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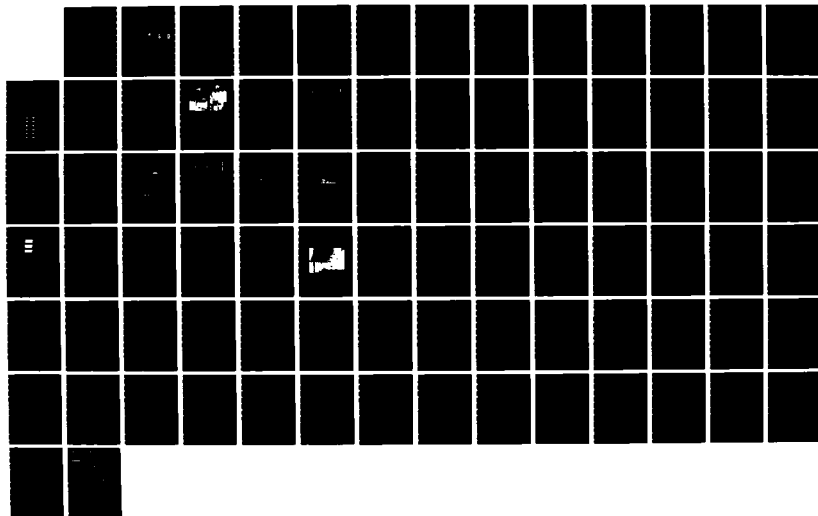
AUTOMATED AIRCRAFT STATIC STRUCTURAL TESTING WITH
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NAVAL POSTGRADUATE SCHOOL

Monterey, California



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THESIS

AUTOMATED AIRCRAFT STATIC STRUCTURAL
TESTING WITH COMPUTER
AIDED INTERPRETATION

by

James J. Miller

September 1986

Thesis Advisor:

E. A. M.

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abstract tensor components.

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Automated Aircraft Static Structural Testing
With Computer Aided Interpretation

by

James John Miller
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1974

Submitted in partial fulfillment of the
requirements for the degree of

MASTERS OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

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ABSTRACT

The objective of this study is to improve three primary aspects of static structural testing at the Naval Postgraduate School. First, computer controlled digital multimeters simultaneously display twelve data locations on the structure while the test is in progress. Second, immediate interaction is permitted. If some unexpected data occurs during the testing, the test plan can be modified to focus in on any area of interest. Third, the operator is presented with two different real-time visual interpretations of the strain gage data reduced to the strain tensor components with animated deformations.

These objectives contribute to enhancing the real-time correlation between input load and output structural response in terms of direct physical measurements rather than indirect abstract tensor components.

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I. INTRODUCTION

During an aircraft's development phase, prior to mass production, the structural strength of a component can be determined by employing destructive testing techniques. Destructive testing is used to determine the performance envelope that will serve as an operational limit throughout the structure's useful life. However, this type of testing is not feasible for in-service structures or as a monitoring process for determining performance degradation with fatigue.

From an accidental overstress or due to simple fatigue with aging, the need to compare actual performance with that predicted or specified in the contract can arise. Several non-destructive evaluation techniques include dye penetrant, eddy current and ultrasound. However, these techniques are limited in that they can only identify failure and can not determine over-stresses or gradual degradations in performance. Dynamic response testing and static load and deformation tests can locate these types of faults. If the results of a particular test are not within the specified envelope, the response testing of the full structure can assist in focusing in on the failed zone or component. Maintenance action can then concentrate on that area and a reduction of cost and down time will result. Therefore, a

working knowledge of non-destructive response methods for determining strength or structural integrity of aircraft components is essential.

The need to upgrade the Naval Postgraduate School Aeronautics Department Structures Laboratory was the motivation for this study. The Aeronautics Department has a section of P2V wing which was being used for laboratory static structural tests in conjunction with several core courses. The former data acquisition system consisted of a patch panel with a manual switching network connected to a single voltmeter. Test operators were capable of observing one data point at a time. The data was recorded manually. After all data points had been taken, the tedious data reduction process commenced. Data interpretation and visualization could only be done after the data had been completely reduced which frequently occurred days after the test had been completed.

The purpose of this thesis was to modernize the data acquisition and control system, and not include the content of the static test. Therefore, the decision was made to retain the P2V wing. While the P2V has not seen active service since the 1970s, the principle of construction in it's wing structure is still being used throughout the aircraft industry. Therefore, the educational content of the structural testing is still appropriate.

This thesis was undertaken with several goals in mind. Improvements would include the opportunity to simultaneously observe multiple data points during the static testing procedure. The operator would be given the chance to interactively change the test plan at any time to investigate an area highlighted by the real-time data reduction and display. Multiple interpretations of the reduced data would be available while the static test was still in progress and decisions could be made affecting the testing plan based on those interpretations.

II. BACKGROUND

The P2V wing section was obtained in the late 1950s from the storage yard at Davis-Monthan Air Force Base. It measures three hundred and eighty-one inches from the outboard side of the starboard engine nacelle to the wing tip, wing station 192 to station 573 [Ref. 1]. One hundred and eight paper backed wire strain gages were mounted on the wing surface and interior structural members. These gages were in single elements and in three-element forty-five degree rectangular rosettes. A manual switching network with an analog voltmeter was used for the strain measurements. The wing's load application structure consisted of hydraulic actuators capable of applying pure torsional loads only. The load monitoring system was analog dynamometers. All data acquisition, reduction and analysis was done manually. In the years since the 1950s, approximately one third of the installed strain gages had deteriorated.

III. MODERNIZATION PROCEDURE

A. HARDWARE

An IBM PC/AT equipped with a National Instruments General Purpose Interface Bus (GPIB) is the center piece for this modernization approach. The GPIB installs into one of the computer's expansion slots and functions as a link or interface system, through which interconnected electronic devices communicate. In this application the electronic devices are digital voltmeters and they were connected to the GPIB in a linear configuration (daisy chained) by shielded twenty-four wire conductor cables with both a plug and receptacle connector at each end.

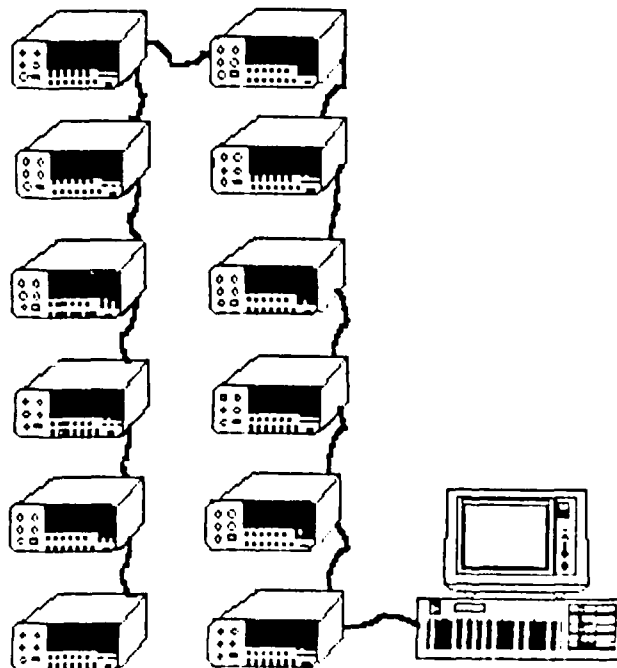


Figure 3.1 Linear GPIB Connection of Digital Voltmeters

In order to achieve the high data transfer rate that the GPIB was designed for between connected electronic devices and the bus, reference 2 lists the physical limitations for all hardware attached to the National Instruments GPIB. However, the data transfer rate of the GPIB was not limited by physical constraints in this application, but by a conflict created by the digital voltmeters command sequence which will be discussed later.

The GPIB comes equipped with an initialization routine which must be run prior to any bus utilization. This routine requires bus address assignments and the naming of all devices connected to it. It then builds a file called GPIB.COM which must be on the default directory during boot-up. When the computer is brought on line, the automatic CONFIG.SYS procedure activates the GPIB.COM file and the bus settings are initialized.

All hardware connected to any GPIB must have the IEEE-488 interface installed. This interface is essential, because it contains the dip switches necessary for device coding and it has the required cable receptacle. Those dip switch setting constitute the device's coded name and are inputted on the GPIB.COM file. It is through those dip switch settings and the initializing GPIB.COM procedure that the computer recognizes the type of device and the location of the device within the linear chain.

There are twelve Fluke 8840A multimeters connected to the GPIB. All twelve have the required IEEE-488 interface option installed. Reference 3 contains further information on the IEEE-488 interface. The Fluke meters were chosen for their accuracy, speed in measurement and primarily their ease in programming. The 8840A has a set of device-dependent commands which correspond directly to the front panel controls and can be sent to the meter via the GPIB bus when in the REMOTE mode of operation [Ref. 4]. The multimeter performs the analog to digital conversion of all measurements and the GPIB can obtain the meter reading directly.

A desirable feature of the Fluke 8840A is the OFFSET function which sets a relative datum from which all subsequent readings are taken. It was this OFFSET function that presented the data transfer problem to the GPIB. The GPIB's data transfer rate is so rapid that if any attempt is made by the computer to set the OFFSET first and then trigger a reading in the same command string, an "ERROR 32" occurs. "ERROR 32" indicates that OFFSET was selected when a reading was unavailable or overrange. The OFFSET feature must be sent exclusive of any trigger command in a single instruction string. The multimeter's output received by the GPIB is in the form of an eleven character alphanumeric string and before any arithmetic operations can be performed on it, conversion to a numerical string is required.

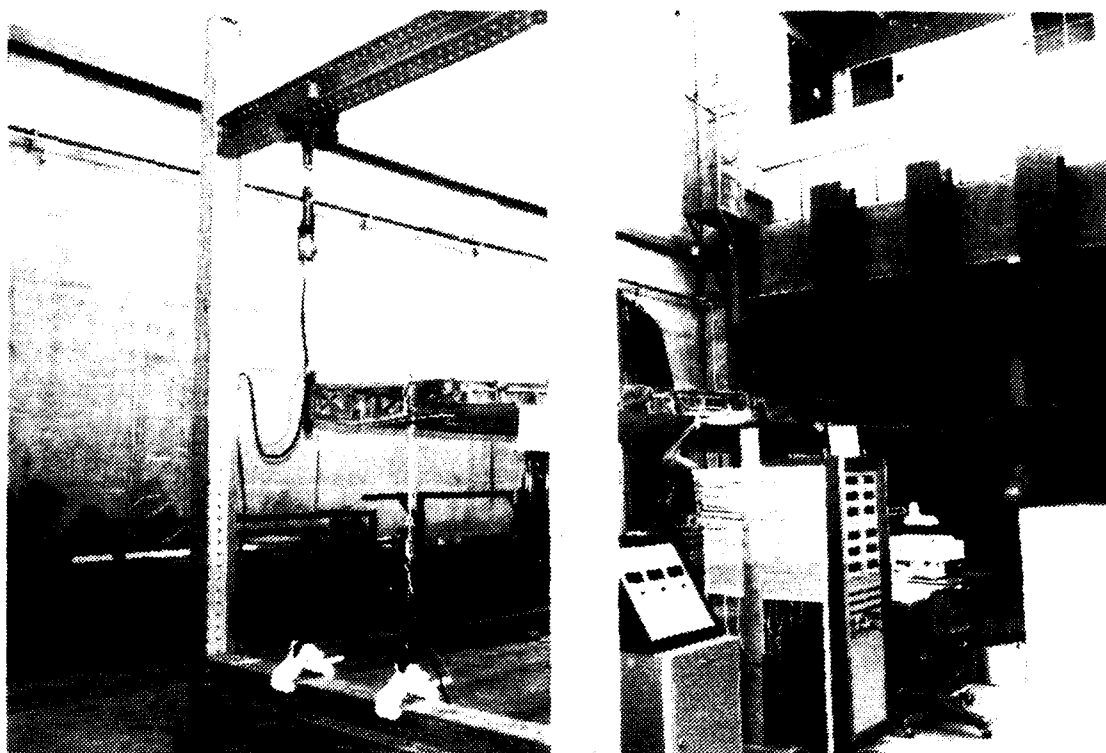


Figure 3.2 Load Application Structure

The entire load application structure was dismantled and a new frame constructed. The frame is made of fifteen and ten foot length beams of one-half inch alloy aluminum attached by bolts to the floor. The frame is designed to provide several load options: pure bending, pure torsion or a combination. Due to the simplicity of the connecting hardware, reconfiguring for different load applications will take minimal time. All connecting hardware was designed or specified to withstand a maximum of four thousand pounds of force in tension. The wing structure's load limitation is two thousand pounds with the front spar web installed. A stability analysis was done on the frame and those results are contained in Appendix C.

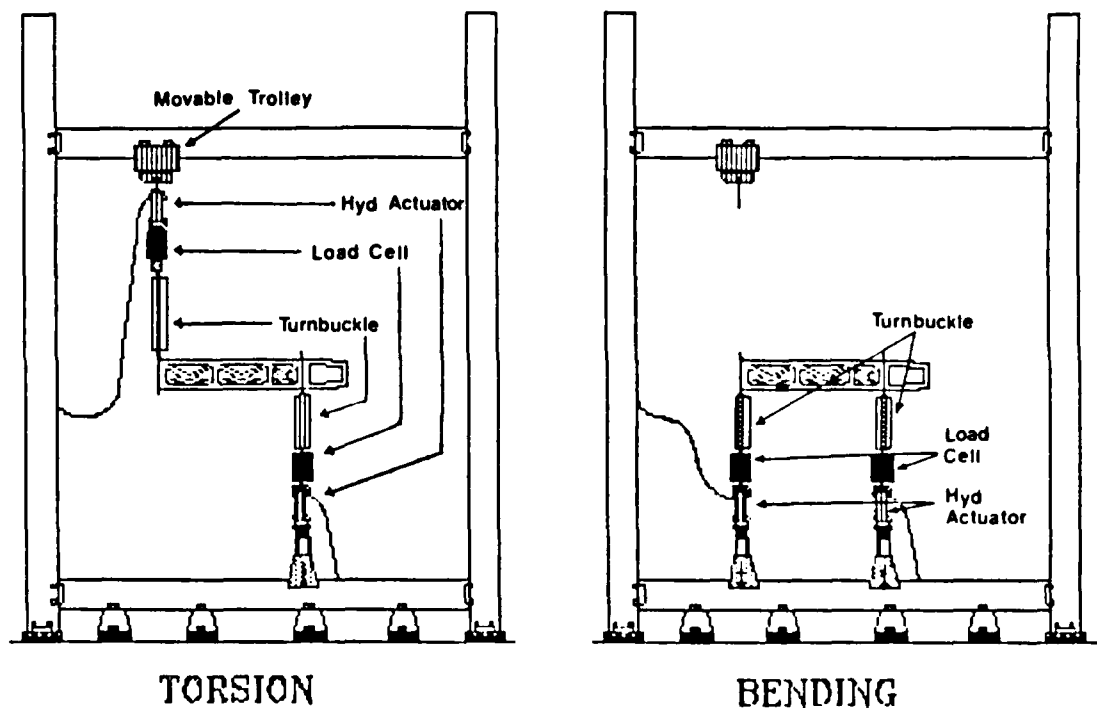


Figure 3.3 Load Application Structure Configurations

A Baldwin-Lima-Hamilton load cell was installed in series with each of the two hydraulic actuators. These load cells provide the load monitoring transducer when connected to separate digital voltmeters at the load cell panel. The meters were calibrated to read directly in pounds of force tension. Appendix B contains the calibration statistics and procedure. These meters can not be read directly by the computer and therefore must be manually monitored during loading and their results entered into the program when prompted. Load cells one and two are currently connected to the structure. The number three load cell is a spare or it can be used as a third load monitor in different multiload configurations.

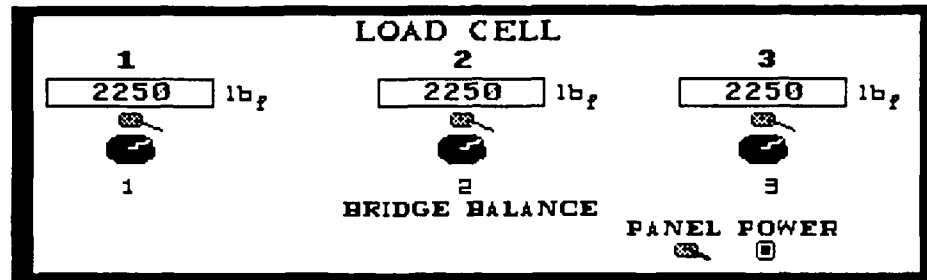


Figure 3.4 Load Cell Monitoring Panel

Approximately thirty of the mounted paper-backed wire strain gages had failed since the 1950s. These were removed and operable paper-backed wire gages were installed in their locations. Additionally, newer generation epoxy-backed foil gages were installed in strategic locations internal to the wing structure on the hat and stringer sections. Appendix A contains the strain gage location information. These new gages were located adjacent to the older style gages in order to provide comparisons between gage types and the different lay-ups of the rosettes.

The new strain gage rosettes were purchased specifically to optimize measurements in shear and they will provide the highest resolution in determining the two Mohr's circle invariants; radius and circle center location along the X-axis. Perry/Lissner and Beer/Johnston provide further information on the Mohr's circle interpretation of strain gage rosette data [Refs. 5, 6].

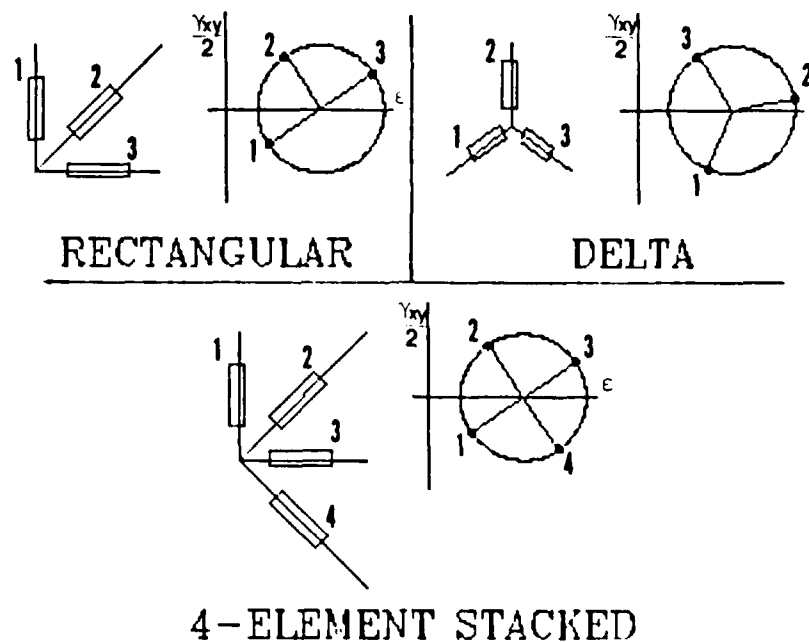


Figure 3.5 Strain Gage Lay-up Mohr's Circle Resolutions

B. SOFTWARE

The National Instruments GPIB comes equipped with a handler written in IBM BASICA. BASIC was chosen as the controlling software for it's general acceptability, ease in programming and powerful color graphics capability. The IBM PC/AT is equipped with an Enhanced Graphics Adapter (EGA) and Enhanced Color Monitor. BASIC is one of only a few programmable languages which currently utilizes the screen resolution and color offered by this combination; 640 screen pixels in horizontal, 350 screen pixels in vertical, sixteen colors.

The BASIC program consists of three separate programs which are linked together by the CHAIN statement; P2V-CAL.BAS, P2V-LOAD.BAS and P2V-ANAL.EXE. All three program listings are contained in Appendix D. These programs perform five major procedures:

- (1) Updating the installed strain gage's resistance in the hard disk's memory.
- (2) Calculating a strain gage's calibration factor based on a shunt resistance measurement.
- (3) Loading the wing and measuring the strain gage output with graphical analysis of the results.
- (4) Graphically analyzing the last set of data displayed.
- (5) Adding, deleting or replacing strain gage hardware installed on the wing.

