax+.2+Xr,Ymin-.3+Yr,Ymax+.2+Yr
7980 CLIP Xmin,Xmax,Ymin,Ymax
7990 AXES Xtic,Ytic,Xint,Yint,Xmaj,Ymaj,6
8000 LINE TYPE 6
8010 IF Y=5 THEN GOTO 8490
8020 MOVE Xmin,D(1,Var1)
8030 IF X=1 THEN GOTO 8030
8040 IF X=3 THEN GOTO 8120
8050 FOR I=1 TO L-1
8060 DRAW Mili(I)/1000,D(I,Var1)
8070 NEXT I
8080 GOTO 8180
8090 FOR I=1 TO L-2
8100 DRAW Dist(1,I+1),D(I,Var1)
8110 NEXT I
8120 GOTO 8180
8130 MAT SORT Dloc(1,*)
8140 FOR I=2 TO L-1
8150 IF (Dloc(1,I)=0) AND (Dloc(2,I)=0) THEN GOTO 8170
8160 DRAW Dloc(1,I),D(I,Var1)
8170 NEXT I
8180 LINE TYPE 1
8190 MOVE Xmin,D(1,Var2)
8200 IF X=1 THEN GOTO 8260
8210 IF X=3 THEN GOTO 8300
8220 FOR I=1 TO L-1
8230 DRAW Mili(I)/1000,D(I,Var2)
8240 NEXT I
8250 GOTO 8350
8260 FOR I=1 TO L-2
8270 DRAW Dist(2,I+1),D(I,Var2)
8280 NEXT I
8290 GOTO 8350
8300 MAT SORT Dloc(2,*)
8310 FOR I=2 TO L-1
8320 IF (Dloc(1,I)=0) AND (Dloc(2,I)=0) THEN GOTO 8340
8330 DRAW Dloc(2,I),D(I,Var2)
8340 NEXT I
8350 IF Y=4 THEN GOTO 8480
8360 LINE TYPE 8
8370 MOVE Xmin,D(1,11)
8380 IF X=1 THEN GOTO 8440
8390 IF X=3 THEN GOTO 8470
8400 FOR I=1 TO L-1
8410 DRAW Mili(I)/1000,D(I,11)
8420 NEXT I
8430 GOTO 8470
8440 FOR I=1 TO L-2
8450 DRAW Dist(2,I+1),D(I,11)
8460 NEXT I
8470 LINE TYPE 1
8480 GOTO 8520
8490 MOVE Xmin,D(1,2)/D(1,1)
8500 IF X=1 THEN GOTO 8560
8510 IF X=3 THEN GOTO 8600
8520 FOR I=1 TO L-1
8530 DRAW Mili(I)/1000,D(I,2)/D(I,1)
8540 NEXT I
8550 GOTO 8650
8560 FOR I=1 TO L-2
8570 DRAW Dist(1,I+1),D(I,2)/D(I,1)
8580 NEXT I
8590 GOTO 8650
8600 MAT SORT Dloc(1,*)
8610 FOR I=2 TO L-1
8620 IF (Dloc(3,I)=0) AND (Dloc(4,I)=0) THEN GOTO 8640
8630 DRAW Dloc(1,I),Dloc(5,I)/Dloc(3,I)

```

