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Shield-Loading Studies at an Eastern Appalachian Minesite

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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	$\mu\varepsilon$	microstrain
ft/d	foot per day	min	minute
h	hour	pct	percent
in	inch	psi	pound per square inch
kips/in	kips per inch	st	short ton
lb	pound	st/min	short ton per minute
m	meter		

SHIELD-LOADING STUDIES AT AN EASTERN APPALACHIAN MINESITE

By Thomas M. Barczak[1] and Stephen J. Kravits[2]

ABSTRACT

A primary objective of the Bureau of Mines geomechanics research program is to develop a better understanding of support behavior and interaction of supports with the strata so that supports can be more closely engineered to the geological conditions in which they are employed.

Four longwall shield supports were instrumented with an eight-transducer instrumentation array to measure leg, canopy capsule, and compression lemniscate link forces from which resultant shield loading was determined. The instrumented supports were monitored over a 4-month period, producing over 75 shield cycles of resultant shield loading. Resultant loading is the true measure of support resistance, providing both roof-to-floor and face-to-waste support reactions as well as the location of the reaction on the shield canopy. Observed roof support reactions were analyzed, with particular emphasis on horizontal shield loading, since it is the least understood design parameter. Average, peak, and change in shield loading during the mining cycle are discussed. Correlations among data parameters are examined, as is the distribution of support loading at the headgate and midface. Conclusions are drawn as to the effectiveness of the shield support at this installation. Recommendations are made for further research needs.

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INTRODUCTION

Longwall mining is a capital-intensive system that requires increased dependence upon single production units. Current costs to equip a modern longwall system can easily exceed $10 to $12 million per installation, with over 50 pct of this cost attributable to the powered roof support system. Better design, selection, and utilization of the powered roof support system should reduce the capital risk while improving the production, health, and safety performance for the longwall operator.

While the importance of proper ground control to successful longwall mining is recognized, strata and the interaction of the powered roof support system with the immediate strata are not well understood. Because of inadequate capacity of powered supports and subsequent failures of several early longwall attempts in the United States, there has been a tendency to increase support capacity with little regard to expected support loading. Since the cost of a support is related to its capacity, the use of excessively large supports represents an unnecessary capital investment and may cause undesirable fracturing of the roof strata, thereby being detrimental to good roof control.

Although several types of powered roof supports exist, the shield design has gained prominence since its introduction into the United States around 1975, being utilized on about 85 pct of the existing longwall faces. The shield design is characterized by the presence of a caving shield, which acts as a connecting structure from the canopy to the base, making the structure stable against horizontal loading.[3] It is this feature, however, that makes the shield design more complex from a kinematic viewpoint than frame-and-chock-type supports, preventing a determination of support resistance simply from the summation of leg forces alone.

Much can be learned about strata behavior from the response of the powered roof support system. The design and selection of more effective roof support systems will only be realized once the interaction between the roof support system and the strata is fully understood. It is important to understand that the roof support elements and the surrounding strata act as a system, responding to changes in the physical mine environment due to the extraction of coal and associated redistribution of stresses. As a first step in analyzing the interaction of the roof support system with the strata, measures of support resistance must be defined to quantify support loading.

A fundamental measure of support resistance is the resultant support load, which is the representation of the horizontal and vertical longwall support reactions to the converging strata.[4] Being a vector, this measure possesses not only a magnitude but spatial parameters of location and direction, as depicted in figure 1. Reference will be made to three resultant load vector parameters:

[3]Peng, S. S. Coal Mine Ground Control. Wiley, 1978, p. 231.

[4]Barczak, T. M., and R. C. Garson. Technique To Measure Resultant Load on Shield Supports. Paper in Rock Mechanics in Productivity and Protection, 25th Symposium on Rock Mechanics. AIME, 1984, pp. 667-679.

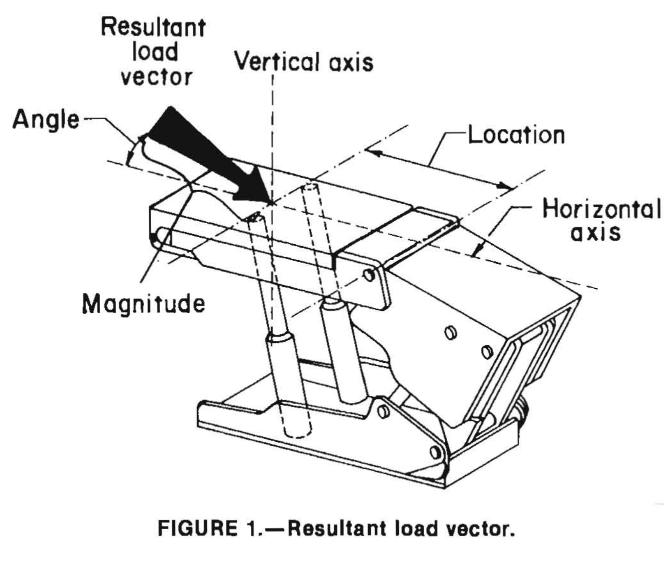

FIGURE 1.—Resultant load vector.

1. Magnitude - resultant of horizontal and vertical support reactions.
2. Location - position of resultant force acting on canopy surface necessary to maintain static equilibrium.
3. Angle - arc tangent of the ratio of horizontal to vertical support reactions.

From these parameters, crucial design information can be ascertained. For example, by knowing the magnitude and angle of the resultant force, the magnitude of horizontal (face-to-waste) shield load can be assessed. Likewise, insight into the caving behavior of the strata can be gained by examination of the resultant location as it moves forward or rearward during the mining cycle. Insight into the interaction of the support element with the immediate strata can be gained by assessment of horizontal to vertical support reaction ratios, which provide information regarding contact friction between the support canopy and the strata.

While it is recognized that resultant loading must be considered as baseline engineering data, the Bureau's mine roof simulator (MRS) enables such information to be further analyzed under controlled laboratory conditions. The MRS, shown in figure 2, is a massive, bidirectional, hydraulic press capable of applying 1,500 st of vertical force and 800 st of horizontal force, either independently or simultaneously, to full-scale roof support elements.[5] A load profile measured underground can be programmed into the MRS computer and simulated by the test rig. This enables comprehensive structural analysis of the support capability under controlled laboratory conditions to evaluate such things as the effectiveness of the lemniscate design in resisting horizontal loading.

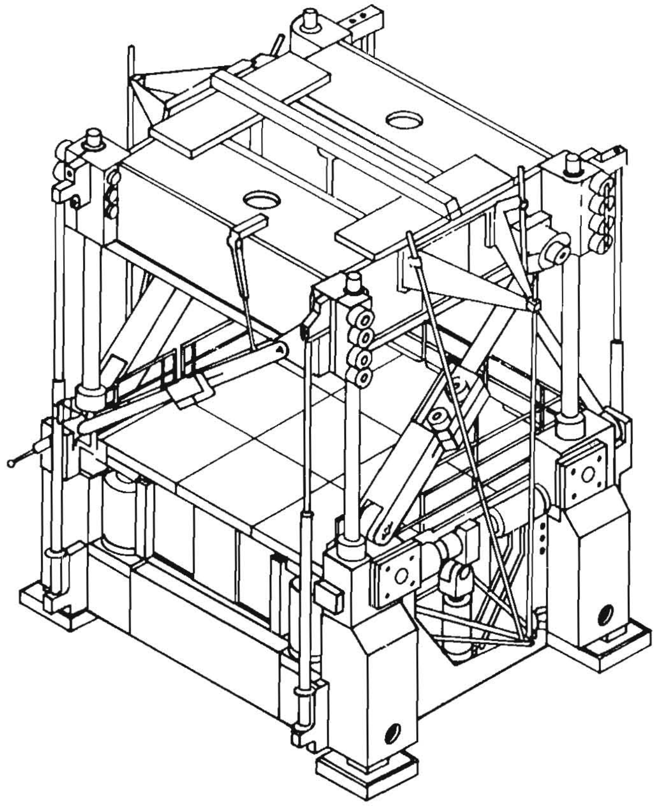

FIGURE 2.—Mine roof simulator.

As part of a continuing effort to develop a data base of longwall face support loading, this report presents results from 75 shield cycles of data from 4 instrumented shield supports operating in an eastern Appalachian minesite. The appendixes contain additional information pertaining to data collected during this study. They are provided for the reader who wishes to analyze other aspects of support behavior or to analyze further the information provided in this report.

ACKNOWLEDGMENTS

Acknowledgment is made to Tom Marshall, Albert Sainto, and Fred Garcia, Pittsburgh Research Center, Bureau of Mines, for the many long and hard hours they spent installing the equipment in the mine and their efforts in collecting data. Special gratitude is extended to John Marshall, also of the Pittsburgh Research Center, who spent hours upon end installing and maintaining

[5]Barczak, T. M., R. C. Garson, P. M. Yavorsky, and F. S. Maayeh. State-of-the-Art Testing of Powered Roof Supports. Paper in Proceedings of Second Conference on Ground Control in Mining (WV Univ., July 19-21, 1982). WV Univ., 1982, pp. 64-77.

instrumentation and collecting and transcribing data with commendable workmanship. This project would not have been a success without the hardship these people endured, and their efforts are very much appreciated.

Gratitude is also extended to the management and miners of the mine, who wish to remain anonymous, for their excellent cooperation and support of our research efforts at their minesite.

SHIELD KINEMATICS AND DETERMINATION OF RESULTANT LOADING

A simplistic, two-dimensional diagram of a generic two-legged shield support is shown in figure 3. The shield structure is an indeterminate structure with multiple load paths created by hydraulic leg and canopy capsule cylinders and the caving shield-lemniscate linkage system. Static equilibrium requirements can be reduced to three independent equations for solution of the resultant forces depicted in figure 1. A static rigid body analysis of the shield structure reveals that these equations can be developed by examining the forces acting on the canopy and canopy-caving shield combination by summation of moments about the canopy hinge pin, the instantaneous center of the lemniscate links, and the tension link-caving shield hinge pin, if the leg, canopy capsule, and compression lemniscate link forces are known.[6] Simultaneous solution of these three independent equations (see appendix A for their derivation) provides a generic solution to the resultant load vector parameters as follows (fig. 3):

[6]Work cited in footnote 4.

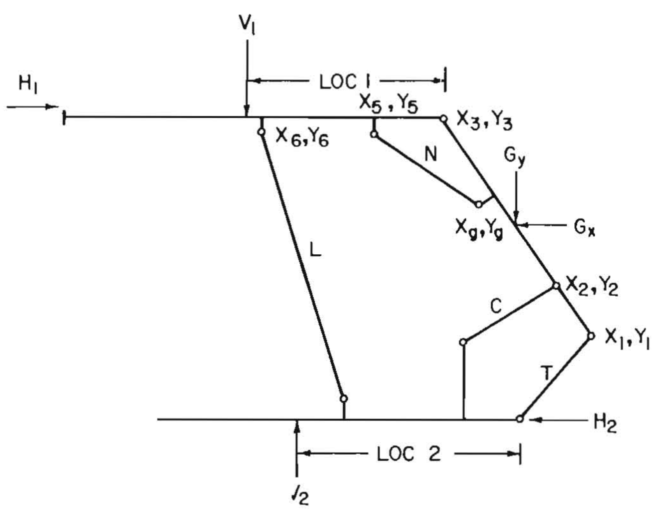

FIGURE 3.—Simplistic two-dimensional diagram of two-leg shield support.

$$\mathrm{VERT} = (A + B + C - D + E - F - G) / (H - I), \tag{1}$$

where

$$A = L*\mathrm{COS}\alpha * (X6 - X3) * \mathrm{CONS1},$$

$$B = N*\mathrm{SIN}\theta * (X5 - X3) * \mathrm{CONS1},$$

$$C = N*\mathrm{COS}\theta * (Y5 - YR4) * \mathrm{CONS1},$$

$$D = L*\mathrm{COS}\alpha * (X6 - X3) * \mathrm{CONS2},$$

$$E = L*\mathrm{COS}\alpha * (X6 - X1),$$

$$F = C*\mathrm{COS}\beta * (Y2 - Y1),$$

$$G = C*\mathrm{SIN}\beta * (X2 - X1),$$

$$H = (X3 - X1),$$

$$I = (X3 - X0) * \mathrm{CONS2},$$

$$\mathrm{CONS1} = (Y3 - Y1)/(Y3 - Y0) + 1,$$

and

$$\mathrm{CONS2} = (Y3 - Y1)/(Y3 - Y0).$$

$$\mathrm{HORZ} = \mathrm{VERTLOC}/(Y3 - Y0) + \mathrm{VERT} * (X3 - X0)/(Y3 - Y0) - L*\mathrm{COS}\alpha * (X6 - X0) / (Y3 - Y0) + L*\mathrm{SIN}\alpha, \tag{2}$$

where

$$\mathrm{VERTLOC} = L*\mathrm{COS}\alpha * (X6 - X3) + N*\mathrm{SIN}\beta * (X5 - X3) + N*\mathrm{COS}\beta * (Y5 - YR4).$$

$$\mathrm{MAGNITUDE} = (\mathrm{VERT}^2 + \mathrm{HORZ}^2)^{1/2} \tag{3}$$

$$\mathrm{ANGLE} = \mathrm{Arctan}\ (\mathrm{HORZ}/\mathrm{VERT}) \tag{4}$$

$$\mathrm{LOC} = \mathrm{VERTLOC}/\mathrm{VERT} \tag{5}$$

Interpretation of the terms follows:

VERT is the vertical shield reaction force,

HORZ is the horizontal shield reaction force,

L is the measured leg force,

N is the measured canopy capsule force,

C is the lemniscate link force determined from link strain measurements,

α is the leg angle relative to the vertical axis,

θ is the canopy capsule angle relative to the horizontal axis,

β is the lemniscate link angle relative to the horizontal axis,

and

Xi, Yi are spatial coordinates of the shield geometry.

A parametric sensitivity study is shown in table 1, which shows the impact of 10-pct changes in individual or measured variables (leg force, canopy capsule force, and lemniscate link force) on resultant load vector parameters. The results show that leg force is the dominant variable in determining resultant shield loading. Also, the resultant magnitude and vertical shield can be reasonably predicted from leg force data alone; however, horizontal loading, resultant angle, and resultant location are significantly dependent on lemniscate link force and canopy capsule pressure.

TABLE 1. - Resultant load vector parametric sensitivity analysis, percent

Vector parameters	10-pct Δ leg force	10-pct Δ capsule force	10-pct Δ link force
Resultant magnitude....	11	<1	1
Resultant angle........	4	<1	5
Resultant location.....	10	8	7
Horizontal force........	15	<1	7
Vertical force........	10	<1	<1

MINESITE DESCRIPTION

The longwall panel under investigation is located within the Appalachian Plateau Province of western Pennsylvania. The panel is 630 ft wide and 5,570 ft long. Gate-road widths are 15 ft, incorporating a four-entry arrangement utilizing square pillars on 90-ft centers. Face support is provided by two-leg, 460-ton shield supports operating at a rated setting pressure of 3,600 psi with a yield pressure of 6,700 psi.

Stratigraphically, the coal deposit is within the Pennsylvania age coal in strata of the Monongahela Group with an overburden depth of approximately 500 to 1,100 ft. The total thickness of the coal deposit is approximately 6.5 ft; extraction is limited to less than 5.5 ft owing to the presence of a weak shale layer in the deposit. Full extraction heights are maintained at the gate ends to provide additional height for equipment and sumping procedures.

As can be seen from the stratigraphic columnar section depicted in figure 4, the immediate roof strata consist of a shalely limestone with three very weak bands of soft clay shale at heights of 8, 10, and 17 ft above the coal seam, providing a weak roof structure that caves immediately behind the support. Data from surface-drilled, borehole extensometers[7] indicate a caving height of less than 23 ft with a swelling factor of approximately 33 pct. A more competent

[7]Listak, J. M., J. L. Hill III, and J. C. Zelanko. Direct Measurement of Longwall Strata Behavior: A Case Study. BuMines RI 9040, 1986, 19 pp.

limestone roof structure with a uniaxial compressive strength of over 40,000 psi is first encountered approximately 40 ft above the seam, becoming interbedded with shale until it reaches a massive limestone structure 60 to 75 ft above the seam. The immediate floor consists of fairly stony, sandy shale compatible with the load distribution provided by the base of the two-leg shield supports.

The longwall face was generally operated on a three-shift production schedule with maintenance performed primarily on weekends. A representative rate of advance for the longwall face was 40 ft/d, producing 6,400 st of raw coal.

FIELD INSTRUMENTATION AND DATA ACQUISITION

Four longwall shields were instrumented with an eight-transducer array depicted in figure 5 consisting of the following:

1. Two pressure transducers, one in each leg cylinder, to measure leg pressure.
2. Two pressure transducers, one each to measure canopy capsule extension and retraction pressure.
3. Four strain gauges, two in each compression link, to measure strain in the lemniscate link.

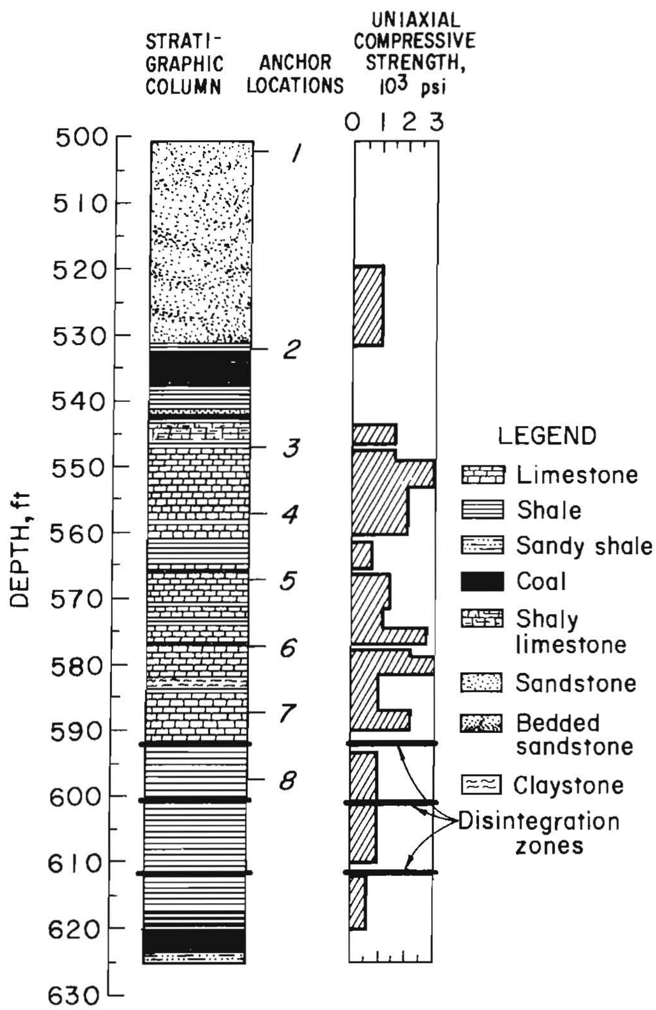

FIGURE 4.—Stratigraphic column section of longwall test site.

All transducers were installed on the shields while in place on the longwall face during idle shifts. Weldable-type, resistance strain gauges (fig. 6) were utilized because of their ease of application in the dusty coal mine environment. Completion bridges were fabricated with precision (0.01 pct) resistors and placed in a 4- by 6-in enclosure, which was installed on the support to minimize gauge lead line resistance errors. Pressure transducers of 5,000 psi (canopy capsule) and 10,000 psi (leg cylinder) with 1-pct accuracy were installed directly in the hydraulic lines of the appropriate cylinders with quick-disconnect fittings to permit their removal for calibration. Individual leads from all eight transducers were routed to a common junction box, also located on the instrumented support, and connected via a 37-pin connector to a multipair shielded cable for transmission to the readout devices several feet from the support. The readout device consisted of a portable, strain indicator, approved by the Mine Safety and Health Administration (MSHA), which requires balance of a Wheatstone bridge for operation. Individual channels were addressed by a 10-channel switching unit. A complete layout of the transducer and data acquisition system is shown in figure 7. Component specifications are documented in appendix B.

KEY

LP Left leg cylinder pressure transducer
RP Right leg cylinder pressure transducer
CE Canopy capsule extend pressure transducer
CR Canopy capsule retract pressure transducer
LTR Left compression lemniscate link rear face strain gauge
RTR Right compression lemniscate link rear face strain gauge
LTF Left compression lemniscate link forward face strain gauge
RTF Right compression lemniscate link forward face strain gauge

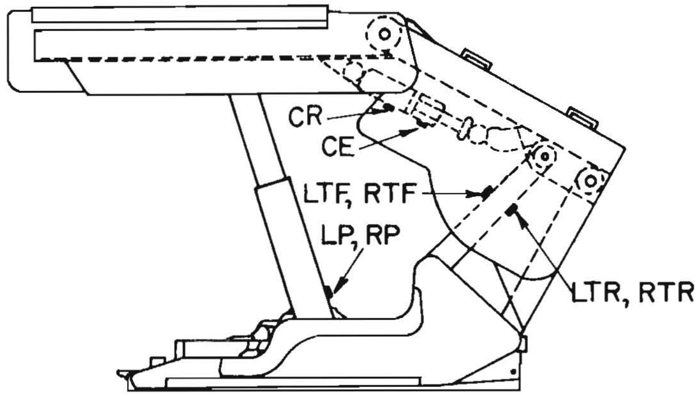

FIGURE 5.—Resultant load shield instrumentation array.

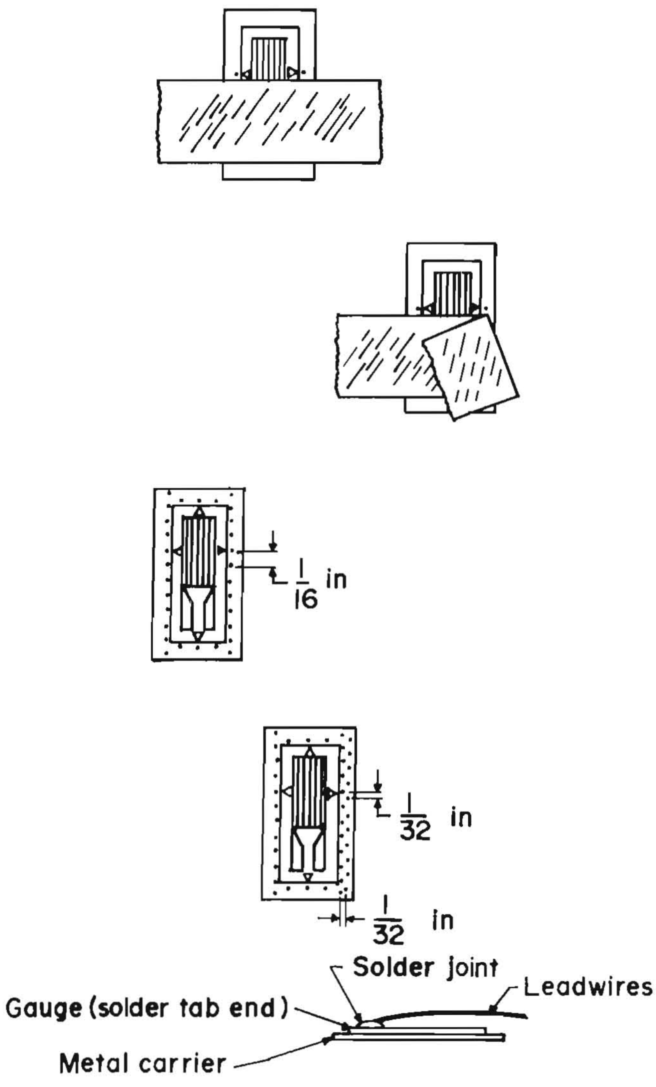

FIGURE 6.—Weldable-type strain gage.

Two adjacent shields were instrumented and monitored near midface as well as headgate shields 4 and 6. Headgate shields were monitored by one data station, and the midface shields were monitored at a separate data station, requiring at least two people to monitor all four shields. Each data station consisted of one strain indicator and two 10-channel switching units. Readings were voice-recorded onto magnetic tape for subsequent transcription and computer input for processing. Sampling rates of 15 to 20 sets per hour, achieved with the manual strain indicators (a data set consisting of time of day and inputs from the eight transducers), provided measurements of the static load acting on the support, but proved too slow to provide good-quality load profiles depicting load changes during the shield cycle. Sampling rates in excess of 100 data sets per hour were achieved with the procurement of digital strain indicators; these balanced the bridge network at the push of a button, providing excellent plots of resultant load vector parameters.

Prior to data acquisition, the entire system was calibrated from the transducer to the strain indicator using a VISHAY[8] model 1550A calibrator accurate to within

[8] Reference to specific products does not imply endorsement by the Bureau of Mines.

FIGURE 7.—Shield transducer and data acquisition system.

1 µε. System calibration, gauge factor, and desensitized gauge factor calibrations are documented in appendix C. All pressure transducers were zeroed in air with the transducer completely removed from the hydraulic circuit. Since the strain gauges were permanently fixed to the support and since the structure could not be calibrated by load application, zeroes for the strain gauges were established by lowering the shield to remove all roof load and then balancing the strain indicator to a null condition.

DATA ACQUISITION SOFTWARE

Five computer programs were written to input, edit, and process the raw shield data into resultant load magnitude, vertical support reaction, horizontal support reaction, resultant location, and resultant angle. Analysis software included programs to integrate load profiles to produce time-weighted averages and software to analyze horizontal shield loading. Software was also written to plot resultant load vector parameters and produce time-at-level histograms of specified parameters. All software was written in Hewlett-Packard (HP) BASIC and executed on a HP9845B minicomputer operating with 500K bytes of storage. The programs are interactive and self-explanatory to enable execution by someone without any computer knowledge or in-depth knowledge of roof support systems. A synopsis of each program and its function is provided below. Complete source listings of all programs are provided in appendix D.

EMFILE. - This program allows the user to input raw data from individual transducers and creates a file of these data for subsequent processing. The computer prompts the user for input by shield number, transducer identification, and data set.

EMEDIT. - This program allows the user to edit the raw data file created by the EMFILE program. Editing is achieved first by computer examination of the data relative to user-defined minimum and maximum values for individual transducers, and finally by operator examination of data sets displayed by the computer. The level of editing is at the individual transducer for any data set.

EMCONV. - The EMCONV program transforms raw data from the shield transducers into engineering units of pressure and microstrain. Included in this transformation are zero subtraction and transmission cable readout device calibrations.

EMGEOM. - This program computes spatial coordinates of generic shield geometries as a function of shield height. Input parameters include basic shield component dimensions. Primary outputs of leg angle, canopy capsule angle, and compression lemniscate link angle are used as input to the static analysis program to calculate resultant loading. Secondary outputs include canopy convergence and lemniscate linkage locus displacements as a function of shield height.

EMVECT. - The EMVECT program creates and solves three simultaneous, static equilibrium equations to obtain resultant load magnitude, horizontal force, vertical force, resultant location, and resultant angle. Engineering units data from the shield transducers are provided from the EMCONV program, and the appropriate shield geometry is selected from the EMGEOM spatial coordinates file to match the operating height of the particular application.

EMPLOT. - The EMPLOT program provides plots of resultant load vector parameters using files created by the EMVECT program. Plotting menu includes the following:

1	Resultant magnitues	vs	Elapsed face time
2	Vertical force	vs	Elapsed face time
3	Horizontal force	vs	Elapsed face time
4	Resultant location	vs	Elapsed face time
5	Resultant angle	vs	Elapsed face time
6	Leg force	vs	Elapsed face time
7	Canopy capsule force	vs	Elapsed face time
8	Lemniscate link force	vs	Elapsed face time
9	Horizontal force	vs	Leg force

10	Vertical force	vs	Leg force
11	Horizontal force	vs	Link force
12	Horizontal-vertical force ratio	vs	Elapsed face time
13	Resultant location	vs	Capsule force
14	Horizontal force	vs	Vertical force

EMTAVG. - This program integrates areas under load profile curves to produce time-weighted load averages.

EMHORZ. - This program analyzes horizontal shield loading by computing coefficients of friction, canopy-caving shield pin reactions, percentage of leg force used to resist horizontal loading, and other parameters critical to horizontal shield load analysis.