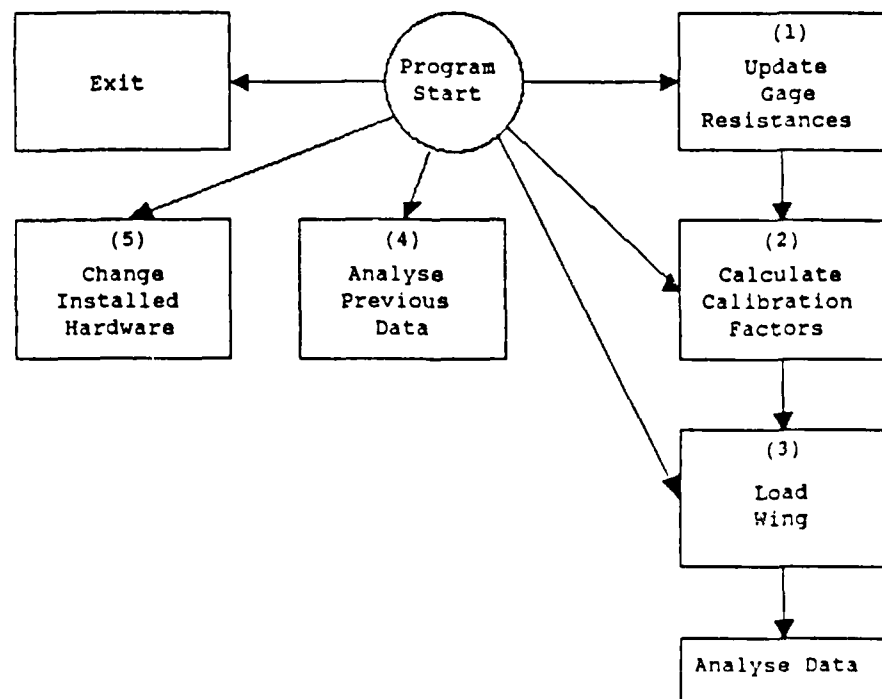


Figure 3.6 Controlling Software Program Structure

Procedures (1) through (3) should be done sequentially. However, since the result of each procedure is stored on the internal hard disk, all three need not be completed in a single session. Procedure (4) exists primarily to demonstrate the graphics portion of the program. Procedure (5) is to be used only when changing the strain gage configuration.

The graphical display of the strain gage data comes in two forms; the traditional Mohr's circle and a pictorial representation of a area's surface element deformation. (See Fig. 3.7) The surface element deformation display presents a square depicting an element of wing surface before load application and the deformed square by the applied load as calculated from the strain gage rosette at the respective location. In order to better observe changes in the loaded element, an isotropic strain multiplier is used if the strain level is below five tenths of a micro-inch per inch. Park's Interactive Microcomputer Graphics contains the information necessary to write algorithms that accurately display the elongations and rotations associated with the strains experienced by the wing's structural members on the computer monitor [Ref. 7].

The most difficult obstacle encountered in programming was interfacing the IBM PC/AT with the Hewlett Packard Laserjet printer. The Laserjet does not have an installed

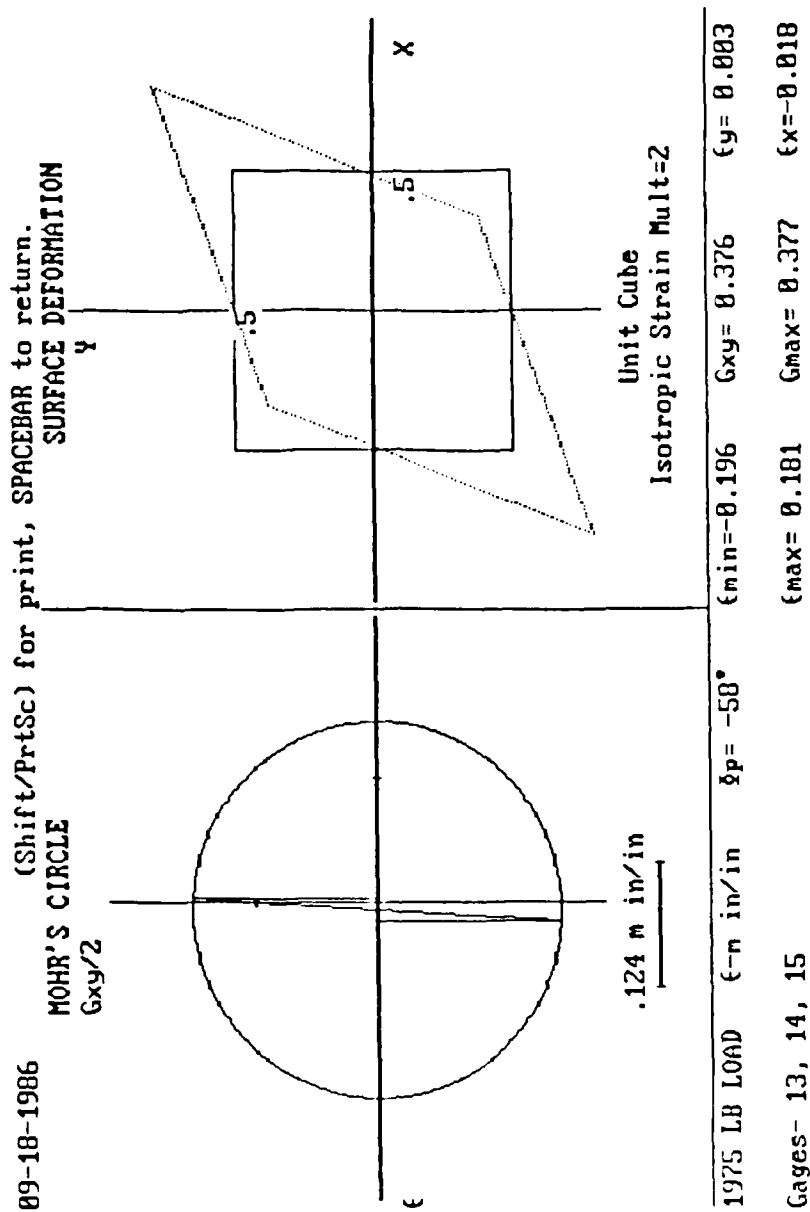


Figure 3.7 Sample Print of Graphical Analysis of Strain Gage Data

screen graphics print capability. As a result, an after-market screen utility GRAFLASR [Ref. 8] was purchased to perform this necessary function. However, the screen print utility was not compatible with IBM BASICA in the highest possible screen resolution mode. Therefore, in order to get high resolution graphics printing directly from the screen display, the program P2V-ANAL.EXE was written in the form of a compiled BASIC executable file. It was compiled using Microsoft's QuickBASIC compiler version 2.0 [Ref. 9]. When graphical analysis is selected immediately after the print of the tabularized loading data, the program stores the current applicable data on the hard disk. Then IBM BASICA is terminated and the compiled executable program takes over and executes the screen graphics commands after it inputs the necessary data from the hard disk. The screen print is not attempted in the BASICA environment but under DOS, the normal operating system's environment and no conflict exists.

Initially, the Laserjet distorted the vertical axis during the screen print. GRAFLASR's printer driver software file for the Hewlett-Packard Laserjet had to be modified with respect to the vertical axis print scale in order to get the exact dimensional proportions displayed on the screen printed on the paper.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

An IBM PC/AT equipped with a GPIB connected to strain measuring devices can provide a real-time data acquisition and display system for complex static structural tests. Software can be written to provide various graphical representations of the results giving several options to the operator.

B. RECOMMENDATIONS

The most time consuming task in the static testing procedure involves the optical deflection measurement system currently installed. Ten rulers are suspended from the wings underside at known wing stations. They are sighted with a surveyor before and after loading to determine deflections. This system is replete with opportunities for human error. One solution would be the installation of a low power laser with several sensor stations along the wing to measure the beam's deflections. Also, the connection of simple deflection gages to various stations along the wing via cable system would give highly accurate readings with the possibility of human error greatly reduced.

Due to simplicity of the load application frame's construction and the availability of additional parts, it

would be easily expanded to adapt to larger and more complex loading configurations. Multiple bending and torsional loads along the wing and an aerodynamic load could be possible.

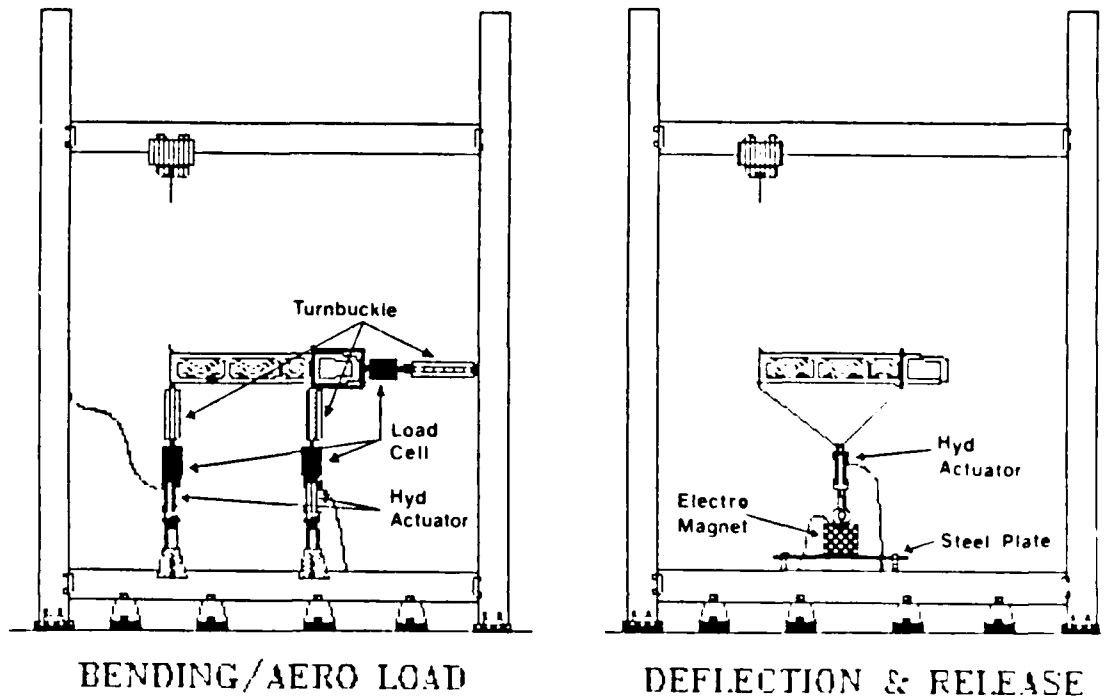


Figure 4.1 Possible Loading Configurations

The IBM PC/AT is expandable to many different applications. The Aeronautics Department has a commercial software program called ENTEK [Ref. 10] which is capable of interpreting dynamic response data. Purchase of a precision hydraulic vibration rig capable of selectable frequencies and amplitudes or the simple deflection/release apparatus shown in Figure 4.1 could expand the current topics of evaluation to include some areas of dynamic response testing.

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APPENDIX A

P2V WING OPERATOR'S GUIDE

A. PRELIMINARY

Prior to commencing this experiment, two decisions must be made. First, the type of load that will be applied to the wing; pure torsion or pure bending. Second, which strain gages will be monitored on the wing during the application of that load. The gages should be chosen based on the type of analysis desired and the load applied.

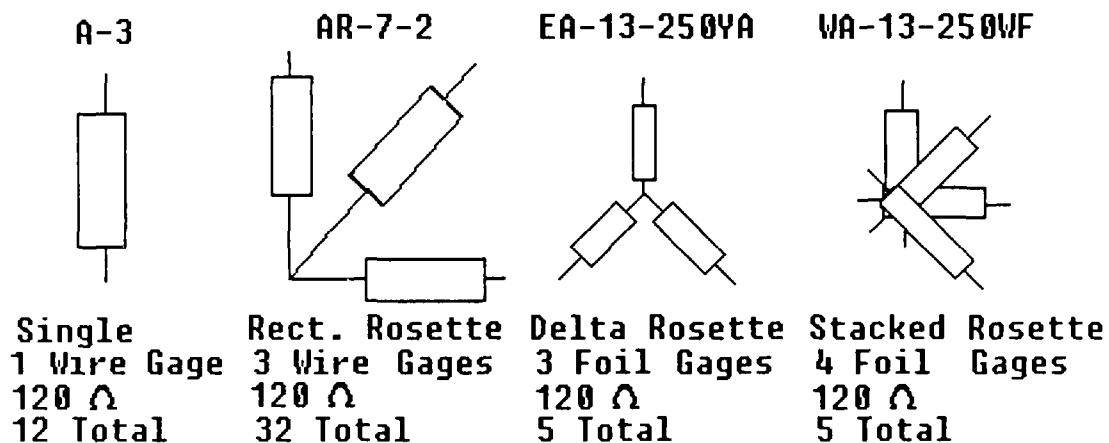


Figure 1.A Strain Gage Descriptions

There are 143 individual strain gages installed on and inside the wing. Most are in strain gage rosettes but there are 12 that are single element gages. 108 are older wire gages and the rest are newer generation foil gages. Table I.A is a listing of strain gages by type. Figures 8.A, 9.A, 10.A and 11.A "P2V STARBOARD WING, Strain Gage Locations" contain a complete description of gage positions.

CAUTION

Twelve gages, all of the same type, should be monitored during each program run. Since there is only one unloaded temperature compensating gage used to complete the Wheatstone bridge circuit for the twelve loaded gages, any attempt to mix strain gage types will result in erroneous data.

B. SETUP

- (1) Remove and stow the equipment covers.
- (2) Connect the desired gages to the DVM leads at the strain gage peg board. Also, connect the compensator leads to the type of strain gage being monitored. The unloaded temperature compensator gage female connectors are in the lower right corner of the upper peg board. They are enclosed in a yellow boarder and are numbered 147-150.

CAUTION

When monitoring rosettes, keep the rosette gages in sequential order with respect to the DVMs.

Example 1: rosette with gages 68, 69, 70 connected to DVMs 1, 2, 3 and then rosette with gages 21, 22, 23 connected to DVMs 4, 5, 6.

Example 2: rosette with gages 136, 137, 138, 139 connected to DVMs 1, 2, 3, 4 and then rosette with gages 140, 141, 142, 143 connected to DVMs 5, 6, 7, 8.

- (3) Apply power to the following equipment:

- Computer and Monitor. As the computer comes up, it will commence a power-on self test. The self test and the subsequent loading of the initial batch file is automatic and requires no action by the operator. The monitor has brightness and contrast controls directly beneath the on/off knob. Do not set the brightness to the extreme as prolonged use at this level may cause permanent damage to the screen.

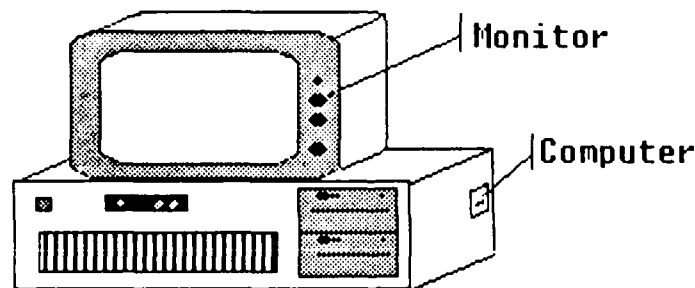


Figure 2.A Computer and Monitor Power Supply Switch Locations

- Printer. The printer has a power-on self test. The computer must be turned on prior to the printer or a logic error will occur in the printer's self test. The printer indicates it's ready to print when the number 00 is in the status window.

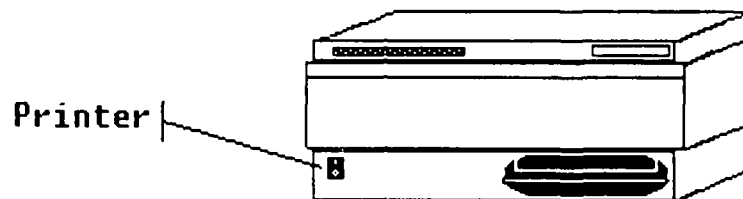


Figure 3.A Printer Power Supply Switch Location

- DVM Column Master, Individual DVMs and the Voltage Power Source. The DVM column master switch is a push button type on/off switch. Wait until the DVM column cooling fans are fully up to speed prior to energizing the individual DVMs and the voltage source. Only the right side of the voltage source is currently being utilized. Do not adjust the DVMs or the voltage source at this time.

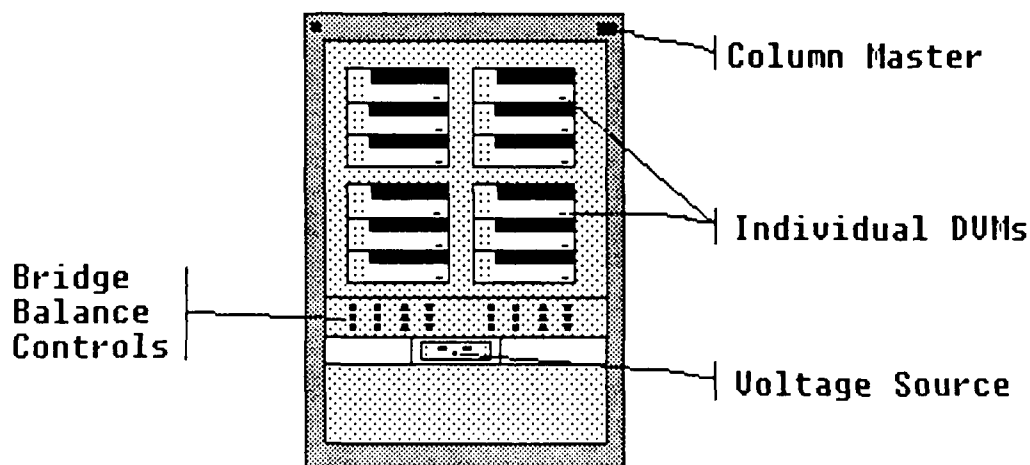


Figure 4.A Digital Voltmeter Column Power Supply Switch Locations

- Load Cell Panel Master and the Individual DVMs. Do not attempt to zero the DVMs.

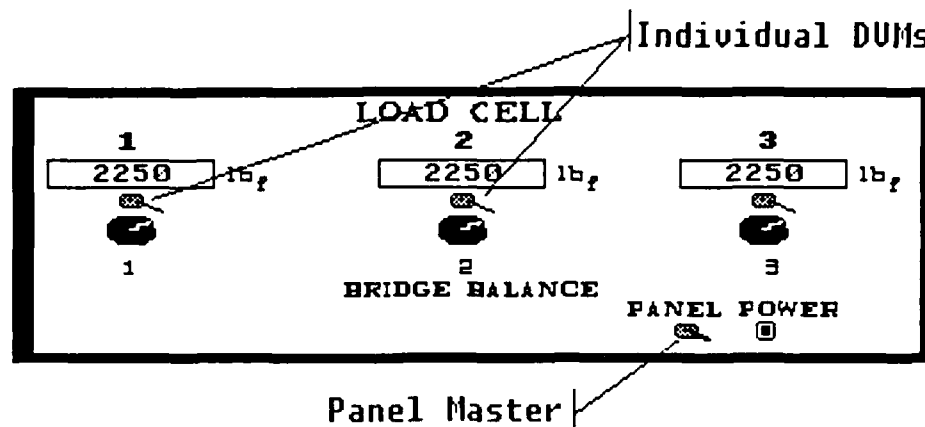


Figure 5.A Load Cell Panel Power Supply Locations

C. PROGRAM EXECUTION

The program (P2V) is stored on the internal hard disk so no disk loading is necessary. P2V and all the utilities necessary to run it are in the \GPIB-PC sub-directory. A batch file is available to make access simple.

(1) At the system prompt, C>, type "P2V" and then hit Enter.

