THESIS

AUTOMATED AIRCRAFT STATIC STRUCTURAL TESTING WITH COMPUTER AIDED INTERPRETATION

by

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September 1986

Thesis Advisor: [Name]

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### Title

Automated Aircraft Static Structural Testing with Computer Aided Interpretation

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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 stress levels. It was found that a significant improvement was achieved in reducing human operator time spent in monitoring and debugging the test equipment. The use of computer controlled instrumentation has eliminated many of the manual and tedious tasks associated with testing. This technology has made it possible to test more complex and intricate structures efficiently, ensuring that the accuracy and reliability of the test data are maintained.

### Subject Terms

- Aircraft Static Structural Test
- Computer Controlled Instrumentation

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of direct physical measurements rather than indirect abstract tensor components.
Automated Aircraft Static Structural Testing
With Computer Aided Interpretation

by

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Lieutenant Commander, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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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
its 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](image-url)
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 settings 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.
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.
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].
B. SOFTWARE

The National Instruments GPIB comes equipped with a handler written in IBM BASICA. BASIC was chosen as the controlling software for its 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.

Figure 3.5 Strain Gage Lay-up Mohr's Circle Resolutions
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 Hewlitt Packard Laserjet printer. The Laserjet does not have an installed
Figure 3.7 Sample Print of Graphical Analysis of Strain Gage Data

MOHR'S CIRCLE
G_xy/2

SURFACE DEFORMATION

Unit Cube
Isotropic Strain Mult=2

1975 LB LOAD ε-n in/in δp = -50° ε_min = -0.196 G_xy = 0.376 ε_y = 0.083

Gages - 13, 14, 15 ε_max = 0.181 G_max = 0.377 ε_x = -0.018
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 Hewlitt-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.

![Bending/Aero Load Diagram](image1)

![Deflection & Release Diagram](image2)

**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.
LIST OF REFERENCES


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.

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.

![Computer and Monitor](image)

*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.

![Printer](image)

**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.

![DVM Column Master and Voltage Source](image)

**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.
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.

![DVM1 Resistance Lead Connection Points](image)

**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

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 overshot 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

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<th>Type</th>
<th>Single Wire Gage 120 Ω</th>
<th>Rect. Rosette 3 Wire Gages 120 Ω</th>
<th>Delta Rosette 3 Foil Gages 120 Ω</th>
<th>Stacked Rosette 4 Foil Gages 120 Ω</th>
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<td>1 Wire Gage 120 Ω</td>
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<td>100-101-102</td>
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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

35
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
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.

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 1.B  Load Cell Panel
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:

<table>
<thead>
<tr>
<th>LOAD CELL 1</th>
<th>LOAD CELL 2</th>
<th>LOAD CELL 3</th>
<th>DATE</th>
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<tbody>
<tr>
<td>-1267</td>
<td>-1226</td>
<td>-1256</td>
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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>
<thead>
<tr>
<th>Load (lb)</th>
<th>Moment (in-lb)</th>
<th>Deflection (in)</th>
<th>Angle (rad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
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<td>2600</td>
<td>0.07</td>
<td>0.0013462</td>
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<tr>
<td>100</td>
<td>5200</td>
<td>0.17</td>
<td>0.0032692</td>
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<td>7540</td>
<td>0.27</td>
<td>0.0051923</td>
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<td>0.82</td>
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<td>22620</td>
<td>0.97</td>
<td>0.0186539</td>
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<td>26000</td>
<td>1.25</td>
<td>0.0240338</td>
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<td>27300</td>
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<td>0.0255714</td>
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<tr>
<td>555</td>
<td>28860</td>
<td>1.42</td>
<td>0.0273009</td>
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</table>

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
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 'DI$ - 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 'ESI - 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 - Maximum 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 forNFLAG
1520 'M - Box print, vertical length // Integer decision variable
1530 'MSG# - Master strain gage number connected to DVM1
1540 'MS$ - 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
REM MAIN PROGRAM - GPIB-PC HANDLER STATEMENTS

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,IBMO,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%)
1990  REM  MAIN PROGRAM - INITIAL ASSIGNMENTS, DIMENSIONS
2000   KEY OFF
2010  DIM D(150), R(150), GF(150), RESULTS(12), CF(12), ESTRN(12), ASTRN(12), G(12), ADD(50)
2020  PRINT ":-L=BACKKEY/"
2030  PRINT ":-K=(BACK),KEYFIX,NOESC,NOMOVE/"
2040  REM  MAIN PROGRAM - COVER SHEET PRINT TO SCREEN
2050   COLOR 5,0:SCREEN 0,1,1,1
2060  K=5:J=5:L=70:M=15:GOSUB 3040
2070   COLOR 3
2080 LOCATE 9,39:PRINT "P2V"
2090 LOCATE 12,35:PRINT "CALIBRATION"
2100 LOCATE 15,37:PRINT "PROGRAM"
2110 COLOR 7:LOCATE 19,25:PRINT "By: LCDR J. J. Miller, SEPT 86"
2120 COLOR 23
2130 LOCATE 23,36:PRINT "STAND BY"
2140 REM  MAIN PROGRAM - SELECTION PAGE PRINT TO SCREEN
2150   SCREEN 0,1,3,1:COLOR K2.0:"CIS:LOCATE 13,36:
2160  PRINT "STANDBY"
2170 SCREEN 0,1,0,1:COLOR 0,7:CLS:COLOR 4,3
2180  K=7:J=10:L=60:M=14:IC=3:GOSUB 3040
2190  COLOR 0,3:LOCATE 10,16:PRINT "Select:"  
2200 LOCATE 12,22:PRINT "(1) Update strain gage resistances."
2210 LOCATE 13,22:PRINT "(2) Calculate strain gage calibration factors"
2220 LOCATE 14,26:PRINT "(5) Add/Delete/Replace strain gages."
2230 LOCATE 15,22:PRINT "(3) Load the wing."
2240 LOCATE 18,22:PRINT "(6) Exit (Return to DOS)
2250 LOCATE 16,22:PRINT "(4) Analyse last recorded load data."
2260 SCREEN 0,1,1,1:COLOR 7,0:CLS
2270 SCREEN 0,1,0,0:COLOR 0,3
2280 LOCATE 17,22:PRINT "".A
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 4790 ELSE IF A=2! THEN GOSUB
     6940 ELSE IF A=5! 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
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 ' REM MAIN PROGRAM - PROGRAM RUN END