DELTA. - The DELTA program determines resultant parameters load at support setting, minimum and maximum observed load, and net change in load after the support has been set.

EMDISP. - This program determines roof-to-floor and face-to-waste shield displacement by analysis of shield forces using a linearly elastic shield displacement model.

DISPLT. - This program provides plots of roof-to-floor and face-to-waste shield displacements calculated from the EMDISP program.

DATA ANALYSIS AND RESULTS

Over 150,000 data points representing nearly 75 shield cycles of data were collected from the 4 instrumented roof supports during a 5-month period. During this time frame, the 5,500-ft panel advanced from approximately midway to panel completion.

All data were processed into resultant shield loading using the software and two-dimensional shield model described in previous sections. The results of these resultant shield load measurements are presented below.

GENERAL TRENDS AND OBSERVATIONS

Resultant Force

The resultant force is the true measure of support resistance, being determined by the vector sum of the horizontal and vertical forces acting on the support canopy. It cannot be determined from leg pressure data alone or from vertical force alone, but owing to the sum of the squares of the vertical and horizontal components, the larger contribution is provided by the vertical force. Since horizontal force is generally present on all shield cycles, the resultant magnitude is always larger than the vertical force, with observed differences as large as 8 pct.

The resultant force generally increases with time during the mining cycle as the strata converge, causing additional support loading. Figure 8 depicts typical resultant magnitude plots. The effect of newly exposed roof created by the passage of the shearer can be clearly seen as an increase in slope in the resultant magnitude plots, representing increased support loading.

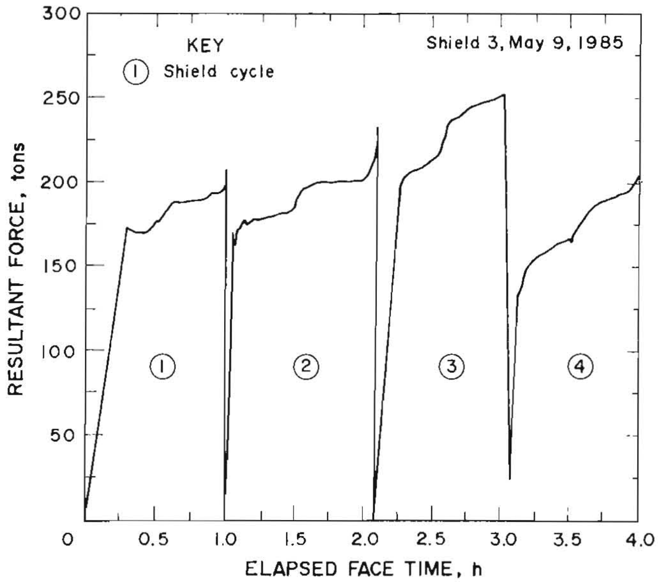

FIGURE 8.—Typical resultant force plots.

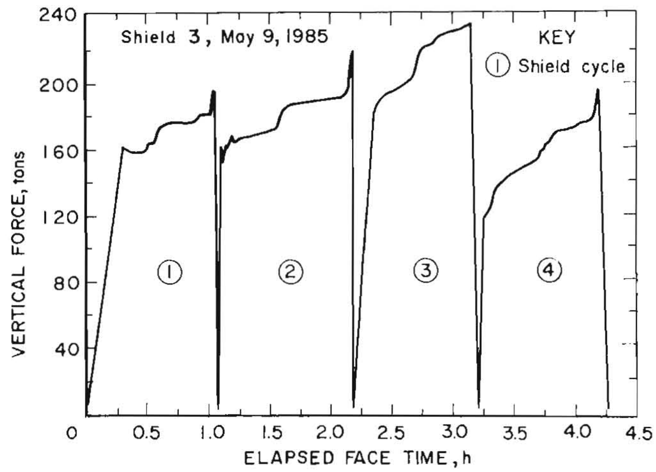

FIGURE 9.—Vertical shield loading profiles.

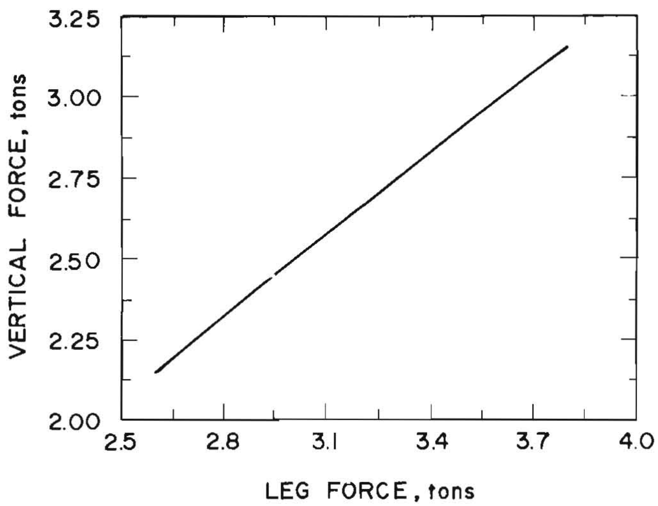

FIGURE 10.—Correlation between vertical support resistance and leg force.

Vertical Support Reactions

The force normal to the plane of the canopy is the vertical support reaction force acting on the support canopy. Mathematically, the vertical reaction force is represented by the vertical component of the resultant magnitude. It is this parameter that is generally referred to as support capacity by the equipment manufacturers, although as discussed previously, in actuality it is not the maximum measure of support resistance. Like the resultant magnitude, vertical support resistance generally increases with time to reflect additional support loading during the mining cycle. Being the major component of the resultant force, the vertical force profiles are nearly identical to that of the resultant (fig. 9). Since the leg cylinders provide nearly all of the supports' resistance to roof-to-floor strata convergence, vertical support resistance is strongly correlated to the leg reaction, as shown in the parametric sensitivity study in table 1 and depicted in figure 10. Analysis indicates that the vertical support resistance is generally overpredicted by 3 to 5 pct from leg force data alone, the accuracy being determined by the amount of horizontal load present and the configuration of the support.

Horizontal Support Reactions

Horizontal load is a primary design consideration for the shield support, with approximately 25 pct of the structure dedicated to the resistance of horizontal loading. Generally speaking, the shield support is designed to resist horizontal loads of up to 30 pct of the rated vertical capacity of the support.

The basis for this design criterion is the 0.30 coefficient of friction between steel and coal measure strata, assuming horizontal load is generated by relative motion between the canopy and the immediate mine roof.

Horizontal support reactions indicated horizontal loading to be present on all shield cycles and of sufficient magnitude to warrant design consideration. Horizontal forces of up to 50 pct of the measured vertical support resistance were observed, but values of 25 to 30 pct are considered typical of observed support behavior. Examples of horizontal force profiles are shown in figure 11. While the horizontal force was generally found to increase with time during the mining cycle, cases of both constant horizontal force (shield cycles 3-6 of figure 12) and decreasing horizontal force (shield cycles 1-6 of figure 13) were observed. A more detailed analysis of horizontal shield loading is presented in a separate section of the report, where the source of the observed loading is examined in detail.

Resultant Location

The location of the resultant force acting on the support canopy is a measure of roof activity and effectiveness of the support to control the strata. The general trend is for the resultant location to move slightly toward the rear of the support as the mining cycle progresses; however, there are numerous cases where the resultant force remains stationary. Generally, the resultant load is positioned close to the leg line, which is considered the ideal position, since

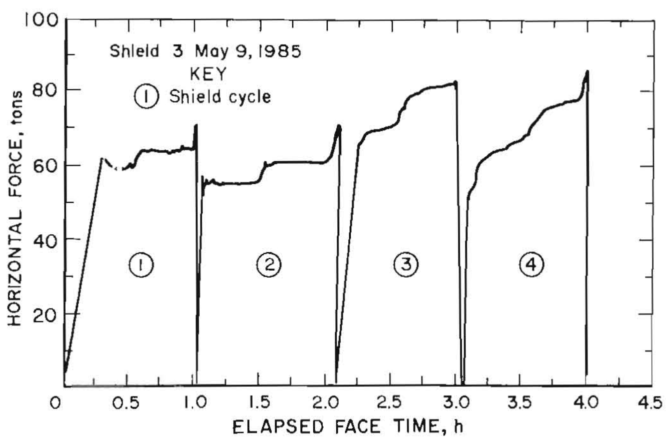

FIGURE 11.—Examples of horizontal shield loading.

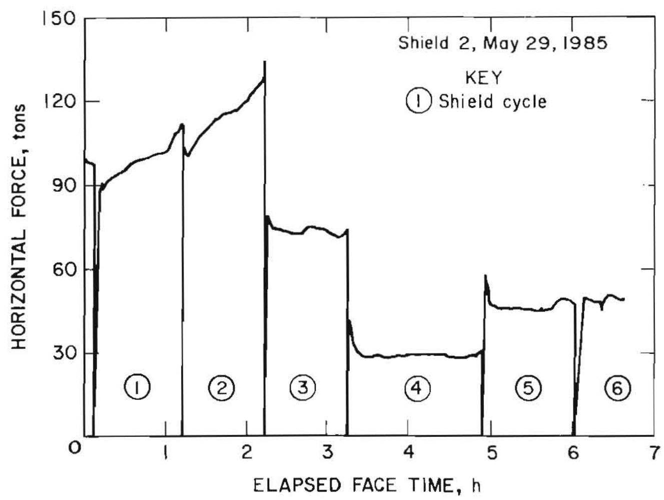

FIGURE 12.—Examples of nearly constant horizontal loading.

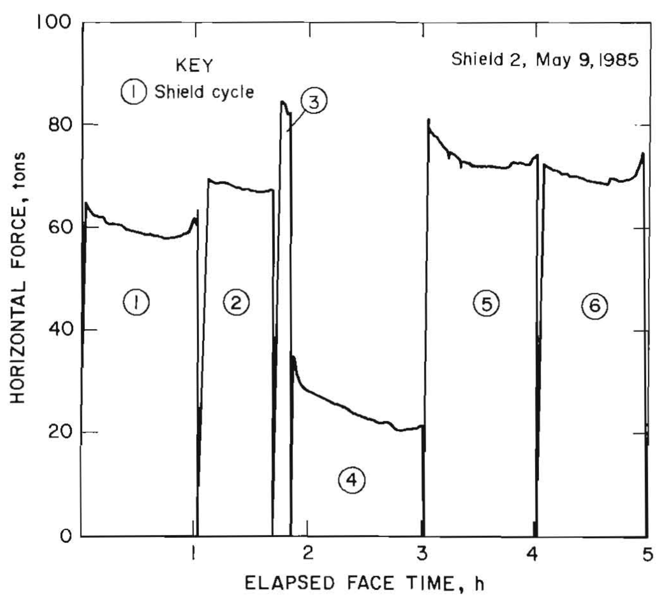

FIGURE 13.—Examples of decreasing horizontal loading.

at this location the leg force offers the maximum support resistance. Positions were found to exist both forward and rearward of the leg line, although the forward position is the most dominant one. The resultant location is dependent upon the setting pressure achieved, but is also influenced by the force exerted by the canopy capsule during the mining cycle. Examples of typical resultant force locations are shown in figure 14.

Resultant Angle

The resultant angle is a measure of the direction of the resultant force acting on the roof support canopy. Generally speaking, since the resultant force is comprised of both a vertical and a horizontal component, the resultant force acts at some angle other than vertical to account for both the roof-to-floor and face-to-waste displacement of the mine roof.

Although there were cases observed where the resultant angle increased after the support was set, the more common behavior was for the direction of the resultant force to become more vertical or remain constant during the mining cycle. The resultant angle also changed significantly from set to set (shield cycle to shield cycle) as a result of differing setting pressures and contact surface conditions with the mine roof. Examples of resultant angle measurements are shown in figure 15.

TIME-WEIGHTED AVERAGE LOAD ANALYSIS

The loads acting on a roof support element change during the mining cycle to reflect the activity of the roof and floor strata. Therefore, meaningful loads can be determined by averaging the loads over the time interval of the mining cycle. Time-weighted average loads are presented for each load parameter. The average loads presented, while not being the maximum loads observed, are considered meaningful design information since the maximum loads generally occur over a relatively small time frame. In terms of strata activity, time-weighted average load provides a meaningful measure of support resistance over the mining cycle. The loads presented below incorporate time-weighted averages using all four instrumented shields as the sample population.

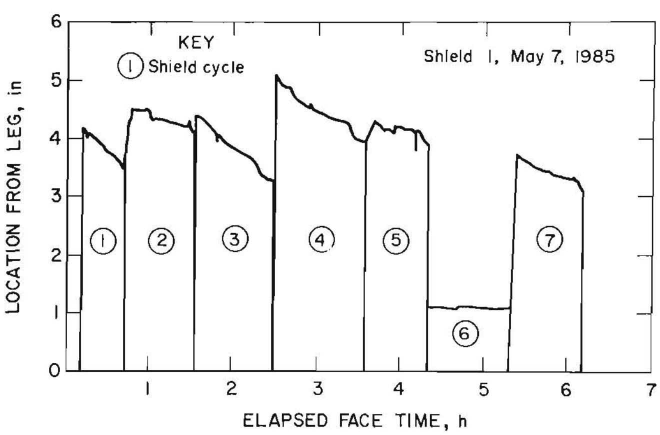

FIGURE 14.—Examples of location profiles of resultant force acting upon shield.

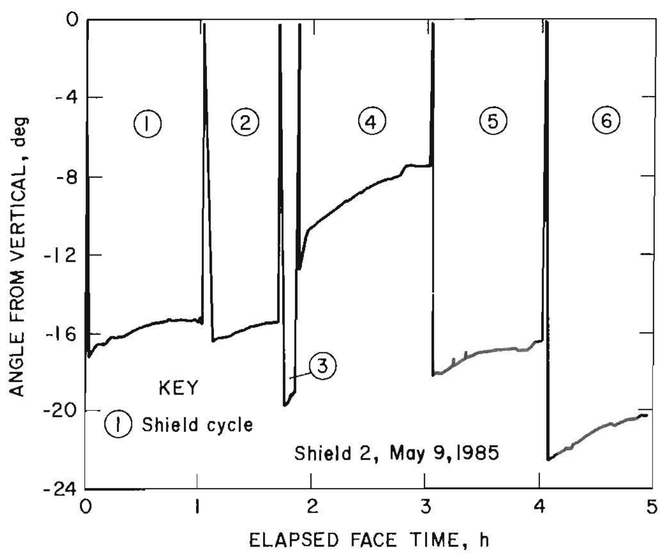

FIGURE 15.—Examples of the inclination at which resultant force acts.

Resultant Force

The time-weighted average resultant support resistance ranged from 56 to 384 st, producing an average force of 223 st with a standard deviation of 56 st. As can be seen from the histogram of time-weighted average loads shown in figure 16, the resultant force is normally distributed, indicating an unbiased representative sample. From the probability distribution shown in figure 16, it is seen that 50 pct of the time, the average resultant force will not exceed approximately 240 st. Comparing this to the rated shield capacity of 460 st, 50 pct of the time only half of the shield capacity is utilized, considering average loading during a shield cycle. (The reader should remember that these values are in reference to average loads rather than maximum loads.) It can also be shown that the probability is 72 pct that the average resultant force will be between 150 and 275 st, or roughly between one-third and two-thirds of the support capacity.

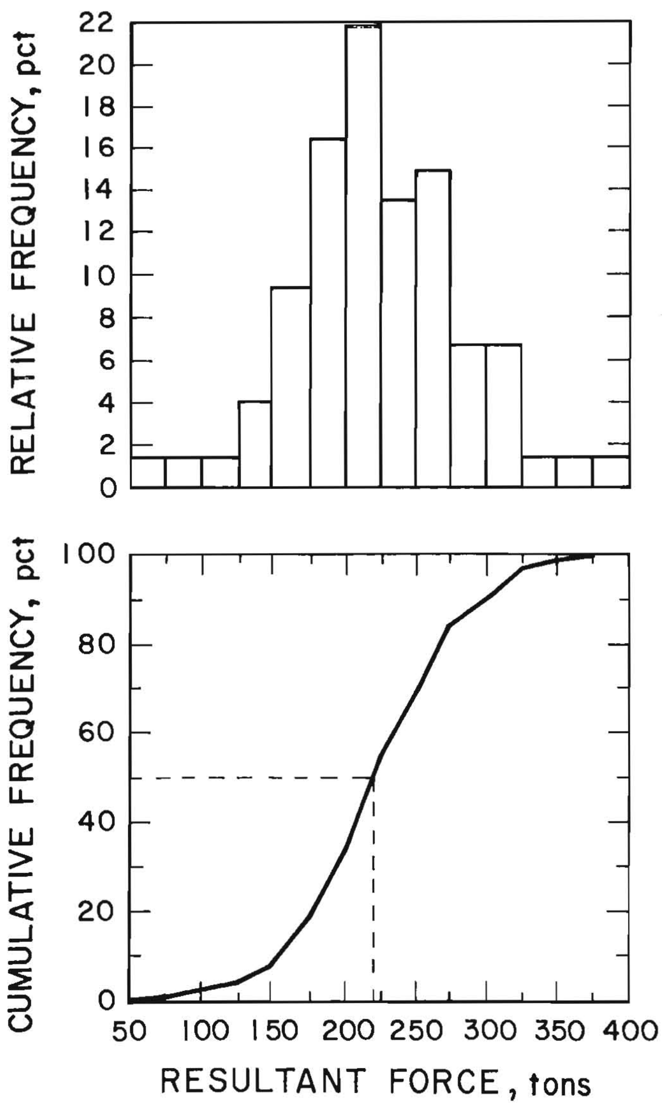

FIGURE 16.—Time-weighted average resultant magnitude shield loading.

Vertical Support Reactions

Statistical inferences relative to vertical support resistance are similar to those for the resultant force since vertical support resistance is the dominant component of the resultant force. Average vertical support resistance ranged from 54 to 378 st with a mean of 214 st and a standard deviation of 54 st. Since the vertical force is generally referred to as support capacity, less than 50 pct of support capacity is utilized on the average when considering average loading during the mining cycle. The probability is 86 pct that the average vertical support resistance will be between 150 and 325 st.

Horizontal Support Reactions

Analysis of the histogram of time-weighted average horizontal shield load reveals a higher variance in the data compared to the vertical support resistance. The data are fairly normally distributed with a mean average horizontal force of 60 st and a standard deviation of 24 st. Compared to the design capacity of 30 pct of rated support capacity, the mean average horizontal force is less than 43 pct of the rated 140-st design capacity. Comparing the mean average horizontal force of 60 st to the mean average vertical force of 214 st, horizontal loads of 28 pct of the vertical load can be expected for this application. Average horizontal loads were found to range from 5 to 110 st with an 85-pct probability that the average load is between 30 and 100 st.

Resultant Location

Average resultant locations were found to range from 1.7 in rearward of the leg line to 6 in forward of the leg line with a mean value of 2.0 in forward of the leg line and a standard deviation of 1.5 in. The 7.7-in range over which the position of the resultant load varied is considered to be well within the stable range for the shield. As indicated previously, the changes in resultant locations from set to set were due largely to inconsistent canopy capsule behavior and partly to the range of setting pressures experienced by the supports. The probability is 79 pct that the average resultant location for any given shield cycle will be between 0.5 and 4.5 in forward of the leg line.

Resultant Angle

Average resultant angle measurements, which are an indication of horizontal loading experienced by the support, were found to range from 24° to 6° from vertical acting in a roof-to-floor and/or face-to-waste direction. The larger the deviation from vertical, the higher the horizontal loading. The ratio of the horizontal to vertical force, equal to the tangent of the resultant angle, is defined as the coefficient of friction acting between the canopy structure and the immediate mine roof. Corresponding to the range of average resultant angle measurements, computed coefficients of friction were found to range from 0.44 to 0.10. The distribution of resultant angle measurements and associated probability distribution is shown in figure 17. The mean average resultant angle was 15.3° with a standard deviation of 4°. The probability is 78 pct that the average resultant angle will be between 22° and 10°, producing horizontal to vertical force ratios of 0.40 to 0.18.

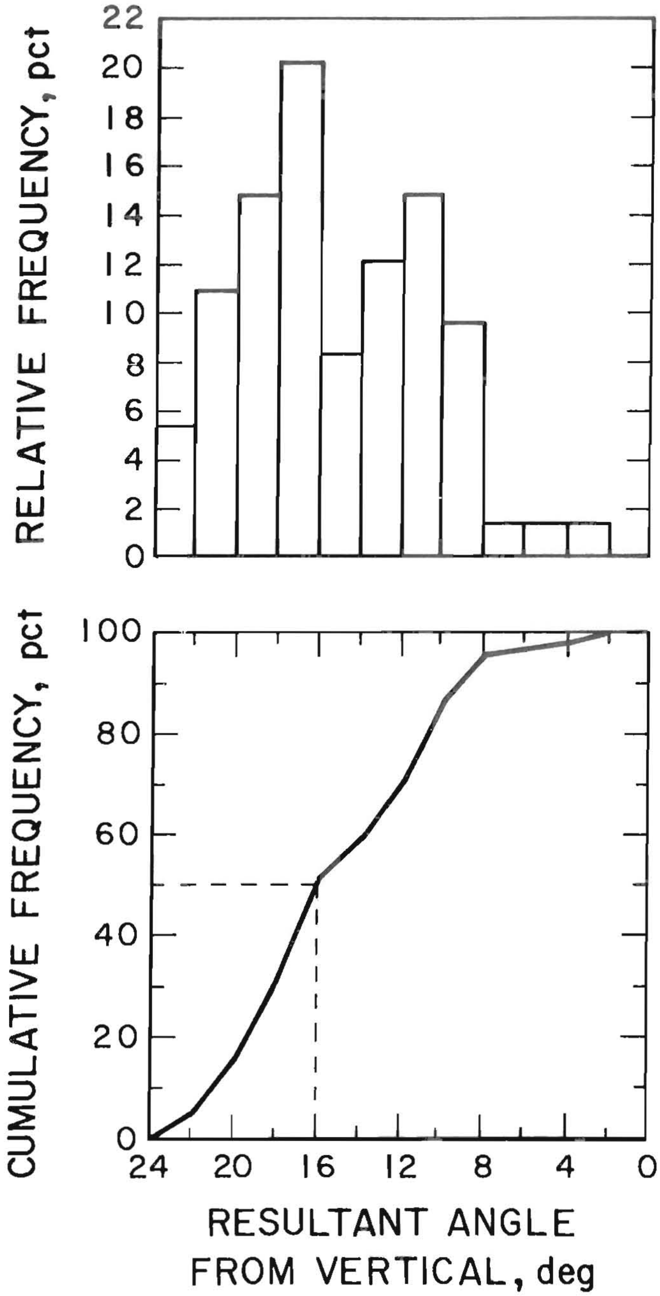

FIGURE 17.—Time-weighted average resultant angle measurements.

PEAK RESULTANT LOADING

Time-weighted average load results presented in the previous section provided meaningful data on expected shield behavior, but design considerations must be given to peak loading conditions. This section presents analysis of maximum shield load. All four instrumented shields are included in the sample population.

Resultant Force

The maximum resultant force was found to range from 63 to 398 st for the 75 shield cycles observed, with a mean of 253 st and a standard deviation of 65 st. The relative frequency histogram and associated probability distribution for the maximum resultant force are shown in figure 18. The probability is 87 pct that the maximum resultant force will be between 150 and 350 st and 76 pct that the maximum resultant force will be less than 300 st, or 65 pct of the rated shield capacity. It can be seen from figure 18 that the majority of the shield loading occurs considerably below the peak load experienced. Statistically, loads within 5 pct of the peak load occur less than 10 pct of the time.

Vertical Force

Vertical support reactions were found to range from 61 to 383 st with a mean of 243 st and a standard deviation of 47 st. The relative frequency distribution and associated probability distribution are shown in figure 19. Comparing the vertical force to the resultant force, it is

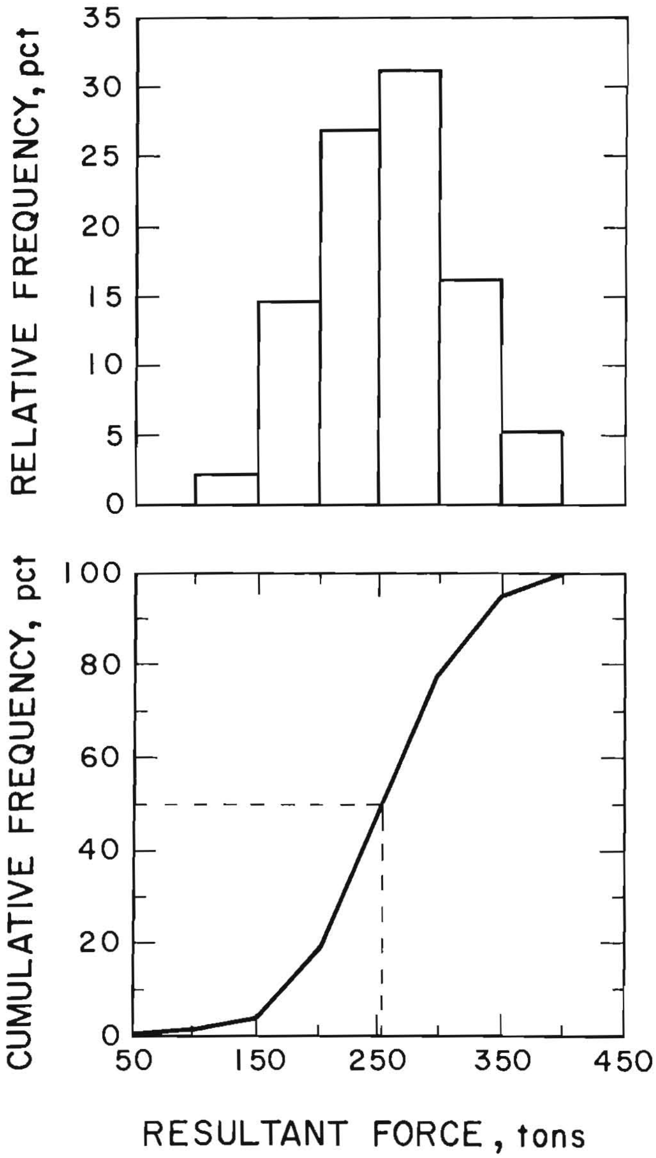

FIGURE 18.—Frequency distribution of peak magnitude loading.

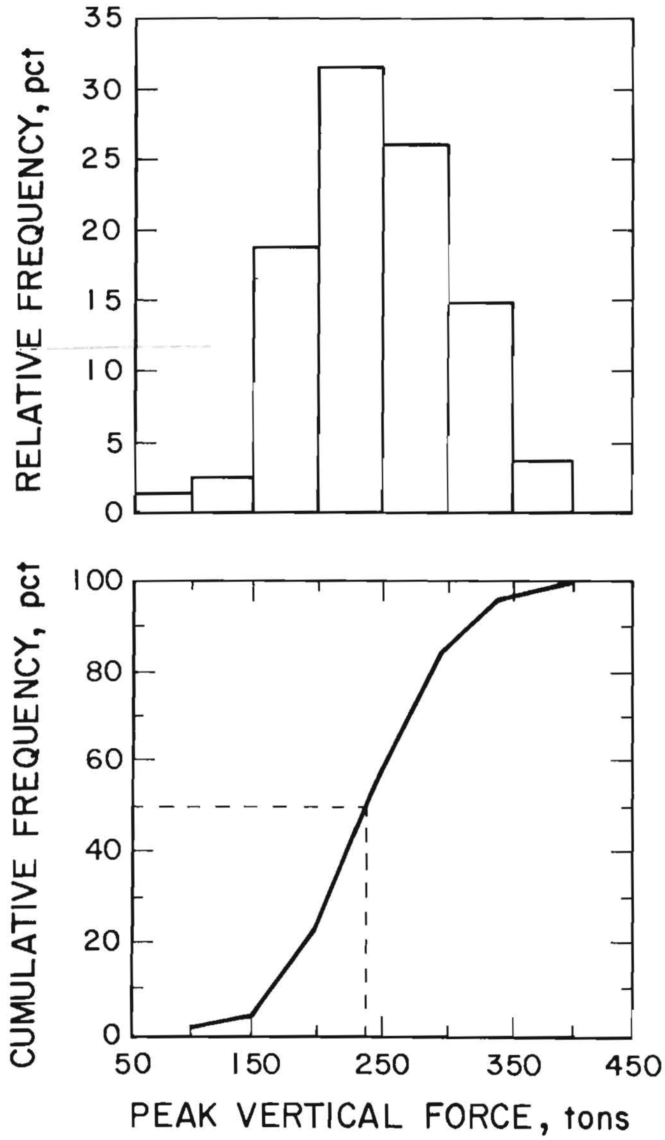

FIGURE 19.—Frequency distribution of peak vertical shield loading.

seen that over 95 pct of the resultant force consists of vertical support resistance. As indicated previously, vertical force is most often referred to as support capacity, and from the probability distribution in figure 19, it is seen that the probability is 89 pct that 35 pct of the shield capacity will never be utilized even during peak shield loading.