First, the utilities load, then the program will run. The program is structured into five main procedures:

1. Updating strain gage resistances.
2. Obtaining calibration factors based on a shunt resistance measurement.
3. Loading and measuring strains with a graphical analysis of rosettes.
4. Analyze the last set of load data which had previously been displayed. This procedure is primarily for demonstration purposes.
5. Adding/deleting/replacing strain gages on the installation.

Procedure 5. is to be used only when changing hardware installed on the wing. The other three procedures should be done sequentially. Since the results of each procedure are stored on the hard disk, it is not necessary to do all three procedures in one sitting. For example, strain gage resistances are updated and then the calibration factors computed. If the system is secured and then restarted the next day, the experiment can commence at procedure 3 since all the previous data has been stored on the hard disk.

Hints on running the program:

- Due to a bug in IBM BASICA the backspace key has been disabled. To correct previously typed errors prior to hitting Enter, use the direction keys on the numeric keypad. If you inadvertently hit the backspace key, a window appears telling you what to do.
- When making strain gage resistance measurements, the leads for DVM 1 should be the only leads connected to the strain gage. If other DVM leads are left connected and a resistance measurement taken across the gage, the reading will include the DVM resistance in parallel with the strain gage.

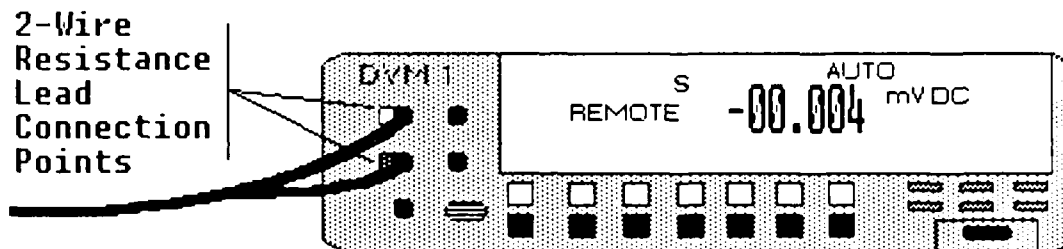


Figure 6.A DVM1 Resistance Lead Connection Points

- Several times in the program a screen dump to the printer occurs. The print takes approximately two minutes for a text screen and three minutes for a graphics screen. A flashing statement will appear when a print is in progress, except for a graphics screen. Program execution halts during a screen dump.
- Do not waste allot of time trying to balance the Wheatstone bridge circuits to zero. Get them as close as possible to keep current flow to a minimum. Since the Fluke meters utilize an OFFSET function, exact zero is not necessary.
- Analysis of the strain gages rosettes being monitored can be accomplished by the program with graphical results only immediately after the screen print of the load summary. If the choice is made to get additional load data without doing the analysis, the opportunity for the program to calculate the analysis is lost for that set of load data.
- Only as a last resort, the program can be terminated at any time by hitting Ctrl/Break simultaneously. To

clear the screen and return to the primary text screen, hit F10. To rerun the program from this point, type SYSTEM, Enter and then P2V. The initial selection menu should now be in view.

CAUTION

Exit from the program using the Ctrl/Break procedure can cause loss of computed data up to that point. For normal program termination, use one of the Exit options in a program selection menu.

D. HYDRAULIC OPERATIONS/WING LOADING

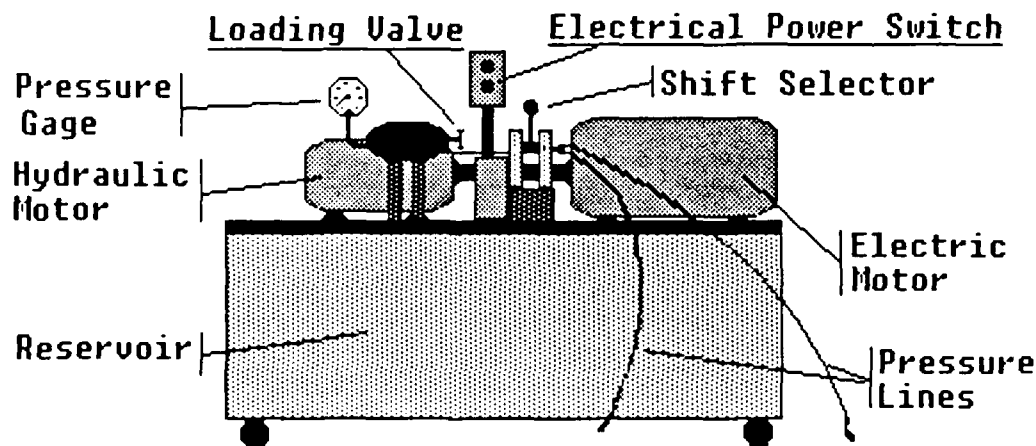


Figure 7.A Hydraulic Loading System Component Location

The hydraulic loading system consists of an electric motor which drives a constant pressure hydraulic pump to provide pressure via two lines to actuating cylinders attached to the wing. Prior to actuating the electric motor ensure that the loading valve is open (spins freely counter clockwise) and the shift selector is in the NEUTRAL position.

- (1) START the electric motor. Allow at least 3 minutes of warm up prior to loading.
- (2) Zero the load reading at the Load Cell Panel by using the bridge balances.
- (3) Place the shift selector in the P2V WING position and pin it. A slight load might appear on the load meters due to leakage at the loading valve.

(4) Slowly turn the loading valve clockwise. Several turns may be required prior to the first indications of hydraulic loading, depending on how far out the previous operator set the valve. Scan the load meters and the hydraulic pressure gage for indications of system loading.

CAUTION

Hydraulic system hysteresis evidenced by a large split in load meter readings is best avoided by a slow, smooth and continuous turn of the loading valve to the desired load. A large split will occur if the desired load reading is overshoot and the system unloaded down to the value. If a gross overshoot occurs, completely unload the system, reset the DVMS to zero and try again.

(5) If a split between load cells exceeds say 2% of the desired value, completely unload the system, reset the DVMS to zero and try again.

(6) Load limits are 2100 lb. with the front spar web installed and 1050 lb. with the front spar web removed.

Hints on successful operation of the hydraulic system include:

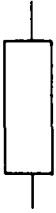
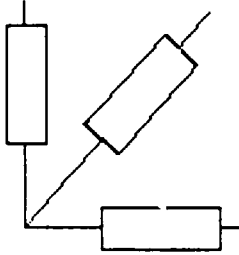
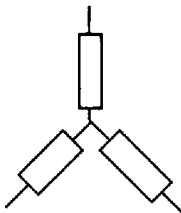
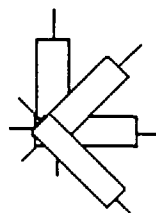
- When turning the loading valve make slow, smooth and continuous turns. Do not lose patience and rapidly turn the valve.
- Set zeros at the Load Cell Panel only when the loading valve spins freely counter-clockwise and the shift selector is in neutral.
- If the system has not been used for an extended period, load the system up to 1000 lb. to exercise the linkage, then unload and set the zeros prior to attempting a program run.
- A plumb bob is suspended from the upper support member. A sliding scale is mounted beneath it. Prior to loading, set a convenient reading as zero and occasionally monitor structure deflection if at the load limit. The deflection should never exceed one-half inch.

E. SECURE

When securing the equipment associated with the wing, order is important for the following:

- DVM Column. First secure the individual DVMS and the voltage source, then the column master.
- Load Cell Panel. First secure the individual DVMS and then the panel master.
- Hydraulics. Always unload the wing at the loading valve and put the shift selector in neutral prior to securing the hydraulic pump electrical motor.

TABLE I.A LIST OF STRAIN GAGES BY TYPE

A-3	AR-7-2	EA-13-250YA	WA-13-250WF
			
Single 1 Wire Gage 120 Ω 12 Total	Rect. Rosette 3 Wire Gages 120 Ω 32 Total	Delta Rosette 3 Foil Gages 120 Ω 5 Total	Stacked Rosette 4 Foil Gages 120 Ω 5 Total
19	1-2-3	109-110-111	124-125-126-127
20	4-5-6	112-113-114	128-129-130-131
36	7-8-9	115-116-117	132-133-134-135
37	10-11-12	118-119-120	136-137-138-139
71	13-14-15	121-122-123	140-141-142-143
72	16-17-18		
103	21-22-23		
104	24-25-26		
105	27-28-29		
106	30-31-32		
107	33-34-35		
108	38-39-40		
	41-42-43		
	44-45-46		
	47-48-49		
	50-51-52		
	53-54-55		
	56-57-58		
	59-60-61		
	62-63-64		
	65-66-67		
	68-69-70		
	73-74-75		
	76-77-78		
	79-80-81		
	82-83-84		
	85-86-87		
	88-89-90		
	91-92-93		
	94-95-96		
	97-98-99		
	100-101-102		

P2V STARBOARD WING

STRAIN GAGE LOCATIONS

TOP OF TEST SECTION
BOTTOM SURFACE OF WING

NOTE: Wing is mounted upside down.

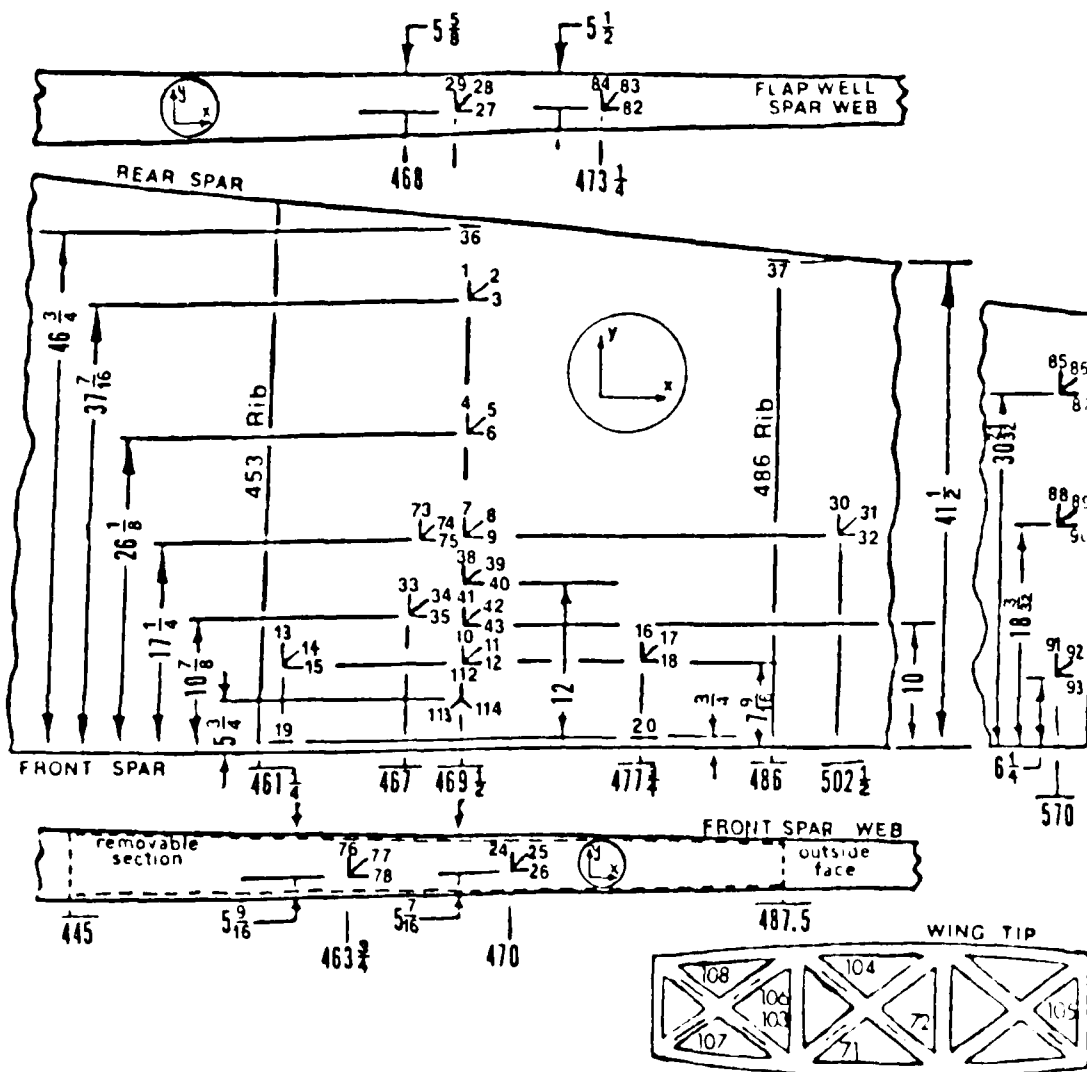


Figure 8.A P2V Starboard Wing, Strain Gage Locations, Top of Test Section

P2V STARBOARD WING

STRAIN GAGE LOCATIONS

TOP OF TEST SECTION
BOTTOM SURFACE OF WING
INTERIOR

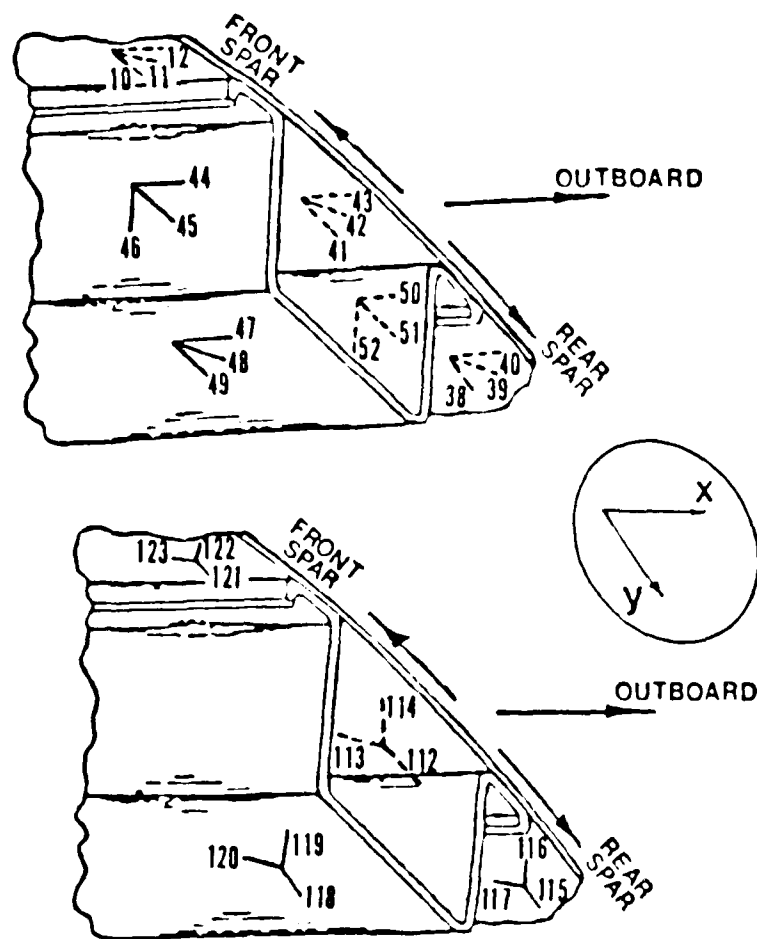


Figure 9.A P2V Starboard Wing, Strain Gage Locations, Top of Test Section, Interior

P2V STARBOARD WING

STRAIN GAGE LOCATIONS

BOTTOM OF TEST SECTION
TOP SURFACE OF WING

NOTE: Wing is mounted upside down.

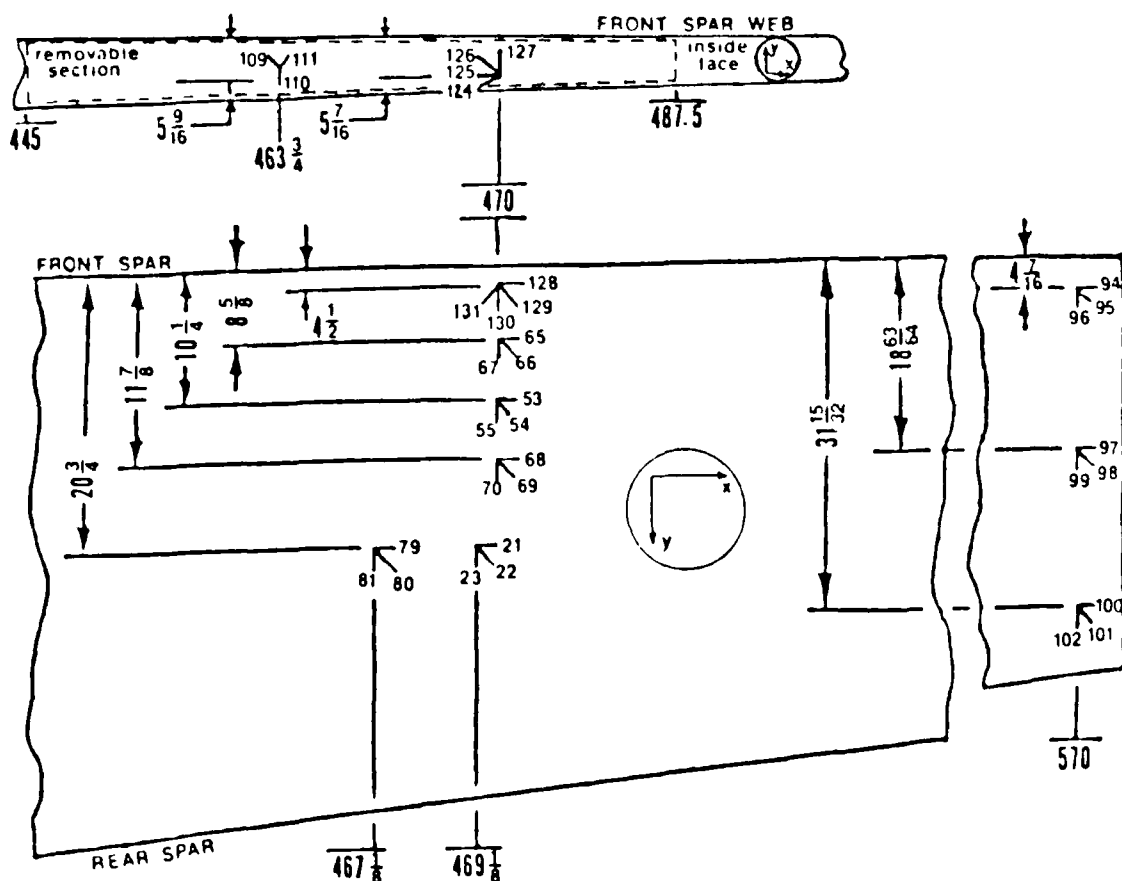


Figure 10.A P2V Starboard Wing, Strain Gage Locations,
Bottom of Test Section

P2V STARBOARD WING

STRAIN GAGE LOCATIONS

BOTTOM OF TEST SECTION
TOP SURFACE OF WING
INTERIOR

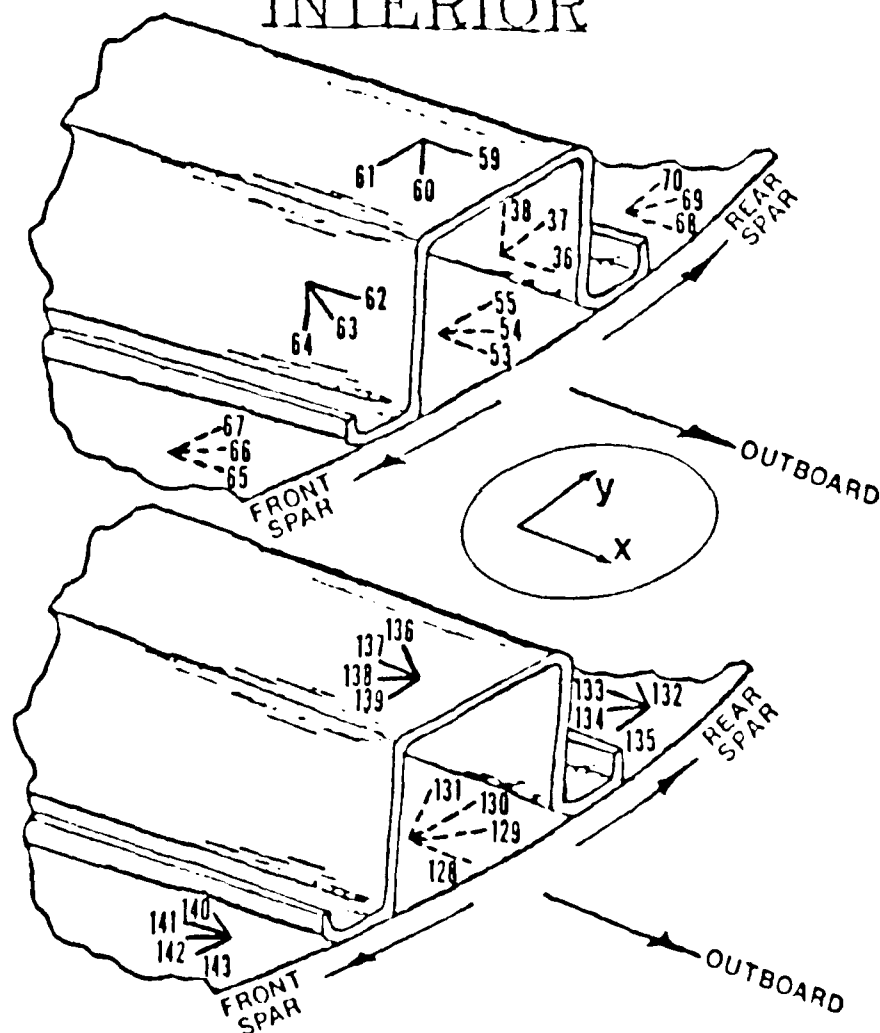


Figure 11.A P2V Starboard Wing Strain Gage Locations,
Bottom of Test Section, Interior

APPENDIX B

P2V WING LOAD CELL CALIBRATION GUIDE

A. PREFERRED METHOD

1. Remove the load cells from the support structure.
2. Install threaded shafts with nuts in both ends of the load cell. Extra threads and the nuts are in the drawer below the load cell panel.
3. Position the load cells in a test machine with proper capacity (Riehle 300,000 lb. testing machine). A solid clamp on the nuts prior to loading the machine is extremely critical for accurate readings. However, some slippage will occur during initial loading and it should be anticipated.
4. Connect the load cell cannon plugs to the load cell panel as would be in normal operations. Remove the front panel screws and tilt the panel forward exposing the interior electronics.