2830 ' COLOR 7:CLS:END

2840 ' REM SUBPROGRAM - PRINT A ROW TO SCREEN (K-START, J-END, L-ROW)

2850 FOR I=K+1 TO J-1

2860 LOCATE L,I

2870 PRINT CHR$(205)

2880 NEXT I

2890 LOCATE L,K:PRINT CHR$(204):LOCATE L,J:PRINT CHR$(185)

2900 RETURN

2910 ' REM SUBPROGRAM - PRINT A COLUMN TO SCREEN (K-START, J-END, L-COLUMN)

2920 FOR I=K+1 TO J-1

2930 LOCATE I,L

2940 PRINT CHR$(186)

2950 NEXT I

2960 LOCATE K,L:PRINT CHR$(203):LOCATE J,L:PRINT CHR$(202)

2970 RETURN

2980 ' REM SUBPROGRAM - PRINT A BOX TO SCREEN (K,J-UPPERLEFT CORNER, L-LENGTH, M-HEIGHT, IC-INTERIOR COLOR.. DEFAULT BLACK 0)

2990 ' LOCATE K,J:PRINT CHR$(201)

3000 FOR I=J+1 TO J+(L-1)

3010 LOCATE K,I
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$(124);TAB(3);"LAST ENTRY - DATE: ";DS;TAB(40);"NAME: ";N$;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 ";
3470 LPRINT TAB(1);CHR$(124);:FOR I=2 TO 78:LPRINT TAB(I);CHR$(246);:NEXT I;LPRINT CHR$(124)
FOR J=1 TO 45
LPRINT TAB(1);CHR$(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)
NEXT J

FOR J=1 TO 79:LPRINT TAB(I);CHR$(176);:NEXT I:
LPRINT CHR$(244)
RETURN

REM SUBPROGRAM - UPDATE STRAIN GAGE RESISTANCES

D$ = DATES
SCREEN 0,1,0,0:COLOR 7,0:CLS:COLOR 15,0
COLOR 4,0:LOCATE 1,23:PRINT "STRAIN GAGE RESISTANCE MEASUREMENT"
COLOR 4,0:LOCATE 1,23:PRINT "STRAIN GAGE RESISTANCE MEASUREMENT"
LOCATE 5,30
PRINT "Enter operator's name."
Instruction page for reading resistances on DVM

1. Power Button - ON.

2. Input Button - FRONT.

Connect the two-wire test leads to the front of the meter.

Enter 0 to end and return to the menu.

When the strain gage is properly connected to DVM1, enter strain gage number and <CR>.

A resistance measurement will be taken using DVM1 immediately following <CR>.

Enter 0 to end and return to the menu.
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$(32) GOTO 4110
4130 SCREEN 0,1,0,0:COLOR 28,0:CLS:LOCATE 13,36:
PRINT "STANDBY":COLOR 7:RETURN
4140 SCREEN 0,1,0,0:CLS
4150 COLOR 28,0:CLS:LOCATE 13,36:PRINT "STAND BY"
4160 GOSUB 4350
4170 'Display resistance measurement page print to screen
4180 CLS
4190 COLOR 3:K=11;J=10;L=60;M=4:GOSUB 3040
4210 K=11;J=15;L=40:GOSUB 2960
4220 COLOR 7:LOCATE 13,15:PRINT "STRAIN GAGE ";SG#
4230 LOCATE 13,45:PRINT "RESISTANCE = ";R#:CHR$(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 '
REM SUBPROGRAM - READ RESISTANCE FROM DVM1

BDNAME$ = "DVM1"
CALL IBFIND (BDNAME$,DVM%)
IF DVM% < 0 THEN GOSUB 4590
CALL IBCLR (DVM%)
IF IBSTA% < 0 THEN GOSUB 4700
WRT$ = "F3R0"
CALL IBWRT (DVM%,WRT$)
IF IBSTA% < 0 THEN GOSUB 4700
J=0:FOR I=1 TO 500:J=J+I:NEXT I 'Program delay
RD$ = SPACE$(16)
CALL IBRD (DVM%,RD$)
IF IBSTA% < 0 THEN GOSUB 4700
R#=VAL(RD$)
RETURN

REM SUBPROGRAM - GPIB-PC ERROR STATEMENTS

'A routine at this location would notify you that the IBFIND call failed, and refer you to the handler software configuration procedures.
PRINT "IBFIND ERROR" : PRINT "E= ";E: END

'An error checking routine at this location would, among other things, check IBERR to determine the exact cause of the error condition and then take action appropriate to the application. For errors during data transfers, IBCNT may be examined to determine the actual number of bytes transferred.
PRINT "GPIB ERROR" : PRINT "E=";E: END

'A routine at this location would analyze the fault code returned in the DVM's status byte and take appropriate action.
PRINT "DVM ERROR" : PRINT "E= ";E: END