```

3640 NEXT I
3650 LINE TYPE 1
3660 MOVE Xmin,D(I,6)/D(I,5)
3670 IF X=1 THEN GOTO 8730
3680 IF X=3 THEN GOTO 8770
3690 FOR I=1 TO L-1
3700 DRAW Mill(I)/1000,D(I,6)/D(I,5)
3710 NEXT I
3720 GOTO 8820
3730 FOR I=1 TO L-2
3740 DRAW Dist(2,I+1),D(I,6)/D(I,5)
3750 NEXT I
3760 GOTO 8820
3770 MAT SORT Div(2,*)
3780 FOR I=2 TO L-1
3790 IF -Div(3,I)=0 AND -Div(4,I)=0 THEN GOTO 8810
3800 DRAW Div(2,I),Div(6,I)/Div(4,I)
3810 NEXT I
3820 LOG 5
3830 FOR J=Xmin TO Xmax STEP Xinc*Xmaj
3840 MOVE J,Yint-.05*Yr
3850 LABEL J
3860 NEXT J
3870 FOR J=Ymin TO Ymax STEP Yinc*Ymaj
3880 MOVE Xint-.07*Nr,J
3890 LABEL J
3900 NEXT J
3910 LOG 4
3920 MOVE Xr/2,Ymin-.2*Yr
3930 LABEL XLabels
3940 DEG
3950 LDIR 90
3960 MOVE Xmin-.2*Xr,(Ymax+Ymin)/2
3970 LABEL YLabels
3980 LDIR 0
3990 CSIZE 2.9,.444
4000 Sp=Xmin+.15*Xr
4010 LOG 2
4020 MOVE Sp,Ymax-.01*Yr
4030 LABEL Locs
4040 MOVE Sp,Ymax-.05*Yr
4050 LABEL "FLNM: ";Ts(2)
4060 MOVE Sp,Ymax-.09*Yr
4070 LABEL "TIRE: ";Ts(5)
4080 MOVE Sp,Ymax-.13*Yr
4090 LABEL Ts(6);" psi"
4100 MOVE Sp,Ymax-.17*Yr
4110 LABEL Ts(7);" TEST"
4120 Sp=5*Sp
4130 MOVE Sp,Ymax-.01*Yr
4140 LOG 8
4150 LABEL "LEFT WHEEL "
4160 MOVE Sp,Ymax-.01*Yr
4170 LINE TYPE 6
4180 LOG 2
4190 FOR I=.1 TO 1.4 STEP .4
4200 DRAW 6*(Xmin+.25*Xr)+I,Ymax-.01*Yr
4210 NEXT I
4220 MOVE Sp,Ymax-.05*Yr
4230 LINE TYPE 1
4240 LOG 8
4250 LABEL "RIGHT WHEEL "
4260 MOVE Sp,Ymax-.05*Yr
4270 LOG 2
4280 FOR I=.1 TO 1.4 STEP .4
4290 DRAW 6*(Xmin+.25*Xr)+I,Ymax-.05*Yr
4300 NEXT I
4310 IF Y>4 THEN GOTO 9410
4320 MOVE Sp,Ymax-.09*Yr
4330 LOG 8
4340 LABEL "5th WHEEL "
4350 MOVE Sp,Ymax-.09*Yr
4360 LINE TYPE 8
4370 LOG 2
4380 FOR I=.1 TO 1.4 STEP .4
4390 DRAW 6*(Xmin+.25*Xr)+I,Ymax-.09*Yr
4400 NEXT I
4410 WAIT 5000
4420 INPUT "DO YOU WANT A HARD COPY (Y OR N)",Pp1s
4430 IF Pp1s<>"Y" THEN GOTO 9480

```

FILE NAME: READ-2:T15 DATE : 09:20:08:14
MAIN PROGRAM

*** DATA CONVERSION IN PROGRESS ***