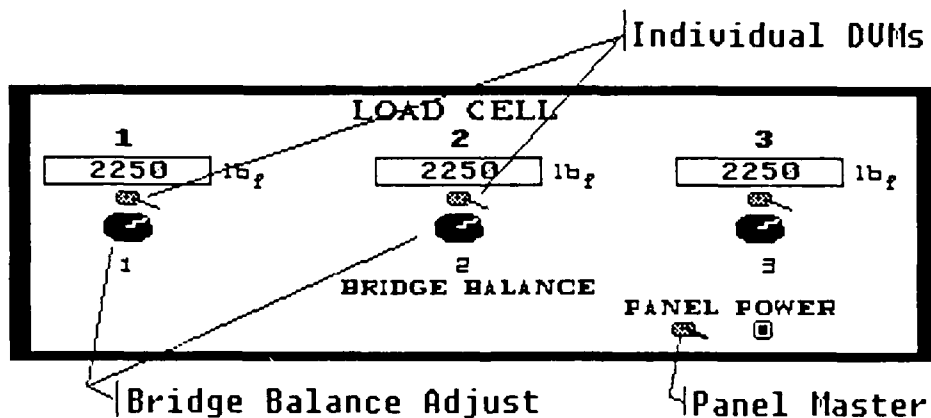


Figure 1.B Load Cell Panel

5. Each load cell has a voltage regulator and amplifier connected to a single plug in board. Locate the amplifier adjust screw that corresponds to the desired load cell being calibrated. They are from top-to-bottom 1,2,3. The adjust screw is mounted sideways on the amplifier.

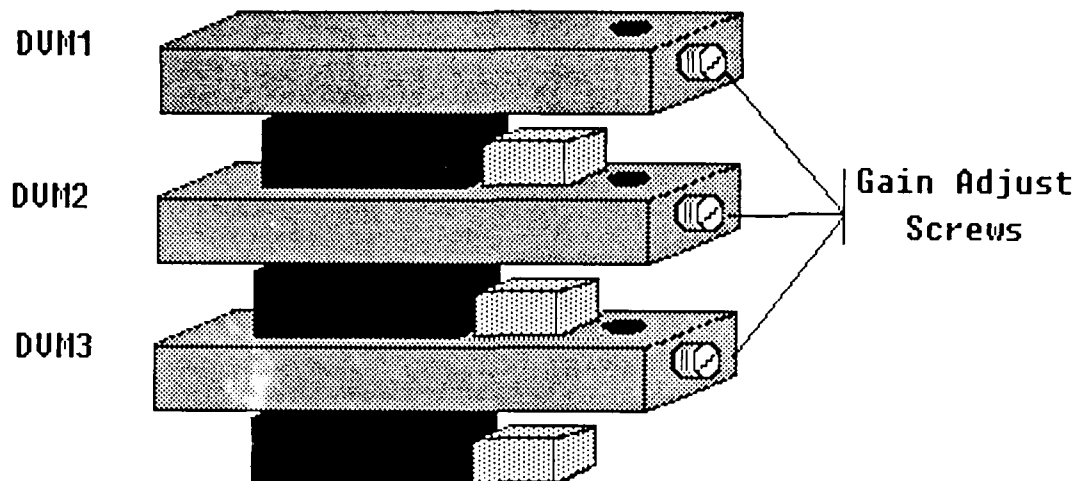


Figure 2.B Load Cell Amplifier Adjust Locations

6. Commence loading of the cell. Do not attempt to calibrate the load cell during initial loading where some clamp slippage will occur. The DVM reading will lag approximately 30 - 50 lb. during transient loading. Stop as close as possible to 2000 lb. The load machine can not hold a constant setting of 2000 lb. Therefore, it will take at least two people to successfully continue the calibration of the cells from this point.

7. One person should give short load bursts on the machine, then call out when the load passes the target of 2000 lb. The other person should attempt to adjust the amplifier so that the 2000 lb DVM reading is on the mark. A successful calibration should be considered when the readings are within 5 lb.

8. Calibrate the remaining cells using the same procedure.

9. Reinstall the load cells on the wing load application structure.

10. Immediately after successfully calibrating all three load cells, place the calibration shunt resistor across the jacks in the back of the load cell panel and record the readings. These readings will be a quick check for load cell calibration when necessary.

B. SECONDARY (QUICK CHECK) METHOD

1. Apply power to the load cell panel and the individual DVMs. After a sufficient warm-up, set zeros using the bridge balances.

2. Place the calibration shunt resistor across the jacks in the back of the load cell panel. Compare the reading against the last calibration run in the load machine. If the reading is off by more than 10 lbf., adjust the amplifier power supply as in the method described in the preferred calibration procedure.

3. Last calibration:

<u>LOAD CELL 1</u>	<u>LOAD CELL 2</u>	<u>LOAD CELL 3</u>	<u>DATE</u>
-1267	-1226	-1256	20/08/86
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

APPENDIX C

LOADING FRAME STABILITY ANALYSIS

A. TEST

The stability test on the loading frame was done with the use of a manila rope, dynamometer and a come-along. One end of the rope was attached to the frame's cross beam, the other to the opposite wall so as to place the load axis perpendicular to the vertical support, Figure 3.C. Deflections were measured with a plumb bob attached to the cross member.

TABLE I.C STABILITY ANALYSIS DATA

<u>Load (lb)</u>	<u>Moment (in-lb)</u>	<u>Deflection (in)</u>	<u>Angle (rad)</u>
0	0	0.0	0.0
50	2600	0.07	0.0013462
100	5200	0.17	0.0032692
145	7540	0.27	0.0051923
185	9620	0.37	0.0071153
242	12584	0.42	0.0080768
312	16224	0.63	0.0121148
345	17940	0.67	0.0128839
395	20540	0.82	0.0157679
435	22620	0.97	0.0186539
485	25220	1.14	0.0232919
500	26000	1.25	0.0240338
525	27300	1.33	0.0255714
555	28860	1.42	0.0273009

B. Simplified Model

In determining the critical load for the loading frame, the following simplifying assumptions were made:

- The complete frame was reduced to a single column.
- The single column was a rigid body.
- Loading on the column was precisely vertical.
- The vertical load was concentric on the column.
- All resistance to torsional load deformation was reduced to a torsional spring located at the base of the column.

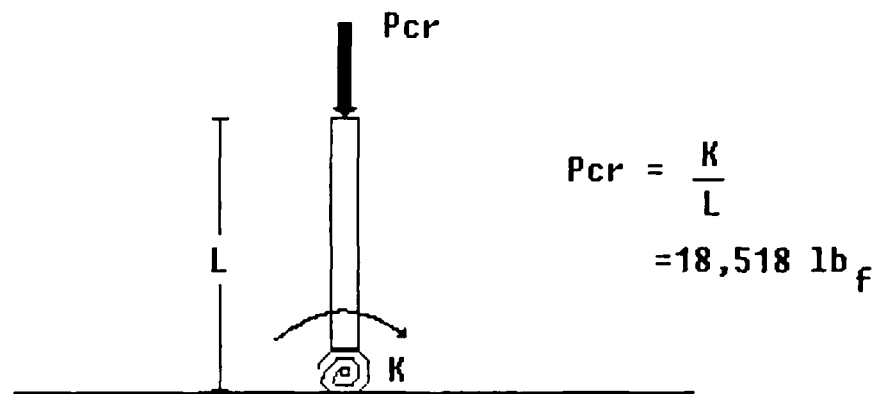


Figure 1.C Simplified Load Frame Model

Figure 2.C contains the plotted data from the deflection test. After a linear regression of that data, a best-fit value for the slope K , the torsional spring constant, was calculated to be 962,936 in-lb. Utilizing energy methods or the simple statics approach found in Beer & Johnston, Mechanics of Materials, Sections 11.1 - 11.3, the value of critical load P_{cr} , was determined to be 18,518 lb.

The value for critical load based on the simplifying assumptions exceeds the operational load limit by nearly ten times. It is judged that even upon given allowances to the simplified calculations, a significant margin of safety is inherent in this set-up.

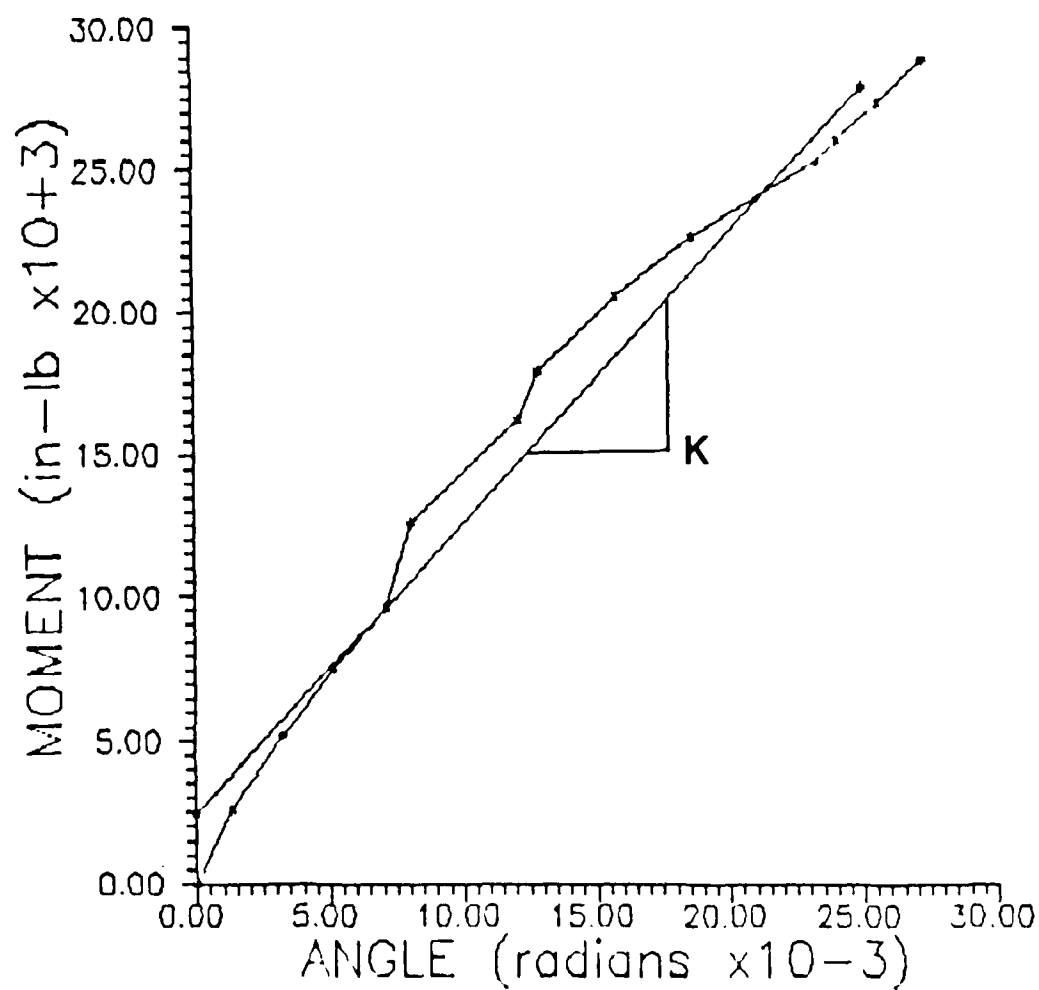


Figure 2.C Plotted Test Data

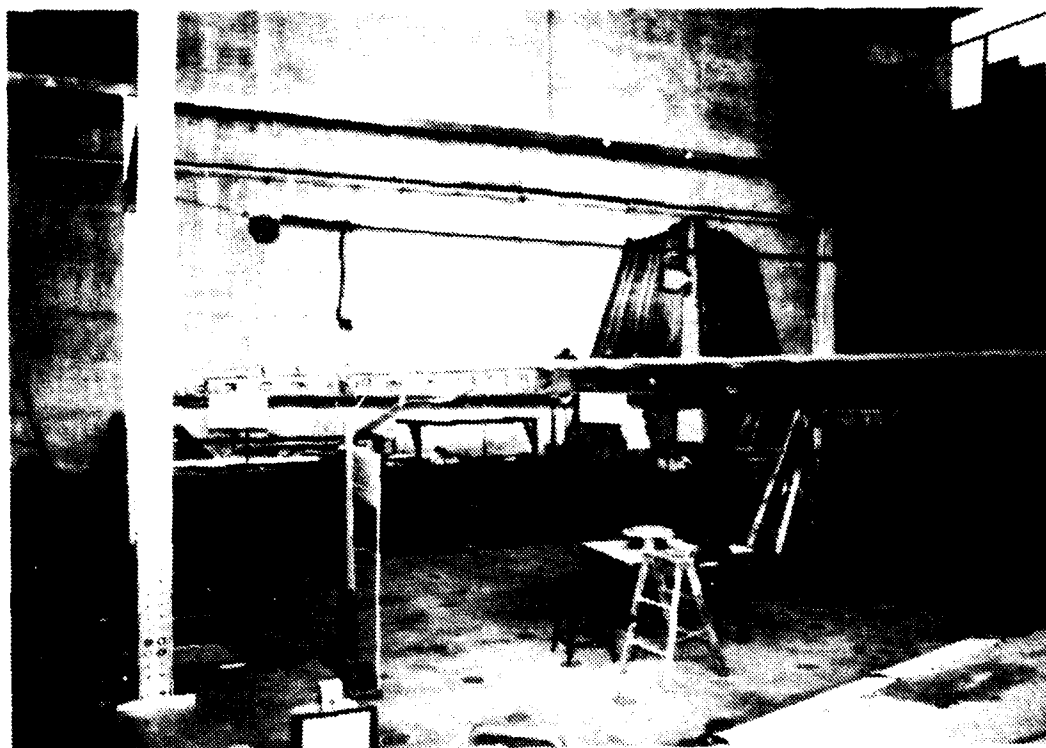


Figure 3.C Load Frame Testing Configuration

APPENDIX D

Program Listing for P2V.CAL, P2V-LOAD and ANAL.EXE

```

1000      'James J.  Miller                THESIS PROJECT
1010      'LCDR          USN
1020      '
1030      'Advisor:
1040      'Prof. Edward M. WU
1050      '
1060      '***** STRAIN GAGE CALIBRATION PROGRAM *****
1070      '
1080          '*****      VARIABLE LISTING      *****
1090          '
1100          'A - Decision variable, main menu
1110          'ADD( ) - Array containing open slots on the
                   strain gage panel
1120          'ASTRN( ) - Actual DVM strain reading
1130          'A$ - Yes/No decision input variable
1140          'BDNAME$ - GPIB variable device name
1150          'B# - DVM reading converted from string
                   variable
1160          'C - Counter
1170          'CF( ) - Correction factor for the gage
                   connected to the DVM
1180          'C# - Counter
1190          'C% - Screen graphics flag used to determine
                   a previous pass at this statement
1200          'D( ) - Dummy array used to temporarily
                   store strain gage resistance updates
1210          'D( , ) - Matrix used to store all DVM
                   readings
1220          'DEX - Element deformation X deflection
1230          'DEY - Element deformation Y deflection
1240          'DG# - Strain gage number being deleted
1250          'DVM% - GPIB device status variable
1260          'D$ - Today's date
1270          'D1$ - Date of last strain gage resistance
                   update
1280          'E - GPIB error indicator
1290          'EMAX - Maximum strain
1300          'EMIN - Minimum strain
1310          'ESTRN( ) - Expected strain reading based on
                   shunt resistance
1320          'ES1 - Intermediate strain calculation

```

variable
1330 'EX - Strain in the X direction
1340 'EY - Strain in the Y direction
1350 'F\$ - Analyze flag
1360 'G() - Gage number associated with a DVM
1370 'GAGE - Lead gage number for the rosette
being analyzed
1380 'GF - Gage factor for the analyze rosette data
1390 'GF() - Gage factor of a gage
1400 'GLE - Element deformation angle of strain
deformation
1410 'GMAX - Maximun shear strain
1420 'GN1-GN4 - Lead gage number of rosette which
can be analyzed
1430 'GXY - Gama XY, shear strain
1440 'G\$ - Single element A-3 type gage flag
1450 'I - Counter
1460 'IBSTA% - GPIB device error variable
1470 'IC - Box print, interior color
1480 'J - Counter // Box print, upper left
corner, row number
1490 'K - Counter // Box print, upper left
corner, column number
1500 'L - Box print, horizontal length
1510 'LFLAG - Temporary storage for NFLAG
1520 'M - Box print, vertical length // Integer
decision variable
1530 'MSG# - Master strain gage number connected
to DVM1
1540 'M\$ - Input variable for analyze data of
rosettes
1550 'N - Counter
1560 'NFLAG - Flag variable used to determine if
the display feature had been used
1570 'NG# - Gage number being added
1580 'NSTOP - While loop termination flag
1590 'N\$ - Name of person currently updating
resistance readings
1600 'N1\$ - Name of last person to update
resistance readings
1610 'PHIP - Angle of principle direction
1620 'PGXY - Mohr's circle pixel position for shear
1630 'PEX - Mohr's circle pixel position for
strain in X
1640 'PEY - Mohr's circle pixel position for
strain in Y