END

REM SUBPROGRAM - CALCULATE STRAIN GAGE CALIBRATION DATA
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:N=1
5090 FOR J=6 TO 18 STEP 4
5100 LOCATE J,5:PRINT "DVM ";PRINT USING "##";N
5110 NEXT J
5120 COLOR 9:N=1
5130 FOR J=6 TO 18 STEP 4
5140 LOCATE J,5:PRINT "DVM ";PRINT USING "##";N+1
5150 LOCATE J+1,5:PRINT "DVM ";PRINT USING "##";N+2
5160 LOCATE J+2,5:PRINT "DVM ";PRINT USING "##";N+3
5170 N=N+3
5180 NEXT J
5190 ' 
5200 'Read the strain gage resistance data and gage factors from "STRAIN.DAT"
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 data in the appropriate location in the calibration data table
5290 'data in the appropriate 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=I TO 12
5340 COLOR 0,0:LOCATE 22,10:PRINT "Enter strain gage # connected to DVM ";N
5350 COLOR 15:LOCATE 23,21:PRINT "Enter strain gage ";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$(219)
5410 LOCATE 5+N+M,15:COLOR 0,7:INPUT "",SG#
5420 IF SG#<1 OR SG#>146 THEN SOUND 1000,18:
5425 LOCATE 22,10:COLOR 31,0:PRINT "STRAIN GAGE ";SG#;
5430 IF R(SG#)=0 THEN SOUND 1000,18:LOCATE 22,10:
5435 COLOR 31,0:PRINT "STRAIN GAGE ";SG#;
5440 G(N)=SG#
5445 LOCATE 5+N+M,15:COLOR 7,0:PRINT USING "###";SG#
5450 LOCATE 5+N+M,24:PRINT USING "###";GF(SG#)
5460 LOCATE 5+N+M,33:PRINT USING "###.###";R(SG#)
5470 ESTRN(N)=(R(SG#)/(GF(SG#)*(59872.5+R(SG#)))*1000000!)
5480 IF N=1 THEN MSG#=SG#
5490 LOCATE 5+N+M,45:PRINT USING "###.###";
5500 ESTRN(N):IF Y=1 GOTO 5530
5510 NEXT N
5520 '
5530 'Check to see if there are any changes
5540 COLOR 4,0:LOCATE 23,15:INPUT "Any
changes? (Y/N)
5550 IF A$ = "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 'Print to screen the directions for hooking up
the calibration shunt
5590 'resistor to DVM 1 which is the master for this
experiment
5600 SCREEN 0,1,2,0:CLS
5610 COLOR 14,1
5620 K=I:J=28:L=25:M=6:IC=I: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 "

59
LOCATE 16,5:COLOR 28,0:PRINT CHR$(219);:COLOR 14,0:
PRINT " Adjust the Wheatstone Bridge power
supply so that the reading on DVM 1";
LOCATE 17,8:PRINT "is as close as possible to the
";CHR$(238);"(expt) of:";
COLOR 0,15:LOCATE 18,36:PRINT CHR$(32);"-";
PRINT USING ".###";ESTRN(1)/1000;:PRINT
CHR$(32)
COLOR 7,0:LOCATE 20,5:PRINT CHR$(219);" Once the
voltage source is set, do not change the
voltage for";
LOCATE 21,8:PRINT "remainder of this session."
COLOR 3,0:LOCATE 23,19:PRINT "When the voltage is
adjusted, <CR> to continue."
Z$ = INKEY$
IF Z$ <> CHR$(13) GOTO 5910
COLOR 7,0:CLS
RETURN to the calibration table and take the
calibration shunt reading
for the other 11 strain gages
SCREEN 0,1,0,0
LOCATE 23,20:PRINT " STAND BY
GOSUB 6860
ASTRN(1) = VAL(RD$)*(-1000000!)
LOCATE 6,58:PRINT USING ".###.##";ASTRN(1)
CF(1) = ESTRN(1)/ASTRN(1)
LOCATE 6,69:COLOR 13,0:PRINT USING ".#####";
CF(1):COLOR 7,0
Y=0!
FOR N=2 TO 12
LOCATE 23,10:PRINT "Balance the bridge
connected to DVM ":N;" SPACEBAR to
continue."
Z$ = INKEY$
IF Z$ <> CHR$(32) GOTO 6070
LOCATE 23,10:PRINT " STAND BY
IF N=2 THEN BDNAME$ = "DVM2":GOSUB 6720
IF N=3 THEN BDNAME$ = "DVM3":GOSUB 6720
IF N=4 THEN BDNAME$ = "DVM4":GOSUB 6720
IF N=5 THEN BDNAME$ = "DVM5":GOSUB 6720
IF N=6 THEN BDNAME$ = "DVM6":GOSUB 6720
IF N=7 THEN BDNAME$ = "DVM7":GOSUB 6720
IF N=8 THEN BDNAME$ = "DVM8":GOSUB 6720
IF N=9 THEN BDNAME$ = "DVM9":GOSUB 6720
IF N=10 THEN BDNAME$ = "DVM10":GOSUB 6720
IF N=11 THEN BDNAME$ = "DVM11":GOSUB 6720
IF N=12 THEN BDNAME$ = "DVM12":GOSUB 6720
LOCATE 23,3:PRINT "Place the shunt resistor across the leads to DVM ";N;" <CR> to continue."
Z$ = INKEY$
IF Z$ <> CHR$(13) GOTO 6220
LOCATE 23,3:PRINT "STAND BY"
GOSUB 6860
ASTRN(N) = VAL(RD$)*(-1000000!)
CF(N) = ESTRN(N)/ASTRN(N)
M=0
IF N>3 THEN M=1
IF N>6 THEN M=2
IF N>9 THEN M=3
LOCATE 5+N+M,58:PRINT USING "####.#";ASTRN(N)
LOCATE 5+N+M,69:COLOR 13,0:PRINT USING ".#####:CF(N)
IF Y=1! GOTO 6370
COLOR 7,0
NEXT N
COLOR 4,0:LOCATE 23,13:INPUT "Want to recalibrate any gages? (Y/N)"
A$
LOCATE 23,1:PRINT ""
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
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
IF Y=1 AND (N<1 OR N>12) THEN SOUND 1000,2:GOTO 6390
'Constructs an output file "CALIBRAT.DAT" which contains the calibration data: DVM #, Strain gage # and Calibration factor
OPEN "CALIBRAT.DAT" FOR OUTPUT AS #2
FOR N=1 TO 12
WRITE #2, N, G(N), CF(N)
NEXT N
CLOSE #2