Horizontal Force

The average of the maximum horizontal load measured during each load cycle was 70 st, which is about one-half the considered design capacity of 30 pct of the rated vertical shield capacity of 460 st. The highest horizontal load observed was 135 st, or about 98 pct of the design capacity. As can be seen from figure 20, peak horizontal shield loading is fairly normally distributed, but with considerable variance in the data with a standard deviation of 30 st.

Resultant Location

The maximum deviation of the position of the resultant force from the ideal location at the leg line was found to vary from 6.8 in forward of the leg line to 2.5 in rearward of the leg line. The average maximum location was 2.1 in forward of the leg line. The probability is 85 pct that the position of the resultant location at its farthest from the leg line during any given mining cycle will be 0 to 7 in forward of the leg line.

Resultant Angle

The maximum inclination of the resultant force acting on the roof support element was found to vary from 26° to 2° from vertical in a direction that implies face-to-waste shield loading. The mean peak angle was 17° with a standard deviation of approximately 5°. The probability is 51 pct that the maximum angle is less than 16.7°, corresponding to the hypothetical design friction coefficient of 0.30 for contact between the canopy and immediate roof strata.

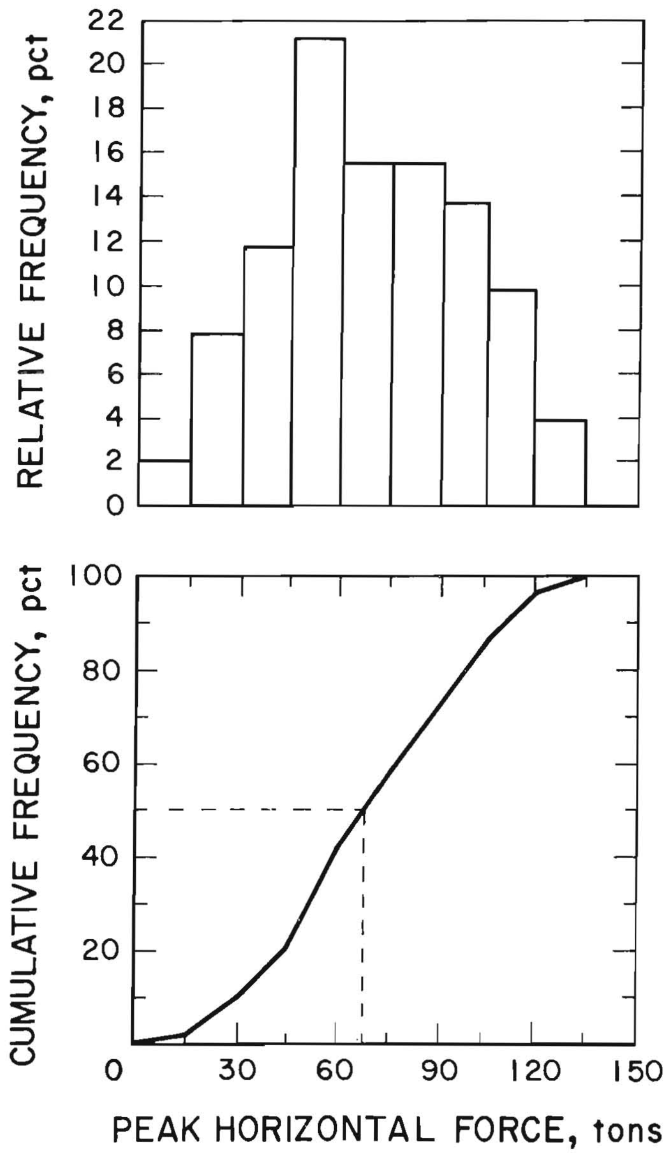

FIGURE 20.—Frequency distribution of peak horizontal shield loading.

SHIELD ACTIVITY DURING THE MINING CYCLE

The time-weighted average load and peak load results presented in previous sections provide meaningful data of expected shield behavior, but design considerations must be given to the change in loading that occurs during the mining cycle, since a considerable portion of the load is experienced immediately upon setting of the support or occurs for a relatively brief period. To analyze shield activity during the mining cycle, the change in loading from the setting of the support to release for the next mining cycle is evaluated. The change in resultant loading during the mining cycle is also normalized by expressing the change in load after support setting as a percentage of peak loading.

Resultant Force

As previously indicated, the resultant force consistently increases with time during the mining cycle, but the change in resultant force after the support is set is relatively small. The average change in resultant force after setting of the support was found to be 49 st, compared to an average peak load of 253 st. Expressed as a percentage of peak loading, the change in resultant force equaled only 19 pct of the peak load, meaning that 81 pct of the load resulted from setting of the support against the roof. Typical resultant force plots were shown in figure 8. From figure 8, it is seen that rate of change of resultant force is dependent upon activities within the mining cycle, with increased rates of loading occurring immediately after setting of the support and following the passage of the shearer. For shield cycle 2 in figure 8, the overall loading rate for the complete mining cycle is approximately 0.7 st/min, with a rate of 1.8 st/min occurring at shearer passage.

Vertical Force

As with the resultant force, the change in vertical support resistance after the support is set is relatively small in comparison to peak loading. The average change in vertical support resistance after support setting was 48 st, equaling 20 pct of the mean peak load observed. As previously discussed, the behavior of the vertical force is nearly identical to that of the resultant magnitude.

Horizontal Force

A similar relationship exists with the horizontal component of the resultant force, with 77 pct of the horizontal force experienced by the shield occurring at support setting. The average change in horizontal force after support setting was found to be 16 st, or 23 pct of the total horizontal load experienced by the support. Horizontal support reactions after support setting ranged from 3 to 54 st, a fairly wide range of loads; the probability is 63 pct that the change in horizontal load will be less than 20 st (fig. 21).

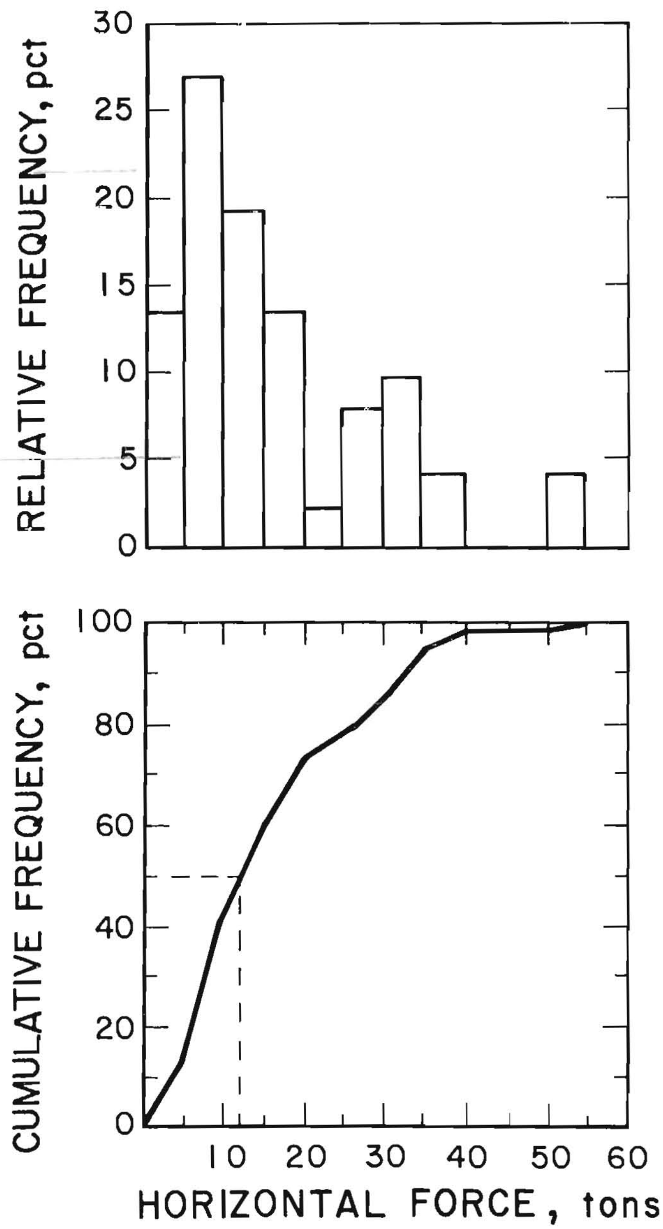

FIGURE 21.—Frequency distribution of the change in horizontal load after support setting.

Generally speaking, horizontal load profiles were of similar shape to vertical load profiles; however, the proportionality between the two measures did not remain constant from set to set, indicating different loading phenomena were occurring. A more detailed analysis of horizontal shield loading is presented later in the report.

Resultant Location

The position of the resultant force acting upon the support canopy changed very little after the support was set, indicating constrained roof behavior, as would be expected with cantilevered strata. The average change in resultant location was approximately 0.5 in, and the probability is 54 pct that the change in resultant location is less than 1 in.

Resultant Angle

While there were considerable variations in the angle at which the resultant force acted from set to set, the resultant angle changed very little once the suport was set. This indicates that the contact condition between the canopy and the immediate mine roof remained constant. The small change in resultant angle also is an indication that the horizontal force is increasing in direct proportion to the vertical force.

The general behavior was for the resultant angle to become more vertical as the mining cycle progressed. The average change in the resultant angle was approximately 2° toward vertical. The probability is only 10 pct that the resultant angle would increase (become less vertical). An increase in the resultant angle would mean that the horizontal load was increasing at a faster rate than the vertical force acting on the roof support element.

COMPARISON OF MIDFACE AND HEADGATE LOADING

A comparison of midface and headgate loading is of interest since the mining practice was to remove more coal at the gate ends to make room for equipment while leaving poor-quality coal at the top of the seam. The average extraction height at the headgate was 68 in compared to 50 in at midface. Since the shield geometry changes as a function of height, this provides an opportunity to evaluate different support configurations under similar loading conditions as well as load distribution at midface and the headgate.

As can be seen from the summary of loading presented in table 2, larger loads were experienced at midface than at the headgate. On average, the two midface shields experienced mean loads of 14 st and peak loads of 31 st higher than the two headgate shields. More horizontal loading was also experienced by the midface shields than by the headgate shields. The ratio of horizontal force to vertical force also increased significantly for the midface shields in comparison to the headgate shields, as indicated by the resultant angle. The location of the resultant force was farther from the leg line for the midface shields than for the headgate shields,

TABLE 2. - Comparison of midface (MF) and headgate (HG) loading

Resultant load vector parameter	Time-weighted average load		Peak load		Change in load	
	MF	HG	MF	HG	MF	HG
Resultant force.....st..	230	216	268	237	67	29
Vertical force......st..	219	210	256	229	65	28
Horizontal force....st..	69	49	83	53	22	9
Location............in..	23	1.7	2.3	1.9	0.5	0.5
Angle..............deg..	177	12.7	19.4	14.3	2.9	1.7

indicating increased tip loading; however, the change in resultant location after the support was set was of equal magnitude for both the headgate and tailgate shields.

Expressed in terms of percent differences between midface and headgate loading as shown in table 2, the change in parameter loading was considerably greater than the time-weighted average and peak loading for respective resultant load parameters, except for the resultant location parameter. The percent difference in the change in horizontal and vertical support loading was of similar magnitude, but the average and peak horizontal load percent differences were significantly greater for the horizontal force than for the vertical force. Of the five resultant load parameters shown in table 2, horizontal load exhibited the most variation in headgate and midface loading. The probability that the change in horizontal load is less than 15 st is 29 pct for midface shields and 80 pct for headgate shields. Likewise, there is an increased probability that the resultant angle will change for the midface shields in comparison to the headgate shields.

If the variation in load is normalized by expression of the change in support loading after support setting as a percentage of peak loading as shown in table 3, it is seen that load change was more severe for the midface shields than for the headgate shields despite the differences in total loading. This would indicate a higher degree of immediate strata behavior (caving) at the midface, which would be expected if it is assumed that the first few headgate shields receive benefit from the support provided by the gate-road pillars.

TABLE 3. - Comparison of change in midface (MF) and headgate (HG) loading normalized to peak loading, percent

Resultant load vector parameter	MF	HG
Resultant force..........st..	0.25	0.12
Vertical force...........st..	0.25	0.12
Horizontal force.........st..	0.27	0.17
Location.................in..	0.21	0.26
Angle...................deg..	0.15	0.12

EVALUATION OF HORIZONTAL SHIELD LOADING

The shield support is characterized by the caving shield-lemniscate system which connects the canopy to the base structure and provides stability to the support against horizontal loading. Horizontal loading is a primary design consideration, being the basis foı the shield concept, with approximately 25 pct of the structure dedicated to the resistance of horizontal loading. Despite being a primary design consideration, the degree of horizontal loading experienced by shield supports underground is relatively unknown, largely because past evaluations of longwall supports have been limited to measurement of leg pressures only, which forbid determination of horizontal loading. As described previously, horizontal loading can only be determined by resolution of the resultant force acting upon the support element through proper kinematic analysis of the support structure. Face-to-waste movement of the strata is not the only force that produces a horizontal shield load. Analysis of the shield mechanics shows that vertical (roof-to-floor) strata convergence also produces a horizontal load reaction. The leg cylinder of a two-legged shield support is generally inclined at some angle, producing a horizontal component of the leg force (fig. 22) that reacts to vertical roof convergence, producing the same effect as the face-to-waste displacement of strata. Since the leg force increases with roof-to-floor convergence,

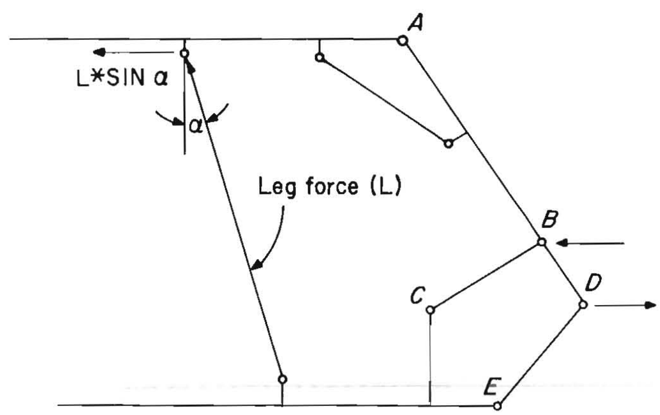

FIGURE 22.—Analysis of internal shield forces.

horizontal loading due to the leg force is likely to increase during the mining cycle. In summary, horizontal force reactions in the shield are produced by relative motion between the canopy and the base and can be either--

Strata generated - by face-to-waste displacement of the strata, or
Shield generated - by internal shield forces reacting to roof-to-floor convergence of the strata.

The implication is that only the strata-generated horizontal loads need to be resisted for successful application of the longwall mining method, since roof-to-floor convergence can be adequately controlled by a chock-type structure.

Analysis of the horizontal shield load measurements provides evidence that a considerable portion of the horizontal load is the result of the shield reaction to vertical roof convergence and is not induced by horizontal displacement of the mine roof. Examination of the horizontal force profiles reveals that in all cases considerable horizontal load is experienced immediately upon setting of the support. Since the roof strata have not had an opportunity to displace upon support setting, all of the horizontal load experienced during support setting is shield-induced by the mechanics of the structure. Figure 21 depicts the change in horizontal load for the sample population of four shields. From the figure, it is seen that the change in horizontal load expressed as a percentage of peak horizontal load was about 23 pct. Therefore, at least 77 pct of the total horizontal load experienced by the shield was due to setting of the support, none of which would have been experienced by a chock-type structure.

The question then becomes, how significant is the 23 pct of the horizontal load experienced during the mining cycle and how much of this load is self-induced by the shield reacting to roof-to-floor convergence as opposed to being strata-induced by face-to-waste strata activity? The average magnitude of the change in horizontal load was about 15 st. While an analysis of a chock-type support has not been made, loads of this magnitude are relatively small and possibly could be resisted by a chock-type structure. While loads of 15 st may be considered somewhat insignificant, changes in horizontal load after support setting as large as 50 st were observed on occasion, which would warrant design consideration. Further analysis of horizontal loading provides evidence that the majority of the horizontal load experienced during the mining cycle is self-induced due to reaction of the support to roof-to-floor convergence and is not due to horizontal strata displacement. Evidence to support this analysis follows:

1. The resultant angle generally remained fairly constant or became more vertical as the mining cycle progressed. A constant resultant angle would imply the horizontal force was increasing in direct proportion to the vertical force, which would be indicative of shield-induced loading reacting to roof-to-floor strata convergence. Resultant angles that become more vertical as the mining cycle progresses are an indication of the support slipping on the mine roof with a decreased rate of horizontal loading.

2. Horizontal load profiles were of similar shape to vertical load profiles, as shown in figure 23. Again, this is an indication of horizontal loading being produced by the support reacting to roof-to-floor convergence. An unconstrained roof being displaced in a face-to-waste direction should act somewhat independently of the vertical convergence and produce horizontal load profiles that do not mimic vertical load profiles.

3. Preliminary analysis derived from a linear elastic model of the shield structure, which relates vertical and horizontal shield displacements to vertical and horizontal force based upon the compliance of the shield structure in these respective axes, indicates a large percentage of the horizontal load is generated by reaction of the structure to roof-to-floor convergence compared to face-to-waste strata movement. The model has not

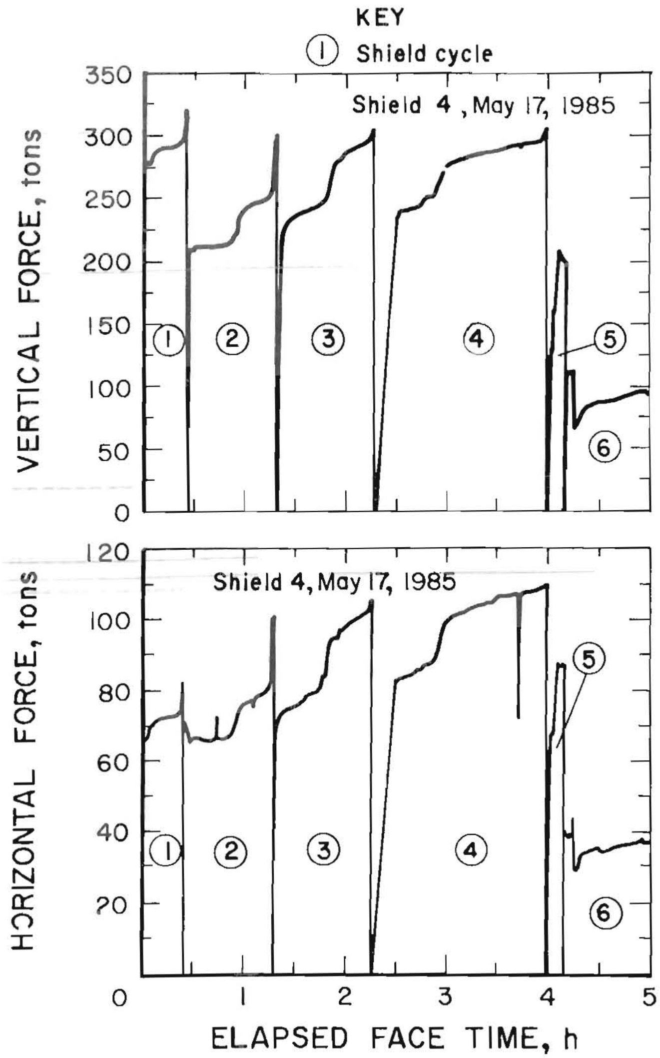

FIGURE 23.—Similarity in shape between horizontal and vertical load profiles.

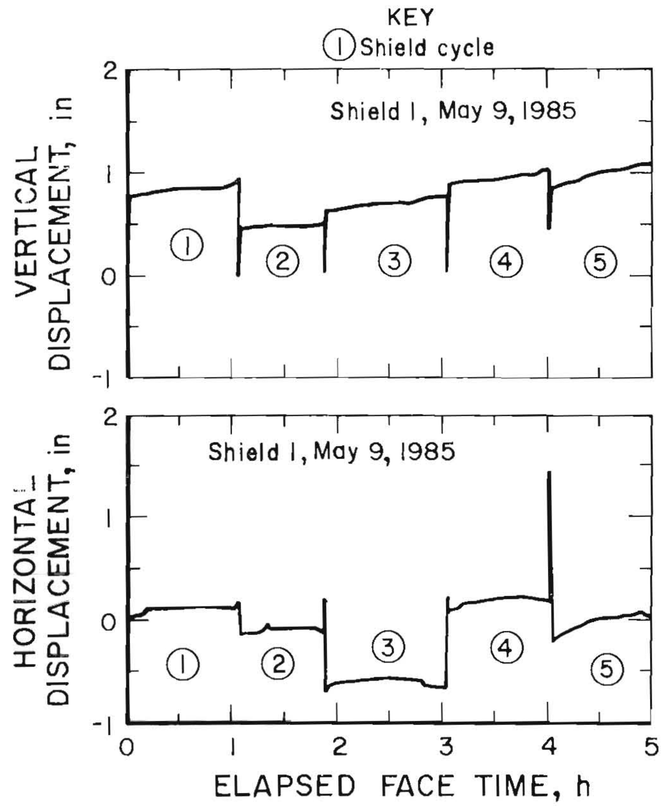

FIGURE 24.—Example of shield displacement activity.

been refined to be used quantitatively, but qualitatively shows general shield behavior. An example of the shield displacements deduced from horizontal and vertical force measurements is shown in figure 24. Decreasing horizontal loads show canopy displacements toward the face, whereas increasing horizontal loads show displacement toward the gob. Several load cases were observed with increasing horizontal loads but relatively constant horizontal displacement, which implies the horizontal load was the result of vertical roof convergence.

DATA CORRELATIONS

Change in resultant force and setting load. - Since increased face convergence has been reported to occur at reduced setting pressures, it would be reasonable to expect increased support loading to also occur at reduced setting loads. A plot of the change in resultant force versus resultant force at support setting (fig. 25) found no such correlation to exist. One possible explanation for the lack of correlation is that the range of setting forces observed was too small to alter roof behavior, or all setting forces achieved were sufficient to prevent increased bed separation and strata convergence.

Change in resultant force and peak loading. - There is a weak correlation between the change in resultant force and the associated peak resultant force

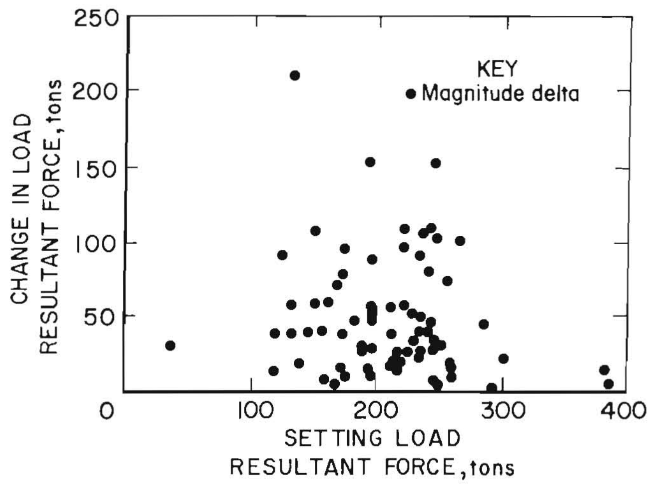

FIGURE 25.—Correlation between change in resultant magnitude and setting load.

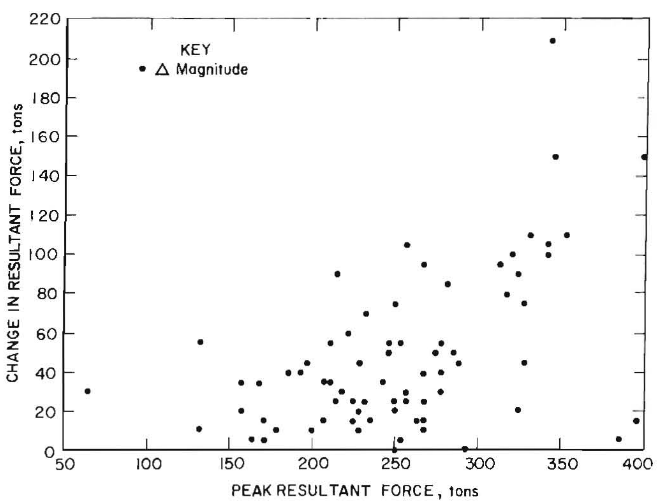

FIGURE 26.—Correlation between change in resultant force and peak shield loading.

(fig. 26). While the correlation is weak, there is a trend suggesting that the larger the peak load, the higher the change in the magnitude of the resultant force acting upon the support. Assuming a constant setting force, a correlation between the change in loading and maximum loading might be expected. The scatter in the data is partly due to inconsistent setting forces, but more probably represents differing roof behavior from shield cycle to shield cycle.

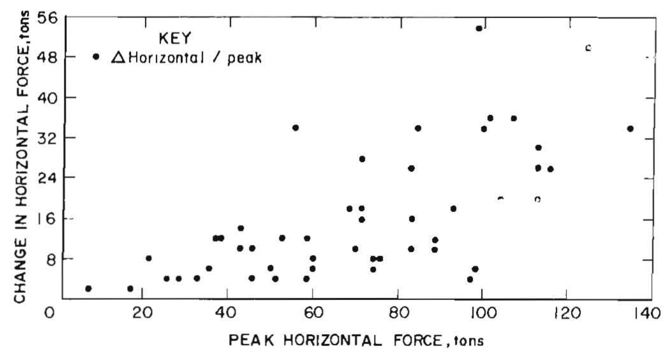

FIGURE 27.—Correlation between change in horizontal load and peak horizontal load.

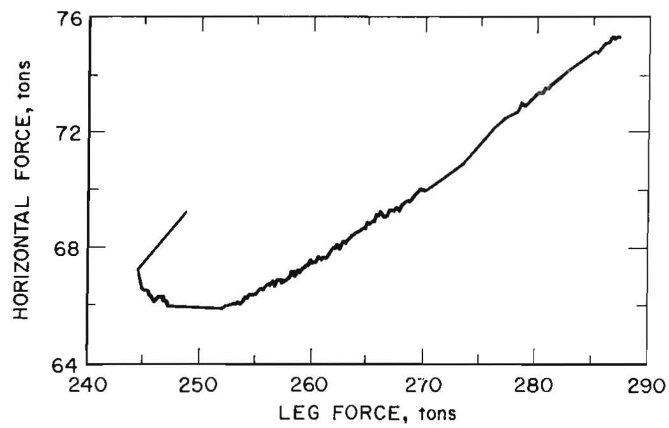

FIGURE 28.—Correlation between horizontal load and leg force.

Change in horizontal load and peak horizontal load. - A similar relationship exists between the change in horizontal force and peak horizontal force as with the change in resultant force and peak loading. The trend of increased change in horizontal force with increased peak horizontal loading is shown in figure 27. As with the resultant force, the correlation is weak.

Horizontal load and leg force. - A fairly strong correlation exists between horizontal load and leg force occurring during an individual shield cycle (fig. 28). The correlation between horizontal load and leg force is further indication that the horizontal force observed is a reaction of the shield to vertical roof convergence.

Resultant location and canopy capsule force. - The resultant location is primarily dependent upon the leg force and the canopy capsule force. The correlation between canopy capsule force and resultant location is provided in figure 29.