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1650-1980

```
1650      'R - Mohr's circle radius
1660      'R( ) - Resistance of a gage CAL program //
           Average of five DVM readings LOAD program
1670      'RD$ - GPIB string variable holding the DVM
           reading
1680      'RESULTS( ) - Corrected readings from the DVMs
1690      'RPG# - Gage number being replaced
1700      'RR( ) - Resistance of a gage LOAD program
1710      'R# - Strain gage resistance
1720      'S - DVM reading summary variable
1730      'SG# - Strain gage number being modified
1740      'SF - Display file gage factor
1750      'SMULT - Isotropic strain multiplier
1760      'T - Timer loop variable
1770      'TX - Timer loop variable
1780      'WRT$ - GPIB command string variable
1790      'XLOAD - Load on the wing
1800      'XIS - Mohr's circle X axis movement in
           pixels from center
1810      'XSLP - Element deformation slope of the
           horizontal lines
1820      'X1 - Element deformation pixel position
1830      'X2 - Element deformation pixel position
1840      'Y - Flag for determining if program
           previously executed this line
1850      'YSLP - Element deformation slope of the
           vertical lines
1860      'Y1 - Element deformation pixel position
1870      'Y2 - Element deformation pixel position
1880      'Z$ - Input dummy variable
1890      '
1900      REM    MAIN PROGRAM - GPIB-PC HANDLER STATEMENTS
1910      '
1920      CLEAR    ,59300!
1930      IBINIT1 = 59300!
1940      IBINIT2 = IBINIT1 + 3
1950      BLOAD "bib.m",IBINIT1
1960      CALL IBINIT1(IBFIND,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,
           IBPPC,IBBNA,IBONL,IBRSC,IBSRE,IBRSV,IBPAD,
           IBSAD,IBIST,IBDMA,IBEOS,IBTMO,IBEOT,IBRDF,
           IBWRTF)
1970      CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRT,
           IBWRTA,IBCMD,IBCMDA,IBRD,IBRDA,IBSTOP,IBRPP,
           IBRSP,IBDIAG,IBXTRC,IBRDI,IBWRTI,IBRDIA,
           IBWRTIA,IBSTA%,IBERR%,IBCNT%)
1980      '
```

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1990-2340

```
1990 REM MAIN PROGRAM - INITIAL ASSIGNMENTS,
      DIMENSIONS
2000 '
2010 KEY OFF
2020 DIM D(150), R(150), GF(150), RESULTS(12), CF(12),
      ESTRN(12), ASTRN(12), G(12), ADD(50)
2030 PRINT "~L=BACKKEY/"
2040 PRINT "~K={BACK},KEYFIX,NOESC,NOMOVE/"
2050 '
2060 REM MAIN PROGRAM - COVER SHEET PRINT TO SCREEN
2070 '
2080 COLOR 5,0:SCREEN 0,1,1,1
2090 CLS
2100 K=5:J=5:L=70:M=15:GOSUB 3040
2110 COLOR 3
2120 LOCATE 9,39:PRINT "P2V"
2130 LOCATE 12,35:PRINT "CALIBRATION"
2140 LOCATE 15,37:PRINT "PROGRAM"
2150 COLOR 7:LOCATE 19,25:PRINT "By: LCDR J. J. Miller,
      SEPT 86"
2160 COLOR 23
2170 LOCATE 23,36:PRINT "STAND BY"
2180 '
2190 REM MAIN PROGRAM - SELECTION PAGE PRINT TO
      SCREEN
2200 '
2210 SCREEN 0,1,3,1:COLOR 23,0:CLS:LOCATE 13,36:
      PRINT "STANDBY"
2220 SCREEN 0,1,0,1:COLOR 0,7:CLS:COLOR 4,3
2230 K=7:J=10:L=60:M=14:IC=3:GOSUB 3040
2240 COLOR 0,3:LOCATE 10,16:PRINT "Select:"
2250 LOCATE 12,22:PRINT "(1) Update strain gage
      resistances."
2260 LOCATE 13,22:PRINT "(2) Calculate strain gage
      calibration factors "
2270 LOCATE 14,26:PRINT "by a shunt resistance
      measurement."
2280 LOCATE 17,22:PRINT "(5) Add/Delete/Replace strain
      gages."
2290 LOCATE 15,22:PRINT "(3) Load the wing."
2300 LOCATE 18,22:PRINT "(6) Exit (Return to DOS)"
2310 LOCATE 16,22:PRINT "(4) Analyse last recorded load
      data."
2320 SCREEN 0,1,1,1:COLOR 7,0:CLS
2330 SCREEN 0,1,0,0:COLOR 0,3
2340 LOCATE 19,11:INPUT "",A
```

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2350-2720

```
2350 IF A=3 THEN CHAIN "P2V-LOAD"
2360 IF A<>4 GOTO 2450
2370 F$ = "Y" 'Analyse Flag only set
2380 OPEN "DISPLAY.DAT" FOR INPUT AS #1
2390 INPUT #1, SF, XLOAD
2400 IF SF=2.09 THEN INPUT #1, GN1,GN2,GN3,GN4,GAGE
      ELSE INPUT #1, GN1,GN2,GN3,GAGE
2410 FOR I=1 TO 12:INPUT #1, RESULTS(I), G(I):NEXT I
2420 CLOSE #1
2430 GF(G(1))=SF
2440 CHAIN "P2V-LOAD",4310,ALL
2450 IF A=1! THEN GOSUB 3580 ELSE IF A=2! THEN GOSUB
      4790 ELSE IF A=5! THEN GOSUB 6940 ELSE IF A=6!
      THEN COLOR 7,0:CLS:SYSTEM ELSE COLOR 0,3:
      LOCATE 19,32:SOUND 1000,2:PRINT "Enter
      1,2,3,4,5 or 6.":GOTO 2340
2460 '
2470 REM MAIN PROGRAM - READ PREVIOUS STRAIN GAGE
      DATA FROM FILE
2480 '
2490 OPEN "STRAIN.DAT" FOR INPUT AS #1
2500 INPUT #1,D1$,N1$
2510 FOR N=1 TO 150
2520 INPUT #1,I,R(N),GF(N)
2530 IF D(N) = 0 GOTO 2550
2540 R(N) = D(N)
2550 NEXT N
2560 CLOSE #1
2570 '
2580 REM MAIN PROGRAM - WRITE REVISED STRAIN GAGE
      DATA TO FILE
2590 '
2600 OPEN "STRAIN.DAT" FOR OUTPUT AS #1
2610 WRITE #1,D$,N$
2620 FOR N=1 TO 150
2630 WRITE #1,N,R(N),GF(N)
2640 NEXT N
2650 CLOSE #1
2660 '
2670 REM MAIN PROGRAM - HARD COPY SELECTION PRINT
      TO SCREEN
2680 '
2690 SCREEN 0,1,0,3
2700 COLOR 3,1:CLS:COLOR 4,7
2710 K=10:J=10:L=60:M=6:IC=7:GOSUB 3040
2720 COLOR 0,7:LOCATE 12,20:PRINT "Do you want a hard
```

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2720-3090

```
                copy of all strain gage"
2730  LOCATE 14,20:PRINT "resistances and gage factors?
      (Y/N)"
2740  SCREEN 0,1,0,0
2750  LOCATE 14,57:INPUT "",A$
2760  IF A$="N" OR A$="n" THEN COLOR 7:CLS:GOTO 2080
2770  IF A$<>"y" AND A$<>"Y" GOTO 2750
2780  SCREEN 0,1,3,3
2790  GOSUB 3370
2800  SCREEN 0,1,0,0:COLOR 7,0:CLS
2810  GOTO 2080
2820  '
2830  REM   MAIN PROGRAM - PROGRAM RUN END
2840  '
2850  COLOR 7:CLS:END
2860  '
2870  REM   SUBPROGRAM - PRINT A ROW TO SCREEN
      (K-START, J-END, L-ROW)
2880  '
2890  FOR I=K+1 TO J-1
2900      LOCATE L,I
2910      PRINT CHR$(205)
2920  NEXT I
2930  LOCATE L,K:PRINT CHR$(204):LOCATE L,J:PRINT
      CHR$(185)
2940  RETURN
2950  '
2960  REM   SUBPROGRAM - PRINT A COLUMN TO SCREEN
      (K-START, J-END, L-COLUMN)
2970  '
2980  FOR I=K+1 TO J-1
2990      LOCATE I,L
3000      PRINT CHR$(186)
3010  NEXT I
3020  LOCATE K,L:PRINT CHR$(203):LOCATE J,L:PRINT
      CHR$(202)
3030  RETURN
3040  '
3050  REM   SUBPROGRAM - PRINT A BOX TO SCREEN
      (K,J-UPPERLEFT CORNER, L-LENGTH,
        M-HEIGHT, IC-INTERIOR COLOR..
        DEFAULT BLACK 0)
3060  '
3070  LOCATE K,J:PRINT CHR$(201)
3080  FOR I=J+1 TO J+(L-1)
3090      LOCATE K,I
```

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3100-3470

```
3100     PRINT CHR$(205)
3110   NEXT I
3120   LOCATE K,J+L:PRINT CHR$(187)
3130   FOR I=K+1 TO K+(M-1)
3140     LOCATE I,J
3150     PRINT CHR$(186)
3160   NEXT I
3170   LOCATE K+M,J:PRINT CHR$(200)
3180   FOR I=J+1 TO J+(L-1)
3190     LOCATE K+M,I
3200     PRINT CHR$(205)
3210   NEXT I
3220   LOCATE K+M,J+L:PRINT CHR$(188)
3230   FOR I=K+1 TO K+(M-1)
3240     LOCATE I,L+J
3250     PRINT CHR$(186)
3260   NEXT I
3270   IF IC=0 GOTO 3360
3280   COLOR IC
3290   FOR I=K+1 TO K+M-1
3300     FOR N=J+1 TO J+L-1
3310       LOCATE I,N:PRINT CHR$(219)
3320     NEXT N
3330   NEXT I
3340   COLOR 7,0
3350   IC=0
3360   RETURN
3370   '
3380   REM   SUBPROGRAM - PRINTS TO THE PRINTER A TABLE
        OF STRAIN GAGE DATA
3390   '
3400   FOR I=1 TO 79:LPRINT TAB(I);CHR$(95);:NEXT I
3410   LPRINT TAB(1);CHR$(124);TAB(79);CHR$(124)
3420   LPRINT TAB(1);CHR$(124);TAB(25);"STRAIN GAGE
        RESISTANCE SUMMARY";TAB(79);CHR$(124)
3430   LPRINT CHR$(124);:FOR I=2 TO 78:LPRINT TAB(I);
        CHR$(246);:NEXT I:LPRINT CHR$(124)
3440   LPRINT TAB(1);CHR$(124);TAB(3);"LAST ENTRY - DATE:
        ";D$;TAB(40);"NAME:  ";N$;TAB(79);CHR$(124)
3450   LPRINT CHR$(124);:FOR I=2 TO 78:LPRINT TAB(I);
        CHR$(246);:NEXT I:LPRINT CHR$(124)
3460   LPRINT TAB(1);CHR$(124);" GAGE #      OHMS      GF
        ";CHR$(124);" GAGE #      OHMS      GF  ";
        CHR$(124);" GAGE #      OHMS      GF ";CHR$(124)
3470   LPRINT TAB(1);CHR$(124);:FOR I=2 TO 78:LPRINT
        TAB(I);CHR$(246);:NEXT I:LPRINT CHR$(124)
```

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3480-3670

```
3480 FOR J=1 TO 45
3490     LPRINT TAB(1);CHR$(124);TAB(3);J;TAB(11);R(J);
        TAB(21);GF(J);TAB(27);CHR$(124);TAB(29);
        J+50;TAB(37);R(J+50);TAB(47);GF(J+50);
        TAB(53);CHR$(124);TAB(55);J+100;TAB(63);
        R(J+100);TAB(73);GF(J+100);TAB(79);CHR$(124)
3500 NEXT J
3510 LPRINT TAB(1);CHR$(124);TAB(4);"46";TAB(11);R(46);
        TAB(21);GF(46);TAB(27);CHR$(124);TAB(30);"96";
        TAB(37);R(96);TAB(47);GF(96);TAB(53);CHR$(124);
        TAB(57);"CALIBRATION GAGES";TAB(79);CHR$(124)
3520 LPRINT TAB(1);CHR$(124);TAB(4);"47";TAB(11);R(47);
        TAB(21);GF(47);TAB(27);CHR$(124);TAB(30);"97";
        TAB(37);R(97);TAB(47);GF(97);TAB(53);CHR$(124);
        TAB(55);"EA-13";TAB(63);R(147);TAB(73);GF(147);
        TAB(79);CHR$(124)
3530 LPRINT TAB(1);CHR$(124);TAB(4);"48";TAB(11);R(48);
        TAB(21);GF(48);TAB(27);CHR$(124);TAB(30);"98";
        TAB(37);R(98);TAB(47);GF(98);TAB(53);CHR$(124);
        TAB(56);"A-3";TAB(63);R(148);TAB(73);GF(148);
        TAB(79);CHR$(124)
3540 LPRINT TAB(1);CHR$(124);TAB(4);"49";TAB(11);R(49);
        TAB(21);GF(49);TAB(27);CHR$(124);TAB(30);"99";
        TAB(37);R(99);TAB(47);GF(99);TAB(53);CHR$(124);
        TAB(55);"AR7-2";TAB(63);R(149);TAB(73);GF(149);
        TAB(79);CHR$(124)
3550 LPRINT TAB(1);CHR$(124);TAB(4);"50";TAB(11);R(50);
        TAB(21);GF(50);TAB(27);CHR$(124);TAB(29);"100";
        TAB(37);R(100);TAB(47);GF(100);TAB(53);
        CHR$(124);TAB(55);"WA-13";TAB(63);R(150);
        TAB(73);GF(150);TAB(79);CHR$(124)
3560 FOR I=1 TO 79:LPRINT TAB(I);CHR$(176);:NEXT I:
        LPRINT CHR$(244)
3570 RETURN
3580 '
3590 REM SUBPROGRAM - UPDATE STRAIN GAGE RESISTANCES
3600 '
3610 'Name entry screen
3620 D$ = DATE$
3630 SCREEN 0,1,0,0:COLOR 7,0:CLS:COLOR 15,0
3640 COLOR 4,0:LOCATE 1,23:PRINT "STRAIN GAGE
        RESISTANCE MEASUREMENT"
3650 COLOR 4,0:LOCATE 1,23:PRINT "STRAIN GAGE
        RESISTANCE MEASUREMENT"
3660 LOCATE 5,30
3670 PRINT "Enter operator's name."
```

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3680-3990

```
3680 COLOR 4,7:K=12:J=30:L=20:M=2:IC=7:GOSUB 3050
3690 LOCATE 13,32:COLOR 0,7
3700 INPUT "",N$
3710 '
3720 'Instruction page for reading resistances on DVM
      1 print to screen
3730 SCREEN 0,1,0,3
3740 COLOR 7,11:CLS:COLOR 4,7
3750 K=3:J=33:L=14:M=3:IC=7:GOSUB 3040
3760 COLOR 1,7:LOCATE 4,35:PRINT "RESISTANCE"
3770 LOCATE 5,35:PRINT "MEASUREMENT"
3780 COLOR 15,0:LOCATE 9,5:PRINT CHR$(219);:COLOR 5,11:
      PRINT " ONLY";:COLOR 0:PRINT " DVM 1 will be
      used for all resistance measurements."
3790 LOCATE 11,5:COLOR 26,11:PRINT CHR$(219);:
      COLOR 0,11:PRINT " Ensure DVM 1 is set up as
      follows:"
3800 LOCATE 13,28:PRINT "1. Power Button - ON."
3810 LOCATE 14,28:PRINT "2. Input Button - FRONT."
3820 LOCATE 16,5:COLOR 28,11:PRINT CHR$(219);:
      COLOR 0,11:PRINT " Connect the two-wire test
      leads to the front of the meter."
3830 COLOR 15,0:LOCATE 20,29:PRINT " SPACEBAR to
      continue "
3840 SCREEN 0,1,0,0
3850 Z$ = INKEY$
3860 IF Z$ <> CHR$(32) GOTO 3850
3870 '
3880 'Input strain gage to be read page print to screen
3890 COLOR 7,0:CLS:SCREEN 0,1,0,3:CLS:COLOR 4,7
3900 K=6:J=10:L=60:M=10:IC=7:GOSUB 3040
3910 COLOR 4,7
3920 K=10:J=70:L=11:GOSUB 2860
3930 COLOR 4,0:LOCATE 1,23:PRINT "STRAIN GAGE
      RESISTANCE MEASUREMENT"
3940 COLOR 1,7
3950 LOCATE 8,11:PRINT "          When the strain gage is
      properly connected          "
3960 LOCATE 9,11:PRINT "          to DVM1, enter strain
      gage number and <CR>.          "
3970 COLOR 5,7:LOCATE 13,11:PRINT "          NOTE:
      A resistance measurement will be taken          "
3980 LOCATE 14,11:PRINT "          using DVM1 immediately
      following <CR>.          "
3990 COLOR 15,0:LOCATE 21,22:PRINT "Enter 0 to end and
      return to the menu."
```

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4000-4350

```
4000 SCREEN 0,1,0,0
4010 COLOR 7:LOCATE 23,1:PRINT "Enter strain gage
      number:      ":LOCATE 23,28
4020 INPUT "",SG#
4030 IF SG#<>0 THEN GOTO 4140
4040 SCREEN 0,1,0,3:COLOR 1,7:CLS:LOCATE 11,5
4050 COLOR 26,7:PRINT CHR$(219);:COLOR 0,7:PRINT "
      Ensure DVM 1 is returned to the following:"
4060 LOCATE 13,28:PRINT "1. Power Button - cycle OFF
      then ON."
4070 LOCATE 14,28:PRINT "2. Input Button - REAR."
4080 LOCATE 15,28:PRINT "3. Remove the two wire test
      leads."
4090 COLOR 15,0:LOCATE 20,29:PRINT " SPACEBAR to
      continue "
4100 SCREEN 0,1,0,0
4110 Z$ = INKEY$
4120 IF Z$ <> CHR$(32) GOTO 4110
4130 SCREEN 0,1,0,0:COLOR 28,0:CLS:LOCATE 13,36:
      PRINT "STANDBY":COLOR 7:RETURN
4140 SCREEN 0,1,0,0:CLS
4150 COLOR 28,0:CLS:LOCATE 13,36:PRINT "STAND BY"
4160 GOSUB 4350
4170 '
4180 'Display resistance measurement page print to
      screen
4190 CLS
4200 COLOR 3:K=11:J=10:L=60:M=4:GOSUB 3040
4210 K=11:J=15:L=40:GOSUB 2960
4220 COLOR 7:LOCATE 13,15:PRINT "STRAIN GAGE ";SG#
4230 LOCATE 13,45:PRINT "RESISTANCE = ";R#;CHR$(234)
4240 LOCATE 20,10:PRINT "Enter: (Y)-Measurement is
      acceptable. (approx. 118.5-123.5 ";CHR$(234);)"
4250 LOCATE 21,10:PRINT " (N)-Cancel the reading."
4260 LOCATE 23,1:COLOR 4:INPUT "NOTE: A (Y) entry will
      file the measurement";A$
4270 IF A$="N" OR A$="n" THEN COLOR 7,0:CLS:GOTO 3880
4280 IF A$<>"Y" AND A$<>"y" THEN PRINT "Enter Y or N.":
      GOTO 4260
4290 D(SG#)=R#
4300 SCREEN 0,1,2,2:COLOR 9:CLS
4310 K=11:J=29:L=23:M=4:GOSUB 3040
4320 COLOR 15:LOCATE 13,34:PRINT "DATA RECORDED"
4330 FOR I=1 TO 100: J=J+I:NEXT I 'Program delay
4340 GOTO 3880
4350 '