'Machine language routine that does a PrtSc
LOCATE 23, 10: COLOR 18, 0: PRINT "HARDCOPY IN PROGRESS"

D$ = DATE$
LPRINT TAB(36); D$
DEFINT A: DIM ARRAY (3)
DATA &HCD55: REM 55H Push BP
DATA &H5D05: REM CD05H INT 5
:REM 5DH POP BP
DATA &H90CB: REM 90H NOP
FOR I = 1 TO 3: READ ARRAY(I): NEXT I
SUBRT = VARPTR(ARRAY(1)): CALL SUBRT

'REturn to the main menu
LPRINT CHR$(27) + "E"
LOCATE 23, 10: COLOR 15, 0: PRINT "Remove the calibration shunt resistor."
COLOR 31: PRINT "SPACEBAR TO CONTINUE."
Z$ = INKEY$
IF Z$ <> CHR$(32) GOTO 6660
GOTO 2080

'Subprogram sets meter REMOTE, clears it, sets function and range then turns on the OFFSET
CALL IBFIND (BDNAME$, DVM%)
IF DVM% < 0 THEN GOSUB 4590
CALL IBCLR (DVM%)
IF IBSTA% < 0 THEN GOSUB 4700
WRT$ = "F1RO"
CALL IBWRT (DVM%, WRT$)
IF IBSTA% < 0 THEN GOSUB 4700
J = 0: FOR I = 1 TO 500: J = J + I: NEXT I
'Program delay
WRT$ = "B1"
CALL IBWRT (DVM%, WRT$)
IF IBSTA% < 0 THEN GOSUB 4700
RETURN

'Subprogram takes meter reading and turns OFFSET off
RD$ = SPACES$(20)
CALL IBRD (DVM%, RD$)
IF IBSTA% < 0 THEN GOSUB 4700
WRT$ = "B0"
CALL IBWRT (DVM%, WRT$)
IF IBSTA% < 0 THEN GOSUB 4700
RETURN

REM SUBROUTINE - ADD/DELETE/REPLACE STRAIN GAGES

' Construct option box
SCREEN 0,1,0,3:COLOR 7,0:CLS
COLOR 2,7:K=8:J=25:L=32:M=9:IC=7:GOSUB 3040
COLOR 0,7:LOCATE 10,27:PRINT "Make a selection:"
LOCATE 12,32:PRINT "1. ADD strain gage"
LOCATE 13,32:PRINT "2. DELETE strain gage"
LOCATE 14,32:PRINT "3. REPLACE strain gage"
LOCATE 15,32:PRINT "4. Return to main menu"

' Read in all stored strain gage data
OPEN "STRAIN.DAT" FOR INPUT AS #1
INPUT #1, D1$, N$
FOR N=1 TO 150
   INPUT #1, I, R(I), GF(I)
NEXT N
CLOSE #1

' Make selection
SCREEN 0,1,0,0
LOCATE 16,26:INPUT "", A
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

' Write to storage all strain gage data
IF D$="" THEN D$=D1$
OPEN "STRAIN.DAT" FOR OUTPUT AS #1
WRITE #1, D$, N$
FOR N=1 TO 150
   WRITE #1, N, R(N), GF(N)
NEXT N
CLOSE #1

' Return to the selection menu
COLOR 7,0:CLS:GOTO 6940
7290 'ADD strain gage subroutine
7300 SCREEN 0,1,0,3
7310 COLOR 7,0:CLS
7320 'Search for the open slots on the strain gage panel
7330 C=0
7340 FOR N=1 TO 150
7350 IF GF(N)=0 THEN C=C+1:ADD(C)=N
7360 NEXT N
7370 'Construct table of open board slots
7380 COLOR 4,0
7390 M=CINT(C/4)+1
7400 K=13-CINT(M/2)
7410 J=26:L=28:GOSUB 3040
7420 C#=0
7430 FOR N=1 TO M-1
7440 LOCATE K+N,30:PRINT USING "###";ADD(C#+1):
7450 LOCATE K+N,36:PRINT USING "###";ADD(C#+2):
7460 LOCATE K+N,43:PRINT USING "###";ADD(C#+3):
7470 LOCATE K+N,49:PRINT USING "###";ADD(C#+4)
7480 C#=C#+4
7490 NEXT N
7500 LOCATE K-2,27:COLOR 15,0:PRINT "STRAIN GAGE BOARD VACANCIES"
7510 SCREEN 0,1,0,0
7520 LOCATE K+M+2,21:COLOR 12,0:PRINT "Select location of new gage from list:"
7530 'Select new strain gage location and verify it as a vacancy
7540 LOCATE K+M+2,61:COLOR 7,0:INPUT "",NG#
7550 FOR N=1 TO C
7560 IF NG# = ADD(N) GOTO 7610
7570 NEXT N
7580 SOUND 1000,18.2:GOTO 7530
7590 'Enter the new gage's resistance and gage factor
7600 CLS:COLOR 9,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
7610 COLOR 11,0:LOCATE 10,22:PRINT "Enter manufacturer's listed resistance."
7620 COLOR 14,0:LOCATE 16,10:PRINT "NOTE: Suggest you run resistance update subprogram after"
7630 LOCATE 17,10:PRINT "completion of this subprogram."
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 'DELETE strain gage subroutine
7740 COLOR 7,0:CLS
7750 COLOR 1,7:K=12;J=37;L=6;M=2;IC=7:GOSUB 3040
7760 COLOR 11,0:LOCATE 10,23:PRINT "Enter strain gage number deleted;"
7770 COLOR 0,7:LOCATE 13,39:INPUT ",DG#
7780 IF DG#<1 OR DG#>150 THEN SOUND 1000,18.2:COLOR 7:LOCATE 13,38:PRINT ",GO TO 7780
7790 COLOR 0,7:LOCATE 13,38:PRINT ",DG#
7800 SCREEN 0,1,0,3:R(DG#)=0:GF(DG#)=0:RETURN
7810 'REPLACE strain gage subroutine
7820 COLOR 7,0:CLS
7830 COLOR 1,7:K=12;J=37;L=6;M=2;IC=7:GOSUB 3040
7840 COLOR 11,0:LOCATE 10,22:PRINT "Enter strain gage number replaced;"
7850 COLOR 0,7:LOCATE 13,39:INPUT ",RPG#
7860 IF RPG#<1 OR RPG#>150 THEN SOUND 1000,18.2:COLOR 7:LOCATE 13,38:PRINT ",GO TO 7860
7870 COLOR 0,7:LOCATE 13,38:PRINT ",RPG#
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
REM MAIN PROGRAM - GPIB-PC HANDLER STATEMENTS