SET-TO-YIELD LOAD ANALYSIS

Set to yield ratios ranging from 0.33 to 0.69 were observed. Yield load of the support is determined at 6,700-psi leg pressure, producing the rated capaciy of the support of 460 st. Average set-to-yield ratios were fairly consistent among the four instrumented supports, ranging from 0.46 to 0.53. As previously indicated, there appears to be little correlation between setting loads and subsequent support loading. As such, the set-to-yield ratio appears to have little effect on support loading.

NONTYPICAL SHIELD BEHAVIOR

For the most part, there was a high degree of consistency in shield behavior; however, there were a few observations that were not typical of normal shield behavior.

Effect of canopy capsule bleedoff on shield loading. - The canopy capsule cylinder acts at such an angle relative to the plane of the canopy as to have little effect on support capacity, and therefore has little effect on the magnitude of the resultant force. However, in a two-leg shield design, the canopy capsule cylinder plays an important role in controlling the attitude of the canopy and the stiffness of the canopy-caving shield member. While the canopy capsule cylinder has little influence on the magnitude of the resultant force, it does significantly affect the location of the resultant force acting upon the support canopy. Shield cycle 5 of figure 30 illustrates a canopy capsule that was unable to hold pressure after being set against the roof, resulting in a sharp reduction in capsule force as the mining

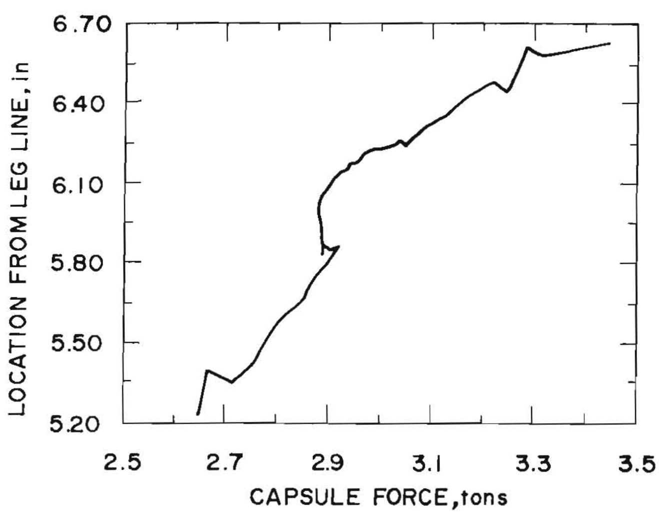

FIGURE 29.—Correlation between resultant location and canopy capsule force.

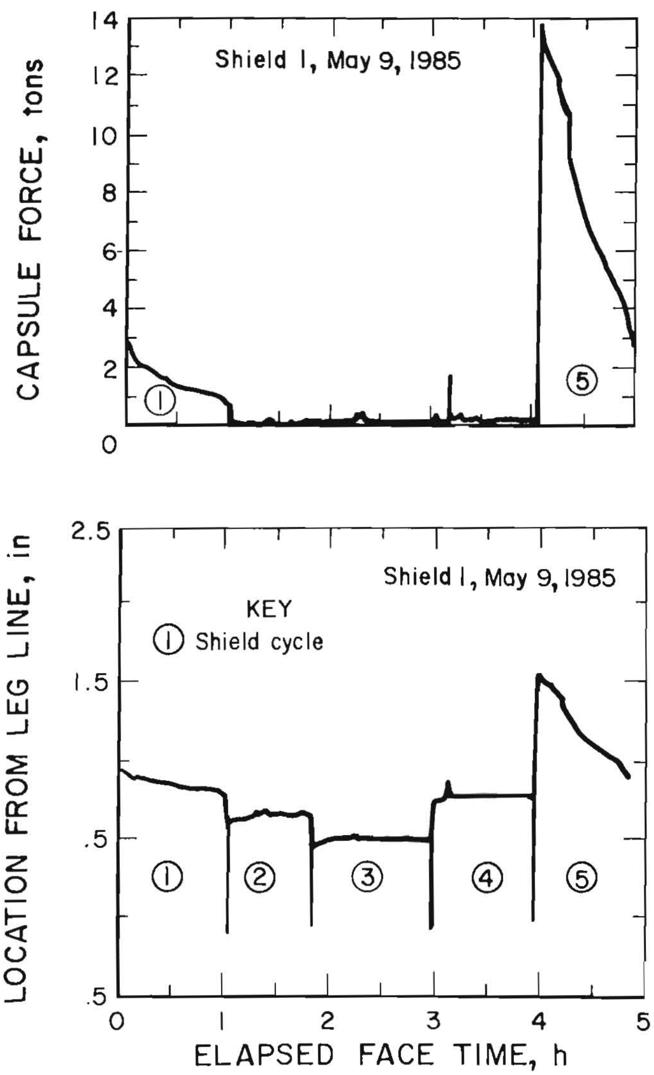

FIGURE 30.—Effect of canopy capsule force on resultant location.

cycle progressed. The effect of the reduced capsule force is shown in figure 30, where the resultant location moved toward the rear of the support at an advanced rate in comparison to the other shield cycles.

Reduction in shield loading after shearer passage. - Normal shield response exhibits a continued increase in shield reaction during the entire mining cycle with increased rates of loading immediately after passage of the shearer and during advancement of the adjacent shields. Abnormal behavior is illustrated in figure 31, particularly shield cycles 2 and 3, which illustrates a drastic load increase immediately after shearer passage (approximately one-third through mining cycle 3 at 2.75 h of elapsed face time). Such response would be indicative of the roof breaking at the face line, causing an immediate deadweight load on the support. The rapid increase in load was followed by a less rapid decrease in load up to the point where the adjacent shields were advanced. One possible explanation for this behavior would be that a portion of fractured strata fell off the rear of the support. The change in resultant location toward the canopy tip supports this claim.

Decreasing horizontal load profiles. - As discussed previously, the horizontal load was generally found to increase during the mining cycle; however, there were isolated cases where the horizontal load actually decreased as the mining cycle progressed. Of particular interest are cases such as shield cycles 5 and 7 in figure 32, where horizontal load decreased among several cycles of increasing horizontal load. This change in load, however, does not necessarily indicate a change in roof behavior. As described previously, the examples of decreasing horizontal load profiles indicate the canopy could be slipping on the mine roof. Therefore, the decreasing horizontal load profiles probably are the result of a change in contact friction between the immediate mine roof and the support canopy and not a change in the displacement action of the mine roof. Another explanation would be the presence of unusually large gob shield loading.

Decreasing horizontal load with increasing leg force. - Normally, an increase in leg force causes an increase in horizontal load as the shield reacts to vertical roof convergence. In the cases of decreasing horizontal load described above, this situation is no longer true. However, it is probably true that in these cases the horizontal load is being generated by the increase in leg force, but the immediate roof contact friction is such that it cannot sustain it.

Inactive load profiles with normal set loads. - Generally, a significant load increase is experienced by a support that has been properly set against the mine

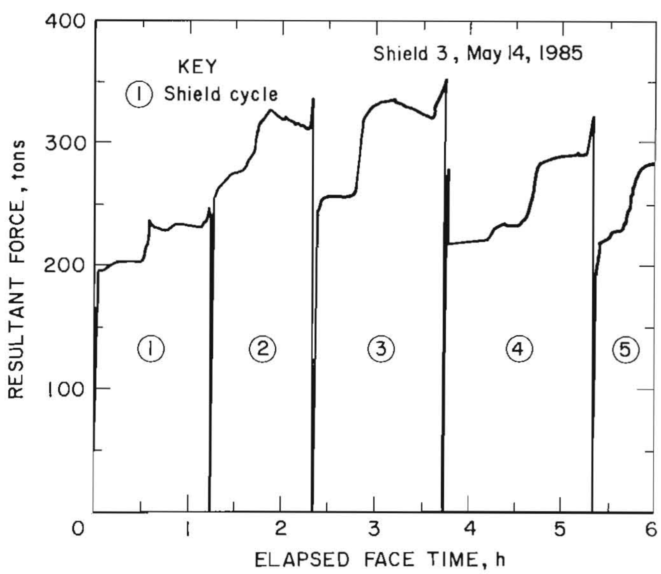

FIGURE 31.—Reduction in shield load after shearer passage.

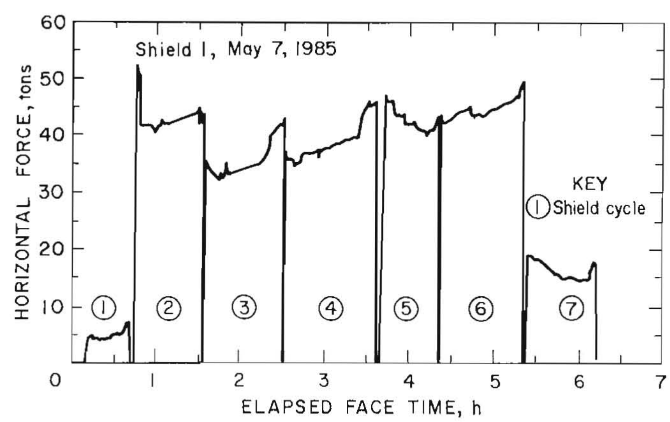

FIGURE 32.—Analysis of decreasing horizontal load profiles.

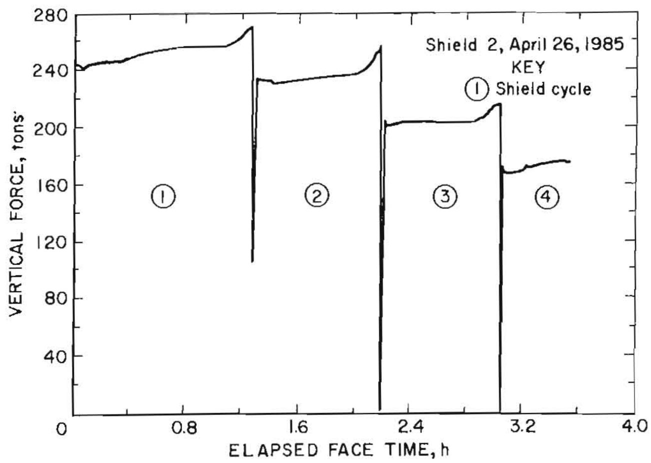

FIGURE 33.—Examples of inactive shield loading.

roof. However, as indicated by figure 33, the fourth shield cycle shows very little response despite similar setting load to other shield cycles. From this it can only be deduced that the roof was being supported elsewhere, and a reasonable assumption would be that the strata are bridging between adjacent supports. Since the adjacent supports were not instrumented, this hypothesis cannot be verified. It is interesting to note that the trend of inactive loading continued for several shield cycles. Another possible explanation for such response would be bridging of the intermediate strata, causing a periodic support weighting. Again, data were not taken on a daily basis to verify the existence of any periodic shield weighting.

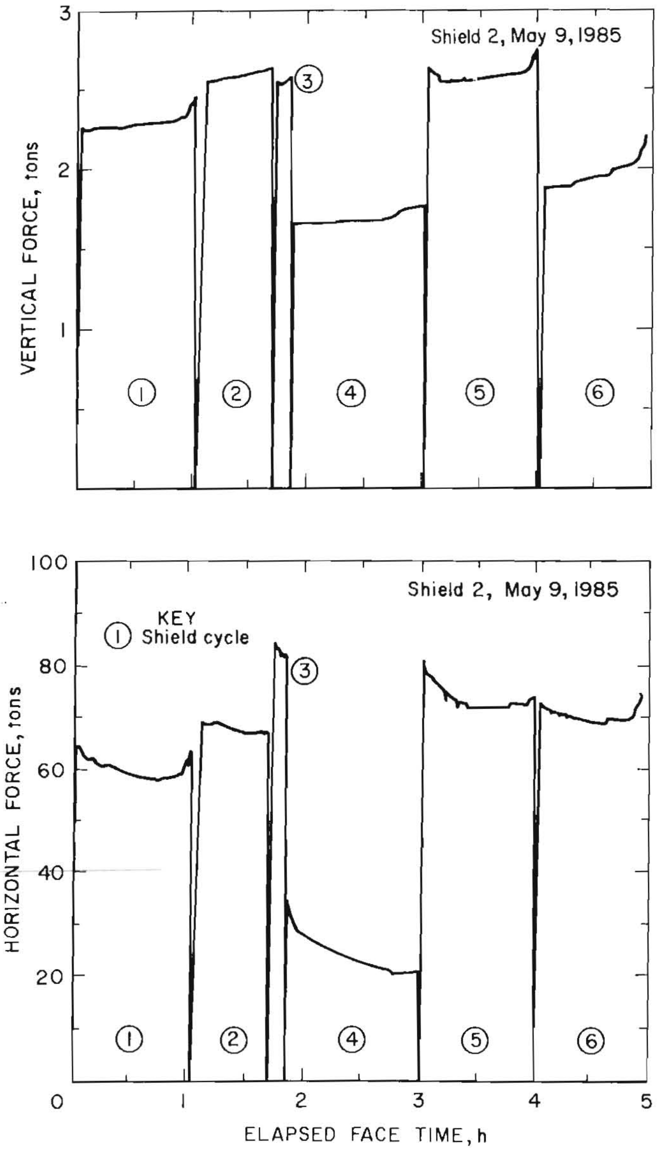

FIGURE 34.—Inconsistent horizontal to vertical force ratios.

Inconsistent horizontal-to-vertical-force ratios. - Generally, the horizontal-to-vertical-force ratio from shield cycle to shield cycle follows a consistent pattern where a reduction in the vertical force level from one cycle to the next is accompanied by a similar reduction in horizontal loading. As can be seen from figure 34, the vertical force magnitude decreased significantly from shield cycle 5 to 6, while the horizontal load remained at approximately the same level. The change in horizontal-to-vertical-force ratios is an indication of changing roof behavior, since the mechanics of the support should produce consistent horizontal-to-vertical-force ratios for shield-induced horizontal loading.

CONCLUSIONS

Analysis of roof support behavior should include determination of both vertical and horizontal support reactions and the location of the resultant force acting on the structure, which are unattainable from leg pressure measurements alone. The conclusions drawn from the resultant load vector measurements on four instrumented shields follow:

1. Resultant shield loading (horizontal and vertical support reactions) cannot be determined from leg forces alone. A comparison of leg force to the resultant force shows differences in excess of 20 pct, depending on the amount of horizontal loading present.

2. Vertical shield load can generally be predicted to within 5 pct from the vertical component of the leg force.

3. The four shields under investigation, operating at 50-pct capacity about half the time, were not utilized to the fullest capacity.

4. The shields experienced a relatively small increase in load after being set. Over 80 pct of the resultant loading was experienced upon support setting. Average increase in load during the mining cycle was approximately 50 st. This behavior indicates a stable roof of competent strata which remains intact and caves regularly behind the supports.

5. Midface loading was consistently higher than headgate loading. On average, midface shields experienced about 30 st of additional load compared to headgate shields.

6. Horizontal loading was present on nearly all shield cycles and was of sufficient magnitude to warrant design consideration. Average horizontal load was less than 50 pct of design capacity, assuming design capacity to equal 30 pct of rated shield (vertical) capacity. The probability is 85 pct that the horizontal load experienced by the support is between 30 and 100 st.

7. The change in horizontal load after support setting was relatively small--about 16 st, or 23 pct of the total horizontal load experienced. Over 75 pct of the horizontal loading was experienced upon support setting.

8. Horizontal load was both strata-generated by face-to-waste displacement of the mine roof and shield-generated by internal shield forces reacting to vertical roof convergence. The majority of the horizontal load experienced by the shield support appears to be due to vertical roof convergence.

9. The shields remained very stable under all loading conditions observed. The location of the resultant force was well within the stable range for the support and changed very little during the mining cycle.

10. Average set-to-yield ratios among the four instrumented supports ranged from 0.40 to 0.53. There appeared to be little correlation between setting loads and subsequent support behavior.

RECOMMENDATIONS

An expanded database is needed to further analyze shield behavior, and recommendation is made to continue these efforts on other supports and longwall faces. Efforts also need to be expanded to include analyses and correlation of rock mass behavior with support loading studies under different geologic conditions. The long-range objective of this research is to develop a more effective predictive model for determining support capacity requirements. Knowledge of support behavior and load conditions may also provide the basis for improved support design concepts.

APPENDIX A.--SOLUTION OF SHIELD SUPPORT STATIC EQUILIBRIUM EQUATIONS

The generic equations from which resultant shield loading is determined were presented on page 4. The derivation of these equations is presented in this appendix. Reference is made to figure 3 of the text in this discussion.

Solution of the three resultant load vector parameters (magnitude, location, angle) requires three independent equations in accordance with the laws of static equilibrium. These equations are derived as follows:

Summation of moments about canopy hinge pin (fig. A-1):

$$\Sigma\ M(A) \circlearrowleft + = -VERT * LOC + L * COS\ (\alpha) * (X6-X3) + N * SIN\ (\theta) * (X5-X3) + N * COS\ (\theta) * (Y5-YR4) = 0. \qquad (A\text{-}1)$$

Summation of moments about instantaneous link center (fig. A-2):

$$\Sigma\ M(I) \circlearrowleft + = -VERT * \{LOC + (X3-X0)\} + HORZ * (Y3-Y0) + L * COS\ (\alpha) * (X6-X0) - L * SIN\ (\alpha) * (Y3-Y0) = 0. \qquad (A\text{-}2)$$

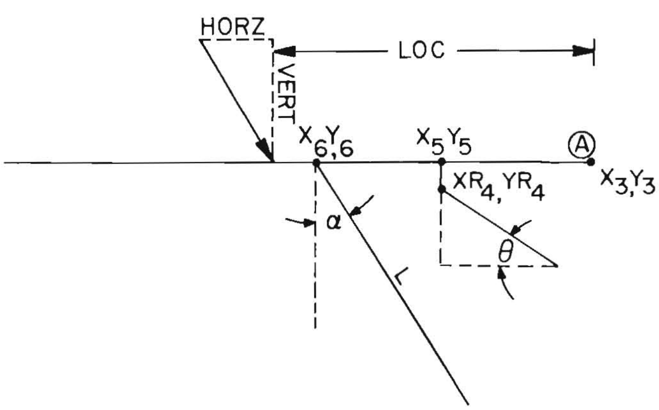

FIGURE A-1.—Summation of moments about canopy hinge pin.

Summation of moments about tension link-caving shield hinge pin (fig. A-3):

$$\Sigma\ M(T) \circlearrowleft + = -VERT * \{LOC + (X3-X1)\} + HORZ * (Y3-Y1) + L * COS\ (\alpha) * (X6-X1) - L * SIN\ (\alpha) * (Y3-Y1) - C * COS\ (\beta) * (Y2-Y1) - C * SIN\ (\beta) * (X2-X1) = 0. \qquad (A\text{-}3)$$

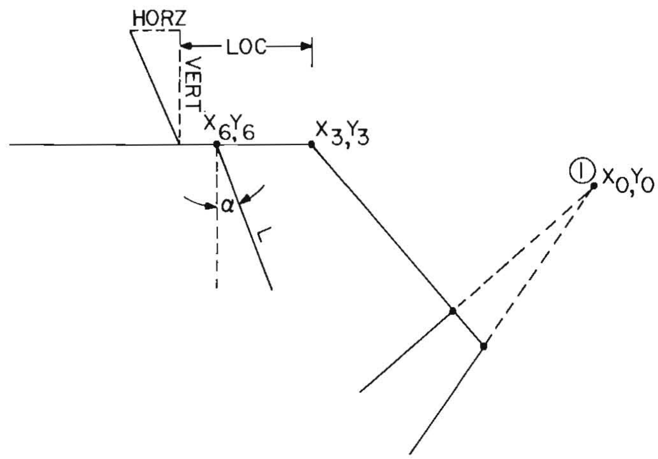

FIGURE A-2.—Summation of moments about instantaneous link center.

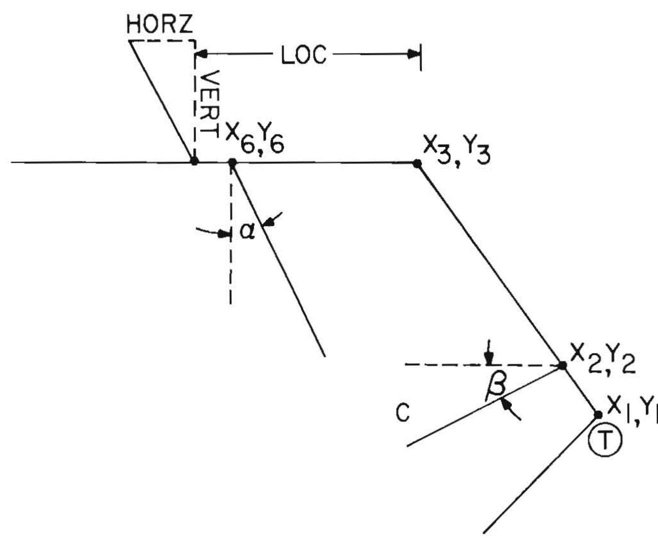

FIGURE A-3.—Summation of moments about tension link-caving shield hinge pin.

Solution of these equations is as follows:

Step 1: Solve equation A-2 for HORZ

$$HORZ = [VERT * \{LOC + (X3-X0)\}$$

$$- L * COS (\alpha) * (X6-X0)$$

$$+ L * SIN (\alpha) * (Y3-Y0)]$$

$$/ (Y3-Y0).$$

Step 2: Solve equation A-1 for VERT * LOC

$$VERT * LOC = L * COS (\alpha) * (X6-X3)$$

$$+ N * SIN (\theta) * (X5-X3)$$

$$+ N * COS (\theta) * (Y5-YR4).$$

Step 3: Substitute VERT * LOC from step 2 and HORZ from step 1 into equation A-3 and solve for VERT

$$VERT = (A + B + C - D + E - F - 6)$$

$$/ (H - I),$$

where

$$A = L * COS (\alpha) * (X6-X3) * CONS1,$$

$$B = N * SIN (\theta) * (X5-X3) * CONS1,$$

$$C = N * COS (\theta) * (Y5-YR4) * CONS1,$$

$$D = L * COS (\alpha) * (X6-X3) * CONS2,$$

$$E = L * COS (\alpha) * (X6-X1),$$

$$F = C * COS (\beta) * (Y2-Y1),$$

$$G = C * SIN (\beta) * (X2-X1),$$

$$H = X3-X1,$$

$$I = (X3-X0) * CONS2,$$

and

$$CONS1 = (Y3-Y1)/(Y3-Y0) + 1,$$

$$CONS2 = (Y3-Y1)/(Y3-Y0).$$

Step 4: Substitute VERT * LOC from step 2 and VERT from step 3 into equation A-1 to determine HORZ

$$HORZ = VERT * LOC/(Y3-Y0)$$

$$+ VERT * (X3-X0)/(Y3-Y0)$$

$$- L * COS (\alpha) * (X6-X0)$$

$$/ (Y3-Y0) + L * SIN (\alpha).$$

Step 5: Solve equation from step 2 for LOC

$$LOC = VERT * LOC / VERT.$$

Step 6: By geometry, the resultant angle equals arctangent of VERT to HORZ ratio

$$ANG = Arc\ tangent\ (VERT/HORZ).$$

APPENDIX B.--FIELD INSTRUMENTATION AND DATA ACQUISITION SYSTEM SPECIFICATIONS

The field instrumentation system included the following components:

- Pressure transducers.
- Strain gauges.
- Switch and balance units.
- Strain indicators.
- Bridge completion circuits.
- Junction boxes.

Details of the first four components and of transducer identification follow:

Pressure transducers

Load range - 5,000, 10,000 psi full scale.

Accuracy - +1 pct, ±0.25 pct, respectively.

Excitation - 10 V dc.

Hydraulic connection - 1/4-in National pipe thread.

Electrical connection - 6-pin Bendix connector.

Strain gauges

Type - weldable, resistance.

Resistance - 120 ohms.

Precision - ±1 pct.

Switch and balance units

Type - Vishay model SB-1, SB-2.

MSHA approval No. 2G-2548-2.

Channels - 10 separate.

Zero balance up to 7,000 $\mu\varepsilon$ gauge factor = 2.0 1/4, 1/2, or full bridge compatibility.

Strain indicator

Type - Vishay model P-3500 (digital).

Range - ±19,999 $\mu\varepsilon$.

Accuracy - ±0.05 pct of reading, ±3 $\mu\varepsilon$ for gauge factor settings 1.0 to 99.

Resolution - ±1 $\mu\varepsilon$.

Internal dummy gauges for 120- and 350-ohm quarter bridges.

Power - six "D" cell batteries.

MSHA approval No. 2G-35333-0.

Transducer identification - Each shield was instrumented with eight transducers identified as follows:

LL - Left leg pressure transducer.

RL - Right leg pressure transducer.

CE - Canopy capsule pressure transducer.

CR - Canopy capsule retraction pressure transducer.

RTF - Right link top surface strain gauge.

LTF - Left link top surface strain gauge.

RTR - Right link bottom surface strain gauge.

LTR - Left link bottom surface strain gauge.

APPENDIX C.--DATA ACQUISITION SYSTEM CALIBRATION PROCEDURES AND RESULTS

The complete data acquisition system from the sensor to the strain indicator was calibrated after installation underground. Since it was impossible to physically load the sensors when installed on the shields, electrically simulated loads were applied to each channel using a Vishay model 1550A strain indicator to simulate unbalance of the bridge sensor network.

The procedure was to remove the appropriate sensor from the circuit, install the 1550A calibrator, and apply known loads in specified increments. The response of the data acquisition system was then measured by the strain indicator, providing calibration of the circuit from the sensor through data transmission lines (excluding the bridges for strain gauges) and through the switch and balance unit to the strain indicator.

In addition to calibration of the data acquisition system, zero adjustments for each sensor were made. The pressure transducers were zeroed by removing them completely from the hydraulic circuit and zeroing the output with the potentiometer provided for that specific channel in the switch and balance unit. Since the strain gauges could not be physically removed from the shield, an artificial zero was obtained by lowering the shield to remove all roof load and then balancing the bridge network with the switching unit's potentiometer.

In addition, the gauge factor of each strain gauge was adjusted to account for load line resistance. Conversion of the raw data into engineering units was then made by multiplying the strain indicator readout by the appropriate scale factor derived from the calibration (sensitivity) of the individual transducer.

Data acquisition system calibration, zero adjustments, gauge factor adjustments, and sensor sensitivities are shown in tables C-1 through C-3. All transducers were zeroed prior to data collection.

TABLE C-1. - Pressure transducer calibration factors

Shield component	Rating, psi	Serial number	Calibration factor	Serial number	Calibration factor
		Shield 1		Shield 2	
LL[1]......	10,000	110476	3.0040	110470	3.0066
RL[2]......	10,000	109438	3.0033	110465	3.0011
CE[3]......	5,000	109310	3.0042	114743	3.0011
CR[4]......	5,000	114729	3.0002	114769	3.0011
		Shield 3		Shield 4	
LL[1]......	10,000	109447	3.0019	106102	3.0069
RL[2]......	10,000	109461	3.0122	110474	3.0053
CE[3]......	5,000	114725	2.9996	114726	3.0020
CR[4]......	5,000	114761	2.9978	114772	3.0022

[1]LL = Left leg. [3]CE = Canopy capsule extension.
[2]RL = Right leg. [4]CR = Canopy capsule retraction.

TABLE C-2. - Data acquisition system calibration factors

Shield component	Calibration factors			
	Shield 1	Shield 2	Shield 3	Shield 4
LL[1]......	1.0064	1.0040	1.0046	1.0033
RL[2]......	1.0057	1.0043	1.0044	1.0044
CE[3]......	1.0070	1.0035	1.0042	1.0034
CR[4]......				
RTF[5].....	1.0122	1.0072	1.0115	1.0140
LTF[6].....	1.0484	1.0087	1.0117	1.0092
RTR[7].....	1.0106	1.0086	1.0063	1.0061
LTR[8].....	1.0135	1.0077	1.0114	1.0093

[1]LL = Left leg.
[2]RL = Right leg.
[3]CE = Canopy capsule extension.
[4]CR = Canopy capsule retraction.
[5]RTF = Right link, top face.
[6]LTF = Left link, top face.
[7]RTR = Right link, bottom face.
[8]LTR = Left link, bottom face.