```

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4360-4800

```
4360 REM SUBPROGRAM - READ RESISTANCE FROM DVM1
4370 '
4380 BDNAMES$ = "DVM1"
4390 CALL IBFIND (BDNAMES$,DVM%)
4400 IF DVM% < 0 THEN GOSUB 4590
4410 CALL IBCLR (DVM%)
4420 IF IBSTA% < 0 THEN GOSUB 4700
4430 WRT$ = "F3R0"
4440 CALL IBWRT (DVM%,WRT$)
4450 IF IBSTA% < 0 THEN GOSUB 4700
4460 J=0:FOR I=1 TO 500:J=J+I:NEXT I 'Program delay
4470 RD$ = SPACE$(16)
4480 CALL IBRD (DVM%,RD$)
4490 IF IBSTA% < 0 THEN GOSUB 4700
4500 R#=VAL(RD$)
4510 RETURN
4520 '
4530 REM SUBPROGRAM - GPIB-PC ERROR STATEMENTS
4540 '
4550 'A routine at this location would notify
4560 'you that the IBFIND call failed, and
4570 'refer you to the handler software
4580 'configuration procedures.
4590 PRINT "IBFIND ERROR" : PRINT "E=";E: END
4600 '
4610 'An error checking routine at this
4620 'location would, among other things,
4630 'check IBERR to determine the exact
4640 'cause of the error condition and then
4650 'take action appropriate to the
4660 'application. For errors during data
4670 'transfers, IBCNT may be examined to
4680 'determine the actual number of bytes
4690 'transferred.
4700 PRINT "GPIB ERROR" : PRINT "E=";E: END
4710 '
4720 'A routine at this location would analyze
4730 'the fault code returned in the DVM's
4740 'status byte and take appropriate action.
4750 PRINT "DVM ERROR" : PRINT "E=";E: END
4760 '
4770 END
4780 '
4790 REM SUBPROGRAM - CALCULATE STRAIN GAGE
CALIBRATION DATA
4800 '
```

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4810-5200

```
4810 SCREEN ,,2,3
4820 'Print to screen CALIBRATION cover page
4830 COLOR 0,1:CLS
4840 COLOR 1,7
4850 K=10:J=26:L=28:M=6:IC=7:GOSUB 3040
4860 COLOR 4,7:LOCATE 11,32:PRINT "CORRECTION FACTOR"
4870 LOCATE 13,35:PRINT "CALCULATION"
4880 LOCATE 15,37:PRINT "PROGRAM"
4890 COLOR 31,1:LOCATE 20,37:PRINT "STAND BY"
4900 '
4910 'Construct the table of strain gage calibration
      data
4920 SCREEN 0,1,0,2:COLOR 3,0:CLS
4930 K=1:J=2:L=77:M=20:IC=0:GOSUB 3040
4940 K=2:J=79:L=3:GOSUB 2870
4950 L=5:GOSUB 2870
4960 K=3:J=21:L=12:GOSUB 2960
4970 L=21:GOSUB 2960
4980 L=30:GOSUB 2960
4990 L=42:GOSUB 2960
5000 L=55:GOSUB 2960
5010 L=66:GOSUB 2960
5020 LOCATE 5,12:PRINT CHR$(206)
5030 LOCATE 5,21:PRINT CHR$(206)
5040 LOCATE 5,30:PRINT CHR$(206)
5050 LOCATE 5,42:PRINT CHR$(206)
5060 LOCATE 5,55:PRINT CHR$(206)
5070 LOCATE 5,66:PRINT CHR$(206)
5080 COLOR 15:LOCATE 2,19:PRINT "STRAIN GAGE
      CALIBRATION DATA (strain-";CHR$(230);" in/in)"
5090 COLOR 11:LOCATE 4,5:PRINT "METER":LOCATE 4,15:
      PRINT "GAGE":LOCATE 4,24:PRINT "G.F."
5100 LOCATE 4,36:PRINT CHR$(234):LOCATE 4,46:
      PRINT CHR$(238);"(expt)"
5110 LOCATE 4,58:PRINT CHR$(238);"(act)":LOCATE 4,71:
      PRINT "C.F."
5120 COLOR 9:N=1
5130 FOR J=6 TO 18 STEP 4
5140     LOCATE J,5:PRINT "DVM ";:PRINT USING "###";N
5150     LOCATE J+1,5:PRINT "DVM ";:PRINT USING "###";N+1
5160     LOCATE J+2,5:PRINT "DVM ";:PRINT USING "###";N+2
5170     N=N+3
5180 NEXT J
5190 '
5200 'Read the strain gage resistance data and gage
      factors from "STRAIN.DAT"
```

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5210-5520

```
5210 OPEN "STRAIN.DAT" FOR INPUT AS #1
5220 INPUT #1,D1$,N1$
5230 FOR N=1 TO 150
5240     INPUT #1,I,R(I),GF(I)
5250 NEXT N
5260 CLOSE #1
5270 '
5280 'Prompt for strain gages connected to the
      respective DVMS then print the
5290 'data in the sppropriate location in the
      calibration data table
5300 SCREEN 0,1,2,2
5310 COLOR 7,0:CLS
5320 SCREEN 0,1,0,0:Y=0
5330 FOR N=1 TO 12
5340     COLOR 0,0:LOCATE 22,10:PRINT "
      "
5350     COLOR 15:LOCATE 23,21:PRINT "Enter strain gage
      # connected to DVM ";N
5360     M=0
5370     IF N>3 THEN M=1
5380     IF N>6 THEN M=2
5390     IF N>9 THEN M=3
5400     COLOR 7:LOCATE 5+N+M,15:PRINT CHR$(219);
      CHR$(219);CHR$(219)
5410     LOCATE 5+N+M,15:COLOR 0,7:INPUT "",SG#
5420     IF SG#<1 OR SG#>146 THEN SOUND 1000,18:
      LOCATE 22,10:COLOR 31,0:PRINT "STRAIN GAGE
      ";SG#;" IS INOPERATIVE OR NOT INSTALLED.
      SELECT ANOTHER.":COLOR 15,0:GOTO 5400
5430     IF R(SG#)=0 THEN SOUND 1000,18:LOCATE 22,10:
      COLOR 31,0:PRINT "STRAIN GAGE ";SG#;
      " IS INOPERATIVE OR NOT INSTALLED. SELECT
      ANOTHER.":COLOR 15,0:GOTO 5400
5440     G(N)=SG#
5450     LOCATE 5+N+M,15:COLOR 7,0:PRINT USING "####";SG#
5460     LOCATE 5+N+M,24:PRINT USING "#.##";GF(SG#)
5470     LOCATE 5+N+M,33:PRINT USING "###.###";R(SG#)
5480     ESTRN(N)=(R(SG#)/(GF(SG#)*(59872.5+R(SG#)))*
      1000000!)
5490     IF N=1 THEN MSG#=SG#
5500     LOCATE 5+M+N,45:PRINT USING "####.###";
      ESTRN(N):IF Y=1 GOTO 5530
5510 NEXT N
5520 '
```

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5530-5840

```
5530 'Check to see if there are any changes
5540 COLOR 4,0:LOCATE 23,15:INPUT "          Any
      changes? (Y/N)          ",A$
5550 IF A$ = "y" OR A$ = "Y" THEN Y=1:LOCATE 23,25:
      PRINT " Which DVM will be changed?
            ":LOCATE 23,56:INPUT "",N:IF Y=1 AND
            N>=1 AND N<=12 GOTO 5340 ELSE SOUND 100,3:
            GOTO 5550
5560 IF A$ <> "N" AND A$ <> "n" GOTO 5540
5570 COLOR 7,0:LOCATE 23,15:PRINT "
      STAND BY
5580 '
5590 'Print to screen the directions for hooking up
      the calibration shunt
5600 'resistor to DVM 1 which is the master for this
      experiment
5610 SCREEN 0,1,2,0:CLS
5620 COLOR 14,1
5630 K=1:J=28:L=25:M=6:IC=1:GOSUB 3040
5640 COLOR 7,1:LOCATE 2,35:PRINT "STRAIN GAGE"
5650 LOCATE 4,35:PRINT "CALIBRATION"
5660 LOCATE 6,37:COLOR 12,1:PRINT "MASTER"
5670 LOCATE 9,5
5680 COLOR 7,0:PRINT CHR$(219);" The strain gage
      connected to DVM 1 will be the master for this
      run.";
5690 LOCATE 11,5:COLOR 25,0:PRINT CHR$(219);:COLOR 11,0
5700 PRINT " Balance the Wheatstone bridge on DVM 1.":
      COLOR 15,0:PRINT " Hit SPACEBAR when balanced."
5710 SCREEN 0,1,2,2
5720 Z$ = INKEY$
5730 IF Z$ <> CHR$(32) GOTO 5720
5740 LOCATE 11,5:COLOR 9,0:PRINT CHR$(219)
5750 LOCATE 11,47:COLOR 7,0:PRINT "
      "
5760 BDNAME$ = "DVM1"
5770 GOSUB 6720
5780 COLOR 26,0:LOCATE 13,5:PRINT CHR$(219);
5790 COLOR 15,0:PRINT " Place the calibration shunt
      resistor across the strain gage leads ";
5800 LOCATE 14,8:PRINT "connected to DVM 1.":
      COLOR 15,0:PRINT " Hit SPACEBAR to continue."
5810 Z$ = INKEY$
5820 IF Z$ <> CHR$(32) GOTO 5810
5830 LOCATE 13,5:COLOR 10,0:PRINT CHR$(219)
5840 LOCATE 14,29:COLOR 7,0:PRINT "
```

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5840-6150

```
"
5850 LOCATE 16,5:COLOR 28,0:PRINT CHR$(219);:COLOR 14,0:
      PRINT " Adjust the Wheatstone Bridge power
            supply so that the reading on DVM 1";
5860 LOCATE 17,8:PRINT "is as close as possible to the
      ";CHR$(238);"(expt) of:";
5870 COLOR 0,15:LOCATE 18,36:PRINT CHR$(32);"-";:
      PRINT USING "#.###";ESTRN(1)/1000;:PRINT
      CHR$(32)
5880 COLOR 7,0:LOCATE 20,5:PRINT CHR$(219);" Once the
      voltage source is set, do not change the
      voltage for";
5890 LOCATE 21,8:PRINT "remainder of this session."
5900 COLOR 3,0:LOCATE 23,19:PRINT "When the voltage is
      adjusted, <CR> to continue."
5910 Z$ = INKEY$
5920 IF Z$ <> CHR$(13) GOTO 5910
5930 COLOR 7,0:CLS
5940 '
5950 'Return to the calibration table and take the
      calibration shunt reading
5960 'for the other 11 strain gages
5970 SCREEN 0,1,0,0
5980 LOCATE 23,20:PRINT "                STAND BY
                        "
5990 GOSUB 6860
6000 ASTRN(1) = VAL(RD$)*(-1000000!)
6010 LOCATE 6,58:PRINT USING "####.#";ASTRN(1)
6020 CF(1) = ESTRN(1)/ASTRN(1)
6030 LOCATE 6,69:COLOR 13,0:PRINT USING "#.#####";
      CF(1):COLOR 7,0
6040 Y=0!
6050 FOR N=2 TO 12
6060 LOCATE 23,10:PRINT "Balance the bridge
      connected to DVM ";N;" SPACEBAR to
      continue."
6070 Z$ = INKEY$
6080 IF Z$ <> CHR$(32) GOTO 6070
6090 LOCATE 23,10:PRINT "
      STAND BY
                        "
6100 IF N=2 THEN BDNAME$ = "DVM2":GOSUB 6720
6110 IF N=3 THEN BDNAME$ = "DVM3":GOSUB 6720
6120 IF N=4 THEN BDNAME$ = "DVM4":GOSUB 6720
6130 IF N=5 THEN BDNAME$ = "DVM5":GOSUB 6720
6140 IF N=6 THEN BDNAME$ = "DVM6":GOSUB 6720
6150 IF N=7 THEN BDNAME$ = "DVM7":GOSUB 6720
```

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6160-6460

```
6160     IF N=8 THEN BDNAMES$ = "DVM8":GOSUB 6720
6170     IF N=9 THEN BDNAMES$ = "DVM9":GOSUB 6720
6180     IF N=10 THEN BDNAMES$ = "DVM10":GOSUB 6720
6190     IF N=11 THEN BDNAMES$ = "DVM11":GOSUB 6720
6200     IF N=12 THEN BDNAMES$ = "DVM12":GOSUB 6720
6210     LOCATE 23,3:PRINT "Place the shunt resistor
        across the leads to DVM ";N;" <CR> to
        continue."
6220     Z$ = INKEY$
6230     IF Z$ <> CHR$(13) GOTO 6220
6240     LOCATE 23,3:PRINT "
        STAND BY
        "
6250     GOSUB 6860
6260     ASTRN(N) = VAL(RD$)*(-1000000!)
6270     CF(N) = ESTRN(N)/ASTRN(N)
6280     M=0
6290     IF N>3 THEN M=1
6300     IF N>6 THEN M=2
6310     IF N>9 THEN M=3
6320     LOCATE 5+N+M,58:PRINT USING "####.#";ASTRN(N)
6330     LOCATE 5+N+M,69:COLOR 13,0:PRINT USING
        "#.#####";CF(N)
6340     IF Y=1! GOTO 6370
6350     COLOR 7,0
6360     NEXT N
6370     COLOR 4,0:LOCATE 23,13:INPUT "        Want to
        recalibrate any gages? (Y/N)
        ",A$
6380     LOCATE 23,1:PRINT "
        "
6390     IF A$ = "y" OR A$ = "Y" THEN Y=1:LOCATE 23,12:
        PRINT "        Which DVM has the gage to be
        recalibrated? ":LOCATE 23,66:INPUT "",N:
        IF Y=1 AND N>=2 AND N<=12 THEN COLOR 7:GOTO 6060
6400     IF N=1 AND Y=1 THEN LOCATE 23,25:PRINT "Since DVM1
        was the master, you must start again.
        SPACEBAR to continue.":INPUT "",Z$:IF
        Z$<>CHR$(32) GOTO 6400:GOTO 2080
6410     IF Y=1 AND (N<1 OR N>12) THEN SOUND 1000,2:GOTO 6390
6420     '
6430     'Constructs an output file "CALIBRAT.DAT" which
        contains the calibration
6440     'data: DVM #, Strain gage # and Calibration factor
6450     OPEN "CALIBRAT.DAT" FOR OUTPUT AS #2
6460     FOR N=1 TO 12
```

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6470-6860

```
6470     WRITE #2,N,G(N),CF(N)
6480     NEXT N
6490     CLOSE #2
6500     '
6510     'Machine language routine that does a PrtSc
6520     LOCATE 23,10:COLOR 18,0:PRINT "
        HARDCOPY IN PROGRESS
        "
6530     D$=DATE$
6540     LPRINT TAB(36);D$
6550     DEFINT A: DIM ARRAY (3)
6560     DATA &HCD55           :REM 55H Push BP
6570     DATA &H5D05           :REM CD05H INT 5
6580     :REM 5DH POP BP
6590     DATA &H90CB           :REM 90H NOP
6600     FOR I=1 TO 3: READ ARRAY(I): NEXT I
6610     SUBRT = VARPTR(ARRAY(1)): CALL SUBRT
6620     '
6630     'Return to the main menu
6640     LPRINT CHR$(27)+"E"
6650     LOCATE 23,10:COLOR 15,0:PRINT "Remove the
        calibration shunt resistor.":COLOR 31:
        PRINT " SPACEBAR TO CONTINUE."
6660     Z$ = INKEY$
6670     IF Z$ <> CHR$(32) GOTO 6660
6680     GOTO 2080
6690     '
6700     'Subprogram sets meter REMOTE, clears it, sets
        function and range then
6710     'turns on the OFFSET
6720     CALL IBFIND (BDNAME$,DVM%)
6730     IF DVM% < 0 THEN GOSUB 4590
6740     CALL IBCLR (DVM%)
6750     IF IBSTA% < 0 THEN GOSUB 4700
6760     WRT$ = "F1R0"
6770     CALL IBWRT (DVM%,WRT$)
6780     IF IBSTA% < 0 THEN GOSUB 4700
6790     J=0:FOR I=1 TO 500:J=J+I:NEXT I    'Program delay
6800     WRT$ = "B1"
6810     CALL IBWRT (DVM%,WRT$)
6820     IF IBSTA% < 0 THEN GOSUB 4700
6830     RETURN
6840     '
6850     'Subprogram takes meter reading and turns OFFSET
        off
6860     RD$ = SPACE$(20)
```

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6870-7280

```
6870 CALL IBRD (DVM%,RD$)
6880 IF IBSTA% < 0 THEN GOSUB 4700
6890 WRT$ = "B0"
6900 CALL IBWRT (DVM%,WRT$)
6910 IF IBSTA% < 0 THEN GOSUB 4700
6920 RETURN
6930 '
6940 REM SUBROUTINE - ADD/DELETE/REPLACE STRAIN GAGES
6950 '
6960 'Construct option box
6970 SCREEN 0,1,0,3:COLOR 7,0:CLS
6980 COLOR 2,7:K=8:J=25:L=32:M=9:IC=7:GOSUB 3040
6990 COLOR 0,7:LOCATE 10,27:PRINT "Make a selection:"
7000 LOCATE 12,32:PRINT "1. ADD strain gage"
7010 LOCATE 13,32:PRINT "2. DELETE strain gage"
7020 LOCATE 14,32:PRINT "3. REPLACE strain gage"
7030 LOCATE 15,32:PRINT "4. Return to main menu"
7040 '
7050 'Read in all stored strain gage data
7060 OPEN "STRAIN.DAT" FOR INPUT AS #1
7070 INPUT #1,D1$,N$
7080 FOR N=1 TO 150
7090 INPUT #1,I,R(I),GF(I)
7100 NEXT N
7110 CLOSE #1
7120 '
7130 'Make selection
7140 SCREEN 0,1,0,0
7150 LOCATE 16,26:INPUT "",A
7160 IF A=1 THEN GOSUB 7300 ELSE IF A=2 THEN GOSUB 7730
      ELSE IF A=3 THEN GOSUB 7810 ELSE IF A=4 GOTO
      2060 ELSE SCREEN 0,1,1,1:LOCATE 17,32:
      SOUND 1000,15:PRINT "Select 1,2,3 or 4!":
      GOTO 7150
7170 '
7180 'Write to storage all strain gage data
7190 IF D$="" THEN D$=D1$
7200 OPEN "STRAIN.DAT" FOR OUTPUT AS #1
7210 WRITE #1,D$,N$
7220 FOR N=1 TO 150
7230 WRITE #1,N,R(N),GF(N)
7240 NEXT N
7250 CLOSE #1
7260 '
7270 'Return to the selection menu
7280 COLOR 7,0:CLS:GOTO 6940
```

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of 20
7290-7660

```
7290 '
7300 'ADD strain gage subroutine
7310 SCREEN 0,1,0,3
7320 COLOR 7,0:CLS
7330 '
7340 'Search for the open slots on the strain gage panel
7350 C=0
7360 FOR N=1 TO 150
7370     IF GF(N) = 0 THEN C=C+1:ADD(C)=N
7380 NEXT N
7390 '
7400 'Construct table of open board slots
7410 COLOR 4,0
7420 M=CINT(C/4)+1
7430 K=13 - CINT(M/2)
7440 J=26:L=28:GOSUB 3040
7450 C#=0
7460 COLOR 11,0
7470 FOR N=1 TO M-1
7480     LOCATE K+N,30:PRINT USING "###";ADD(C#+1):
7490         LOCATE K+N,36:PRINT USING "###";ADD(C#+2):
7500             LOCATE K+N,43:PRINT USING "###";ADD(C#+3):
7510                 LOCATE K+N,49:PRINT USING "###";ADD(C#+4)
7520     C#=C#+4
7530 NEXT N
7540 LOCATE K-2,27:COLOR 15,0:PRINT "STRAIN GAGE BOARD
7550     VACANCIES"
7560 SCREEN 0,1,0,0
7570 LOCATE K+M+2,21:COLOR 12,0:PRINT "Select location
7580     of new gage from list:      "
7590 '
7600 'Select new strain gage location and verify it as
7610     a vacancy
7620 LOCATE K+M+2,61:COLOR 7,0:INPUT "",NG#
7630 FOR N=1 TO C
7640     IF NG# = ADD(N) GOTO 7610
7650 NEXT N
7660 SOUND 1000,18.2:GOTO 7530
7670 '
7680 'Enter the new gage's resistance and gage factor
7690 CLS:COLOR 9,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
7700 COLOR 11,0:LOCATE 10,22:PRINT "Enter manufacture
7710     r's listed resistance."
7720 COLOR 14,0:LOCATE 16,10:PRINT "NOTE:  Suggest you
7730     run resistance update subprogram after "
7740 LOCATE 17,10:PRINT "completion of this subprogram."
```