CLEAR ,59300!
IBINIT1 = 59300!
IBINIT2 = IBINIT1 + 3
BLOAD "bib.m",IBINIT1
CALL IBINIT1(IBFIND,IBTRG,IBPCT,IBSIC,IBLOC,
IBPCC,IBBNA,IBONL,IBRSC,IBSRE,IBRSCV,IBPAD,
IBSAD,IBIST,IBDMA,IBEOS,IBEOT,IBRDF,
IBWRTF)
CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRT,
IBWRTA,IBCMD,IBCMDA,IBRD,IBRDA,IBSTOP,IBRPP,
IBRSP,IBDIAG,IBXTRC,IBRDIA,IBWRTI,IBRDI,
IBWRTIA,IBSTA%,IBERR%,IBCNT%)

REM MAIN PROGRAM-COVER SHEET PRINT TO SCREEN
PRINT "-L=BACKKEY/"
PRINT "-K={BACK),KEYFIX,NOESC,NOMOVE/"
KEY OFF:SCREEN 1,0:COLOR 1,0
DEF SEG = &HB800
BLOAD "C:P2WING.DRW",0
DEF SEG
ON TIMER (5) GOSUB 1300
TIMER ON
WHILE T=0
   TX=1
WEND
TIMER OFF:GOTO 1320
RETURN
SCREEN 2,0:SCREEN 0,1:KEY OFF
SCREEN 0,1,2,2:COLOR 29,0:CLS:LOCATE 13,37:
PRINT "STANDBY"
REM MAIN PROGRAM-INITIAL ASSIGNMENTS,
DIMENSIONS AND SETUP
DEFINT A
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, DI$, NI$
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:
1790 PRINT "STANDBY"
1800 SCREEN 0,1,0,2
1800 COLOR 14,4:CLS:COLOR 1,7
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 REM MAIN PROGRAM-AVERAGE DVM READINGS
2090 FOR M=1 TO 12
2100 S=0
2110 FOR N=1 TO 5
2120 S=S+D(M,N)
2130 NEXT N
2140 R(M)=S/5!
2150 NEXT M
2160 REM MAIN PROGRAM-PRINT DVM MEASUREMENT SUMMARY
2170 68
SCREEN 0,1,0,2
COLOR 7,0:CLS
COLOR 9:K=2:J=14:L=52:M=20:GOSUB 3650
K=14:J=66:L=6:GOSUB 3560
K=14:J=66:L=4:GOSUB 3560
K=4:J=22:L=22:GOSUB 3470
K=4:J=44:L=44:GOSUB 3470
K=4:J=22:L=55:GOSUB 3470
LOCATE 6,22:PRINT CHR$(206)
LOCATE 6,32:PRINT CHRS(206)
LOCATE 6,44:PRINT CHR$(206)
LOCATE 6,55:PRINT CHRS(206)
LOCATE 3,16:PRINT USING "####;XLOAD:;
PRINT "1 lb LOAD MEASUREMENT SUMMARY (strain-m in/in)
COLOR 13:LOCATE 5,17:PRINT "DVM":LOCATE 5,25:
PRINT "GAGE#
LOCATE 5,37:PRINT "mV":LOCATE 5,48:PRINT "C.F."
LOCATE 5,60:PRINT CHR$(238)
FOR N=1 TO 12
M = 0
IF N>3 THEN M=1
IF N>6 THEN M=2
IF N>9 THEN M=3
COLOR 7:LOCATE 6+N+M,18:PRINT USING "###":N
LOCATE 6+N+M,26:PRINT USING "###":G(N)
LOCATE 6+N+M,35:PRINT USING "###.###":R(N)
LOCATE 6+N+M,47:PRINT USING "###.###":CF(N)
RESULTS(N) = CF(N)*R(N)
COLOR 15
LOCATE 6+N+M,57:PRINT USING "###.###":RESULTS(N)
NEXT N
IF GF(G(1))=2.04 THEN G$="A3"
IF GF(G(1))<>1.95 AND GF(G(1))<>1.92 GOTO 2650
M = 0:L=0:COLOR 15
FOR N=1 TO 12
IF N=4 THEN M=1:L=0
IF N=7 THEN M=2:L=0
IF N=10 THEN M=3:L=0
L=L+1
IF L=1 THEN RESULTS(N)=RESULTS(N)+.005*RESULTS(N+2)
IF L=3 THEN RESULTS(N)=RESULTS(N)+.005*RESULTS(N-2)
IF L=2 THEN RESULTS(N) = (RESULTS(N) * .995) +
(0.005 * (RESULTS(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 'REM MAIN PROGRAM-PRINT THE DVM OUTPUT
2700 D$=DATE$
2710 LPRINT TAB(30) ;D$
2720 GOSUB 3980
2730 LPRINT CHR$(13)
2740 COLOR 26:LOCATE 12,70:PRINT
2750 LOCATE 13,72:PRINT "SELECT:
2760 LOCATE 14,69:PRINT "1) Obtain":LOCATE 15,72:
PRINT "new load"
2770 LOCATE 11,72:PRINT "data."
2780 IF G$="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
2790 LOCATE 12,69:PRINT "2) Analyse":LOCATE 13,72:
PRINT "rosette"
2800 LOCATE 14,72:PRINT "data.":LOCATE 15,69:
PRINT "3) Exit"
2810 LOCATE 16,72:PRINT "program."
2820 LOCATE 17,69:INPUT "",M
2830 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
2840 LOCATE 12,69:PRINT "2) Analyse":LOCATE 13,72:
PRINT "rosette"
2850 LOCATE 14,72:PRINT "data.":LOCATE 15,69:
PRINT "3) Exit"
2860 LOCATE 16,72:PRINT "program."
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 REM MAIN PROGRAM-TERMINATE EXECUTION
2890 'SCREEN 0,1,0,0
2900 COLOR 7,0
2910 CLS
2920 LOCATE 12,22:SOUND 1000,2:SOUND 1500,2:SOUND 2000,2
2930 PRINT "Program run completed."
2940 CLS:CHAIN "P2V-CAL",8030