TABLE C-3. - Strain gauge bridge circuit data

	GR[1]	WR[2]	GF[3]	P350[4]	DSGF[5]		GR[1]	WR[2]	GF[3]	P350[4]	DSGF[5]
	Shield 1						Shield 3				
RTF[6]	120.7	0.0	2.07	2.00	2.07	RTF[6]	120.7	0.0	2.07	2.00	2.07
LTF[7]	120.2	.0	2.07	2.00	2.08	LTF[7]	120.6	.0	2.07	2.00	2.07
RTR[8]	120.6	.7	2.07	2.00	2.06	RTR[8]	120.8	.7	2.07	2.00	2.06
LTR[9]	120.6	.7	2.07	2.00	2.06	LTR[9]	120.8	.7	2.07	2.00	2.06
	Shield 2						Shield 4				
RTF[6]	120.6	0.0	2.07	2.00	2.07	RTF[6]	120.8	0.0	2.07	2.00	2.07
LTF[7]	120.8	.0	2.07	2.00	2.07	LTF[7]	120.7	.0	2.07	2.00	2.07
RTR[8]	120.8	.7	2.07	2.00	2.06	RTR[8]	120.7	.7	2.07	2.00	2.06
LTR[9]	120.8	.7	2.07	2.00	2.06	LTR[9]	120.8	.7	2.07	2.00	2.06

[1]GR = Gauge resistance, ohm.
[2]WR = Lead wire resistance, ohm.
[3]GF = Gauge factor.
[4]P350 = P350 gauge factor setting.
[5]DSGF = Desensitized gauge factor.
[6]RTF = Right link, top face.
[7]LTF = Left link, top face.
[8]RTR = Right link, bottom face.
[9]LTR = Left link, bottom face.