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7670-8030

```
7670 COLOR 0,7:LOCATE 13,38:INPUT "",R(NG#)
7680 COLOR 7,0:CLS
7690 COLOR 9,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
7700 COLOR 11,0:LOCATE 10,21:PRINT "Enter manufacture
      r's listed gage factor."
7710 COLOR 0,7:LOCATE 13,38:INPUT "",GF(NG#)
7720 COLOR 7,0:CLS:SCREEN 0,1,0,3:RETURN
7730 '
7740 'DELETE strain gage subroutine
7750 COLOR 7,0:CLS
7760 COLOR 1,7:K=12:J=37:L=6:M=2:IC=7:GOSUB 3040
7770 COLOR 11,0:LOCATE 10,23:PRINT "Enter strain gage
      number deleted:"
7780 COLOR 0,7:LOCATE 13,39:INPUT "",DG#
7790 IF DG#<1 OR DG#>150 THEN SOUND 1000,18.2:COLOR 7:
      LOCATE 13,38:PRINT "      ":GOTO 7780
7800 SCREEN 0,1,0,3:R(DG#)=0:GF(DG#)=0:RETURN
7810 '
7820 'REPLACE strain gage subroutine
7830 COLOR 7,0:CLS
7840 COLOR 1,7:K=12:J=37:L=6:M=2:IC=7:GOSUB 3040
7850 COLOR 11,0:LOCATE 10,22:PRINT "Enter strain gage
      number replaced:"
7860 COLOR 0,7:LOCATE 13,39:INPUT "",RPG#
7870 IF RPG#<1 OR RPG#>150 THEN SOUND 1000,18.2:COLOR 7:
      LOCATE 13,38:PRINT "      ":GOTO 7860
7880 COLOR 7,0:CLS
7890 COLOR 11,0:LOCATE 10,9:PRINT "Enter replacement
      strain gage manufacturer's listed resistance:"
7900 COLOR 1,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
7910 COLOR 14,0:LOCATE 16,10:PRINT "NOTE: Suggest you
      run resistance update subprogram after "
7920 LOCATE 17,10:PRINT "completion of this subprogram."
7930 COLOR 0,7:LOCATE 13,37:INPUT "",R(RPG#)
7940 COLOR 7,0:CLS
7950 COLOR 9,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
7960 COLOR 11,0:LOCATE 10,21:PRINT "Enter manufacture
      r's listed gage factor."
7970 COLOR 0,7:LOCATE 13,38:INPUT "",GF(RPG#)
7980 COLOR 7,0:CLS:SCREEN 0,1,0,3:RETURN
7990 LFLAG=0
8000 OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #1
8010 WRITE #1, LFLAG
8020 CLOSE #1
8030 SYSTEM:STOP:END
```

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of 12
1000-1370

```
1000      ' James J. Miller                THESIS PROJECT
1010      ' LCDR                USN
1020      '
1030      ' Advisor:
1040      ' Prof. Edward M. WU
1050      '
1060      '
1070      REM    MAIN PROGRAM - GPIB-PC HANDLER STATEMENTS
1080      '
1090      CLEAR    ,59300!
1100      IBINIT1 = 59300!
1110      IBINIT2 = IBINIT1 + 3
1120      BLOAD "bib.m",IBINIT1
1130      CALL IBINIT1(IBFIND,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,
                     IBPPC,IBBNA,IBONL,IBRSC,IBSRE,IBRSV,IBPAD,
                     IBSDA,IBIST,IBDMA,IBEOS,IBTMO,IBEOT,IBRDF,
                     IBWRTF)
1140      CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRT,
                     IBWRTA,IBCMD,IBCMDA,IBRD,IBRDA,IBSTOP,IBRPP,
                     IBRSP,IBDIAG,IBXTRC,IBRDI,IBWRTI,IBRDIA,
                     IBWRTIA,IBSTA%,IBERR%,IBCNT%)
1150      '
1160      REM    MAIN PROGRAM-COVER SHEET PRINT TO SCREEN
1170      '
1180      PRINT "-L=BACKKEY/"
1190      PRINT "-K={BACK},KEYFIX,NOESC,NOMOVE/"
1200      KEY OFF:SCREEN 1,0:COLOR 1,0
1210      DEF SEG = &HB800
1220      BLOAD "C:P2WING.DRW",0
1230      DEF SEG
1240      ON TIMER (5) GOSUB 1300
1250      TIMER ON
1260      WHILE T=0
1270          TX=1
1280      WEND
1290      TIMER OFF:GOTO 1320
1300      T=1
1310      RETURN
1320      SCREEN 2,0:SCREEN 0,1:KEY OFF
1330      SCREEN 0,1,2,2:COLOR 29,0:CLS:LOCATE 13,37:
          PRINT "STANDBY"
1340      '
1350      REM    MAIN PROGRAM-INITIAL ASSIGNMENTS,
          DIMENSIONS AND SETUP
1360      '
1370      DEFINT A
```

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1380-1800

```
1380 DIM D(12,5),R(12),G(12),CF(12),ARRAY(3),RESULTS(12)
      ,RR(150),GF(150)
1390 OPEN "DIS-FLAG.DAT" FOR INPUT AS #3
1400 INPUT #3, NFLAG
1410 CLOSE #3
1420 OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #3
1430 LFLAG=0
1440 WRITE #3, LFLAG
1450 CLOSE #3
1460 OPEN "CALIBRAT.DAT" FOR INPUT AS #1
1470 FOR N=1 TO 12
1480     INPUT #1,M,G(N),CF(N)
1490 NEXT N
1500 CLOSE #1
1510 OPEN "STRAIN.DAT" FOR INPUT AS #2
1520 INPUT #2, D1$,N1$
1530 FOR N=1 TO 150
1540     INPUT #2,I,RR(N),GF(N)
1550 NEXT N
1560 CLOSE #2
1570 IF NFLAG=1 GOTO 1740
1580 '
1590 REM MAIN PROGRAM-DVM CONTROL: CLEAR, FUNCTION,
      RANGE, OFFSET
1600 '
1610 BDNAME$ = "DVM1": M=1: GOSUB 3020
1620 BDNAME$ = "DVM2": M=2: GOSUB 3020
1630 BDNAME$ = "DVM3": M=3: GOSUB 3020
1640 BDNAME$ = "DVM4": M=4: GOSUB 3020
1650 BDNAME$ = "DVM5": M=5: GOSUB 3020
1660 BDNAME$ = "DVM6": M=6: GOSUB 3020
1670 BDNAME$ = "DVM7": M=7: GOSUB 3020
1680 BDNAME$ = "DVM8": M=8: GOSUB 3020
1690 BDNAME$ = "DVM9": M=9: GOSUB 3020
1700 BDNAME$ = "DVM10": M=10: GOSUB 3020
1710 BDNAME$ = "DVM11": M=11: GOSUB 3020
1720 BDNAME$ = "DVM12": M=12: GOSUB 3020
1730 '
1740 REM MAIN PROGRAM-DVM READ
1750 '
1760 PRINT "~L=BACKKEY/"
1770 PRINT "~K={BACK},KEYFIX,NOESC,NOMOVE/"
1780 SCREEN 0,1,2,2:COLOR 20,0:CLS:LOCATE 13,37:
      PRINT "STANDBY"
1790 SCREEN 0,1,0,2
1800 COLOR 14,4:CLS:COLOR 1,7
```

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1810-2200

```
1810 K=11:J=8:L=65:M=3:IC=7:GOSUB 3650
1820 COLOR 0,7
1830 LOCATE 12,10:PRINT "When the wing is properly
      loaded, enter load applied and <CR>."
1840 LOCATE 13,12:PRINT "NOTE: DVM readings will be
      taken immediately after <CR>."
1850 COLOR 2,7
1860 K=16:J=36:L=10:M=2:IC=7:GOSUB 3650
1870 COLOR 7,4:LOCATE 20,18:PRINT "Enter 0 when ready
      to terminate this program."
1880 COLOR 0,7:LOCATE 17,43:PRINT "LB.":SCREEN 0,1,0,0:
      LOCATE 17,38:INPUT "",XLOAD
1890 IF XLOAD = 0 GOTO 2890
1900 FOR N=1 TO 5
1910     COLOR 10,1+N:CLS
1920     LOCATE 11,23:PRINT "The program is reading all
          twelve DVMs"
1930     COLOR 31,N+1:LOCATE 13,38:PRINT "PASS ";N
1940     COLOR 15:LOCATE 15,25:PRINT "NOTE: DVMs being
          scanned in rack."
1950     BDNAME$ = "DVM1": M=1: GOSUB 3290
1960     BDNAME$ = "DVM2": M=2: GOSUB 3290
1970     BDNAME$ = "DVM3": M=3: GOSUB 3290
1980     BDNAME$ = "DVM4": M=4: GOSUB 3290
1990     BDNAME$ = "DVM5": M=5: GOSUB 3290
2000     BDNAME$ = "DVM6": M=6: GOSUB 3290
2010     BDNAME$ = "DVM7": M=7: GOSUB 3290
2020     BDNAME$ = "DVM8": M=8: GOSUB 3290
2030     BDNAME$ = "DVM9": M=9: GOSUB 3290
2040     BDNAME$ = "DVM10": M=10: GOSUB 3290
2050     BDNAME$ = "DVM11": M=11: GOSUB 3290
2060     BDNAME$ = "DVM12": M=12: GOSUB 3290
2070 NEXT N
2080 '
2090 REM MAIN PROGRAM-AVERAGE DVM READINGS
2100 '
2110 FOR M=1 TO 12
2120     S=0
2130     FOR N=1 TO 5
2140         S=S+D(M,N)
2150     NEXT N
2160     R(M)=S/5!
2170 NEXT M
2180 '
2190 REM MAIN PROGRAM-PRINT DVM MEASUREMENT SUMMARY
2200 '
```

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of 12
2210-2610

```
2210 SCREEN 0,1,0,2
2220 COLOR 7,0:CLS
2230 COLOR 9:K=2:J=14:L=52:M=20:GOSUB 3650
2240 K=14:J=66:L=6:GOSUB 3560
2250 K=14:J=66:L=4:GOSUB 3560
2260 K=4:J=22:L=22:GOSUB 3470
2270 K=4:J=22:L=32:GOSUB 3470
2280 K=4:J=22:L=44:GOSUB 3470
2290 K=4:J=22:L=55:GOSUB 3470
2300 LOCATE 6,22:PRINT CHR$(206)
2310 LOCATE 6,32:PRINT CHR$(206)
2320 LOCATE 6,44:PRINT CHR$(206)
2330 LOCATE 6,55:PRINT CHR$(206)
2340 COLOR 13:LOCATE 3,16:PRINT USING "####";XLOAD;:
      PRINT " lb LOAD MEASUREMENT SUMMARY (strain-m
      in/in)"
2350 COLOR 11:LOCATE 5,17:PRINT "DVM":LOCATE 5,25:
      PRINT "GAGE#"
2360 LOCATE 5,37:PRINT "mV":LOCATE 5,48:PRINT "C.F."
2370 LOCATE 5,60:PRINT CHR$(238)
2380 FOR N=1 TO 12
2390     M = 0
2400     IF N>3 THEN M=1
2410     IF N>6 THEN M=2
2420     IF N>9 THEN M=3
2430     COLOR 7:LOCATE 6+N+M,18:PRINT USING "###";N
2440     LOCATE 6+N+M,26:PRINT USING "###";G(N)
2450     LOCATE 6+N+M,35:PRINT USING "###.###";R(N)
2460     LOCATE 6+N+M,47:PRINT USING "#.####";CF(N)
2470     RESULTS(N) = CF(N)*R(N)
2480     COLOR 15
2490     LOCATE 6+N+M,57:PRINT USING "###.###";RESULTS(N)
2500 NEXT N
2510 IF GF(G(1))=2.04 THEN G$="A3"
2520 IF GF(G(1))<>1.95 AND GF(G(1))<>1.92 GOTO 2650
2530 M = 0:L=0:COLOR 15
2540 FOR N=1 TO 12
2550     IF N=4 THEN M=1:L=0
2560     IF N=7 THEN M=2:L=0
2570     IF N=10 THEN M=3:L=0
2580     L=L+1
2590     IF L=1 THEN RESULTS(N)=RESULTS(N)+.005*RESULTS(
      N+2)
2600     IF L=3 THEN RESULTS(N)=RESULTS(N)+.005*RESULTS(
      N-2)
2610     IF L=2 THEN RESULTS(N) = (RESULTS(N) * .995) +
```

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2610-2960

```
      (.005 * (RESLUTS(N-1) + RESULTS(N+1)))
2620      LOCATE 6+N+M,57:PRINT USING "###.###";RESULTS(N)
2630      NEXT N
2640      LOCATE 23,6:PRINT "Strain measurement includes
      poisson ratio correction for wire gages."
2650      COLOR 26:LOCATE 12,70:PRINT "PRINT"
2660      LOCATE 13,72:PRINT "IN"
2670      LOCATE 14,69:PRINT "PROGRESS"
2680      SCREEN 0,1,0,0
2690      '
2700      REM      MAIN PROGRAM-PRINT THE DVM OUTPUT
2710      '
2720      D$=DATE$
2730      LPRINT TAB(30);D$
2740      GOSUB 3980
2750      LPRINT CHR$(13)
2760      COLOR 26:LOCATE 12,70:PRINT "      "
2770      LOCATE 13,72:PRINT "      "
2780      LOCATE 14,69:PRINT "      "
2790      COLOR 4:LOCATE 7,68:PRINT "SELECT:"
2800      LOCATE 9,69:PRINT "1) Obtain":LOCATE 10,72:
      PRINT "new load"
2810      LOCATE 11,72:PRINT "data."
2820      IF G$="A3" THEN LOCATE 12,69:PRINT "2) Exit":
      LOCATE 13,72:PRINT "program.":LOCATE 14,69:
      INPUT "",M:IF M=1 GOTO 1740 ELSE IF M=2 THEN
      CLS:CHAIN "P2V-CAL",8030 ELSE SOUND 100,3:
      GOTO 2810
2830      LOCATE 12,69:PRINT "2) Analyse":LOCATE 13,72:
      PRINT "rosette"
2840      LOCATE 14,72:PRINT "data.":LOCATE 15,69:
      PRINT "3) Exit"
2850      LOCATE 16,72:PRINT "program."
2860      LOCATE 17,69:INPUT "",M
2870      IF M=1 GOTO 1740 ELSE IF M=2 GOTO 4310 ELSE IF M=3
      THEN CHAIN "P2V-CAL",8030 ELSE SOUND 100,3:
      GOTO 2850
2880      '
2890      REM      MAIN PROGRAM-TERMINATE EXECUTION
2900      '
2910      SCREEN 0,1,0,0
2920      COLOR 7,0
2930      CLS
2940      LOCATE 12,22:SOUND 1000,2:SOUND 1500,2:SOUND 2000,2
2950      PRINT "Program run completed."
2960      CLS:CHAIN "P2V-CAL",8030
```

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Pg 6
of 12
2970-3390

```
2970 '
2980 END
2990 '
3000 REM SUBROUTINE-DVM CONTROL: CLEAR, FUNCTION,
      RANGE, OFFSET
3010 '
3020 CALL IBFIND (BDNAME$,DVM%)
3030 IF DVM% < 0 THEN E=1: GOSUB 4110
3040 CALL IBCLR (DVM%)
3050 IF IBSTA% < 0 THEN E=2: GOSUB 4160
3060 WRT$ = "F1R0"
3070 CALL IBWRT (DVM%,WRT$)
3080 IF IBSTA% < 0 THEN E=3: GOSUB 4160
3090 J=0 'Program delay
3100 FOR I=1 TO 100 'Program delay
3110 J=J+I 'Program delay
3120 NEXT I 'Program delay
3130 IF M<>1 GOTO 3220
3140 SCREEN 0,1,0,2:COLOR 2,1:CLS:COLOR 0,7
3150 K=12:J=11:L=60:M=3:IC=7:GOSUB 3650
3160 LOCATE 13,13:COLOR 0,7:PRINT "Balance the
      Wheatstone bridge for all strain gages, then"
3170 LOCATE 14,13:COLOR 0,7
3180 PRINT "enter SPACEBAR when ready to set the OFFSET
      for all DVMs.":SCREEN 0,1,0,0
3190 Z$ = INKEY$
3200 IF Z$ <> CHR$(32) GOTO 3190
3210 COLOR 23,1:LOCATE 20,37:PRINT "STANDBY"
3220 WRT$ = "B1"
3230 CALL IBWRT (DVM%,WRT$)
3240 IF IBSTA% < 0 THEN E=4: GOSUB 4160
3250 RETURN
3260 '
3270 REM SUBROUTINE-READ DVM
3280 '
3290 CALL IBFIND (BDNAME$,DVM%)
3300 IF DVM% < 0 THEN E=5:GOSUB 4110
3310 WRT$ = "T3"
3320 CALL IBWRT (DVM%,WRT$)
3330 IF IBSTA% < 0 THEN E=6: GOSUB 4160
3340 CALL IBTRG (DVM%)
3350 IF IBSTA% < 0 THEN E=8: GOSUB 4160
3360 RD$ = SPACE$(16)
3370 CALL IBRD (DVM%,RD$)
3380 IF IBSTA% < 0 THEN E=12: GOSUB 4160
3390 B# = VAL(RD$) * 1000!
```

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of 12
3400-3780

```
3400 D(M,N) = B#
3410 IF N<>5 GOTO 3450
3420 WRT$ = "T0"
3430 CALL IBWRT (DVM%,WRT$)
3440 IF IBSTA% < 0 THEN E=7: GOSUB 4160
3450 RETURN
3460 '
3470 REM SUBPROGRAM - PRINT A COLUMN TO SCREEN
      (K-START, J-END, L-COLUMN)
3480 '
3490 FOR I=K+1 TO J-1
3500     LOCATE I,L
3510     PRINT CHR$(186)
3520 NEXT I
3530 LOCATE K,L:PRINT CHR$(203):LOCATE J,L:PRINT
      CHR$(202)
3540 RETURN
3550 '
3560 REM SUBPROGRAM - PRINT A ROW TO SCREEN
      (K-START, J-END, L-ROW)
3570 '
3580 FOR I=K+1 TO J-1
3590     LOCATE L,I
3600     PRINT CHR$(205)
3610 NEXT I
3620 LOCATE L,K:PRINT CHR$(204):LOCATE L,J:PRINT
      CHR$(185)
3630 RETURN
3640 '
3650 REM SUBPROGRAM - PRINT A BOX TO SCREEN
      (K,J-UPPERLEFT CORNER, L-LENGTH,
        M-HEIGHT, IC-INTERIOR COLOR..
        DEFAULT BLACK 0)
3660 '
3670 LOCATE K,J:PRINT CHR$(201)
3680 FOR I=J+1 TO J+(L-1)
3690     LOCATE K,I
3700     PRINT CHR$(205)
3710 NEXT I
3720 LOCATE K,J+L:PRINT CHR$(187)
3730 FOR I=K+1 TO K+(M-1)
3740     LOCATE I,J
3750     PRINT CHR$(186)
3760 NEXT I
3770 LOCATE K+M,J:PRINT CHR$(200)
3780 FOR I=J+1 TO J+(L-1)
```