```

640 IMAGE 0, " "
650 PRINT USING 640
660 PRINT LIN(1), "FILE NAME: "; TS(2)
670 PRINT LIN(1), "LOCATION: "; Locs
680 PRINT LIN(1), "AMBIENT TEMP: "; TS(3); " DEG C"
690 PRINT LIN(1), "DATE AND TIME: "; TS(4)
700 PRINT LIN(1), "TIRE CODE: "; TS(5)
710 PRINT LIN(1), "TIRE INFLATION PRESS: "; TS(6); " PSI"
720 PRINT LIN(1), "TEST TYPE: "; TS(7)
730 PRINT LIN(1), "CALIBRATION FILE NAME: "; TS(14)
740 PRINT LIN(3), "TEST MATERIAL: "; TS(8)
750 PRINT LIN(1), "TYPE OR UNDERLYING SURFACE: "; TS(9)
760 PRINT LIN(1), "DEPTH OR THICKNESS: "; TS(10); " CM"
770 PRINT LIN(1), "MATERIAL TEMP: "; TS(11); " DEG C", LIN(1)
780 IF TS(8)="SNOW" THEN PRINT "SNOW DENSITY: "; TS(12); " G CC"
790 IF TS(8)="THAWING SOIL" THEN PRINT "FROZEN LAYER THICK: "; TS(12); " CM"
800 PRINT LIN(1), "SOLAR INPUT (CLOUD COVER, SHADE) "; TS(13); " "
810 SUBEND
820 SUB Rawdata
830 OPTION BASE 1
840 DIM Locs(50), TS(14*(30)), YLabels(50), XLabels(50), SHORT Dist(4), Dist(4), Dist(4)
850 INTEGER L, Millisec
860 PRINTER IS 16
870 INPUT "HARD COPY OR ON CRT (H OR C) ", PpIs
880 IF PpIs="H" THEN PRINTER IS 0
890 IMAGE 1X, "LV", 5X, "LL", 5X, "LS", 5X, "LV1", 7X, "RV", 5X, "RL", 5X, "PS", 5X, "RV1", 6X,
900 "SV1", 4X, "M111",
910 IMAGE 0, 4D, 3X
920 IMAGE 0, 3X, 4D, 3X
930 IMAGE 0, DD, D, 3X
940 IMAGE 0, 2X, DD, D, 3X
950 IMAGE 0, 6D
960 IMAGE 1, 20X
970 PRINT CHR$(27) & "H"
980 PRINT USING 380
990 PRINT CHR$(27) & "I"
1000 FOR J=1 TO L-1
1010 PRINT USING 940
1020 FOR I=1 TO 8
1030 IF K=5 THEN GOTO 1050
1040 IF (K=4) OR (I=8) THEN GOTO 1070
1050 PRINT USING 890; D(I, K)
1060 GOTO 1080
1070 PRINT USING 910; D(I, K)
1080 NEXT K
1090 PRINT USING 920; D(I, 11)
1100 PRINT USING 930; Millisec(J)
1110 NEXT J
1120 PRINT LIN(2)
1130 PRINT CHR$(27) & "M"
1140 SUBEND
1150 SUB Average
1160 OPTION BASE 1
1170 DIM Ave(8), A(L+1), Prnt(4)
1180 DIM Locs(50), TS(14*(30)), YLabels(50), XLabels(50), SHORT Dist(4), Dist(4), Dist(4)
1190 INTEGER L, Millisec
1200 MAT Ave=ZER
1210 Mkr=0
1220 PRINTER IS 16
1230 PRINT LIN(20), " VERTICAL - 1"
1240 PRINT " LONGITUDINAL - 2"
1250 PRINT " SIDE - 3"
1260 PRINT " VELOCITY - 4"
1270 PRINT " LONG./VERT. - 5"
1280 PRINT LIN(5)
1290 INPUT "CHOOSE CODE FOR CHANNEL TO BE AVERAGED ", Ch
1300 IF Ch<>5 THEN GOTO 1320
1310 Ch=2
1320 Mkr=1
1330 PRINT LIN(20)
1340 PRINT " WHAT PERCENT OF THE DATA POINTS DO YOU WANT AVERAGED ?"
1350 PRINT LIN(2), "ANYTHING LESS THAN 100% WILL AVERAGE THE UPPER (ABSOLUTE VAL
UE) PERCENT CHOSEN"
1360 INPUT Prnt(Ch)
1370 Prnt(Ch+4)=Prnt(Ch)
1380 PRINT LIN(20), TAB(30), "I'M WORKING"
1390 PRINT LIN(5)
1400 FOR G=Ch TO Ch+4 STEP 4

```