APPENDIX D.--DATA PROCESSING AND REDUCTION SOFTWARE

```
1     REM ******************** PROGRAM NAME -- EMFILE ************************
10 DIM Nodtpt(500)
20 REM  DATA FILE CREATION PROGRAM
40 PRINTER IS 16
50 PRINT "THIS PROGRAM CREATES A FILE(S) FROM FIELD DATA."
60 PRINT LIN(3),"PLEASE FOLLOW THE INSTRUCTIONS CAREFULLY AND INPUT DATA IN THE
FORMAT REQUESTED!"
70 PRINT LIN(3),"IF YOU MAKE A MISTAKE WHILE ENTERING THE DATA FOR THE SHIELDS,D
ON'T WORRY. YOU  WILL BE ABLE TO CHANGE DATA AFTER ALL OF IT HAS BEEN ENTERED."
80 INPUT "DATE DATA WAS TAKEN?, mmddyy",Date$
90 INPUT "WAS DATA TAKEN FOR ALL FOUR SHIELDS: YES or NO",Ans$
100 IF Ans$="YES" THEN 160
110 INPUT "WAS DATA TAKEN FOR SHIELD #1",Shld$(1)
120 INPUT "WAS DATA TAKEN FOR SHIELD #2",Shld$(2)
130 INPUT "WAS DATA TAKEN FOR SHIELD #3",Shld$(3)
140 INPUT "WAS DATA TAKEN FOR SHIELD #4",Shld$(4)
150 GOTO 200
160 Shld$(1)="YES"
170 Shld$(2)="YES"
180 Shld$(3)="YES"
190 Shld$(4)="YES"
200 F$=Date$[1,4]
210 F$=F$&Date$[6,6]
220 Sh1$="1"&F$
230 Sh2$="2"&F$
240 Sh3$="3"&F$
250 Sh4$="4"&F$
260 FOR I=1 TO 4
270 IF Shld$(I)="NO" THEN 330
280 PRINT PAGE,"INPUT THE NUMBER OF DATA SETS FOR SHIELD #";I
290 PRINT LIN(3),"A data set consists of a time and data for eight transducers o
n the shield.      Hence each data set will contain nine values."
300 INPUT Nodtpt(I)
310 INPUT "SHIELD HEIGHT,inches",Shht(I)
320 GOTO 340
330 Nodtpt(I)=1
340 NEXT I
350 CREATE Sh1$,Nodtpt(1)+4,74
360 CREATE Sh2$,Nodtpt(2)+4,74
370 CREATE Sh3$,Nodtpt(3)+4,74
380 CREATE Sh4$,Nodtpt(4)+4,74
390 ASSIGN #1 TO Sh1$
400 ASSIGN #2 TO Sh2$
410 ASSIGN #3 TO Sh3$
420 ASSIGN #4 TO Sh4$
430 PRINT #1,1;"EMERALD MINE-SHIELD 1"
440 PRINT #2,1;"EMERALD MINE-SHIELD 2"
450 PRINT #3,1;"EMERALD MINE-SHIELD 3"
460 PRINT #4,1;"EMERALD MINE-SHIELD 4"
470 PRINT #1,2;Date$
480 PRINT #2,2;Date$
490 PRINT #3,2;Date$
500 PRINT #4,2;Date$
510 FOR I=1 TO 4
520 PRINT #I,3;Nodtpt(I)
525 PRINT #I,4;Shht(I)
530 NEXT I
540 FOR I=1 TO 4
550 IF Shld$(I)="YES" THEN 570
```

```
560 PRINT #I,5;0,0,0,0,0,0,0,0,0
570 NEXT I
580 FOR I=1 TO 4
590 IF Shld$(I)="NO" THEN 740
600 PRINT PAGE,"INPUT DATA FOR SHIELD #";I
610 FOR J=5 TO Nodtpt(I)+4
620 PRINT LIN(3),"DATA SET";J-4
630 INPUT "TIME, hhmmss",T
640 INPUT "LEFT LEG PRESSURE (LL), microstrain",L1
650 INPUT "RIGHT LEG PRESSURE (RL), microstrain",R1
660 INPUT "CANOPY CAPSULE EXTEND PRESSURE (CE), microstrain",Ce
670 INPUT "CANOPY CAPSULE RETRACT PRESSURE (CR), microstrain",Cr
680 INPUT "RIGHT LINK FORWARD GAGE STRAIN (RTF), microstrain",Rtf
690 INPUT "LEFT LINK FORWARD GAGE STRAIN (LTF), microstrain",Ltf
700 INPUT "RIGHT LINK REAR GAGE STRAIN (RTR), microstrain",Rtr
710 INPUT "LEFT LINK REAR GAGE STRAIN (LTR), microstrain",Ltr
720 PRINT #I,J;T,L1,R1,Ce,Cr,Rtf,Ltf,Rtr,Ltr
730 NEXT J
740 NEXT I
750 ASSIGN * TO #1
760 ASSIGN * TO #2
770 ASSIGN * TO #3
780 ASSIGN * TO #4
790 Finish=9999
800 CALL Ghost
```

```
10 REM ***************** PROGRAM NAME -- EMEDIT ****************************
100 DIM Lt$(4,999)
1300 DIM Llmx(999),Llmn(999),Rlmx(999),Rlmn(999),Cemx(999),Cemn(999),Crmx(999),C
rmn(999),Rtfmx(999),Rtfmn(999),Ltfmx(999),Ltfmn(999),Rtrmx(999),Rtrmn(999)
1400 DIM Ltrmx(999),Ltrmn(999),Nodtpt(999)
1500 DIM T(999),Ll(999),Rl(999),Ce(999),Cr(999),Rtf(999),Ltf(999),Rtr(999),Ltr(9
99)
1600 DIM File$[50],D$[50],Desc$[50]
1700 REM EMERALD MINE FILE EDIT PROGRAM
1800 PRINTER IS 16
1900 PRINT "THIS PROGRAM ALLOWS THE USER TO EDIT FILE(S) CREATED FROM RAW FIELD
DATA."
2000 PRINT LIN(3),"PLEASE FOLLOW INSTRUCTIONS CAREFULLY AND INPUT DATA IN THE RE
QUESED FORMAT!"
2005 PRINT LIN(3),"INSERT RAW DATA TAPE INTO TAPE DRIVE T15!!!"
2100 PRINT LIN(7),"PRESS CONT WHEN READY TO CONTINUE!!!"
2200 PAUSE
2300 PRINT PAGE,"INPUT THE DATE THE DATA WAS TAKEN FOR WHICH YOU WANT TO EDIT"
2400 INPUT "DATE? mmddyy",Date$
2500 DIM A$[250]
2600 PRINT PAGE
2700*PRINT "I will first make a check of the data to see is there are any obviou
s errors.   To do this, I will require you to give me maximum and minimum values
2800 PRINT "for each channel. When asked, input the maximum value, a comma, then
 the minimum value for each channel.",LIN(5)
2900 INPUT "ARE THE MAXIMUM AND MINIMUM VALUES THE SAME FOR EACH SHIELD? Y/N",An
s$
3000 FOR I=1 TO 4
3100 IF I=1 THEN 5000
3200 IF Ans$="N" THEN 5000
3300 Llmx(I)=Llmx(I-1)
3400 Llmn(I)=Rlmn(I-1)
3500 Rlmx(I)=Rlmx(I-1)
3600 Rlmn(I)=Rlmn(I-1)
3700 Cemx(I)=Cemx(I-1)
3800 Cemn(I)=Cemn(I-1)
3900 Crmx(I)=Crmx(I-1)
4000 Crmn(I)=Crmn(I-1)
4100 Rtfmx(I)=Rtfmx(I-1)
4200 Rtfmn(I)=Rtfmn(I-1)
4300 Ltfmx(I)=Ltfmx(I-1)
4400 Ltfmn(I)=Ltfmn(I-1)
4500 Rtrmx(I)=Rtrmx(I-1)
4600 Rtrmn(I)=Rtrmn(I-1)
4700 Ltrmx(I)=Ltrmx(I-1)
4800 Ltrmn(I)=Ltrmn(I-1)
4900 GOTO 10900
5000 PRINT LIN(1),"INPUT THE MAXIMUM AND MINIMUM VALUES FOR SHIELD #";I
5100 INPUT "MAX,MIN FOR LL?",Llmx(I),Llmn(I)
5200 INPUT "MAX,MIN FOR RL?",Rlmx(I),Rlmn(I)
5300 INPUT "MAX,MIN FOR CE?",Cemx(I),Cemn(I)
5400 INPUT "MAX,MIN FOR CR?",Crmx(I),Crmn(I)
5500 INPUT "MAX,MIN FOR RTF?",Rtfmx(I),Rtfmn(I)
5600 INPUT "MAX,MIN FOR LTF?",Ltfmx(I),Ltfmn(I)
5700 PRINT LIN(0)
5800 INPUT "MAX,MIN FOR RTR?",Rtrmx(I),Rtrmn(I)
5900 INPUT "MAX,MIN FOR LTR?",Ltrmx(I),Ltrmn(I)
6000 IF Ans$="Y" THEN 6300
6100 PRINT PAGE,TAB(24),"MAX/MIN VALUES FOR SHIELD #";I,LIN(1)
```

```
6200 GOTO 6400
6300 PRINT PAGE,TAB(24),"MAX/MIN VALUES FOR ALL SHIELDS"
6400 PRINT TAB(40),"MAX";SPA(6);"MIN"
6500 IMAGE 26X,3A,8X,M4D,4X,M4D
6600 PRINT USING 6500;"LL ",Llmx(I),Llmn(I)
6700 PRINT USING 6500;"RL ",Rlmx(I),Rlmn(I)
6800 PRINT USING 6500;"CE ",Cemx(I),Cemn(I)
6900 PRINT USING 6500;"CR ",Crmx(I),Crmn(I)
7000 PRINT USING 6500;"RTF",Rtfm~(I),Rtfmn(I)
7100 PRINT USING 6500;"LTF",Ltfmx(I),Ltfmn(I)
7200 PRINT USING 6500;"RTR",Rtrmx(I),Rtrmn(I)
7300 PRINT USING 6500;"LTR",Ltrmx(I),Ltrmn(I)
7400 INPUT "DO YOU WANT TO CHANGE ANY OF THESE LIMITS? Y/N",Q$
7500 IF Q$="N" THEN 10900
7600 PRINT LIN(3),"WHICH PARAMETER DO YOU WANT TO CHANGE?"
7700  PRINT LIN(1),"YOU CAN CHANGE ANY PARAMETER,BUT ONLY ONE AT A TIME,USING
THE DESIGNATIONS SHOWN ON THE SCREEN LISTING:i.e. LL,RL,CE,CR,RTF,LTF,RTR,LTR"
7800 PRINT LIN(1)
7900  INPUT "PARAMETER DESIGNATION?:",Par$
8000  IF Par$="LL" THEN 9300
8100  IF Par$="RL" THEN 9500
8200  IF Par$="CE" THEN 9700
8300 IF Par$="CR" THEN 9900
8400  IF Par$="RTF" THEN 1010
8500  IF Par$="LTF" THEN 10300
8600  IF Par$="RTR" THEN 10500
8700  IF Par$="LTR" THEN 10700
8800 IMAGE +,46A,1X,3A
8900  PRINT USING 8800;"ERROR MESSAGE - INVALID PARAMETER DESIGNATION:",Par$
9000 INPUT "PARAMETER DESIGNATION:",Par$
9100 PRINT "                                                              "
9200 GOTO 8000
9300  INPUT "INPUT NEW MAX/MIN FOR LL",Llmx(I),Llmn(I)
9400  GOTO 6000
9500  INPUT "INPUT NEW MAX/MIN FOR RL",Rlmx(I),Rlmn(I)
9600 GOTO 10800
9700  INPUT "INPUT NEW MAX/MIN FOR CE",Cemx(I),Cemn(I)
9800  GOTO 6000
9900  INPUT "INPUT NEW MAX/MIN FOR CR",Crmx(I),Crmn(I)
10000 GOTO 6000
10100 INPUT "INPUT NEW MAX/MIN FOR RTF",Rtfmx(I),Rtfmn(I)
10200 GOTO 6000
10300 INPUT "INPUT NEW MAX/MIN FOR LTF",Ltfmx(I),Ltfmn(I)
10400 GOTO 6000
10500 INPUT "INPUT NEW MAX/MIN FOR RTR",Rtrmx(I),Rtrmn(I)
10600 GOTO 6000
10700 INPUT "INPUT NEW MAX/MIN FOR LTR",Ltrmx(I),Ltrmn(I)
10800 GOTO 6000
10900 NEXT I
11000 F$=Date$[1,4]
11100 F$=F$&Date$[6,6]
11200 Sh1$="1"&F$
11300 Sh2$="2"&F$
11400 Sh3$="3"&F$
11500 Sh4$="4"&F$
11600 ASSIGN #1 TO Sh1$
11700 ASSIGN #2 TO Sh2$
11800 ASSIGN #3 TO Sh3$
11900 ASSIGN #4 TO Sh4$
```

```
12000 FOR I=1 TO 4
12100 READ #I,1;File$
12200 READ #I,2;D$
12300 READ #I,3;Nodtpt(I)
12400 FOR J=5 TO Nodtpt(I)+4
12500 READ #I,J;T(J-4),L1(J-4),R1(J-4),Ce(J-4),Cr(J-4),Rtf(J-4),Ltf(J-4),Rtr(J-4
),Ltr(J-4)
12600 IF L1(J-4)<L1mn(I) THEN 14200
12700 IF L1(J-4)>L1mx(I) THEN 14200
12800 IF R1(J-4)<R1mn(I) THEN 14200
12900 IF R1(J-4)>R1mx(I) THEN 14200
13000 IF Ce(J-4)<Cemn(I) THEN 14200
13100 IF Ce(J-4)>Cemx(I) THEN 14200
13200 IF Cr(J-4)<Crmn(I) THEN 14200
13300 IF Cr(J-4)>Crmx(I) THEN 14200
13400 IF Rtf(J-4)<Rtfmn(I) THEN 14200
13500 IF Rtf(J-4)>Rtfmx(I) THEN 14200
13600 IF Ltf(J-4)<Ltfmn(I) THEN 14200
13700 IF Ltf(J-4)>Ltfmx(I) THEN 14200
13750 IF Rtr(J-4)<Rtrmn(I) THEN 14200
13800 IF Rtr(J-4)>Rtrmx(I) THEN 14200
13900 IF Ltr(J-4)<Ltrmn(I) THEN 14200
14000 IF Ltr(J-4)>Ltrmx(I) THEN 14200
14100 GOTO 15500
14200 Lt$(I,J-4)="*"
14300 PRINT PAGE,"DATA SET #";J-4;"FOR SHIELD #";I;"EXCEEDED THE LIMITS FOR ONE
OR MORE OF THE DATA     VALUES",LIN(2)
14400 IMAGE 2X,3A,2X,4A,5X,A,7X,2A,5X,2A,5X,2A,5X,2A,5X,3A,4X,3A,4X,3A,4X,3A
14500 PRINT USING 14400;"SH#","REC#","T","LL","RL","CE","CR","RTF","LTF","RTR","
LTR"
14600 PRINT
14700 IMAGE 2X,2D,4X,3D,3X,6D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2
X,M4D
14800 PRINT USING 14700;I,J-4,T(J-4),L1(J-4),R1(J-4),Ce(J-4),Cr(J-4),Rtf(J-4),Lt
f(J-4),Rtr(J-4),Ltr(J-4)
14900 INPUT "DO YOU WANT TO CHANGE THIS RECORD? Y/N",Ans$
15000 IF Ans$="N" THEN 15500
15100 PRINT LIN(3),"PLEASE ENTER THE CORRECT DATA FOR THIS RECORD IN THE FOLLOWI
NG FORMAT:"
15200 PRINT "LL,RL,CE,CR,RTF,LTF,LTR,RTR"
15300 INPUT L1(J-4),R1(J-4),Ce(J-4),Cr(J-4),Rtf(J-4),Ltf(J-4),Rtr(J-4),Ltr(J-4)
15400 PRINT #I,J;T(J-4),L1(J-4),R1(J-4),Ce(J-4),Cr(J-4),Rtf(J-4),Ltf(J-4),Rtr(J-
4),Ltr(J-4)
15500 NEXT J
15600 NEXT I
15610 FOR I=1 TO 4
15611 FOR J=5 TO Nodtpt(I)+4
15612 L1(J-4)=0
15613 R1(J-4)=0
15614 Ce(J-4)=0
15615 Cr(J-4)=0
15616 Rtf(J-4)=0
15617 Ltf(J-4)=0
15618 Rtr(J-4)=0
15619 Ltr(J-4)=0
15620 T(J-4)=0
15621 NEXT J
15622 NEXT I
```

```
15700 PRINT PAGE,LIN(10),"ALL DATA SETS HAVE NOW PASSED THE LIMIT DETECTION TEST
!"
15800 PRINT LIN(5),"PRESS CONT WHEN READY TO CONTINUE!!!"
15900 PAUSE
16000 PRINT PAGE,"I WILL NOW LIST ALL THE DATA SETS IN GROUPS OF 10 FOR EACH SHI
ELD FOR YOUR      REVIEW."
16010 PRINT LIN(5),"AN  *  WILL BE USED TO DESIGNATE THOSE RECORDS WHICH WERE TR
IPPED BY THE LIMIT DETECTORS!!"
16100 WAIT 2500
16200 FOR I=1 TO 4
16300 FOR J=5 TO Nodtpt(I)+4
16400 READ #I,J;T(J-4),L1(J-4),R1(J-4),Ce(J-4),Cr(J-4),Rtf(J-4),Ltf(J-4),Rtr(J-4
),Ltr(J-4)
16500 NEXT J
16600 FOR M=1 TO Nodtpt(I) STEP 10
16700 PRINT PAGE
16800 IMAGE 2X,3A,2X,4A,8X,A,7X,2A,5X,2A,5X,2A,5X,2A,5X,3A,4X,3A,4X,3A,4X,3A
16900 PRINT USING 16800;"SH#","REC#","T","LL","RL","CE","CR","RTF","LTF","RTR","
LTR"
17000 PRINT
17100 FOR N=M TO M+9
17200 IMAGE 2X,2D,4X,3D,X,A,X,3X,6D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2X
,M4D,2X,M4D
17300 PRINT USING 17200;I,N,Lt$(I,N),T(N),L1(N),R1(N),Ce(N),Cr(N),Rtf(N),Ltf(N),
Rtr(N),Ltr(N)
17400 NEXT N
17500 INPUT "ARE ALL THESE DATA VALUES CORRECT? Y/N",An$
17600 IF An$="Y" THEN 24300
17700 INPUT "INPUT THE NUMBER OF THE RECORD WHICH IS INCORRECT",L
17800 IF L<N-10 THEN 18100
17900 IF L>N-1 THEN 18100
18000 GOTO 18300
18100 PRINT "ERROR MESSAGE - RECORD CHOSEN IS NOT IN THIS DATA SET!"
18110 PRINT "                                                   "
18200 INPUT "CHOOSE ANOTHER RECORD:",L
18300 Badln=L
18400 PRINT PAGE
18500 PRINT USING 16800;"SH#","REC#","T","LL";"RL","CE","CR","RTF","LTF","RTR","
LTR"
18600 PRINT
18700 FOR N=M TO M+9
18800 IF Badln=M THEN 19000
18900 GOTO 19300
19000 IF N-M+1>1 THEN 19500
19100 PRINT CHR$(129)
19200 GOTO 20100
19300 IF N=Badln-1 THEN 19800
19400 IF N=Badln THEN 20100
19500 PRINT USING 17200;I,N,Lt$(I,N),T(N),L1(N),R1(N),Ce(N),Cr(N),Rtf(N),Ltf(N),
Rtr(N),Ltr(N)
19600 GOTO 20300
19700 IMAGE #,2X,2D,4X,3D,X,A,X,3X,6D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,2X,M4D,
2X,M4D,2X,M4D
19800 PRINT USING 19700;I,N,Lt$(I,N),T(N),L1(N),R1(N),Ce(N),Cr(N),Rtf(N),Ltf(N),
Rtr(N),Ltr(N)
19900 PRINT CHR$(129)
20000 GOTO 20300
```

```
20100 PRINT USING 19700;I,N,Lt$(I,N),T(N),L1(N),R1(N),Ce(N),Cr(N),Rtf(N),Ltf(N),
Rtr(N),Ltr(N)
20200 PRINT CHR$(128)
20300 NEXT N
20400 PRINT LIN(2),"WHICH PARAMETER DO YOU WANT TO CHANGE ON RECORD #";L
20500 PRINT LIN(1),"YOU CAN CHANGE ANY PARAMETER,BUT ONLY ONE AT A TIME,USING
THE DESIGNATIONS SHOWN ON THE SCREEN LISTING:i.e. T,LL,RL,CE,CR,RTF,LTF,RTR,LTR"
20600 INPUT "PARAMETER DESIGNATION?:",Par$
20700 IF Par$="T" THEN 22100
20800 IF Par$="LL" THEN 22300
20900 IF Par$="RL" THEN 22500
21000 IF Par$="CE" THEN 22700
21100 IF Par$="CR" THEN 22900
21200 IF Par$="RTF" THEN 23100
21300 IF Par$="LTF" THEN 23300
21400 IF Par$="RTR" THEN 23500
21500 IF Par$="LTR" THEN 23700
21600 PRINT USING 8800;"ERROR MESSAGE - INVALID PARAMETER DESIGNATION:",Par$
21700 INPUT "PARAMETER DESIGNATION?:",Par$
21800 PRINT "                                                              "
21900 GOTO 20700
22000 GOTO 20600
22100 INPUT "INPUT NEW VALUE FOR T",T(L)
22200 GOTO 23800
22300 INPUT "INPUT NEW VALUE FOR LL",L1(L)
22400 GOTO 23800
22500 INPUT "INPUT NEW VALUE FOR RL",R1(L)
22600 GOTO 23800
22700 INPUT "INPUT NEW VALUE FOR CE",Ce(L)
22800 GOTO 23800
22900 INPUT "INPUT NEW VALUE FOR CR",Cr(L)
23000 GOTO 23800
23100 INPUT "INPUT NEW VALUE FOR RTF",Rtf(L)
23200 GOTO 23800
23300 INPUT "INPUT NEW VALUE FOR LTF",Ltf(L)
23400 GOTO 23800
23500 INPUT "INPUT NEW VALUE FOR RTR",Rtr(L)
23600 GOTO 23800
23700 INPUT "INPUT NEW VALUE FOR LTR",Ltr(L)
23800 INPUT "DO YOU WANT TO CHANGE ANY MORE PARAMETERS IN THIS RECORD? Y/N",Ans$
23900 IF Ans$="Y" THEN 18400
24000 PRINT #I,L+4;T(L),L1(L),R1(L),Ce(L),Cr(L),Rtf(L),Ltf(L),Rtr(L),Ltr(L)
24100 N=M
24200 GOTO 16700
24300 NEXT M
24400 PRINT PAGE,LIN(10),"ALL DATA FOR SHIELD #";I;"HAS BEEN VERIFIED."
24500 INPUT "DO YOU WANT A HARD COPY OF THIS DATA? Y/N",Ans$
24600 IF Ans$="N" THEN 28100
24620 PRINT PAGE,LIN(10),"PLEASE BE SURE THE HIGH SPEED PRINTER IS TURNED ON!"
24630 PRINT LIN(2),"PRESS CONT WHEN READY TO CONTINUE."
24635 PAUSE
24700 READ #I,1;Desc$
24800 READ #I,2;Dat$
24900 READ #I,3;Nodtpt(I)
25000 Mo$=Dat$[1,2]&"/"
25100 Dy$=Mo$&Dat$[3,4]
25200 Dy$=Dy$&"/"
```

```
25300 Yr$=Dy$&Dat$[5,6]
25400 PRINTER IS 7,1,WIDTH(160)
25500 PRINT PAGE,TAB(52),"RAW DATA FOR SHIELD #";I
25600 PRINT LIN(2),"FILE DESCRIPTION - ";Desc$
25700 PRINT "DATE DATA WAS TAKEN:";Yr$
25800 PRINT "NUMBER OF DATA POINTS - ";Nodtpt(I),LIN(2)
25900 FOR K=1 TO Nodtpt(I) STEP 50
26000 A$="SHIELD NO."
26100 B$="RECORD NO."
26200 C$="TIME"
26300 D$="LT. LEG"
26400 E$="RT. LEG"
26500 F$="CAN. EXT."
26600 G$="CAN. RET."
26700 H$="RT.TOP GAGE"
26800 I$="LT.TOP GAGE"
26900 J$="RT.BOT GAGE"
27000 K$="LT.BOT GAGE"
27100 IMAGE 10A,3X,10A,4X,4A,6X,7A,4X,7A,4X,8A,4X,8A,3X,11A,3X,11A,3X,11A,3X,11A
27200 PRINT USING 27100;A$,B$,C$,D$,E$,F$,G$,H$,I$,J$,K$
27300 IMAGE 29X,A,10X,2A,9X,2A,9X,2A,10X,2A,11X,3A,11X,3A,11X,3A,11X,3A
27400 PRINT USING 27300;"T","LL","RL","CE","CR","RTF","LTF","RTR","LTR"
27500 FOR L=K TO K+49
27600 IMAGE 3X,2D,9X,3D,8X,8D,5X,M4D,6X,M4D,6X,M4D,7X,M4D,8X,M4D,9X,M4D,9X,M4D,9
X,M4D
27700 PRINT USING 27600;I,L,T(L),L1(L),R1(L),Ce(L),Cr(L),Rtf(L),Ltf(L),Rtr(L),Lt
r(L)
27800 NEXT L
27900 NEXT K
28000 PRINTER IS 16
28100 INTEGER Z
28200 FOR Z=1 TO Nodtpt(I)
28300 T(Z)=0
28400 L1(Z)=0
28500 R1(Z)=0
28600 Ce(Z)=0
28700 Cr(Z)=0
28800 Rtf(Z)=0
28900 Ltf(Z)=0
29000 Rtr(Z)=0
29100 Ltr(Z)=0
29200 NEXT Z
29300 NEXT I
29310 ASSIGN * TO #1
29320 ASSIGN * TO #2
29330 ASSIGN * TO #3
29340 ASSIGN * TO #4
29400 CALL Ghost
29500 END
```

```
1   REM ********************** PROGRAM NAME -- EMCONV ***************************
10 PRINTER IS 16
20 DIM Des$(4)[100],Dat$(4)[100]
30 DIM Llslope(4),Rlslope(4),Ceslope(4),Crslope(4),Rtfslope(4),Ltfslope(4),Rtrsl
ope(4),Ltrslope(4)
40 DIM Llyint(4),Rlyint(4),Ceyint(4),Cryint(4),Rtfyint(4),Ltfyint(4),Rtryint(4),
Ltryint(4)
50 DIM Llzero(4),Rlzero(4),Cezero(4),Crzero(4),Rtfzero(4),Ltfzero(4),Rtrzero(4),
Ltrzero(4)
60 DIM Llsn(4),Rlsn(4),Cesn(4),Crsn(4),Llptcal(4),Rlptcal(4),Ceptcal(4),Crptcal(
4),Llrat(4),Rlrat(4),Cerat(4),Crrat(4)
70*DIM Rtfgagres(4),Ltfgagres(4),Rtrgagres(4),Ltrgagres(4),Rtfwirres(4),Ltfwirre
s(4),Rtrwirres(4),Ltrwirres(4),Rtfgagfac(4),Ltfgagfac(4),Rtrgagfac(4),Ltrgagfac(
80 DIM Rtfset350(4),Ltfset350(4),Rtrset350(4),Ltrset350(4),Rtfcorgf(4),Ltfcorgf(
4),Rtrcorgf(4),Ltrcorgf(4)
100 DIM Lleng(4,999),Rleng(4,999),Ceeng(4,999),Creng(4,999),Rtfeng(4,999),Ltfeng
(4,999),Rtreng(4,999),Ltreng(4,999),T(4,999)
110    REM PROGRAM NAME: EMCONV
120    PRINT PAGE,"THIS PROGRAM CONVERTS DATA INTO ENGINEERING UNITS AND CREATES
A FILE FOR SUBSEQUENT PROCESSING."
130    PRINT LIN(5),"PLEASE FOLLOW INSTRUCTIONS CAREFULLY!"
135 PRINT LIN(3),"INSERT CALIBRATION TAPE INTO TAPE DRIVE T15!!!"
140    PRINT LIN(5),"PRESS CONT WHEN READY TO CONTINUE!"
150    PAUSE
160    REM DATA ACQUISITION CALIBRATION FACTORS ******
170 ASSIGN #1 TO "CALSH1"
180 ASSIGN #2 TO "CALSH2"
190 ASSIGN #3 TO "CALSH3"
200 ASSIGN #4 TO "CALSH4"
210    FOR I=1 TO 4
220    READ #I,1;Des1$,Llslope(I),Llyint(I)
230    READ #I,2;Des1$,Rlslope(I),Rlyint(I)
240    READ #I,3;Des3$,Ceslope(I),Ceyint(I)
250    READ #I,4;Des4$,Crslope(I),Cryint(I)
260    READ #I,5;Des5$,Rtfslope(I),Rtfyint(I)
270    READ #I,6;Des6$,Ltfslope(I),Ltfyint(I)
280    READ #I,7;Des7$,Rtrslope(I),Rtryint(I)
290    READ #I,8;Des8$,Ltrslope(I),Ltryint(I)
300    NEXT I
310    REM EDIT CALIBRATION FACTORS ******
320    PRINTER IS 16
330    FOR I=1 TO 4 STEP 2
340    PRINT PAGE,TAB(20),"DATA ACQUISITION CALIBRATION FACTORS"
350    PRINT LIN(3),TAB(18),"SHIELD #";I;SPA(30);"SHIELD #";I+1
360    PRINT LIN(1),TAB(17),"SLOPE";SPA(6);"Y-INT";SPA(25);"SLOPE";SPA(6);"
Y-INT"
370    IMAGE 5X,3A,5X,MD.6D,2X,MD.6D,13X,3A,5X,MD.6D,2X,MD.6D
380    PRINT USING 370;"LL ",Llslope(I),Llyint(I),"LL",Llslope(I+1),Llyint(I+1)
390    PRINT USING 370;"RL ",Rlslope(I),Rlyint(I),"RL ",Rlslope(I+1),Rlyint(I+1)
400    PRINT USING 370;"CE ",Ceslope(I),Ceyint(I),"CE ",Ceslope(I+1),Ceyint(I+1)
410    PRINT USING 370;"CR ",Crslope(I),Cryint(I),"CR ",Crslope(I+1),Cryint(I+1)
420    PRINT USING 370;"RTF",Rtfslope(I),Rtfyint(I),"RTF",Rtfslope(I+1),Rtfyint(I
+1)
430    PRINT USING 370;"LTF",Ltfslope(I),Ltfyint(I),"LTF",Ltfslope(I+1),Ltfyint(I
+1)
440    PRINT USING 370;"RTR",Rtrslope(I),Rtryint(I),"RTR",Rtrslope(I+1),Rtryint(I
+1)
450    PRINT USING 370;"LTR",Ltrslope(I),Ltryint(I),"LTR",Ltrslope(I+1),Ltryint(I
+1)
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```
460   INPUT "DO YOU WANT TO CHANGE ANY OF THESE CALIBRATION FACTORS? Y/N",Ans$
470   IF Ans$="N" THEN 1340
480   INPUT "SHIELD NUMBER FOR WHICH PARAMETER IS TO BE CHANGED: 1,2,3,4?",Shno
490   INPUT "TRANSDUCER CIRCUIT TO BE CHANGED: LL,RL,CE,CR,RTF,LTF,RTR,LTR?",Tra
ns$
500   IF Trans$="LL" THEN 630
510   IF Trans$="RL" THEN 710
520   IF Trans$="CE" THEN 800
530   IF Trans$="CR" THEN 890
540   IF Trans$="RTF" THEN 980
550   IF Trans$="LTF" THEN 1070
560   IF Trans$="RTR" THEN 1160
570   IF Trans$="LTR" THEN 1250
580   PRINT LIN(3)
590 IMAGE +,46A,1X,3A
600   PRINT USING 590;"ERROR MESSAGE - INVALID TRANSDUCER DESIGNATION";Trans$
610   PRINT "                                                                  "
620   GOTO 490
630   INPUT "PARAMETER DESIGNATION: YINT or SLOPE?",Par$
640   IF Par$="YINT" THEN 680
650   PRINT LIN(3),"NEW VALUE FOR SLOPE FOR LL FOR SHIELD #";Shno
660   INPUT Llslope(Shno)
670    GOTO 695
680   PRINT LIN(3),"NEW VALUE FOR YINT FOR LL FOR SHIELD #";Shno
690   INPUT Llyint(Shno)
695 PRINT #Shno,1;"LL",Llslope(Shno),Llyint(Shno)
700   GOTO 340
710   INPUT "PARAMETER DESIGNATION: YINT OR SLOPE?",Par$
720   IF Par$="YINT" THEN 760
730   PRINT LIN(3),"INPUT NEW VALUE FOR SLOPE FOR RL FOR SHIELD #";Shno
740   INPUT Rlslope(Shno)
750   GOTO 780
760   PRINT LIN(3),"INPUT NEW VALUE FOR YINT FOR RL FOR SHIELD #";Shno
770   INPUT Rlyint(Shno)
780   PRINT #Shno,2;"RL ",Rlslope(Shno),Rlyint(Shno)
790   GOTO 340
800   INPUT "PARAMETER DESIGNATION: YINT OR SLOPE?",Par$
810   IF Par$="YINT" THEN 850
820   PRINT LIN(3),"INPUT NEW VALUE FOR SLOPE FOR CE FOR SHIELD #";Shno
830   INPUT Ceslope(Shno)
840   GOTO 870
850   PRINT LIN(3),"NEW VALUE FOR YINT FOR CE FOR SHIELD #";Shno
860  INPUT Ceyint(Shno)
870   PRINT #Shno,3;"CE ",Ceslope(Shno),Ceyint(Shno)
880   GOTO 340
890   INPUT "PARAMETER DESIGNATION: YINT OR SLOPE?",Par$
900   IF Par$="YINT" THEN 940
910   PRINT LIN(3),"NEW VALUE FOR SLOPE FOR CR FOR SHIELD #";Shno
920   INPUT Crslope(Shno)
930   GOTO 960
940   PRINT "NEW VALUE FOR YINT FOR CR FOR SHIELD #";Shno
950   INPUT Cryint(Shno)
960   PRINT #Shno,4;"CR ",Crslope(Shno),Cryint(Shno)
970   GOTO 340
980   INPUT "PARAMETER DESIGNATION: YINT OR SLOPE?",Par$
990   IF Par$="YINT" THEN 1030
1000  PRINT LIN(3),"NEW VALUE FOR SLOPE FOR RTF FOR SHIELD #";Shno
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1010  INPUT Rtfslope(Shno)
1020  GOTO 1050
1030  PRINT LIN(3),"INPUT NEW VALUE FOR YINT FOR RTF FOR SHIELD #";Shno
1040  INPUT Rtfyint(Shno)
1050  PRINT #Shno,5;"RTF",Rtfslope(Shno),Rtfyint(Shno)
1060  GOTO 340
1070  INPUT "PARAMETER DESIGNATION: YINT OR SLOPE?",Par$
1080  IF Par$="YINT" THEN 1120
1090  PRINT "INPUT NEW VALUE FOR SLOPE FOR LTF FOR SHIELD #";Shno
1100  INPUT Ltfslope(Shno)
1110  GOTO 1140
1120  PRINT "INPUT NEW VALUE FOR YINT FOR LTF FOR SHIELD #";Shno
1130  INPUT Ltfyint(Shno)
1140  PRINT #Shno,6;"LTF",Ltfslope(Shno),Ltfyint(Shno)