70
REM SUBROUTINE-DVM CONTROL: CLEAR, FUNCTION,
RANGE, OFFSET

CALL IBFIND (BDNAME$, DVM%)
IF DVM% < 0 THEN E=1: GOSUB 4110
CALL IBCLR (DVM%)
IF IBSTA% < 0 THEN E=2: GOSUB 4160
WRT$ = "F1RO"
CALL IWBRT (DVM%, WRT$)
IF IBSTA% < 0 THEN E=3: GOSUB 4160
J=0 'Program delay
FOR I=1 TO 100 'Program delay
J=J+I 'Program delay
NEXT I 'Program delay
IF M<>1 GOTO 3220
SCREEN 0,1,0,2:COLOR 2,1:CLS:COLOR 4,7
K=12:J=11:L=60:M=3:IC=7:GOSUB 3650
LOCATE 13,13:COLOR 0,7:PRINT "Balance the
Wheatstone bridge for all strain gages, then"
LOCATE 14,13:COLOR 0,7
PRINT "enter SPACEBAR when ready to set the OFFSET
for all DVMs.":SCREEN 0,1,0,0
Z$ = INKEY$
IF Z$ <> CHR$(32) GOTO 3190
COLOR 23,1:LOCATE 20,37:PRINT "STANDBY"
WRT$ = "B1"
CALL IWBRT (DVM%, WRT$)
IF IBSTA% < 0 THEN E=4: GOSUB 4160
RETURN
REM SUBROUTINE-READ DVM

CALL IBFIND (BDNAME$, DVM%)
IF DVM% < 0 THEN E=5:GOSUB 4110
WRT$ = "T3"
CALL IWBRT (DVM%, WRT$)
IF IBSTA% < 0 THEN E=6: GOSUB 4160
CALL IBTRG (DVM%)
IF IBSTA% < 0 THEN E=8: GOSUB 4160
RD$ = SPACE$(16)
CALL IBRD (DVM%, RD$)
IF IBSTA% < 0 THEN E=12: GOSUB 4160
B# = VAL(RD$) * 1000!
3400 D(M,N) = B#
3410 IF N<>5 GOTO 3450
3420 WRT$ = "TO"
3430 CALL IBWRT (DVM%,WRT$)
3440 IF IBSTA% < 0 THEN E=7: GOSUB 4160
3450 RETURN
3460 'REM
3470 REM SUBPROGRAM - PRINT A COLUMN TO SCREEN
3480 ' (K-START, J-END, L-COLUMN)
3490 FOR I=K+1 TO J-1
3500 LOCATE I,L
3510 PRINT CHR$(186)
3520 NEXT I
3530 LOCATE K,L:PRINT CHR$(203):LOCATE J,L:PRINT
3540 RETURN
3550 'REM
3560 REM SUBPROGRAM - PRINT A ROW TO SCREEN
3570 ' (K-START, J-END, L-ROW)
3580 FOR I=K+1 TO J-1
3590 LOCATE L,I
3600 PRINT CHR$(205)
3610 NEXT I
3620 LOCATE L,K:PRINT CHR$(204):LOCATE L,J:PRINT
3630 RETURN
3640 'REM
3650 REM SUBPROGRAM - PRINT A BOX TO SCREEN
3660 ' (K,J-UPPERLEFT CORNER, L-LENGTH,
3670 'M-HEIGHT, IC-INTERIOR COLOR.
3680 'DEFAULT BLACK 0)
3690 LOCATE K,J:PRINT CHR$(201)
3700 FOR I=J+1 TO J+(L-1)
3710 LOCATE K,I
3720 PRINT CHR$(205)
3730 NEXT I
3740 LOCATE K,J+L:PRINT CHR$(187)
3750 FOR I=K+1 TO K+(M-1)
3760 LOCATE I,J
3770 PRINT CHR$(186)
3780 NEXT I
3790 LOCATE K+M,J:PRINT CHR$(200)
3800 FOR I=J+1 TO J+(L-1)
LOCATE K+M,I
PRINT CHR$(205)
NEXT I
LOCATE K+M,J+L:PRINT CHR$(188)
FOR I=K+1 TO K+(M-1)
LOCATE I,L+J
PRINT CHR$(186)
NEXT I
IF IC=0 GOTO 3960
COLOR IC
FOR I=K+1 TO K+M-1
FOR N=J+1 TO J+L-1
LOCATE I,N:PRINT CHR$(219)
NEXT N
NEXT I
COLOR 7,0
IC=0
RETURN
REM SUBROUTINE-PRINT SCREEN
A=0:RESTORE
DATA &HCD55 :REM 55H Push BP
DATA &H5D05 :REM CD05H INT 5
DATA &H90CB :REM 90H NOP
FOR I=1 TO 3: READ ARRAY(I): NEXT I
SUBRT = VARPTR(ARRAY(1)): CALL SUBRT
RETURN
REM ERROR SUBROUTINE LOCATIONS
A routine at this location would notify
you that the IBFIND call failed, and
refer you to the handler software
configuration procedures.
PRINT "IBFIND ERROR" : PRINT "E= ";E: PRINT "DVM ";
M: STOP
An error checking routine at this
location would, among other things,
check IBERR to determine the exact
cause of the error condition and then
take action appropriate to the
application. For errors during data
transfers, IBCNT may be examined to
determine the actual number of bytes
transferred.