```

1400 FOR H=1 TO L-1
1410 A(H)=D(H,G)
1420 IF H=1 THEN A(H)=D(H,G)-D(H,G-1)
1430 NEXT H
1440 IF Pcnt=100 THEN GOTO 1560
1450 MAT SORT A
1460 Sum2=0
1470 FOR P=1 TO L-20
1480 Sum2=Sum2+A(P)
1490 NEXT P
1500 Aven=Sum2/(L-20)
1510 IF Aven>0 THEN GOTO 1560
1520 FOR H2=1 TO L-1
1530 A(H2)=ABS(A(H2))
1540 NEXT H2
1550 MAT SORT A
1560 Sum1=0
1570 Count=INT(Pcnt/100*(L-1))
1580 FOR P=L-Count TO L-1
1590 Sum1=Sum1+A(P)
1600 NEXT P
1610 Ave(G)=Sum1/Count
1620 NEXT G
1630 PRINT LIN(20)
1640 INPUT " DO YOU WANT TO CALCULATE ANY OTHER AVERAGES (Y OR N)?",Overs
1650 IF Overs="Y" THEN GOTO 1210
1660 INPUT "DO YOU WANT THE OUTPUT ON THE CRT OR A HARD COPY (C OR H)?",Rs
1670 IF Rs="H" THEN GOTO 1700
1680 PRINTER IS 0
1690 GOTO 1710
1700 PRINTER IS 16
1710 INPUT "DO YOU WANT TO SUPPRESS THE HEADING (DOCUMENTARY DATA) (Y OR N)?",Rs
1720 IF Rs="Y" THEN GOTO 1790
1730 PRINT USING 1910;Locs
1740 PRINT USING 1920;"FILE ";TS(2);TS(7);" TEST"
1750 PRINT USING 1920;"TYPE ";TS(5);TS(6);" psi"
1760 PRINT USING 1930;"MATERIAL: ";TS(8)
1770 PRINT USING 1930;TS(10);" CM THICKNESS"
1780 PRINT USING 1920;TS(12);" g/cc";TS(11);" DEG C (AMBIENT)"
1790 PRINT LIN(2)
1800 FOR I=1 TO 8
1810 IF Ave(I)=0 THEN GOTO 1950
1820 Sds="LEFT "
1830 IF I=4 THEN Sds="RIGHT "
1840 Units=" LBS"
1850 IF (I=4) OR (I=8) THEN Units=" MPH"
1860 IF (I=1) OR (I=5) THEN Chs="VERTICAL"
1870 IF (I=2) OR (I=6) THEN Chs="LONGITUDINAL"
1880 IF (I=3) OR (I=7) THEN Chs="SIDE"
1890 IF (I=4) OR (I=8) THEN Chs="VELOCITY"
1900 PRINT USING 1940;"AVERAGE OF UPPER ";Pcnt/100;"% OF DATA = ";Sds;Chs;" - "
1910 Ave(I)/Units
1910 IMAGE K
1920 IMAGE 2(Y),4X,2(X)
1930 IMAGE 3(K)
1940 IMAGE /K,DDD.D,4(X),DDDD.DDDD,K
1950 NEXT I
1960 IF Rs="H" THEN GOTO 1990
1970 PRINT LIN(5)
1980 INPUT " PRESS CONT TO RESUME",Dum
1990 SUBEND
2000 SUB Plots
2010 OPTION BASE 1
2020 COM Locs(50),TS(14)-(30),YLabels(50),XLabels(50),SHORT Dist(+),Dist(+),Dist(+),
INTEGER L,M111(+);
2030 Flag1=0
2040 Flag2=0
2050 PLOTTER IS 13,"GRAPHICS"
2060 PRINTER IS 16
2070 PRINT LIN(50)
2080 PRINT " VERTICAL - 1"
2090 PRINT " LONGITUDINAL - 2"
2100 PRINT " SIDE - 3"
2110 PRINT " VELOCITY - 4"
2120 PRINT " LONG. VERTICAL - 5"
2130 PRINT LIN(3)
2140 INPUT "CHOOSE VERTICAL AXIS FORCE CODE ",Y
2150 PRINT LIN(3)

```

```

2160 PRINT "          DISTANCE - 1"
2170 PRINT "          TIME - 2"
2180 PRINT "          DIV - 3"
2190 PRINT LIN(3)
2200 INPUT "CHOOSE HORIZONTAL AXIS CODE ",X
2210 ON Y GOTO 2220,2310,2400,2490,2580
2220 Var1=1
2230 YLabel$="VERTICAL FORCE (LBS) "
2240 Var2=5
2250 Ymin=0
2260 Ymax=3000
2270 Ytic=50
2280 Yint=0
2290 Ymaj=10
2300 GOTO 2640
2310 Var1=2
2320 YLabel$="LONGITUDINAL FORCE (LBS) "
2330 Var2=6
2340 Ymin=-200
2350 Ymax=1000
2360 Ytic=25
2370 Yint=-200
2380 Ymaj=0
2390 GOTO 2640
2400 Var1=3
2410 YLabel$="SIDE FORCE (LBS) "
2420 Var2=7
2430 Ymin=-300
2440 Ymax=801
2450 Ytic=50
2460 Yint=-800
2470 Ymaj=4
2480 GOTO 2640
2490 Var1=4
2500 YLabel$="WHEEL SPEED (MPH) "
2510 Var2=8
2520 Ymin=0
2530 Ymax=30
2540 Ytic=.5
2550 Yint=0
2560 Ymaj=6
2570 GOTO 2640
2580 Ymin=0
2590 Ymax=.8001
2600 Ytic=.05
2610 Yint=0
2620 Ymaj=2
2630 YLabel$="LONGITUDINAL/VERTICAL FORCE"
2640 IF X=2 THEN GOTO 3030
2650 IF X=3 THEN GOTO 3110
2660 PRINT LIN(3)
2670 INPUT "DISTANCE TRAVELED BY VEHICLE (0) OR DISTANCE TRAVELED BY WHEEL (1) "
,R
2680 IF R=0 THEN GOTO 2910
2690 Flag1=Flag1+1
2700 IF Flag1>1 THEN GOTO 2910
2710 Dist(1,1)=0
2720 Dist(2,1)=0
2730 FOR I=2 TO L-1
2740 Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,4)+D(I-1,4))/2)*((M(I)-M(I-1))/1000)
2750 Dist(2,I)=Dist(2,I-1)+5280/3600*((D(I,3)+D(I-1,3))/2)*((M(I)-M(I-1))/1000)
2760 NEXT I
2770 PRINT LIN(5),"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
2780 PRINT LIN(1),"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
2790 INPUT "PRESS CONT TO RESUME",Dum
2800 GOTO 2920
2810 Flag2=Flag2+1
2820 IF Flag2>1 THEN GOTO 2910
2830 Dist(1,1)=0
2840 Dist(2,1)=0
2850 FOR I=2 TO L-1
2860 Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,11)+D(I-1,11))/2)*((M(I)-M(I-1))/1000)
2870 Dist(2,I)=Dist(2,I-1)
2880 NEXT I
2890 PRINT LIN(5),"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
2900 INPUT "PRESS CONT TO RESUME",Dum
2910 IF R=0 THEN GOTO 2940

```