1150  GOTO 340
1160  INPUT "PARAMETER DESIGNATION: YINT OR SLOPE?",Par$
1170  IF Par$="YINT" THEN 1210
1180  PRINT LIN(3),"INPUT NEW VALUE FOR SLOPE FOR RTR FOR SHIELD #";Shno
1190  INPUT Rtrslope(Shno)
1200  GOTO 1230
1210  PRINT "INPUT NEW VALUE FOR YINT FOR RTR FOR SHIELD #";Shno
1220  INPUT Rtryint(Shno)
1230  PRINT #Shno,7;"RTR",Rtrslope(Shno),Rtryint(Shno)
1240  GOTO 340
1250  INPUT "PARAMETER DESIGNATION: YINT OR SLOPE?",Par$
1260  IF Par$="YINT" THEN 1300
1270  PRINT LIN(3),"INPUT NEW VALUE FOR SLOPE FOR LTR FOR SHIELD #";Shno
1280  INPUT Ltrslope(Shno)
1290  GOTO 1320
1300  PRINT "INPUT NEW VALUE FOR YINT FOR LTR FOR SHIELD #";Shno
1310  INPUT Ltryint(Shno)
1320  PRINT #Shno,8;"LTR",Ltrslope(Shno),Ltryint(Shno)
1330  GOTO 340
1340  NEXT I
1350  REM EDIT ZEROES
1360  ASSIGN #1 TO "ZERSH1"
1370  ASSIGN #2 TO "ZERSH2"
1380  ASSIGN #3 TO "ZERSH3"
1390  ASSIGN #4 TO "ZERSH4"
1400  FOR I=1 TO 4
1410  READ #I,1;Zdes1$,Llzero(I)
1420  READ #I,2;Zdes2$,Rlzero(I)
1430  READ #I,3;Zdes3$,Cezero(I)
1440  READ #I,4;Zdes4$,Crzero(I)
1450  READ #I,5;Zdes5$,Rtfzero(I
1460  READ #I,6;Zdes6$,Ltfzero(I)
1470  READ #I,7;Zdes7$,Rtrzero(I)
1480  READ #I,8;Zdes8$,Ltrzero(I)
1490   NEXT I
1500  PRINT PAGE,TAB(33),"TRANSDUCER ZEROES",LIN(2)
1510  PRINT SPA(6),"SHIELD 1",SPA(6),"SHIELD 2",SPA(6),"SHIELD 3",SPA(6),"SHIELD
 4"
1520 IMAGE 5X,3A,3X,4D,10X,3A,3X,4D,10X,3A,3X,4D,10X,3A,3X,4D
1530  PRINT USING 1520;"LL ",Llzero(1),"LL ",Llzero(2),"LL ",Llzero(3),"LL ",Llz
ero(4)
1540  PRINT USING 1520;"RL ",Rlzero(1),"RL ",Rlzero(2),"RL ",Rlzero(3),"RL ",Rlz
ero(4)
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1550  PRINT USING 1520;"CE  ",Cezero(1),"CE  ",Cezero(2),"CE  ",Cezero(3),"CE  ",Cez
ero(4)
1560  PRINT USING 1520;"CR  ",Crzero(1),"CR  ",Crzero(2),"CR  ",Crzero(3),"CR  ",Crz
ero(4)
1570  PRINT USING 1520;"RTF",Rtfzero(1),"RTF",Rtfzero(2),"RTF",Rtfzero(3),"RTF",
Rtfzero(4)
1580  PRINT USING 1520;"LTF",Ltfzero(1),"LTF",Ltfzero(2),"LTF",Ltfzero(3),"LTF",
Ltfzero(4)
1590  PRINT USING 1520;"RTR",Rtrzero(1),"RTR",Rtrzero(2),"RTR",Rtrzero(3),"RTR",
Rtrzero(4)
1600  PRINT USING 1520;"LTR",Ltrzero(1),"LTR",Ltrzero(2),"LTR",Ltrzero(3),"LTR",
Ltrzero(4)
1610  INPUT "DO YOU WANT TO CHANGE ANY OF THESE ZEROES? Y/N",Ans$
1620  IF Ans$="N" THEN 2080
1630  INPUT "SHIELD NUMBER FOR WHICH YOU WANT ZEROES TO BE CHANGED? 1,2,3,4",Shn
o
1640  INPUT "TRANSDUCER ZERO TO BE CHANGED? LL,RL,CE,CR,RTF,LTF,RTR,LTR",Trans$
1650  IF Trans$="LL" THEN 1760
1660  IF Trans$="RL" THEN 1800
1670  IF Trans$="CE" THEN 1840
1680  IF Trans$="CR" THEN 1880
1690  IF Trans$="RTF" THEN 1920
1700  IF Trans$="LTF" THEN 1960
1710  IF Trans$="RTR" THEN 2000
1720  IF Trans$="LTR" THEN 2040
1730  PRINT USING 590;"ERROR MESSAGE - INVALID TRANSDUCER SELECTION"
1740  PRINT "                                                              "
1750  GOTO 1640
1760  PRINT LIN(3),"INPUT NEW ZERO FOR LL FOR SHIELD #";Shno
1770  INPUT Llzero(Shno)
1780  PRINT #Shno,1;"LL  ",Llzero(Shno)
1790  GOTO 1500
1800  PRINT LIN(3),"INPUT NEW ZERO FOR RL FOR SHIELD #";Shno
1810  INPUT Rlzero(Shno)
1820  PRINT #Shno,2;"RL  ",Rlzero(Shno)
1830  GOTO 1500
1840  PRINT LIN(3),"INPUT NEW ZERO FOR CE FOR SHIELD #";Shno
1850  INPUT Cezero(Shno)
1860  PRINT #Shno,3;"CE  ",Cezero(Shno)
1870  GOTO 1500
1880  PRINT LIN(3),"INPUT NEW ZERO FOR CR FOR SHIELD #";Shno
1890  INPUT Rtfzero(Shno)
1900  PRINT #Shno,4;"CR  ",Crzero(Shno)
1910  GOTO 1500
1920  PRINT LIN(3),"INPUT NEW ZERO FOR RTF FOR SHIELD #";Shno
1930  INPUT Rtfzero(Shno)
1940  PRINT #Shno,5;"RTF",Rtfzero(Shno)
1950  GOTO 1500
1960  PRINT LIN(3),"INPUT NEW ZERO FOR LTF FOR SHIELD #";Shno
1970  INPUT Ltfzero(Shno)
1980  PRINT #Shno,6;"LTF",Ltfzero(Shno)
1990  GOTO 1500
2000  PRINT LIN(3),"INPUT NEW ZERO FOR RTR FOR SHIELD #";Shno
2010  INPUT Rtrzero(Shno)
2020  PRINT #Shno,7;"RTR",Rtrzero(Shno)
2030  GOTO 1500
2040  PRINT LIN(3),"INPUT NEW ZERO FOR LTR FOR SHIELD #";Shno
```

```
2050  INPUT Ltrzero(Shno)
2060  PRINT #Shno,8;"LTR",Ltrzero(Shno)
2070  GOTO 1500
2080  ASSIGN #1 TO "PTCAL1"
2090  ASSIGN #2 TO "PTCAL2"
2100  ASSIGN #3 TO "PTCAL3"
2110  ASSIGN #4 TO "PTCAL4"
2120  FOR I=1 TO 4
2130  READ #I,1;Ptdes1$,Llsn(I),Llptcal(I),Llrat(I)
2140  READ #I,2;Ptdes2$,Rlsn(I),Rlptcal(I),Rlrat(I)
2150  READ #I,3;Ptdes3$,Cesn(I),Ceptcal(I),Cerat(I)
2160  READ #I,4;Ptdes4$,Crsn(I),Crptcal(I),Crrat(I)
2170  NEXT I
2180  PRINT PAGE,TAB(21),"PRESSURE TRANSDUCER CALIBRATION FACTORS"
2190  PRINT LIN(2),SPA(8),"SHIELD 1",SPA(7),"SHIELD 2",SPA(7),"SHIELD 3",SPA(7),
"SHIELD 4"
2200  IMAGE 5X,3A,3X,MD.DDDD,7X,3A,3X,MD.DDDD,7X,3A,3X,MD.DDDD,7X,3A,3X,MD.DDDD
2210  PRINT USING 2200;"LL ",Llptcal(1),"LL ",Llptcal(2),"LL ",Llptcal(3),"LL ",
Llptcal(4)
2220  PRINT USING 2200;"RL ",Rlptcal(1),"RL ",Rlptcal(2),"RL ",Rlptcal(3),"RL ",
Rlptcal(4)
2230  PRINT USING 2200;"CE ",Ceptcal(1),"CE ",Ceptcal(2),"CE ",Ceptcal(3),"CE ",
Ceptcal(4)
2240  PRINT USING 2200;"CR ",Crptcal(1),"CR ",Crptcal(2),"CR ",Crptcal(3),"CR ",
Crptcal(4)
2250  INPUT "DO YOU WANT TO CHANGE ANY OF THESE PT CALIBRATION FACTORS? Y/N",Ans
$
2260  IF Ans$="N" THEN 2520
2270  INPUT "SHIELD NUMBER FOR WHICH YOU WANT TO CHANGE PT CALIBRATION FACTOR? 1
,2,3,4",Shno
2280  INPUT "PT TPO BE CHANGED: LL,RL,CE,CR ?",Trans$
2290  IF Trans$="LL" THEN 2360
2300  IF Trans$="RL" THEN 2400
2310  IF Trans$="CE" THEN 2440
2320  IF Trans$="CR" THEN 2480
2330  PRINT USING 590;"ERROR MESSAGE - INVALID TRANSDUCER SELECTION!"
2340  PRINT "                                                             "
2350  GOTO 2280
2360  PRINT LIN(3),"INPUT NEW CALIBRATION FACTOR FOR LL FOR SHIELD #";Shno
2370  INPUT Llptcal(Shno)
2380  PRINT #Shno,1;"LL ",Llsn(Shno),Llptcal(Shno),Llrat(Shno)
2390  GOTO 2180
2400  PRINT LIN(3),"INPUT NEW CALIBRATION FACTOR FOR RL FOR SHIELD #";Shno
2410  INPUT Rlptcal(Shno)
2420  PRINT #Shno,2;"RL ",Rlsn(Shno),Rlptcal(Shno),Rlrat(Shno)
2430  GOTO 2180
2440  PRINT LIN(3),"INPUT NEW CALIBRATION FACTOR FOR CE FOR SHIELD #";Shno
2450  INPUT Ceptcal(Shno)
2460  PRINT #Shno,3;"CE ",Cesn(Shno),Ceptcal(Shno),Cerat(Shno)
2470  GOTO 2180
2480  PRINT LIN(3),"INPUT NEW CALIBRATION FACTOR FOR CR FOR SHIELD #";Shno
2490  INPUT Crptcal(Shno)
2500  PRINT #Shno,4;"CR ",Crsn(Shno),Crptcal(Shno),Crrat(Shno)
2510  GOTO 2180
2520  ASSIGN #1 TO "CGFSH1"
2530  ASSIGN #2 TO "CGFSH2"
2540  ASSIGN #3 TO "CGFSH3"
```

```
2550  ASSIGN #4 TO "CGFSH4"
2560  FOR I=1 TO 4
2570  READ #I,1;Rtfgfdes$,Rtfgagres(I),Rtrwirres(I),Rtfgagfac(I),Rtfset350(I),Rt
fcorgf(I)
2580  READ #I,2;Ltfgfdes$,Ltfgagres(I),Ltrwirres(I),Ltfgagfac(I),Ltfset350(I),Lt
fcorgf(I)
2590  READ #I,3;Rtrgfdes$,Rtrgagres(I),Rtrwirres(I),Rtrgagfac(I),Rtrset350(I),Rt
rcorgf(I)
2600  READ #I,4;Ltrgfdes$,Ltrgagres(I),Ltrwirres(I),Ltrgagfac(I),Ltrset350(I),Lt
rcorgf(I)
2610  NEXT I
2620  PRINT PAGE,TAB(26),"GAGE FACTOR SETTINGS ON P350A"
2630  PRINT LIN(2),SPA(8),"SHIELD 1",SPA(7),"SHIELD 2",SPA(6),"SHIELD 3",SPA(5),
"SHIELD 4"
2640  IMAGE 6X,3A,3X,MD.DD,8X,3A,3X,MD.DD,8X,3A,3X,MD.DD,8X,3A,3X,MD.DD
2650  PRINT USING 2640;"RTF",Rtfset350(1),"RTF",Rtfset350(2),"RTF",Rtfset350(3),
"RTF",Rtfset350(4)
2660  PRINT USING 2640;"LTF",Ltfset350(1),"LTF",Ltfset350(2),"LTF",Ltfset350(3),
"LTF",Ltfset350(4)
2670  PRINT USING 2640;"RTR",Rtrset350(1),"RTR",Rtrset350(2),"RTR",Rtrset350(3),
"RTR",Rtrset350(4)
2680  PRINT USING 2640;"LTR",Ltrset350(1),"LTR",Ltrset350(2),"LTR",Ltrset350(3),
"LTR",Ltrset350(4)
2690  INPUT "DO YOU WANT TO CHANGE ANY OF THESE GAGE FACTOR SETTINGS? Y/N",Ans$
2700  IF Ans$="N" THEN 2890
2710  INPUT "SHIELD NUMBER FOR WHICH GAGE FACTOR IS TO BE CHANGED: 1,2,3,4?",Shn
o
2720  INPUT "TRANSDUCER FOR WHICH GAGE FACTOR IS TO BE CHANGED: RTF,LTF,RTR,LTR?
",Trans$
2730  IF Trans$="RTF" THEN 2770
2740  IF Trans$="LTF" THEN 2800
2750  IF Trans$="RTR" THEN 2830
2760  IF Trans$="LTR" THEN 2860
2770  PRINT LIN(3),"INPUT NEW GAGE FACTOR SETTING FOR RTF FOR SHIELD #";Shno
2780  INPUT Rtfset350(Shno)
2790  GOTO 2620
2800  PRINT LIN(3),"INPUT NEW GAGE FACTOR SETTING FOR LTF FOR SHIELD #";Shno
2810  INPUT Ltfset350(Shno)
2820  GOTO 2620
2830  PRINT LIN(3),"INPUT NEW GAGE FACTOR SETTING FOR RTR FOR SHIELD #";Shno
2840  INPUT Rtrset350(Shno)
2850  GOTO 2620
2860  PRINT LIN(3),"INPUT NEW GAGE FACTOR SETTING FOR LTR FOR SHIELD #";Shno
2870  INPUT Ltrset350(Shno)
2880  GOTO 2620
2890  REM ***** DESENITIZED GAGE FACTOR CALCULATION*****
2900  FOR I=1 TO 4
2910  Rtfcorgf(I)=Rtrgagres(I)/(Rtfgagres(I)+Rtfwirres(I))*Rtfgagfac(I)
2920  Ltfcorgf(I)=Ltrgagres(I)/(Ltfgagres(I)+Ltfwirres(I))*Ltfgagfac(I)
2930  Rtrcorgf(I)=Rtrgagres(I)/(Rtrgagres(I)+Rtrwirres(I))*Rtrgagfac(I)
2940  Ltrcorgf(I)=Ltrgagres(I)/(Ltrgagres(I)+Ltrwirres(I))*Ltrgagfac(I)
2950  PRINT #I,1;Rtfgfdes$,Rtfgagres(I),Rtfwirres(I),Rtfgagfac(I),Rtfset350(I),R
tfcorgf(I)
2960  PRINT #I,2;Ltfgfdes$,Ltfgagres(I),Ltfwirres(I),Ltfgagfac(I),Ltfset350(I),L
tfcorgf(I)
2970  PRINT #I,3;Rtrgfdes$,Rtrgagres(I),Rtrwirres(I),Rtrgagfac(I),Rtrset350(I),R
trcorgf(I)
```

```
2980  PRINT #I,4;Ltrgfdes$,Ltrgagres(I),Ltrwirres(I),Ltrgagfac(I),Ltrset350(I),L
trcorgf(I)
2990  NEXT I
3000 PRINT PAGE,"INPUT DATA TAPE BEFORE PROCEEDING!!!!"
3010 PRINT LIN(5),"PRESS CONT AFTER INSERTING DATA TAPE"
3020 PAUSE
3030  INPUT "DATE DATA WAS TAKEN: mmddyy?",Date$
3040  F$=Date$[1,4]
3050  F$=F$&Date$[6,6]
3060  Sh1$="1"&F$
3070  Sh2$="2"&F$
3080  Sh3$="3"&F$
3090  Sh4$="4"&F$
3100  ASSIGN #1 TO Sh1$
3110  ASSIGN #2 TO Sh2$
3120  ASSIGN #3 TO Sh3$
3130  ASSIGN #4 TO Sh4$
3140  FOR I=1 TO 4
3150  READ #I,1;Des$(I)
3160  READ #I,2;Dat$(I)
3170  READ #I,3;Nodtpt(I)
3175 READ #I,4;Shht(I)
3230  Llfs=Llptcal(I)/5E-4
3240  Rlfs=Rlptcal(I)/5E-4
3250  Cefs=Ceptcal(I)/5E-4
3260  Crfs=Crptcal(I)/5E-4
3270  Llconfac=Llrat(I)/Llfs
3280  Rlconfac=Rlrat(I)/Rlfs
3290  Ceconfac=Cerat(I)/Cefs
3300  Crconfac=Crrat(I)/Crfs
3310  FOR J=1 TO Nodtpt(I)
3315  READ #I,J+4;T(I,J),Ll,Rl,Ce,Cr,Rtf,Ltf,Rtr,Ltr
3320  Lleng(I,J)=(Ll*Llslope(I)+Llyint(I)-Llzero(I))*Llconfac
3330  Rleng(I,J)=(Rl*Rlslope(I)+Rlyint(I)-Rlzero(I))*Rlconfac
3340  Ceeng(I,J)=(Ce*Ceslope(I)+Ceyint(I)-Cezero(I))*Ceconfac
3350  Creng(I,J)=(Cr*Crslope(I)+Cryint(I)-Crzero(I))*Crconfac
3360  Rtfeng(I,J)=(Rtf*Rtfslope(I)+Rtfyint(I)-Rtfzero(I))*Rtfcorgf(I)/Rtfset350(
I)
3370  Ltfeng(I,J)=(Ltf*Ltfslope(I)+Ltfyint(I)-Ltfzero(I))*Ltfcorgf(I)/Ltfset350(
I)
3380  Rtreng(I,J)=(Rtr*Rtrslope(I)+Rtryint(I)-Rtrzero(I))*Rtrcorgf(I)/Rtrset350(
I)
3390  Ltreng(I,J)=(Ltr*Ltrslope(I)+Ltryint(I)-Ltrzero(I))*Ltrcorgf(I)/Ltrset350(
I)
3400  NEXT J
3410  NEXT I
3420  PRINTER IS 7,1,WIDTH(140)
3430  PRINT PAGE,TAB(49),"EMERALD MINE - RESULTANT LOAD VECTOR STUDIES"
3440  PRINT LIN(3),TAB(52),"TRANSDUCER AND CALIBRATION INFORMATION"
3450  PRINT LIN(3),TAB(53),"DATA ACQUITION CALIBRATION FACTORS"
3460  PRINT LIN(1),SPA(15);"SHIELD 1";SPA(26);"SHIELD 2";SPA(26);"SHIELD 3";SPA(
26);"SHIELD 4",LIN(1)
3470  PRINT SPA(14);"SLOPE";SPA(6);"Y-INT";SPA(18);"SLOPE";SPA(6);"Y-INT";SPA(18
);"SLOPE";SPA(6);"Y-INT";SPA(18);"SLOPE";SPA(6);"Y-INT"
3480  IMAGE 6X,3A,3X,MD.DDDDDD,2X,MD.DDDDDD,8X,3A,3X,MD.DDDDDD,2X,MD.DDDDDD,8X,3
A,3X,MD.DDDDDD,2X,MD.DDDDDD,8X,3A,3X,MD.DDDDDD,2X,MD.DDDDDD
3490  PRINT USING 3480;"LL ",Llslope(1),Llyint(1),"LL ",Llslope(2),Llyint(2),"LL
 ",Llslope(3),Llyint(3),"LL ",Llslope(4),Llyint(4)
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3500  PRINT USING 3480;"RL ",Rlslope(1),Rlyint(1),"RL ",Rlslope(2),Rlyint(2),"RL
 ",Rlslope(3),Rlyint(3),"RL ",Rlslope(4),Rlyint(4)
3510  PRINT USING 3480;"CE ",Ceslope(1),Ceyint(1),"CE ",Ceslope(2),Ceyint(2),"CE
 ",Ceslope(3),Ceyint(3),"CE ",Ceslope(4),Ceyint(4)
3520  PRINT USING 3480;"CR ",Crslope(1),Cryint(1),"CR ",Crslope(2),Cryint(2),"CR
 ",Crslope(3),Cryint(3),"CR ",Crslope(4),Cryint(4)
3530  PRINT USING 3480;"RTF",Rtfslope(1),Rtfyint(1),"RTF",Rtfslope(2),Rtfyint(2)
,"RTF",Rtfslope(3),Rtfyint(3),"RTF",Rtfslope(4),Rtfyint(4)
3540  PRINT USING 3480;"LTF",Ltfslope(1),Ltfyint(1),"LTF",Ltfslope(2),Ltfyint(2)
,"LTF",Ltfslope(3),Ltfyint(3),"LTF",Ltfslope(4),Ltfyint(4)
3550  PRINT USING 3480;"RTR",Rtrslope(1),Rtryint(1),"RTR",Rtrslope(2),Rtryint(2)
,"RTR",Rtrslope(3),Rtryint(3),"RTR",Rtrslope(4),Rtryint(4)
3560  PRINT USING 3480;"LTR",Ltrslope(1),Ltryint(1),"LTR",Ltrslope(2),Ltryint(2)
,"LTR",Ltrslope(3),Ltryint(3),"LTR",Ltrslope(4),Ltryint(4)
3570  PRINT LIN(5),TAB(62),"TRANSDUCER ZEROES"
3580  PRINT LIN(1);SPA(36);"SHIELD 1";SPA(13);"SHIELD 2";SPA(13);"SHIELD 3";SPA(
13);"SHIELD 4",LIN(1)
3590  IMAGE 35X,3A,3X,MDDDD,10X,3A,3X,MDDDD,10X,3A,3X,MDDDD,10X,3A,3X,MDDDD
3600  PRINT USING 3590;"LL ",Llzero(1),"LL ",Llzero(2),"LL ",Llzero(3),"LL ",Llz
ero(4)
3610  PRINT USING 3590;"RL ",Rlzero(1),"RL ",Rlzero(2),"RL ",Rlzero(3),"RL ",Rlz
ero(4)
3620  PRINT USING 3590;"CE ",Cezero(1),"CE ",Cezero(2),"CE ",Cezero(3),"CE ",Cez
ero(4)
3630  PRINT USING 3590;"CR ",Crzero(1),"CR ",Crzero(2),"CR ",Crzero(3),"CR ",Crz
ero(4)
3640  PRINT USING 3590;"RTF",Rtfzero(1),"RTF",Rtfzero(2),"RTF",Rtfzero(3),"RTF",
Rtfzero(4)
3650  PRINT USING 3590;"LTF",Ltfzero(1),"LTF",Ltfzero(2),"LTF",Ltfzero(3),"LTF",
Ltfzero(4)
3660  PRINT USING 3590;"RTR",Rtrzero(1),"RTR",Rtrzero(2),"RTR",Rtrzero(3),"RTR",
Rtrzero(4)
3670  PRINT USING 3590;"LTR",Ltrzero(1),"LTR",Ltrzero(2),"LTR",Ltrzero(3),"LTR",
Ltrzero(4)
3680  PRINT LIN(5),TAB(50),"PRESSURE TRANSDUCER CALIBRATION FACTORS",LIN(2)
3690  PRINT LIN(1);SPA(15);"SHIELD 1";SPA(26);"SHIELD 2";SPA(26);"SHIELD 3";SPA(
26);"SHIELD 4",LIN(1)
3700  IMAGE 7X,3A,2X,7A,2X,6A,16X,3A,2X,7A,2X,6A,16X,3A,2X,7A,2X,6A,16X,3A,2X,7A
,2X,6A
3710  PRINT USING 3700;"S/N","CAL.FAC","RATING","S/N","CAL.FAC","RATING","S/N","
CAL.FAC","RATING","S/N","CAL.FAC","RATING"
3720  IMAGE 2A,2X,6D,2X,MD.DDDD,2X,6D,9X,2A,2X,6D,2X,MD.DDDD,2X,6D,9X,2A,2X,6D,2
X,MD.DDDD,2X,6D,9X,2A,2X,6D,2X,MD.DDDD,2X,6D
3730  PRINT USING 3720;"LL ",Llsn(1),Llptcal(1),Llrat(1),"LL ",Llsn(2),Llptcal(2
),Llrat(2),"LL ",Llsn(3),Llptcal(3),Llrat(3),"LL ",Llsn(4),Llptcal(4),Llrat(4)
3740  PRINT USING 3720;"RL ",Rlsn(1),Rlptcal(1),Rlrat(1),"RL ",Rlsn(2),Rlptcal(2
),Rlrat(2),"RL ",Rlsn(3),Rlptcal(3),Rlrat(3),"RL ",Rlsn(4),Rlptcal(4),Rlrat(4)
3750  PRINT USING 3720;"CE ",Cesn(1),Ceptcal(1),Cerat(1),"CE ",Cesn(2),Ceptcal(2
),Cerat(2),"CE ",Cesn(3),Ceptral(3),Cerat(3),"CE ",Cesn(4),Ceptcal(4),Cerat(4)
3760  PRINT USING 3720;"CR ",Crsn(1),Crptcal(1),Crrat(1),"CR ",Crsn(2),Crptcal(2
),Crrat(2),"CR ",Crsn(3),Crptcal(3),Crrat(3),"CR ",Crsn(4),Crptcal(4),Crrat(4)
3770  PRINT LIN(5),TAB(54),"STRAIN GAGE BRIDGE CIRCUIT DATA"
3780  PRINT LIN(1),TAB(68),"KEY"
3790  PRINT TAB(54),"GR = GAGE RESISANCE"
3800  PRINT TAB(54),"WR = GAGE WIRE RESISANCE"
3810  PRINT TAB(54),"GF = GAGE FACTOR"
3820  PRINT TAB(54),"P350 = P350 GAGE FACTOR SETTING"
3830  PRINT TAB(54),"DSGF = DESENITIZED GAGE FACTOR"
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3840  PRINT LIN(1),SPA(41);"SHIELD 1";SPA(50);"SHIELD 2"
3850 IMAGE 35X,2A,4X,2A,3X,2A,3X,4A,2X,4A,35X,2A,4X,2A,3X,2A,3X,4A,2X,4A
3860  PRINT USING 3850;"GR","WR","GF","P350","DSGF","GR","WR","GF","P350","DSGF"
3870  IMAGE 29X,3A,1X,DDD.D,2X,D.D,2X,D.DD,2X,D.DD,2X,D.DD,29X,3A,1X,DDD.D,2X,D.
D,2X,D.DD,2X,D.DD,2X,D.DD
3880  IMAGE 2X,3A,1X,DDD.D,2X,D.D,2X,D.DD,2X,D.DD,2X,D.DD,2X,3A,1X,DDD.D,2X,D.D,
2X,D.DD,2X,D.DD,2X,D.DD
3890*PRINT USING 3870;"RTF",Rtfgagres(1),Rtfwirres(1),Rtfgagfac(1),Rtfset350(1),
Rtfcorgf(1),"RTF",Rtfgagres(2),Rtfwirres(2),Rtfgagfac(2),Rtfset350(2),Rtfcorgf(2
3900*PRINT USING 3870;"LTF",Ltfgagres(1),Ltfwirres(1),Ltfgagfac(1),Ltfset350(1),
Ltfcorgf(1),"LTF",Ltfgagres(2),Ltfwirres(2),Ltfgagfac(2),Ltfset350(2),Ltfcorgf(2
3910*PRINT USING 3870;"RTR",Rtrgagres(1),Rtrwirres(1),Rtrgagfac(1),Rtrset350(1),
Rtrcorgf(1),"RTR",Rtrgagres(2),Rtrwirres(2),Rtrgagfac(2),Rtrset350(2),Rtrcorgf(2
3920*PRINT USING 3870;"LTR",Ltrgagres(1),Ltrwirres(1),Ltrgagfac(1),Ltrset350(2),
Ltrcorgf(2),"LTR",Ltrgagres(2),Ltrwirres(2),Ltrgagfac(2),Ltrset350(2),Ltrcorgf(2
3930  PRINT LIN(2),SPA(41);"SHIELD 3";SPA(50);"SHIELD 4"
3940  PRINT USING 3850;"GR","WR","GF","P350","DSGF","GR","WR","GF","P350","DSGF"
3950*PRINT USING 3870;"RTF",Rtfgagres(3),Rtfwirres(3),Rtfgagfac(3),Rtfset350(3),
Rtfcorgf(3),"RTF",Rtfgagres(4),Rtfwirres(4),Rtfgagfac(4),Rtfset350(4),Rtfcorgf(4
3960*PRINT USING 3870;"LTF",Ltfgagres(3),Ltfwirres(3),Ltfgagfac(3),Ltfset350(3),
Ltfcorgf(3),"LTF",Ltfgagres(4),Ltfwirres(4),Ltfgagfac(4),Ltfset350(4),Ltfcorgf(4
3970*PRINT USING 3870;"RTR",Rtrgagres(3),Rtrwirres(3),Rtrgagfac(3),Rtrset350(3),
Rtrcorgf(3),"RTR",Rtrgagres(4),Rtrwirres(4),Rtrgagfac(4),Rtrset350(4),Rtrcorgf(4
3980*PRINT USING 3870;"LTR",Ltrgagres(3),Ltrwirres(3),Ltrgagfac(3),Ltrset350(3),
Ltrcorgf(3),"LTR",Ltrgagres(4),Ltrwirres(4),Ltrgagfac(4),Ltrset350(4),Ltrcorgf(4
3990  FOR I=1 TO 4
4000  PRINT PAGE,TAB(49),"EMERALD MINE - RESULTANT LOAD VECTOR STUDIES"
4010  PRINT LIN(1),TAB(55),"DATA FOR SHIELD #";I
4020 PRINT LIN(1),TAB(55),"UNITS: LL,RL,CE,CR - psi"
4030 PRINT TAB(62),"RTF,LTF,RTR,LTR - microstrain"
4040  PRINT LIN(2),"FILE DESCRIPTION - ";Des$(I)
4050  Mo$=Dat$(I)[1,2]&"/"
4060  Dy$=Mo$&Dat$(I)[3,4]
4070  Dy$=Dy$&"/"
4080  Yr$=Dy$&Dat$(I)[5,6]
4090 PRINT "DATE DATA TAKEN - ";Yr$
4100 PRINT "NUMBER OF DATA POINTS -";Nodtpt(I)
4110 FOR K=1 TO Nodtpt(I) STEP 50
4120  A$="SHIELD NO."
4130  B$="RECORD NO."
4140  C$="TIME"
4150  D$="LT. LEG"
4160  E$="RT. LEG"
4170  F$="CAN. EXT."
4180  G$="CAN. RET."
4190  H$="RT.TOP GAGE"
4200  I$="LT.TOP GAGE"
4210  J$="RT.BOT GAGE"
4220  K$="LT.BOT GAGE"
4230  IMAGE 10A,3X,10A,4X,4A,6X,7A,4X,7A,4X,8A,4X,8A,3X,11A,3X,11A,3X,11A,3X,11A
4240  PRINT USING 4230;A$,B$,C$,D$,E$,F$,G$,H$,I$,J$,K$
4250  IMAGE 29X,A,10X,2A,9X,2A,9X,2A,10X,2A,11X,3A,11X,3A,11X,3A,11X,3A
4260  PRINT USING 4250;"T","LL","RL","CE","CR","RTF","LTF","RTR","LTR"
4270  FOR L=K TO K+49
4280  IMAGE 3X,2D,9X,3D,8X,8D,5X,M4D,6X,M4D,6X,M4D,7X,M4D,8X,M4D,9X,M4D,9X,M4D,9
X,M4D
4290  PRINT USING 4280;I,L,T(I,L),Lleng(I,L),Rleng(I,L),Ceeng(I,L),Creng(I,L),Rt
feng(I,L),Ltfeng(I,L),Rtreng(I,L),Ltreng(I,L)
```

```
4300  NEXT L
4310  NEXT K
4320  NEXT I
4330  PRINTER IS 16
4340  PRINT PAGE,"INSERT ENGINEERING TAPE INTO T15 TAPE DRIVE BEFORE PROCEEDING
!"
4350 PRINT LIN(3),"PRESS CONT WHEN READY TO CONTINUE - AFTER INSERTING ENGINEERI
NG TAPE."
4360 PAUSE
4370  CREATE Sh1$,Nodtpt(1)+4,74
4380  CREATE Sh2$,Nodtpt(2)+4,74
4390  CREATE Sh3$,Nodtpt(3)+4,74
4400  CREATE Sh4$,Nodtpt(4)+4,74
4410  ASSIGN #1 TO Sh1$
4420  ASSIGN #2 TO Sh2$
4430  ASSIGN #3 TO Sh3$
4440  ASSIGN #4 TO Sh4$
4450  FOR I=1 TO 4
4460  PRINT #I,1;Des$(I)
4470  PRINT #I,2;Dat$(I)
4480  PRINT #I,3;Nodtpt(I)
4485 PRINT #I,4;Shht(I)
4490  FOR J=1 TO Nodtpt(I)
4500  PRINT #I,J+4;T(I,J),Lleng(I,J),Rleng(I,J),Ceeng(I,J),Creng(I,J),Rtfeng(I,J
),Ltfeng(I,K),Rtreng(I,J),Ltreng(I,J)
4510  NEXT J
4520  NEXT I
4530 PRINTER IS 16
4540 PRINT LIN(10),TAB(5),"JOB  FINISHED"
4550 END
```

```
1   REM ******************** PROGRAM NAME -- EMGEOM ****************************
10 DEG
11    Count=0
20 PRINTER IS 16
30 FIXED 2
40 COM X1(99),Y1(99),X2(99),Y2(99),X3(99),Y3(99),X4(99),Y4(99),X5(99),Y5(99),X6(
99),Y6(99),X7(99),Y7(99),X8(99),Y8(99),Xr3(99),Yr3(99),Xr4(99),Yr4(99),H(99)
50 COM Xr6(99),Yr6(99),Angs,Angf,H1,H4,V1,V4
60 DIM Ag(99),Thet2(99),Thet3(99),Thetr4(99),Thetr6(99),Legang(99),Capang(99),Li
nang(99),Thet6(99),X0(99),Y0(99)
70 PRINT "THIS PROGRAM DETERMINES SPATIAL PARAMETERS AS A FUNCTION OF SHIELD HEI
GHT. THESE PARAMETERS ARE THEN UTILIZED TO DETERMINE MOMENT ARM LENGTHS AND "
80 PRINT "LINES OF ACTION IN THE STATIC ANALYSIS PROGRAM TO DETERMINE RESULTANT
SHIELD LOADING."
90*PRINT LIN(2),"THE SPATIAL PARAMETERS ARE GENERATED USING THE BASE/TENSION LIN
K HINGE PIN AS A STARTING REFERENCE POINT HAVING COORDINATES (0,0) IN THE GLOBAL
100 PRINT "RECTANGULAR COORDINATE SYSTEM."
110 PRINT LIN(2),"TO BEGIN THE SIMULATION, YOU MUST FIRST INPUT THE RANGE YOU WA
NT THE TENSION LINK TO VARY WITH RESPECT TO THE PLANE OF THE BASE."
120 PRINT LIN(1.00),"THE DEFAULT OPTION FOR THIS INPUT IS 125 TO 135 DEGREES."
130 INPUT "DO YOU WANT TO USE THE DEFAULT OPTION? Y/N",Ans$
140 IF Ans$="N" THEN 180
150 Angs=125
160 Angf=135
170 GOTO 230
180 INPUT "ANGLE VARIANCE(BASE AND TENSION LINK) :BEGINNING ANGLE,ENDING ANGLE",
Angs,Angf
190 FIXED 2
200 IMAGE ZZZ.DD,3A,ZZZ.DD,4X,ZZZ.DD,3A,ZZZ.DD,5X,ZZZ.DD,3A,ZZZ.DD,5X,ZZZ.DD,3A,
ZZZ.DD,5X,ZZZ.DD,3A,ZZZ.DD,5X,ZZZ.DD,3A,ZZZ.DD,5X,ZZZ.DD,3A,ZZZ.DD
210 IMAGE 2X,ZZZ.DD,3A,ZZZ.DD,5X,ZZZ.DD,3A,ZZZ.DD,5X,ZZZ.DD,3A,ZZZ.DD,5X,ZZZ.DD,
3A,ZZZ.DD,5X,ZZZ.DD,3A,ZZZ.DD,5X,MZZZ.DD,3A,MZZZ.DD
220 IMAGE DDD.DD,10X,DDD.DD,4X,DDD.DD,5X,DDD.DD,5X,DDD.DD,5X,DDD.DD,12X,DDD.DD,1
2X,DDD.DD,17X,DDD.DD
230 DEG
240    ASSIGN #1.00 TO "EMSHDM"
250   ASSIGN #2 TO "GEOFIL"
255 PRINT #2,1.00;(Angf-Angs)*2+1.00
260    READ #1.00,1.00;Des1$,L5
270    READ #1.00,2;Des2$,L3
280    READ #1.00,3;Des3$,L9
290    READ #1.00,4;Des4$,L7
300    READ #1.00,5;Des5$,L1
310    READ #1.00,6;Des6$,L2
320    READ #1.00,7;Des7$,L6
330    READ #1.00,8;Des8$,R2
340    READ #1.00,9;Des9$,R1