A routine at this location would analyze the fault code returned in the DVM's status byte and take appropriate action.

PRINT "DVM ERROR" : PRINT "E=  ";E:PRINT "DVM ";M:STOP

END

REM Portion of program which does the rosette analysis

SCREEN 0,1,0,0:COLOR 7:CLS
PRINT "~k={(BACK)/" 
SCREEN 2
KEY OFF:SCREEN 1,0:CLS
COLOR 1,0
IF C%=0 THEN DIM PIX#(700):C%=1
DEF SEG
PIX.PTR=VARPTR(PIX#(0))
BLOAD "C:ROSETTE.PIX",PIX.PTR
VIEW (70,39)-(250,159),,3
PUT (40,5),PIX#
ON TIMER(3) GOSUB 4510
TIMER ON:T=0
WHILE T=0
SUM =0
VIEW
GOTO 4530
T=1
RETURN
SCREEN 1,0:COLOR 1,0:CLS
DEF SEG
PIX.PTR=VARPTR(PIX#(0))
BLOAD "C:ANALIZE2.PIX",PIX.PTR
PUT (18,1),PIX#
WHILE GF(G(1))=2.09
LOCATE 15,3:PRINT USING "###";XLOAD:;
PRINT " LB. LOAD"
LOCATE 15,18:PRINT CHR$(214);CHR$(196);
"A 
LOCATE 16,6:PRINT "SELECT":LOCATE 16,18:
PRINT CHR$(186);" ";PRINT USING "###";
G(l);PRINT USING "#####";G(5):
PRINT USING "#####";G(9);PRINT " ";CHR$(186)
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)

LOCATE 18,18:PRINT CHR$(186);" ";PRINT USING
"#####":G(3);PRINT USING "#####":G(7);
PRINT USING "#####":G(11);PRINT " ";
CHR$(186)

LOCATE 19,18:PRINT CHR$(186);" ";PRINT USING
"#####":G(4);PRINT USING "#####":G(8);
PRINT USING "#####":G(12);PRINT " ";
CHR$(186)

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)

VIEW (5,163)-(314,187),,,2
LOCATE 22,7:PRINT "For rosette ENTER A,B OR C."
IF M$<>"Y" THEN LOCATE 23,4:PRINT "ENTER L to
return to Load program." ELSE LOCATE 23,4:
PRINT "ENTER X to end."
LOCATE 23,38:INPUT "",M$
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

IF M$="L" OR M$ = "l" THEN CLS:GOSUB 4940
IF M$="A" OR M$="a" THEN GN1=1:GN2=2:GN3=3:
GN4=4:GAGE=G(1):GOSUB 4940
IF M$="B" OR M$="b" THEN GN1=5:GN2=6:GN3=7:
GN4=8:GAGE=G(5):GOSUB 4940
IF M$="C" OR M$="c" THEN GN1=9:GN2=10:GN3=11:
GN4=12:GAGE=G(9):GOSUB 4940
SOUND 100,3:GOTO 4690

WEND
LOCATE 15,3:PRINT USING "###";XLOAD;PRINT " LB.
LOAD"
LOCATE 16,18:PRINT CHR$(214);CHR$(196);
A B C D";CHR$(196);CHR$(183)
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)
LOCATE 18,5:PRINT "ROSETTE":LOCATE 18,18:
PRINT CHR$(186); PRINT USING "###"; G(2);
PRINT USING "####"; G(5); PRINT USING "#####"; G(8);
PRINT USING "#####"; G(11); PRINT " "; CHR$(186)

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)

LOCATE 20,18: PRINT CHR$(211); CHRS(196); CHRS(196);
CHRS(196); CHRS(196); CHRS(196); "GAGES"; CHRS(196); CHRS(196);
CHRS(196); CHRS(196); CHRS(196); CHRS(196);
VIEW (5,163)-(314,187),,2

LOCATE 22,7: PRINT "For rosette ENTER A,B,C or D."
IF F$<>"Y" THEN LOCATE 23,4: PRINT "ENTER L to return to Load program."
ELSE LOCATE 23,4: PRINT "ENTER X to end."

LOCATE 23,38: INPUT "", M$
IF M$="X" OR M$="x" THEN CLS: SCREEN 2: SCREEN 0:
LFLAG=0: OPEN "DISPLAY.DAT" FOR OUTPUT AS #2:
WRITE #2, LFLAG: CLOSE #2: CHAIN "P2V-CAL", 8030

OPEN "DISPLAY.DAT" FOR OUTPUT AS #1
WRITE #1, GF(G(1)), XLOAD
IF GF(G(1)) = 2.09 THEN WRITE #1, GN1, GN2, GN3,
GN4, GAGE ELSE WRITE #1, GN1, GN2, GN3, GAGE
FOR I=1 TO 12
WRITE #1, RESULTS(I), G(I)
NEXT I
CLOSE #1
IF M$="L" OR M$="l" THEN CLS: SCREEN 2: SCREEN 0:
IF NFLAG=1 THEN RETURN 1000 ELSE RETURN 1740
SHELL "ANALYZE.BAT"
NFLAG = 1
OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #3

76
5060 WRITE #3, NFLAG
5070 CLOSE #3
5080 RETURN 4330
REM This is a compiled executable BASIC program which does the high resolution display portion of the rosette analysis

'Variable declarations
DIM RESULTS(12), G(12)