```

2920 KLabel$="DISTANCE TRAVELED BY WHEEL (FT)"
2930 GOTO 2950
2940 KLabel$="DISTANCE TRAVELED BY VEHICLE (FT)"
2950 Kmin=0
2960 Kmax=Dist(1,L-1)+10
2970 IF Dist(2,L-1)-Dist(1,L-1) THEN Kma=Dist(2,L-1)+10
2980 Kint=0
2990 Kmaj=5
3000 Ktic=2
3010 IF Kmax>110 THEN Ktic=4
3020 GOTO 3380
3030 KLabel$="TIME (SEC)"
3040 Kmin=0
3050 Kma=INT(L/1000)*Milli+50-Milli+40000+1
3060 Ktic=5
3070 Kint=0
3080 Kmaj=2
3090 IF Kmax>16 THEN Kmaj=4
3100 GOTO 3380
3110 KLabel$="DIFFERENTIAL INTERFACE VELOCITY (FT/SEC)"
3120 MAT Dio=ZER
3130 IF Y<5 THEN GOTO 3180
3140 Var1=1
3150 Var2=5
3160 Var3=2
3170 Var4=6
3180 FOR I=1 TO L-1
3190 Dio(1,I)=(D(I,4)-D(I,11))*+5280/3600
3200 IF Dio(1,I)=0 THEN Dio(1,I)=0
3210 Dio(2,I)=(D(I,3)-D(I,11))*+5280/3600
3220 IF Dio(2,I)=0 THEN Dio(2,I)=0
3230 Dio(3,I)=D(I,Var1)
3240 Dio(4,I)=D(I,Var2)
3250 IF Y<5 THEN GOTO 3280
3260 Dio(5,I)=D(I,Var3)
3270 Dio(6,I)=D(I,Var4)
3280 NEXT I
3290 GOTO 3300
3300 Kmin=0
3310 MAT SORT Dio(1,+)
3320 Kmax=Dio(1,L-1)+5
3330 MAT SORT Dio(2,+)
3340 IF Dio(2,L-1)+5>Kmax THEN Kmax=Dio(2,L-1)+5
3350 Ktic=5
3360 Kmaj=10
3370 IF Kmax>50 THEN Kmaj=20
3380 X=ABS(Kmax-Kmin)
3390 Y=ABS(Ymax-Ymin)
3400 PRINTER IS 16
3410 GRAPHICS
3420 SCALE Xmin-.3*Xr,Kmax+.2*Xr,Ymin-.3*Yr,Ymax+.2*Yr
3430 CLIP Xmin,Xmax,Ymin,Ymax
3440 AXES Ktic,Ytic,Kint,Yint,Kmaj,Ymaj,6
3450 LINE TYPE 6
3460 IF Y=5 THEN GOTO 3940
3470 MOVE Xmin,D(I,Var1)
3480 IF X=1 THEN GOTO 3540
3490 IF X=3 THEN GOTO 3580
3500 FOR I=1 TO L-1
3510 DRAW Milli(I/1000,D(I,Var1))
3520 NEXT I
3530 GOTO 3630
3540 FOR I=1 TO L-2
3550 DRAW Dist(1,I+1),D(I,Var1)
3560 NEXT I
3570 GOTO 3630
3580 MAT SORT Dio(1,+)
3590 FOR I=2 TO L-1
3600 IF (Dio(1,I)=0) AND (Dio(2,I)=0) THEN GOTO 3620
3610 DRAW Dio(1,I),D(I,Var1)
3620 NEXT I
3630 LINE TYPE 1
3640 MOVE Xmin,D(I,Var2)
3650 IF X=1 THEN GOTO 3710
3660 IF X=3 THEN GOTO 3750
3670 FOR I=1 TO L-1
3680 DRAW Milli(I/1000,D(I,Var2))
3690 NEXT I
3700 GOTO 3800
3710 FOR I=1 TO L-2

```