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3790-4230

```
3790     LOCATE K+M,I
3800     PRINT CHR$(205)
3810     NEXT I
3820     LOCATE K+M,J+L:PRINT CHR$(188)
3830     FOR I=K+1 TO K+(M-1)
3840         LOCATE I,L+J
3850         PRINT CHR$(186)
3860     NEXT I
3870     IF IC=0 GOTO 3960
3880     COLOR IC
3890     FOR I=K+1 TO K+M-1
3900         FOR N=J+1 TO J+L-1
3910             LOCATE I,N:PRINT CHR$(219)
3920         NEXT N
3930     NEXT I
3940     COLOR 7,0
3950     IC=0
3960     RETURN
3970     '
3980     REM     SUBROUTINE-PRINT SCREEN
3990     '
4000     A=0:RESTORE
4010     DATA &HCD55                :REM 55H Push BP
4020     DATA &H5D05                :REM CD05H INT 5
4030     :REM 5DH POP BP
4040     DATA &H90CB                :REM 90H NOP
4050     FOR I=1 TO 3: READ ARRAY(I): NEXT I
4060     SUBRT = VARPTR(ARRAY(1)): CALL SUBRT
4070     RETURN
4080     '
4090     REM     ERROR SUBROUTINE LOCATIONS
4100     '
4110     '         A routine at this location would notify
4120     '         you that the IBFIND call failed, and
4130     '         refer you to the handler software
4140     '         configuration procedures.
4150     PRINT "IBFIND ERROR" : PRINT "E= ";E: PRINT "DVM ";
        M: STOP
4160     '         An error checking routine at this
4170     '         location would, among other things,
4180     '         check IBERR to determine the exact
4190     '         cause of the error condition and then
4200     '         take action appropriate to the
4210     '         application. For errors during data
4220     '         transfers, IBCNT may be examined to
4230     '         determine the actual number of bytes
```

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4240-4610

```
4240 ' transferred.
4250 PRINT "GPIB ERROR" : PRINT "E=";E: STOP
4260 ' A routine at this location would analyze
4270 ' the fault code returned in the DVM's
4280 ' status byte and take appropriate action.
4290 PRINT "DVM ERROR" : PRINT "E=";E:PRINT "DVM ";M:
      STOP
4300 END
4310 REM Portion of program which does the rosette
      analysis
4320 '
4330 SCREEN 0,1,0,0:COLOR 7:CLS
4340 PRINT "~K={BACK}/"
4350 SCREEN 2
4360 KEY OFF:SCREEN 1,0:CLS
4370 COLOR 1,0
4380 IF C%=0 THEN DIM PIX$(700):C%=1
4390 DEF SEG
4400 PIX.PTR=VARPTR(PIX$(0))
4410 BLOAD "C:ROSETTE.PIX",PIX.PTR
4420 VIEW (70,39)-(250,159),,3
4430 PUT (40,5),PIX#
4440 ON TIMER(3) GOSUB 4510
4450 TIMER ON:T=0
4460 WHILE T=0
4470 SUM = 0
4480 WEND
4490 VIEW
4500 GOTO 4530
4510 T=1
4520 RETURN
4530 SCREEN 1,0:COLOR 1,0:CLS
4540 DEF SEG
4550 PIX.PTR=VARPTR(PIX$(0))
4560 BLOAD "C:ANALIZE2.PIX",PIX.PTR
4570 PUT (18,1),PIX#
4580 WHILE GF(G(1))=2.09
4590 LOCATE 15,3:PRINT USING "####";XLOAD;:
      PRINT " LB. LOAD"
4600 LOCATE 15,18:PRINT CHR$(214);CHR$(196);
      " A B C ";CHR$(196);CHR$(183)
4610 LOCATE 16,6:PRINT "SELECT":LOCATE 16,18:
      PRINT CHR$(186);" ";;PRINT USING "####";
      G(1);:PRINT USING "#####";G(5);:
      PRINT USING "#####";G(9);:PRINT " ";
      CHR$(186)
```

```
4620 LOCATE 17,6:PRINT "ROSETTE":LOCATE 17,18:
      PRINT CHR$(186);" ";;PRINT USING "###";
      G(2);:PRINT USING "#####";G(6);:
      PRINT USING "#####";G(10);:PRINT " ";
      CHR$(186)
4630 LOCATE 18,18:PRINT CHR$(186);" ";;PRINT USING
      "###";G(3);:PRINT USING "#####";G(7);:
      PRINT USING "#####";G(11);:PRINT " ";
      CHR$(186)
4640 LOCATE 19,18:PRINT CHR$(186);" ";;PRINT USING
      "###";G(4);:PRINT USING "#####";G(8);:
      PRINT USING "#####";G(12);:PRINT " ";
      CHR$(186)
4650 LOCATE 20,18:PRINT CHR$(211);CHR$(196);
      CHR$(196);CHR$(196);CHR$(196);CHR$(196);
      "GAGES";CHR$(196);CHR$(196);CHR$(196);
      CHR$(196);CHR$(196);CHR$(189)
4660 VIEW (5,163)-(314,187),,2
4670 LOCATE 22,7:PRINT "For rosette ENTER A,B OR C."
4680 IF F$<>"Y" THEN LOCATE 23,4:PRINT "ENTER L to
      return to Load program." ELSE LOCATE 23,4:
      PRINT "ENTER X to end."
4690 LOCATE 23,38:INPUT "",M$
4700 IF M$="X" OR M$="x" THEN CLS:SCREEN 2:SCREEN 0:
      LFLAG=0:OPEN "DIS-FLAG.DAT" FOR OUTPUT AS
      #2:WRITE #2,LFLAG:CLOSE #2:CHAIN
      "P2V-CAL",8030
4710 IF M$ = "L" OR M$ = "1" THEN CLS:GOSUB 4940
4720 IF M$="A" OR M$="a" THEN GN1=1:GN2=2:GN3=3:
      GN4=4:GAGE=G(1):GOSUB 4940
4730 IF M$="B" OR M$="b" THEN GN1=5:GN2=6:GN3=7:
      GN4=8:GAGE=G(5):GOSUB 4940
4740 IF M$="C" OR M$="c" THEN GN1=9:GN2=10:GN3=11:
      GN4=12:GAGE=G(9):GOSUB 4940
4750 SOUND 100,3:GOTO 4690
4760 WEND
4770 LOCATE 15,3:PRINT USING "#####";XLOAD;:PRINT " LB.
      LOAD"
4780 LOCATE 16,18:PRINT CHR$(214);CHR$(196);" A B
      C D";CHR$(196);CHR$(183)
4790 LOCATE 17,5:PRINT "SELECT":LOCATE 17,18:
      PRINT CHR$(186);:PRINT USING "###";G(1);:
      PRINT USING "#####";G(4);:PRINT USING "#####";
      G(7);:PRINT USING "#####";G(10);:PRINT " ";
      CHR$(186)
4800 LOCATE 18,5:PRINT "ROSETTE":LOCATE 18,18:
```

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4800-5050

```
PRINT CHR$(186);:PRINT USING "###";G(2);:
PRINT USING "#####";G(5);:PRINT USING "#####";
G(8);:PRINT USING "#####";G(11);:PRINT " ";
CHR$(186)
4810 LOCATE 19,18:PRINT CHR$(186);:PRINT USING "###";
G(3);:PRINT USING "#####";G(6);:PRINT USING
"#####";G(9);:PRINT USING "#####";G(12);:
PRINT " ";CHR$(186)
4820 LOCATE 20,18:PRINT CHR$(211);CHR$(196);CHR$(196);
CHR$(196);CHR$(196);CHR$(196);CHR$(196);
CHR$(196);"GAGES";CHR$(196);CHR$(196);
CHR$(196);CHR$(196);CHR$(196);CHR$(196);
CHR$(196);CHR$(189)
4830 VIEW (5,163)-(314,187),,2
4840 LOCATE 22,7:PRINT "For rosette ENTER A,B,C or D."
4850 IF F$<>"Y" THEN LOCATE 23,4:PRINT "ENTER L to
return to Load program." ELSE LOCATE 23,4:
PRINT "ENTER X to end."
4860 LOCATE 23,38:INPUT "",M$
4870 IF M$="X" OR M$="x" THEN CLS:SCREEN 2:SCREEN 0:
LFLAG=0:OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #2:
WRITE #2,LFLAG:CLOSE #2:CHAIN "P2V-CAL",8030
4880 IF M$ = "L" OR M$ = "l" THEN CLS:GOSUB 4940
4890 IF M$="A" OR M$="a" THEN GN1=1:GN2=2:GN3=3:
GAGE=G(1):GOSUB 4940
4900 IF M$="B" OR M$="b" THEN GN1=4:GN2=5:GN3=6:
GAGE=G(4):GOSUB 4940
4910 IF M$="C" OR M$="c" THEN GN1=7:GN2=8:GN3=9:
GAGE=G(7):GOSUB 4940
4920 IF M$="D" OR M$="d" THEN GN1=10:GN2=11:GN3=12:
GAGE=G(10):GOSUB 4940
4930 SOUND 100,3:GOTO 4860
4940 '
4950 OPEN "DISPLAY.DAT" FOR OUTPUT AS #1
4960 WRITE #1, GF(G(1)), XLOAD
4970 IF GF(G(1)) = 2.09 THEN WRITE #1, GN1, GN2, GN3,
GN4, GAGE ELSE WRITE #1, GN1, GN2, GN3, GAGE
4980 FOR I=1 TO 12
4990 WRITE #1, RESULTS(I), G(I)
5000 NEXT I
5010 CLOSE #1
5020 IF M$="L" OR M$="l" THEN CLS:SCREEN 2:SCREEN 0:
IF NFLAG=1 THEN RETURN 1000 ELSE RETURN 1740
5030 SHELL "ANALIZE.BAT"
5040 NFLAG = 1
5050 OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #3
```

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5060 WRITE #3, NFLAG
5070 CLOSE #3
5080 RETURN 4330

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1000-1370

```
1000 REM This is a compiled executable BASIC program
      REM which does the
1010 REM high resolution display portion of the
      rosette analysis
1020 '
1030 'Variable declarations
1040 DIM RESULTS(12), G(12)
1050 '
1060 'Retrieve data to be displayed from the hard disk
1070 OPEN "DISPLAY.DAT" FOR INPUT AS #1
1080 INPUT #1, GF, XLOAD
1090 IF GF=2.09 THEN INPUT #1, GN1, GN2, GN3, GN4, GAGE
      ELSE INPUT #1, GN1, GN2, GN3, GAGE
1100 FOR I=1 TO 12
1110 INPUT #1, RESULTS(I), G(I)
1120 NEXT I
1130 CLOSE #1
1140 '
1150 KEY OFF
1160 '
1170 'Calculations for the older AR-7-2 wire rosette
1180 WHILE (GF=1.92 OR GF=1.95) AND NSTOP=0
1190 EX = RESULTS(GN1):EY = RESULTS(GN3)
1200 IF GAGE<17 OR GAGE=24 OR GAGE=30 OR GAGE=33 OR
      GAGE=85 OR GAGE=38 OR GAGE=88 OR GAGE=91
      OR GAGE=41 OR GAGE=73 OR GAGE=76 THEN
      EX=RESULTS(GN3):EY=RESULTS(GN1)
1210 GXY = (2! * RESULTS(GN2)) - (EX + EY)
1220 IF GAGE=56 OR GAGE=59 OR GAGE=62 OR GAGE=50
      THEN GXY=-1! * GXY
1230 ES1 = (EX + EY)/2!
1240 GMAX = SQR((EX - EY)^2 + GXY^2)
1250 EMAX = ES1 + .5*GMAX
1260 EMIN = ES1 - .5*GMAX
1270 PHIP = (.5 + ATN(GXY/(EX - EY))) * 57.2958
1280 NSTOP=1
1290 WEND
1300 NSTOP=0
1310 '
1320 'Calculations for the new EA-13-250YA delta rosette
1330 WHILE GF=2.07 AND NSTOP=0
1340 EY=RESULTS(GN1)
1350 GXY=(RESULTS(GN3)-RESULTS(GN2))/ .8660254
1360 EX=(RESULTS(GN2)+(.4330127*GXY)-(.25*EY))/ .75
1370 IF GAGE=112 THEN GXY=(RESULTS(GN2)-RESULTS(GN3)
      )/.8660254:EX=(RESULTS(GN3)+(.4330127*GXY)-
```

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1370-1750

```
      (.25*EY))/.75
1380   IF GAGE=109 THEN EY=RESULTS(GN2):GXY=(RESULTS(
      GN3)-RESULTS(GN1))/.8660254:EX=(RESULTS(
      GN1)+(.4330127*GXY)-(.25*EY))/.75
1390   ES1 = (EX + EY)/2!
1400   GMAX = SQR((EX - EY)^2 + GXY^2)
1410   EMAX = ES1 + .5*GMAX
1420   EMIN = ES1 - .5*GMAX
1430   PHIP = (.5 + ATN(GXY/(EX - EY))) * 57.2958
1440   NSTOP=1
1450 WEND
1460 NSTOP = 0
1470 '
1480 'Calculation for the new WA-13-250WF stacked
      rosette
1490 WHILE GF=2.09 AND NSTOP=0
1500   EX=RESULTS(GN2):EY=RESULTS(GN4)
1510   GXY=(RESULTS(GN3) - RESULTS(GN1)) - (EX - EY)
1520   IF GAGE=128 THEN EX=RESULTS(GN1):EY=RESULTS(
      GN3):GXY=(RESULTS(GN2)-RESULTS(GN4))-(EX-EY)
1530   IF GAGE=124 THEN EX=RESULTS(GN2):EY=RESULTS(
      GN4):GXY=(RESULTS(GN1)-RESULTS(GN3))-(EX-EY)
1540   ES1 = (EX + EY)/2!
1550   GMAX = SQR((EX - EY)^2 + GXY^2)
1560   EMAX = ES1 + .5*GMAX
1570   EMIN = ES1 - .5*GMAX
1580   PHIP = (.5 + ATN(GXY/(EX - EY))) * 57.2958
1590   NSTOP=1
1600 WEND
1610 NSTOP = 0
1620 '
1630 'Calculation for Mohr's circle radius
1640 R = .5 * SQR((EX - EY)^2 + GXY^2)
1650 '
1660 'Construct the display screen
1670 CLS:SCREEN 9:COLOR 15
1680 LINE (1,306)-(639,306) 'Screen Dividers
1690 LINE (319,0)-(319,306)
1700 LOCATE 2,14:PRINT "MOHR'S CIRCLE"
1710 LOCATE 2,52:PRINT "SURFACE DEFORMATION"
1720 COLOR 9
1730 LOCATE 23,29:PRINT CHR$(232);"p=";:PRINT USING
      "####";PHIP;:PRINT CHR$(248);
1740 LOCATE 25,56:PRINT "Gmax=";:PRINT USING "###.###";
      GMAX;
1750 LOCATE 23,41:PRINT CHR$(238);"min=";:PRINT USING
```

```
      "###.###";EMIN;
1760 LOCATE 25,41:PRINT CHR$(238);"max=";:PRINT USING
      "###.###";EMAX;
1770 LOCATE 23,56:PRINT "Gxy=";:PRINT USING "###.###";GXY;
1780 LOCATE 23,71:PRINT CHR$(238);"y=";:PRINT USING
      "###.###";EY;
1790 LOCATE 25,71:PRINT CHR$(238);"x=";:PRINT USING
      "###.###";EX;
1800 LOCATE 23,1:PRINT USING "####";XLOAD;:PRINT " LB
      LOAD"
1810 LOCATE 23,16:PRINT CHR$(238);"-m in/in"
1820 LOCATE 1,1:PRINT DATE$
1830 IF GF<>2.09 THEN LOCATE 25,1:PRINT "Gages-";:
      PRINT USING "####";G(GN1);:PRINT ",,,:
      PRINT USING "####";G(GN2);:PRINT ",,,:
      PRINT USING "####";G(GN3);
1840 IF GF=2.09 THEN LOCATE 25,1:PRINT "Gages-";:
      PRINT USING "####";G(GN1);:PRINT ",,,:
      PRINT USING "####";G(GN2);:PRINT ",,,:
      PRINT USING "####";G(GN3);:PRINT ",,,:
      PRINT USING "####";G(GN4);
1850 SCALE = R/1.5151515#
1860 XIS = (ES1 * 100! / R) * -1
1870 COLOR 10
1880 LINE (5,160)-(315,160) 'X and Y axis
1890 LINE (159 + XIS,260)-(159 + XIS,43)
1900 LINE (323,160)-(635,160)
1910 LINE (479,27)-(479,260)
1920 COLOR 2
1930 LOCATE 13,1:PRINT CHR$(238) 'Axis Labels
1940 LOCATE 3,14:PRINT "Gxy/2"
1950 LOCATE 3,58:PRINT "Y"
1960 LOCATE 13,78:PRINT "X"
1970 IF ABS(EX)<.5 AND ABS(EY)<.5 AND ABS(GXY)<.5 THEN
      SMULT=2! ELSE SMULT=1!
1980 EX = SMULT * EX:EY = SMULT * EY:GXY=SMULT * GXY
1990 'calculations for the element deformation shape
2000 DEX = 75 * (EX/2!)
2010 DEY = 61 * (EY/2!)
2020 GLE = ATN(ABS(GXY/2!))
2030 IF GXY < 0 THEN GLE = GLE * -1!
2040 YSLP = TAN(1.5707963# - GLE) * .77272727#
2050 XSLP = TAN(GLE) * .77272727#
2060 X1 = ((61! + DEY) + YSLP * (75! + DEX))/(YSLP -
      XSLP)
2070 X2 = ((61! + DEY) + YSLP * (-75! - DEX))/(YSLP -
```

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```

      XSLP)
2080 Y1 = (((XSLP * YSLP) * (75! + DEX)) + (YSLP * (61!
      + DEY)))/(YSLP - XSLP)
2090 Y2 = (((XSLP * YSLP) * (-75! - DEX)) + (YSLP *
      (61! + DEY)))/(YSLP - XSLP)
2100 COLOR 7
2110 LINE (404,99)-(554,221),,B
2120 LOCATE 8,59:PRINT ".5"
2130 LOCATE 13,68:PRINT ".5"
2140 COLOR 3
2150 LOCATE 20,56:PRINT "Unit Cube"
2160 LOCATE 21,49:PRINT "Isotropic Strain Mult=";:
      PRINT USING "#";SMULT
2170 COLOR 10
2180 LINE (118,284)-(184,284)
2190 LINE (118,282)-(118,286)
2200 LINE (184,282)-(184,286)
2210 COLOR 3
2220 LOCATE 20,14:PRINT USING ".###";SCALE;:PRINT " m
      in/in"
2230 COLOR 12
2240 LINE (479+X1,160-Y1)-(479-X2,160+Y2),,,&HAAAA
2250 LINE (479-X2,160+Y2)-(479-X1,160+Y1),,,&HAAAA
2260 LINE (479-X1,160+Y1)-(479+X2,160-Y2),,,&HAAAA
2270 LINE (479+X2,160-Y2)-(479+X1,160-Y1),,,&HAAAA
2280 COLOR 7
2290 'Calculations for the Mohr's circle position
2300 CIRCLE (159,160),100,,,,.81
2310 IF SMULT=2 THEN EX = EX/2!:EY = EY/2!:GXY = GXY/2!
2320 PEY = ((EY * 66!) / SCALE)
2330 PEX = ((EX * 66!) / SCALE)
2340 PGXY = (((GXY/2!) * 53.5) / SCALE)
2350 COLOR 12
2360 LINE (159 + XIS + PEY,160)-(159 + XIS + PEY,160 -
      PGXY)
2370 LINE -(159 + XIS + PEX,160 + PGXY)
2380 LINE -(159 + XIS + PEX,160)
2390 COLOR 10
2400 LINE (159+XIS+66,158)-(159+XIS+66,162) 'Scale Marker
2410 LINE (157+XIS,107)-(161+XIS,107)
2420 COLOR 4:LOCATE 1,23:PRINT "(Shift/PrtSc) for
      print, SPACEBAR to return."
2430 Z$ = INKEY$
2440 IF Z$ <> CHR$(32) GOTO 2430
2450 LPRINT CHR$(13)
2460 END
```

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END

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