'REtrieve data to be displayed from the hard disk
OPEN "DISPLAY.DAT" FOR INPUT AS #1
INPUT #1, GF, XLOAD
IF GF=2.09 THEN INPUT #1, GN1, GN2, GN3, GN4, GAGE ELSE INPUT #1, GN1, GN2, GN3, GAGE
FOR I=1 TO 12
   INPUT #1, RESULTS(I), G(I)
NEXT I
CLOSE #1

KEY OFF

'Calculations for the older AR-7-2 wire rosette
WHILE (GF=1.92 OR GF=1.95) AND NSTOP=0
   EX = RESULTS(GN1): EY = RESULTS(GN3)
   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)
   GXY = (21 * RESULTS(GN2)) - (EX + EY)
   IF GAGE=56 OR GAGE=59 OR GAGE=62 OR GAGE=63 THEN GXY=-1! * GXY
   ESI = (EX + EY)/2!
   GMAX = SQR((EX - EY)^2 + GXY^2)
   EMAX = ESI + .5*GMAX
   EMIN = ESI - .5*GMAX
   PHIP = (.5 + ATN(GXY/(EX - EY))) * 57.2958
   NSTOP=1
WEND

'Calculations for the new EA-13-250YA delta rosette
WHILE GF=2.07 AND NSTOP=0
   EY=RESULTS(GN1)
   GXY=(RESULTS(GN3)-RESULTS(GN2))/.8660254
   EX=(RESULTS(GN2)+(.4330127*GXY)-(.25*EY))/.75
   IF GAGE=112 THEN GXY=(RESULTS(GN2)-RESULTS(GN3))/.8660254
   EY=(RESULTS(GN3)-RESULTS(GN2))/.8660254: EX=(RESULTS(GN3)+(.4330127*GXY)-

(\(0.25*EY\))/.75

1380 IF GAGE=109 THEN EY=RESULTS\(GN2\):GXY=(RESULTS\(GN3\)-RESULTS\(GN1\))/.6660254:EX=(RESULTS\(GN4\)+.4330127*GXY)-(\(0.25*EY\))/.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 '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 'Calculation for Mohr's circle radius
1640 R = .5 * SQR((EX - EY)^2 + GXY^2)
1650 'Construct the display screen
1660 '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$(238);"min=";PRINT USING
LOCATE 25,41:PRINT CHR$(238);"max=";PRINT USING "###.###";EMAX;
LOCATE 23,56:PRINT "Gxy=";PRINT USING "###.###";GXY;
LOCATE 23,71:PRINT CHR$(238);"1y=";PRINT USING "###.###";EY;
LOCATE 23,96:PRINT CHR$(238);"x-";PRINT USING "###.###";EX;
LOCATE 23,121:PRINT CHR$(238);"Load";
LOCATE 23,146:PRINT CHR$(238);"-m in/in"
LOCATE 1,1:PRINT DATE$
IF GF<>2.09 THEN LOCATE 25,1:PRINT "Gages-";
PRINT USING "###.###";G(GN1);PRINT "";
PRINT USING "###.###";G(GN2);PRINT "";
PRINT USING "###.###";G(GN3);
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);
SCALE = R/1.5151515#
XIS = (ESi * 100! / R) * -1
COLOR 10
LINE (5,160)-(315,160) 'X and Y axis
LINE (159 + XIS,260)-(159 + XIS,43)
LINE (323,160)-(635,160)
LINE (479,27)-(479,260)
COLOR 2
LOCATE 13,1:PRINT CHR$(238) 'Axis Labels
LOCATE 3,14:PRINT "Gxy/2"
LOCATE 3,58:PRINT "Y"
LOCATE 13,78:PRINT "X"
IF ABS(EX)<.5 AND ABS(EY)<.5 AND ABS(GXY)<.5 THEN
SMULT=2! ELSE SMULT=1!
EX = SMULT * EX:EY = SMULT * EY:GXY=SMULT * GXY
'Calculations for the element deformation shape
DEX = 75 * (EX/2!)
DEY = 61 * (EY/2!)
GLE = ATN(ABS(GXY/2!))
IF GXY < 0 THEN GLE = GLE * -1!
YSLP = TAN(1.5707963# - GLE) * .77272727#
XSLP = TAN(GLE) * .77272727#
X1 = ((61! + DEY) + YSLP * (75! + DEX))/(YSLP - XSLP)
X2 = ((61! + DEY) + YSLP * (-75! - DEX))/(YSLP -
XSLP)

2080 \[ Y_1 = \frac{((XSLP \ast YSLP) \ast (75! + DEX)) \ast (YSLP \ast (61! + DEY)))}{(YSLP - XSLP)} \]

2090 \[ Y_2 = \frac{((XSLP \ast YSLP) \ast (-75! - DEX)) \ast (YSLP \ast (61! + DEY)))}{(YSLP - XSLP)} \]

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)-(184,286)

2200 LINE (184,282)-(118,286)

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 \ast 66!) / SCALE)

2330 PEX = ((EX \ast 66!) / SCALE)

2340 PGXY = (((GXY/2!) \ast 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
<table>
<thead>
<tr>
<th>No.</th>
<th>Distribution List</th>
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| 1.  | Defense Technical Information Center  
     Cameron Station  
     Alexandria, Virginia  
     22304-6145 |
| 2.  | Library, Code 0142  
     Naval Postgraduate School  
     Monterey, California  
     93943-5002 |
| 3.  | Department Chairman, Code 67  
     Department of Aeronautical Engineering  
     Naval Postgraduate School  
     Monterey, California  
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| 4.  | Dr. E. M. Wu, Code 67  
     Department of Aeronautical Engineering  
     Naval Postgraduate School  
     Monterey, California  
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| 5.  | LCDR C. Heard, Code 67  
     Department of Aeronautical Engineering  
     Naval Postgraduate School  
     Monterey, California  
     93943-5000 |
| 6.  | LCDR James J. Miller, USN  
     Patrol Squadron One (VP-1)  
     FPO San Francisco, CA  
     96601-5900 |
END

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