```

3720 DRAW Dist(2,I+1,D(I,Var2)
3730 NEXT I
3740 GOTO 3800
3750 MAT SORT Dist(2,*)
3760 FOR I=2 TO L-1
3770 IF (Dist(1,I)=0) AND (Dist(2,I)=0) THEN GOTO 3790
3780 DRAW Dist(2,I),D(I,Var2)
3790 NEXT I
3800 IF Y<4 THEN GOTO 3930
3810 LINE TYPE 8
3820 MOVE Xmin,D(1,1)
3830 IF X=1 THEN GOTO 3890
3840 IF X=3 THEN GOTO 3920
3850 FOR I=1 TO L-1
3860 DRAW Mill(1)1000,D(1,1)
3870 NEXT I
3880 GOTO 3920
3890 FOR I=1 TO L-2
3900 DRAW Dist(2,I+1),D(I,1)
3910 NEXT I
3920 LINE TYPE 1
3930 GOTO 4270
3940 MOVE Xmin,D(1,2) D(1,1)
3950 IF X=1 THEN GOTO 4010
3960 IF X=3 THEN GOTO 4050
3970 FOR I=1 TO L-1
3980 DRAW Mill(1)1000,D(1,2) D(1,1)
3990 NEXT I
4000 GOTO 4100
4010 FOR I=1 TO L-2
4020 DRAW Dist(1,I+1),D(1,2) D(1,1)
4030 NEXT I
4040 GOTO 4100
4050 MAT SORT Dist(1,*)
4060 FOR I=2 TO L-1
4070 IF (Dist(3,I)=0) AND (Dist(4,I)=0) THEN GOTO 4090
4080 DRAW Dist(1,I),Dist(5,I) Dist(3,I)
4090 NEXT I
4100 LINE TYPE 1
4110 MOVE Xmin,D(1,6) D(1,5)
4120 IF X=1 THEN GOTO 4180
4130 IF X=3 THEN GOTO 4220
4140 FOR I=1 TO L-1
4150 DRAW Mill(1)1000,D(1,6) D(1,5)
4160 NEXT I
4170 GOTO 4270
4180 FOR I=1 TO L-2
4190 DRAW Dist(2,I+1),D(1,6) D(1,5)
4200 NEXT I
4210 GOTO 4270
4220 MAT SORT Dist(2,*)
4230 FOR I=2 TO L-1
4240 IF (Dist(3,I)=0) AND (Dist(4,I)=0) THEN GOTO 4260
4250 DRAW Dist(2,I),Dist(6,I) Dist(4,I)
4260 NEXT I
4270 LOG 5
4280 FOR J=Xmin TO Xmax STEP Xinc*Xmaj
4290 MOVE J,Yint-.05*Yr
4300 LABEL J
4310 NEXT J
4320 FOR J=Ymin TO Ymax STEP Yinc*Ymaj
4330 MOVE Xint-.07*Xr,J
4340 LABEL J
4350 NEXT J
4360 LOG 4
4370 MOVE Xr/2,Ymin-.2*Yr
4380 LABEL Xlabel8
4390 DEG
4400 LDIR 90
4410 MOVE Xmin-.2*Xr,(Ymax+Ymin)/2
4420 LABEL Ylabel8
4430 LDIR 0
4440 CSIZE 2.9,.444
4450 Sp=Xmin+.15*Xr
4460 LOG 2
4470 MOVE Sp,Ymax-.01*Yr
4480 LABEL Loc8
4490 MOVE Sp,Ymax-.05*Yr
4500 LABEL "FLNN: ";TS(2)
4510 MOVE Sp,Ymax-.09*Yr

```

74

```

5280 Dist(2,I)=Dist(2,I-1)+5280/3600*((D(I,8)+D(I-1,8))/2)*((M(I,1)-M(I-1,1))/1000)
5290 NEXT I
5300 PRINT LIN(2),"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5310 PRINT LIN(1),"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
5320 FOR I=2 TO L-1
5330 Energy(1,I)=Energy(1,I-1)+(D(I,2)+D(I-1,2))/2*(Dist(1,I)-Dist(1,I-1))
5340 Energy(2,I)=Energy(2,I-1)+(D(I,6)+D(I-1,6))/2*(Dist(2,I)-Dist(2,I-1))
5350 NEXT I
5360 GOTO 5730
5370 MAT Dist=ZER
5380 MAT Energy=ZER
5390 FOR I=2 TO L-1
5400 Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,11)+D(I-1,11))/2)*((M(I,1)-M(I-1,1))/1000)
5410 Dist(2,I)=Dist(1,I)
5420 NEXT I
5430 PRINT LIN(2),"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5440 FOR I=2 TO L-1
5450 Energy(1,I)=Energy(1,I-1)+(D(I,2)+D(I-1,2))/2*(Dist(1,I)-Dist(1,I-1))
5460 Energy(2,I)=Energy(2,I-1)+(D(I,6)+D(I-1,6))/2*(Dist(2,I)-Dist(2,I-1))
5470 NEXT I
5480 GOTO 5730
5490 MAT Dist=ZER
5500 MAT Energy=ZER
5510 FOR I=2 TO L-1
5520 Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,4)+D(I-1,4))/2)*((M(I,1)-M(I-1,1))/1000)
5530 Dist(2,I)=Dist(2,I-1)+5280/3600*((D(I,8)+D(I-1,8))/2)*((M(I,1)-M(I-1,1))/1000)
5540 NEXT I
5550 PRINT LIN(2),"TOTAL LEFT WHEEL DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5560 PRINT LIN(1),"TOTAL RIGHT WHEEL DISTANCE TRAVELED = ";Dist(2,L-1);" FT"
5570 FOR I=2 TO L-1
5580 Energy(1,I)=Energy(1,I-1)+(D(I,2)+D(I,4)+D(I-1,2)+D(I-1,4))/2*(Dist(1,I)-Dist(1,I-1))
5590 Energy(2,I)=Energy(2,I-1)+(D(I,6)+D(I,5)+D(I-1,6)+D(I-1,5))/2*(Dist(2,I)-Dist(2,I-1))
5600 NEXT I
5610 GOTO 5730
5620 MAT Dist=ZER
5630 MAT Energy=ZER
5640 FOR I=2 TO L-1
5650 Dist(1,I)=Dist(1,I-1)+5280/3600*((D(I,11)+D(I-1,11))/2)*((M(I,1)-M(I-1,1))/1000)
5660 Dist(2,I)=Dist(1,I)
5670 NEXT I
5680 PRINT LIN(2),"TOTAL VEHICLE DISTANCE TRAVELED = ";Dist(1,L-1);" FT"
5690 FOR I=2 TO L-1
5700 Energy(1,I)=Energy(1,I-1)+(D(I,2)+D(I,11)+D(I-1,2)+D(I-1,11))/2*(Dist(1,I)-Dist(1,I-1))
5710 Energy(2,I)=Energy(2,I-1)+(D(I,6)+D(I,5)+D(I-1,6)+D(I-1,5))/2*(Dist(2,I)-Dist(2,I-1))
5720 NEXT I
5730 IMAGE .K,DDDDDDDD.D,K
5740 Labels=" FT"
5750 IF (Intg=1) OR (Intg=2) THEN Labels=" FT-LBS"
5760 PRINT USING 5730;"LEFT WHEEL ENERGY = ";Energy(1,L-1);Labels
5770 PRINT USING 5730;"RIGHT WHEEL ENERGY = ";Energy(2,L-1);Labels
5780 PRINTER IS 16
5790 INPUT "DO YOU WANT TO INTEGRATE ANY OTHER CURVES (Y OR N)?",Rp1$
5800 IF Rp1$="Y" THEN GOTO 5080
5810 INPUT "PRESS CONT TO RESUME",Dum
5820 SUBEND

```