350    READ #1.00,10;Des10$,R3
360    READ #1.00,11;Des11$,R4
370    READ #1.00,12;Des12$,R6
380    READ #1.00,13;Des13$,V4
390    READ #1.00,14;Des14$,H1
400    READ #1.00,15;Des15$,H4
410    READ #1.00,16;Des16$,V1
420    READ #1.00,17;Des17$,Deltc
430    READ #1.00,18;Des18$,Delth
```

```
440   READ #1.00,19;Des19$,Thet3
450   READ #1.00,20;Des20$,Thet6
460  GOSUB Rptgeom
470   INPUT "DO YOU WNAT TO CHANGE ANY OF THESE PARAMETERS? Y/N",Ans$
480   IF Ans$="N" THEN 1300
490   INPUT "INPUT PARAMETER:L5,L3,L9,L7,L1,L2,L6,R2,R1,R3,R4,R6,V4,H1,H4,V1,DC,
DB,T3,T6",Par$
500   IF Par$="L5" THEN 700
510   IF Par$="L3" THEN 730
520   IF Par$="L9" THEN 760
530   IF Par$="L7" THEN 790
540   IF Par$="L1" THEN 820
550   IF Par$="L2" THEN 850
560   IF Par$="L6" THEN 880
570   IF Par$="R2" THEN 910
580   IF Par$="R1" THEN 940
590   IF Par$="R3" THEN 970
600   IF Par$="R4" THEN 1000
610   IF Par$="R6" THEN 1030
620   IF Par$="V4" THEN 1060
630   IF Par$="H1" THEN 1090
640   IF Par$="H4" THEN 1120
650   IF Par$="V1" THEN 1150
660   IF Par$="DC" THEN 1180
670   IF Par$="DB" THEN 1210
680   IF Par$="T3" THEN 1240
690   IF Par$="T6" THEN 1270
700   INPUT "INPUT NEW VALUE FOR L5",L5
710   PRINT #1.00,1.00;Des1$,L5
720   GOTO 460
730   INPUT "INPUT NEW VALUE FOR L3",L3
740   PRINT #1.00,2;Des2$,L3
750   GOTO 460
760   INPUT "INPUT NEW VALUE FOR L9",L9
770   PRINT #1.00,3;Des3$,L9
780   GOTO 460
790   INPUT "INPUT NEW VALUE FOR L7",L7
800   PRINT #1.00,4;Des4$,L7
810   GOTO 460
820   INPUT "INPUT NEW VALUE FOR L1",L1
830   PRINT #1.00,5;Des5$,L1
840   GOTO 460
850   INPUT "INPUT NEW VALUE FOR L2",L2
860   PRINT #1.00,6;Des6$,L2
870 GOTO 460
880   INPUT "INPUT NEW VALUE FOR L6",L6
890   PRINT #1.00,7;Des7$,L6
900   GOTO 460
910   INPUT "INPUT NEW VALUE FOR R2",R2
920   PRINT #1.00,8;Des8$,R2
930   GOTO 460
940   INPUT "INPUT NEW VALUE FOR R1",R1
950   PRINT #1.00,9;Des9$,R1
960   GOTO 460
970   INPUT "INPUT NEW VALUE FOR R3",R3
980   PRINT #1.00,10;Des10$,R3
990   GOTO 460
1000  INPUT "INPUT NEW VALUE FOR R4",R4
```

```
1010  PRINT #1.00,11;Des11$,R4
1020  GOTO 460
1030  INPUT "INPUT NEW VALUE FOR R6",R6
1040  PRINT #1.00,12;Des12$,R6
1050  GOTO 460
1060  INPUT "INPUT NEW VALUE FOR V4",V4
1070  PRINT #1.00,13;Des13$,V4
1080  GOTO 460
1090  INPUT "INPUT NEW VALUE FOR H1",H1
1100  PRINT #1.00,14;Des$,H1
1110  GOTO 460
1120  INPUT "INPUT NEW VALUE FOR H4",H4
1130  PRINT #1.00,15;Des15$,H4
1140  GOTO 460
1150  INPUT "INPUT NEW VALUE FOR V1",V1
1160  PRINT #1.00,16;Des16$,V1
1170  GOTO 460
1180  INPUT "INPUT NEW VALUE FOR DC",Deltc
1190  PRINT #1.00,17;Des17$,Deltc
1200  GOTO 460
1210  INPUT "INPUT NEW VALUE FOR DB",Deltb
1220  PRINT #1.00,18;Des18$,Deltb
1230  GOTO 460
1240  INPUT "INPUT NEW VALUE FOR T3",Thet3
1250  PRINT #1.00,19;Des19$,Thet3
1260  GOTO 460
1270  INPUT "INPUT NEW VALUE FOR T6",Thet6
1280  PRINT #1.00,20;Des20$,Thet6
1290  GOTO 460
1300 FOR Ang=Angs TO Angf STEP .5
1301  Count=Count+1.00
1310 I=Count
1320 Ag(I)=Ang
1330 C1=SQR(R1^2+H1^2+V1^2-2*R1*(H1*COS(Ang)+V1*SIN(Ang)))
1340 A=(L1^2+C1^2-R2^2)/(2*L1*C1)
1350 B=(V1-R1*SIN(Ang))/(H1-R1*COS(Ang))
1360 Thet2(I)=ACS((L1^2+C1^2-R2^2)/(2*L1*C1))-ATN((R1*SIN(Ang)-V1)/(H1-R1*COS(An
g)))-Thet3
1370 X1(I)=R1*COS(Ang)
1380  Xx1=X1(I)
1390 Y1(I)=R1*SIN(Ang)
1400  Yy1=Y1(I)
1410 X2(I)=X1(I)+L1*COS(Thet2(I))
1420  Xx2=X2(I)
1430 Y2(I)=Y1(I)+L1*SIN(Thet2(I))
1440  Yy2=Y2(I)
1450 X3(I)=X2(I)+L2*COS(Thet2(I))
1460  Xx3=X3(I)
1470 Y3(I)=Y2(I)+L2*SIN(Thet2(I))
1480  Yy3=Y3(I)
1490 X4(I)=X3(I)+L3*COS(Thet6)
1500  Xx4=X4(I)
1510 Y4(I)=Y3(I)+L3*SIN(Thet6)
1520  Yy4=Y4(I)
1530 X5(I)=X3(I)+L7*COS(Thet6)
1540  Xx5=X5(I)
1550 Y5(I)=Y3(I)+L7*SIN(Thet6)
1560  Yy5=Y5(I)
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```
1570 X6(I)=X3(I)+L9*COS(Thet6)
1580  Xx6=X6(I)
1590 Y6(I)=Y3(I)+L9*SIN(Thet6)
1600  Yy6=Y6(I)
1610 X7(I)=X2(I)+L6*COS(Thet2(I))
1620  Xx7=X7(I)
1630 Y7(I)=Y2(I)+L6*SIN(Thet2(I))
1640  Yy7=Y7(I)
1650 X8(I)=L5
1660 Y8(I)=0
1670 X0(I)=X1(I)*(X2(I)*V1-H1*Y2(I))/(X1(I)*(V1-Y2(I))+Y1(I)*(X2(I)-H1))
1675 Xx0=X0(I)
1680 Y0(I)=X0(I)*TAN(Ang)
1685 Yy0=Y0(I)
1690 H(I)=Y3(I)+Deltc+Deltb
1700  Hh=H(I)
1710 Xr3(I)=X2(I)+L6*COS(Thet2(I))+R3*SIN(Thet2(I))
1720  Xxr3=Xr3(I)
1730 Yr3(I)=Y2(I)+L6*SIN(Thet2(I))-R3*COS(Thet2(I))
1740  Yyr3=Yr3(I)
1750 Xr4(I)=X3(I)+L7*COS(Thet6(I))+R4*SIN(Thet6)
1760  Xxr4=Xr4(I)
1770 Yr4(I)=Y3(I)+L7*SIN(Thet6(I))-R4*COS(Thet6)
1780  Yyr4=Yr4(I)
1790 Xr6(I)=X3(I)+L9*COS(Thet6(I))+R6*SIN(Thet6)
1800  Xxr6=Xr6(I)
1810 Yr6(I)=Y3(I)+L9*SIN(Thet6(I))-R6*COS(Thet6)
1820  Yyr6=Yr6(I)
1830 Thetr4(I)=ACS((Xr4(I)-Xr3(I))/SQR((Xr4(I)-Xr3(I))^2+(Yr4(I)-Yr3(I))^2))
1840 Thetr6(I)=ASN((Xr6(I)-H4)/SQR((Xr6(I)-H4)^2+(Yr6(I)-V4)^2))
1850  T6=Thetr6(I)
1860 Legang(I)=Thetr6(I)
1870  Lega=Legang(I)
1880 Capang(I)=Thetr4(I)
1890  Capa=Capang(I)
1900 Linang(I)=ASN((Y2(I)-V1)/R2)
1910  Lina=Linang(I)
1920 PRINT #2,I+1.00;Hh,Xx0,Yy0,Xx1,Yy1,Xx2,Yy2,Xx3,Yy3,Xx4,Yy4,Xx5,Yy5,Xx6,Yy6,
Xx7,Yy7,Xxr3,Yyr3,Xxr4,Yyr4,Xxr6,Yyr6,H1,V1,H4,V4,Ag(I),Lega,Capa,Lina
1930 NEXT Ang
1940 PRINTER IS 7,1.00,WIDTH(160)
1950 GOSUB Rptgeom
1960 GOTO 2190
1970 Rptgeom: PRINT PAGE,TAB(25),"SHIELD DIMENSIONAL REPORT"
1980 PRINT TAB(2),"LENGTH OF BASE,inches ------------------------------------- L
5";SPA(3);L5
1990 PRINT TAB(2),"LENGTH OF CANOPY,inches ----------------------------------- L
3";SPA(3);L3
2000 PRINT TAB(2),"DISTANCE FROM CANOPY HINGE TO LEG,inches ------------------ L
9";SPA(3);L9
2010 PRINT TAB(2),"DISTANCE FROM CANOPY HINGE TO CAPSULE --------------------- L
7";SPA(3);L7
2020 PRINT TAB(2),"DISTANCE BETWEEN LEMNISCATE PINS ON CAVING SHIELD,inches -- L
1";SPA(3);L1
2030 PRINT TAB(2),"LENGTH OF CAVING SHIELD,inches ---------------------------- L
2";SPA(3);L2
2040 PRINT TAB(2),"DISTANCE FROM COMPRESSION LINK TO CAPSULE,inches ---------- L
6";SPA(3);L6
```

```
2050 PRINT TAB(2),"LENGTH OF COMPRESSION LEMNISCATE LINK,inches --------------- R
2";SPA(3);R2
2060 PRINT TAB(2),"LENGTH OF TENSION LEMNISCATE,inches ------------------------ R
1";SPA(3);R1
2070 PRINT TAB(2),"CAPSULE/CAVING SHIELD ARM,inches --------------------------- R
3";SPA(3);R3
2080 PRINT TAB(2),"CAPSULE/CANOPY ARM,inches ---------------------------------- R
4";SPA(3);R4
2090 PRINT TAB(2),"LEG/CANOPY ARM,inches -------------------------------------- R
6";SPA(3);R6
2100 PRINT TAB(2),"LEG/BASE ARM,inches ---------------------------------------- V
4";SPA(3);V4
2110  PRINT TAB(2),"DISTANCE FROM TENSION LINK/BASE HINGE TO COMP. LINK,in. ---
H1";SPA(3);H1
2120  PRINT TAB(2),"DISTANCE FROM TENSION LINK/BASE HINGE TO LEG,in. ----------
H4";SPA(3);H4
2130  PRINT TAB(2),"COMPRESSION LINK BASE ARM, inches -------------------------
V1";SPA(3);V1
2140  PRINT TAB(2),"THICKNESS OF CANOPY,inches --------------------------------
DC";SPA(3);Deltc
2150  PRINT TAB(2),"THICKNESS OF BASE  ,inches --------------------------------
DB";SPA(3);Deltb
2160  PRINT TAB(2),"ANGLE CANOPY MAKES WITH HORIZONTAL, degrees ---------------
T6";SPA(3);Thet6
2170  PRINT TAB(2),"ANGLE BETWEEN CAVING SHIELD AND LINKAGE SHIELD,degrees ----
T3";SPA(3);Thet3
2180 RETURN
2190 PRINT PAGE,TAB(45.00),"SPATIAL PARAMETERS -- SHIELD GEOMETRY REPORT"
2200 PRINT LIN(2),SPA(5);"X1,Y1";SPA(14);"X2,Y2";SPA(15);"X3,Y3";SPA(15);"X4,Y4"
;SPA(15);"X5,Y5";SPA(15);"X6,Y6";SPA(15);"X7,Y7",LIN(1.00)
2210 A$=" , "
2220 FOR J=1.00 TO I
2230 PRINT USING 200;X1(J);A$;Y1(J);X2(J);A$;Y2(J);X3(J);A$;Y3(J);X4(J);A$;Y4(J)
;X5(J);A$;Y5(J);X6(J);A$;Y6(J);X7(J);A$;Y7(J)
2240 NEXT J
2250 PRINT PAGE,TAB(40),"SPATIAL PARAMETERS -- SHIELD GEOMETRY REPORT continued"
2260 PRINT LIN(2),TAB(7),"XR3,YR3";SPA(13);"XR4,YR4";SPA(13);"XR6,YR6";SPA(14);"
H1,V1";SPA(15);"H4,V4";SPA(15);"X0,Y0",LIN(1.00)
2270 A$=" , "
2280 FOR J=1.00 TO I
2290 PRINT USING 210;Xr3(J);A$;Yr3(J);Xr4(J);A$;Yr4(J);Xr6(J);A$;Yr6(J);H1;A$;V1
;H4;A$;V4;X0(J);A$;Y0(J)
2300 NEXT J
2310 PRINT PAGE,TAB(40),"SHIELD GEOMETRY -- SUPPORT HEIGHT AND FORCE INCLINATION
 REPORT"
2320*PRINT LIN(2),"HEIGHT";SPA(12);"01";SPA(9);"02";SPA(9);"03";SPA(9);"04";SPA(
9);"06";SPA(12);"LEG ANGLE";SPA(7);"CAPSULE ANGLE";SPA(7);"COMPRESSION LINK ANGL
2330 FOR J=1.00 TO I
2340 PRINT USING 220;H(J);Ag(J);Thet2(J);Thet3;Thetr4(J);Thet6(J);Legang(J);Capa
ng(J);Linang(J)
2350 NEXT J
2360 CALL Plot
2370 CALL Dimplot
2380 END
2390 SUB Plot
2400 COM X1(99),Y1(99),X2(99),Y2(99),X3(99),Y3(99),X4(99),Y4(99),X5(99),Y5(99),X
6(99),Y6(99),X7(99),Y7(99),X8(99),Y8(99),Xr3(99),Yr3(99),Xr4(99),Yr4(99),H(99)
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```
2410 COM Xr6(99),Yr6(99),Angs,Angf,H1,H4,V1,V4
2420 DIM Agl(99)
2430 PRINT PAGE
2440 INPUT "HOW MANY SHIELD GEOMETRIES DO YOU WISH TO PLOT?",Nogeom
2450  FOR X=1 TO Nogeom
2460 INPUT "ANGLE FOR SHIELD GEOMETRY NO.",Agl(X)
2470 NEXT X
2480 Xmin=1000
2490 Xmax=-1000
2500 Ymin=0
2510 Ymax=-1000
2520 FOR M=1 TO Nogeom
2530 I=Agl(M)-Angs+1
2540 IF X4(I)>X8(I) THEN 2570
2550 Bigx=X8(I)
2560 GOTO 2580
2570 Bigx=X4(I)
2580 IF Bigx>Xmax THEN 2600
2590 GOTO 2610
2600 Xmax=Bigx
2610 IF Xmin>X1(I) THEN 2630
2620 GOTO 2640
2630 Xmin=X1(I)
2640 IF Y3(I)>Y4(I) THEN 2670
2650 Bigy=Y4(M)
2660 GOTO 2680
2670 Bigy=Y3(I)
2680 IF Bigy>Ymax THEN 2700
2690 GOTO 2710
2700 Ymax=Bigy
2710 IF Ymax>Y5(I) THEN 2740
2720 Ymax=Y5(I)
2730 GOTO 2750
2740 IF Ymax>Y6(I) THEN 2760
2750 Ymax=Y6(I)
2760 IF Ymin>V4 THEN 2780
2770 GOTO 2790
2780 Ymin=V4
2790 NEXT M
2800 PLOTTER IS 13,"GRAPHICS"
2810 GRAPHICS
2820 LOCATE 5,130,5,100
2830 SCALE -50,150,-50,150
2840 FOR M=1 TO Nogeom
2850 I=Agl(M)-Angs+1
2860 MOVE 0,0
2870 DRAW X8(I),0
2880 MOVE 0,0
2890 DRAW X1(I),Y1(I)
2900 DRAW X2(I),Y2(I)
2910 DRAW X3(I),Y3(I)
2920 DRAW X4(I),Y4(I)
2930 MOVE H4,0
2940 DRAW Xr6(I),Yr6(I)
2950 DRAW X6(I),Y6(I)
2960 MOVE X5(I),Y5(I)
2970 DRAW Xr4(I),Yr4(I)
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```
2980 DRAW Xr3(I),Yr3(I)
2990 DRAW X7(I),Y7(I)
3000 MOVE X2(I),Y2(I)
3010 DRAW H1,V1
3020 DRAW H1,0
3030 DUMP GRAPHICS
3040 NEXT M
3050 SUBEND
3060 SUB Dimplot
3070 PLOTTER IS 13,"GRAPHICS"
3080 GRAPHICS
3090 LOCATE 5,130,5,100
3100 SCALE -50,150,-50,150
3110 MOVE 0,0
3120 DRAW 69.1,0
3130 MOVE 0,0
3140 DRAW -17.5,48.2
3150 DRAW 22.9,106.4
3160 DRAW 134.7,106.4
3170 MOVE 20.7,0
3180 DRAW 20.7,20.6
3190 DRAW -8.6,61.1
3200 MOVE 3.6,78.6
3210 DRAW 10.7,73.6
3220 DRAW 27.7,98.
3230 DRAW 27.7,106.4
3240 MOVE 33.3,0
3250 DRAW 33.3,8
3260 DRAW 52,98.4
3270 DRAW 52,106.4
3280 IF Flag$="SPAT" THEN 3980
3290 MOVE 0,-5
3300 DRAW 0,-10
3310 MOVE 0,-7.5
3320 DRAW 69.1,-7.5
3330 MOVE 69.1,-5
3340 DRAW 69.1,-10
3350 MOVE 32,-15
3360 LABEL "L5"
3370 MOVE 22.9,110
3380 DRAW 22.9,126
3390 MOVE 27.7,110
3400 DRAW 27.7,114
3410 MOVE 52,116
3420 DRAW 52,120
3430 MOVE 134.7,122
3440 DRAW 134.7,126
3450 MOVE 22.9,112
3460 DRAW 27.7,112
3470 MOVE 29.0,110
3480 LABEL "L7"
3490 MOVE 22.9,118
3500 DRAW 52,118
3510 MOVE 35,119
3520 LABEL "L9"
3530 MOVE 22.9,124
3540 DRAW 134.7,124
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3550 MOVE 75,125
3560 LABEL "L3"
3570 MOVE -21,50
3580 DRAW -25,54
3590 MOVE -12,63
3600 DRAW -22,73.5
3610 MOVE 20,108
3620 DRAW 16.5,111.5
3630 MOVE -23,52
3640 DRAW -14,65
3650 DRAW 18,110
3660 MOVE -4.5,86
3670 DRAW -9,91
3680 MOVE -7.25,88.5
3690 DRAW -19.5,71
3700 MOVE -21,58.0
3710 DEG
3720 LDIR 53
3730 LABEL "L1"
3740 MOVE 1,88
3750 LABEL "L2"
3760 MOVE -15.5,79
3770 LDIR 51
3780 LABEL "L6"
3790 LDIR 0
3800 MOVE 29.0,100
3810 LABEL "R4"
3820 MOVE 54,100
3830 LABEL "R6"
3840 MOVE 6.5,78
3850 LABEL "R3"
3860 MOVE 7,41
3870 LABEL "R2"
3880 MOVE -7,25
3890 LABEL "R1"
3900 MOVE 22,10
3910 LABEL "V1"
3920 MOVE 35,4
3930 LABEL "V4"
3940 DUMP GRAPHICS
3950 Flag$="SPAT"
3960  GCLEAR
3970 GOTO 3110
3980 MOVE -7,-6
3990 LABEL "(0,0)"
4000 MOVE 10,-6
4010 LABEL "(H1,0)"
4020 MOVE 28,-6
4030 LABEL "(H4,0)"
4040 MOVE 62,-7
4050 LABEL "(L5,0)"
4060 MOVE -2,19
4070 LABEL "(H1,V1)"
4080 MOVE 35,3
4090 LABEL "(H4,V4)"
4100 MOVE -40,46
4110 LABEL "(X1,Y1)"
4120 MOVE -31,59
```

```
4130 LABEL "(X2,Y2)"
4140 MOVE -20,77
4150 LABEL "(X7,Y7)"
4160 MOVE 0,105
4170 LABEL "(X3,Y3)"
4180 MOVE 20,110
4190 LABEL "(X5,Y5)"
4200 MOVE 43,110
4210 LABEL "(X6,Y6)"
4220 MOVE 118,110
4230 LABEL "(X4,Y4)"
4240 MOVE 54,98
4250 LABEL "(XR6,YR6)"
4260 MOVE 26,92
4270 LABEL "(XR4,YR4)"
4280 MOVE 12,68
4290 LABEL "(XR3,YR3)"
4300 DUMP GRAPHICS
4310 SUBEND
```

```
1 REM ******************** PROGRAM NAME -- EMVECT ******************************
2 DEG
5 DIM H(85),X1(85),Y1(85),X2(85),Y2(85),X3(85),Y3(85),X4(85),Y4(85),X5(85),Y5(85
),X6(85),Y6(85),X7(85),Y7(85),Xr3(85),Yr3(85),Xr4(85),Yr4(85),Xr6(85),Yr6(85)
6 DIM Legang(85),Canang(85),Linang(85),X0(85),Y0(85)
10 DIM Des$(5)[75],Nodtpt(959),Dat$(4)[75],Dy$[25],Mo$[25],Ag(85)
20 DIM T(4,950),Lleng(950),Rleng(950),Ceeng(950),Creng(950),Rtfeng(950),Ltfeng(9
50),Rtreng(950),Ltreng(950)
30 DIM Totlegf(4,950),Netcanf(4,950),Totlinkf(4,950)
40 DIM Mag(4,950),Vert(4,950),Horz(4,950),Loc(4,950),Ang(4,950)
50    REM PROGRAM NAME - EMSTAT
60    PRINTER IS 16
70    PRINT PAGE,"THIS PROGRAM READS ENGINEERING UNITS FILES AND SHIELD GEOMETRY
 FILES TO PROCESS DATA INTO RESULTANT LOAD VECTOR PARAMETERS."
80    PRINT LIN(2),"PLEASE FOLLOW INSTRUCTIONS CAREFULLY!!"
90    PRINT "PRESS CONT WHEN READY TO CONTINUE."
100   PAUSE
110   PRINT PAGE,"BEFORE BEGINNING, INSERT TAPE MARKED SHIELD GEOMETRY FILES I
NTO TAPE DRIVE T15."
120   PRINT LIN(5),"PRESS CONT AFTER INSERTING SHIELD GEOMETRY FILES INTO T15.
"
130   PAUSE
140  ASSIGN #6 TO "EMLKSP"
150  READ #6,1;Id1$,Legarea
160  READ #6,2;Id2$,Cearea
165  READ #6,3;Id3$,Crarea
170  READ #6,4;Id4$,Linkthick
180  READ #6,5;Id5$,Centdist
190  READ #6,6;Id6$,Modelas
200  READ #6,7;Id7$,Linkxsect
205 READ #6,8;Id8$,Legline
210 PRINT PAGE,"PLEASE INSERT TAPE MARKED ENGINEERING UNITS FILES INTO TAPE DR
IVE T15"
220 PRINT LIN(5),"PRESS CONT AFTER INSERTING ENGINEERING UNITS FILES TAPE INTO
 T15"
230 PAUSE
240   INPUT "DATE DATA WAS TAKEN: mmddyy",Date$
250   F$=Date$[1,4]
260   F$=F$&Date$[6,6]
270   Sh1$="1"&F$
280   Sh2$="2"&F$
290   Sh3$="3"&F$
300   Sh4$="4"&F$
310   ASSIGN #1 TO Sh1$
320   ASSIGN #2 TO Sh2$
330   ASSIGN #3 TO Sh3$
340   ASSIGN #4 TO Sh4$
350   FOR I=1 TO 4
360   READ #I,1;Des$(I)
365 READ #I,2;Dat$(I)
370   READ #I,3;Nodtpt(I)
375 READ #I,4;Shht(I)
380   FOR J=1 TO Nodtpt(I)
390   READ #I,J+4;T(I,J),Lleng(J),Rleng(J),Ceeng(J),Creng(J),Rtfeng(J),Ltfeng(J)
,Rtreng(J),Ltreng(J)
400   NEXT J
420   REM  *****CALCULATION OF LEG AND LINK FORCES*****
440   FOR J=1 TO Nodtpt(I)
```

```
441   Llforce=Lleng(J)*Legarea/2000
442   Rlforce=Rleng(J)*Legarea/2000
470   Totlegf(I,J)=Llforce+Rlforce
480   Ceforce=Ceeng(J)*Cearea/2000
490   Crforce=Creng(J)*Crarea/2000
500   Netcanf(I,J)=Ceforce-Crforce
510   Ltlemslope=(Ltfeng(J)-Ltreng(J))/Linkthick
515   Rtlemslope=(Rtfeng(J)-Rtreng(J))/Linkthick
516   Ltlemyint=(Ltfeng(J)+Ltreng(J))/2
520   Rtlemyint=(Rtfeng(J)+Rtreng(J))/2
525   Ltlemcent=Ltlemslope*Centdist+Ltlemyint
530   Rtlemcent=Rtlemslope*Centdist+Rtlemyint
540   Ltlemforce=Ltlemcent*Modelas*Linkxsect/2000
550   Rtlemforce=Rtlemcent*Modelas*Linkxsect/2000
560   Totlinkf(I,J)=Ltlemforce+Rtlemforce
570   NEXT J
580   NEXT I
920 PRINT PAGE,"REMOVE ENGINEERING UNITS FILES TAPE FROM T15 AND INSERT SHIEL
D GEOMETRY FILES TAPE INTO T15"
930 PRINT LIN(5),"PRESS CONT AFTER CHANGING TAPES!!!"
940 PAUSE
950   ASSIGN #5 TO "GEOFIL"
960   READ #5,1;Nogeom
970   FOR I=1 TO Nogeom
980   READ #5,I+1;Hh,Xx0,Yy0,Xx1,Yy1,Xx2,Yy2,Xx3,Yy3,Xx4,Yy4,Xx5,Yy5,Xx6,Yy6,Xx7
,Yy7,Xxr3,Yyr3,Xxr4,Yyr4,Xxr6,Yyr6,H1,V1,H4,V4,Ag(I),Lega,Capa,Lina
990   H(I)=Hh
1000  X1(I)=Xx1
1010  Y1(I)=Yy1
1020  X2(I)=Xx2
1030  Y2(I)=Yy2
1040  X3(I)=Xx3
1050  Y3(I)=Yy3
1060  X4(I)=Xx4
1070  Y4(I)=Yy4
1080  X5(I)=Xx5
1090  Y5(I)=Yy5
1100  X6(I)=Xx6
1110  Y6(I)=Yy6
1120  X7(I)=Xx7
1130  Y7(I)=Yy7
1140  Xr3(I)=Xxr3
1150  Yr3(I)=Yyr3
1160  Xr4(I)=Xxr4
1170  Yr4(I)=Yyr4
1180  Xr6(I)=Xxr6
1190  Yr6(I)=Yyr6
1195 X0(I)=Xx0
1196 Y0(I)=Yy0
1200  Legang(I)=Lega
1210  Canang(I)=Capa
1220  Linang(I)=Lina
1230  NEXT I
1240  FOR I=1 TO 4
1260  FOR K=1 TO Nogeom
1270  IF INT(Shht(I)+.5)<>INT(H(K)+.5) THEN 1510
1280  X1v(I)=X1(K)
```

```
1290  Y1v(I)=Y1(K)
1300  X2v(I)=X2(K)
1310  Y2v(I)=Y2(K)
1320  X3v(I)=X3(K)
1330  Y3v(I)=Y3(K)
1340  X4v(I)=X4(K)
1350  Y4v(I)=Y4(K)
1360  X5v(I)=X5(K)
1370  Y5v(I)=Y5(K)
1380  X6v(I)=X6(K)
1390  Y6v(I)=Y6(K)
1400  X7v(I)=X7(K)
1410  Y7v(I)=Y7(K)
1420  Xr3v(I)=Xr3(K)
1430  Yr3v(I)=Yr3(K)
1440  Xr4v(I)=Xr4(K)
1450  Yr4v(I)=Yr4(K)
1460  Xr6v(I)=Xr6(K)
1470  Yr6v(I)=Yr6(K)
1475 X0v(I)=X0(K)
1476 Y0v(I)=Y0(K)
1480  Legagv(I)=Legang(K)
1490  Canagv(I)=Canang(K)
1500  Linagv(I)=Linang(K)
1510  NEXT K
1520  NEXT I
1530  FOR I=1 TO 4
1540  FOR J=1 TO Nodtpt(I)
1550  Vblue=Totlegf(I,J)*COS(Legagv(I))*(X6v(I)-X3v(I))+Netcanf(I,J)*SIN(Canagv(
I))*(X5v(I)-X3v(I))+Netcanf(I,J)*COS(Canagv(I))*(Y5v(I)-Yr4v(I))
1560  Vgreen=Totlegf(I,J)*COS(Legagv(I))*(X6v(I)-X3v(I))+Netcanf(I,J)*SIN(Canagv
(I))*(X5v(I)-X3v(I))+Netcanf(I,J)*COS(Canagv(I))*(Y5v(I)-Yr4v(I))
1570  Vyellow=-Totlegf(I,J)*COS(Legagv(I))*(X6v(I)-X0v(I))+Totlegf(I,J)*SIN(Lega
gv(I))*(Y3v(I)-Y0v(I))
1580  Vpink=Y3v(I)-Y0v(I)
1590  Vdtblue=Y3v(I)-Y1v(I)
1600  Vdtblack=Totlegf(I,J)*COS(Legagv(I))*(X6v(I)-X1v(I))-Totlegf(I,J)*SIN(Lega
gv(I))*(Y3v(I)-Y1v(I))
1610  Vdtgreen=-Totlinkf(I,J)*COS(Linagv(I))*(Y2v(I)-Y1v(I))-Totlinkf(I,J)*SIN(L
inagv(I))*(X2v(I)-X1v(I))
1620  Vred=-(X3v(I)-X1v(I))+(X3v(I)-X0v(I))/(Y3v(I)-Y0v(I))*(Y3v(I)-Y1v(I))
1630  Vert(I,J)=(Vblue-(Vyellow+Vgreen)/Vpink*Vdtblue-Vdtblack-Vdtgreen)/Vred
1640  Vertloc=Totlegf(I,J)*COS(Legagv(I))*(X6v(I)-X3v(I))+Netcanf(I,J)*SIN(Canag
v(I))*(X5v(I)-X3v(I))+Netcanf(I,J)*COS(Canagv(I))*(Y5v(I)-Yr4v(I))
1650  Horz(I,J)=(Vertloc+Vert(I,J)*(X3v(I)-X0v(I))-Totlegf(I,J)*COS(Legagv(I))*(
X6v(I)-X0v(I))+Totlegf(I,J)*SIN(Legagv(I))*(Y3v(I)-Y0v(I)))/(Y3v(I)-Y0v(I))
1660  Loc(I,J)=Vertloc/Vert(I,J)-Legline
1670  Ang(I,J)=-ATN(Horz(I,J)/Vert(I,J))
1680  Mag(I,J)=(Vert(I,J)^2+Horz(I,J)^2)^.5
1690  NEXT J
1700  NEXT I
1705 PRINTER IS 7,1,WIDTH(160)
1710  A$="SH. #"
1720  B$="REC. #"
1730  C$="LEG FORCE"
1740  D$="CAN.FORCE"
1750  E$="LINK FORCE"
```

```
1760  F$="MAG"
1770  G$="VERT"
1780  H$="HORZ"
1790  I$="LOC"
1800  J$="ANG"
1810  FOR I=1 TO 4
1820  PRINT PAGE,TAB(49),"EMERALD MINE - RESULTANT LOAD VECTOR STUDIES"
1830  PRINT LIN(1),TAB(55),"DATA FOR SHIELD #";I
1835 PRINT LIN(1),TAB(35),"UNITS:  LEC FORCE, CAN. FORCE,LINK FORCE,MAG,VERT,HOR
Z  -  tons"
1836 PRINT TAB(35),"         LOC   -  inches from leg line: + FORWARD - REARWARD"
1837 PRINT TAB(35),"         ANG   -  degrees from vertical + WASTE-TO-FACE - FACE
-TO-WASTE"
1840  PRINT LIN(2),"FILE DESCRIPTION - ";Des$(I)
1850  PRINT "DATE DATA WAS TAKEN - ";Dat$(I)
1860  PRINT "NUMBER OF DATA POINTS - ";Nodtpt(I),LIN(1)
1870  FOR M=1 TO Nodtpt(I) STEP 50
1880  PRINT USING 1890;A$,B$,C$,D$,E$,F$,G$,H$,I$,J$
1890  IMAGE 5X,5A,5X,6A,9X,9A,4X,9A,4X,10A,15X,3A,7X,4A,7X,4A,7X,3A,7X,3A
1900  FOR N=M TO M+49
1910  PRINT USING 1920;I,N,Totlegf(I,N),Netcanf(I,N),Totlinkf(I,N),Mag(I,N),Vert
(I,N),Horz(I,N),Loc(I,N),Ang(I,N)
1920  IMAGE 9X,1D,9X,3D,12X,DDD.D,7X,MDDD.D,7X,MDDD.D,15X,MDDD.D,4X,MDDD.D,5X,MD
DD.D,6X,MDD.DD,5X,MDD.DD
1930  NEXT N
1940  NEXT M
1950  NEXT I
1960 PRINTER IS 16
1970 PRINT PAGE,"REMOVE SHIELD GEOMETRY FILES FROM T15 AND INSERT RESULTANT L
OAD FILES!!!"
1980 PRINT LIN(5),"PRESS CONT AFTER CHANGING TAPES!!"
1990 PAUSE
1991 CREATE Sh1$,Nodtpt(1),90
1992 CREATE Sh2$,Nodtpt(2),90
1993 CREATE Sh3$,Nodtpt(3),90
1994 CREATE Sh4$,Nodtpt(4),90
1995 ASSIGN #1 TO Sh1$
1996 ASSIGN #2 TO Sh2$
1997 ASSIGN #3 TO Sh3$
1998 ASSIGN #4 TO Sh4$
2000 FOR I=1 TO 4
2010 FOR J=1 TO Nodtpt(I)
2020 PRINT #I,J;I,J,T(I,J),Totlegf(I,J),Netcanf(I,J),Totlinkf(I,J),Mag(I,J),Vert
(I,J),Horz(I,J),Loc(I,J),Ang(I,J)
2030 NEXT J
2040 NEXT I
9999 END
```

```
1       REM ******************* PROGRAM NAME -- EMTAVG *************************
2       DIM T(999).Legf(999),Capf(999),Linf(999),Mag(999),Vert(999),Horz(999),Loc(
999),Ang(999)
10      REM PROGRAM NAME - EMTAVG
20      PRINTER IS 16
30      INPUT "INPUT DATE DATA WAS TAKEN? mmddyy",Date$
40      F$=Date$[1,4]
50      F$=F$&Date$[6,6]
60      Sh1$="1"&F$
70      Sh2$="2"&F$
80      Sh3$="3"&F$
90      Sh4$="4"&F$
100     ASSIGN #1 TO Sh1$
110     ASSIGN #2 TO Sh2$
120     ASSIGN #3 TO Sh3$
130     ASSIGN #4 TO Sh4$
131     FOR I=1 TO 4
132     Magsum=0
133     Vertsum=0
134     Horzsum=0
135     Locsum=0
136     Angsum=0
150     PRINT PAGE,"NO. OF DATA POINTS FOR SHIELD #";I
151     INPUT "#OF DATA POINTS",Nodtpt(I)
180     FOR J=1 TO Nodtpt(I)
190     READ #I,J;I,J,T(J),Legf(J),Capf(J),Linf(J),Mag(J),Vert(J),Horz(J),Loc(J),A
ng(J)
200     NEXT J
230     PRINT PAGE,"DO YOU WANT TO AVERAGE BY SHIELD CYCLE OR FOR ALL DATA?"
240     INPUT "INPUT A FOR ALL DATA OR S FOR SHIELD CYCLE",Ans$
250     IF Ans$="S" THEN 300
260     Nocycles=1
270     Begcyc=1
280     Endcyc=Nodtpt(I)
290     GOTO 320
300     PRINT PAGE,"HOW MANY SHIELD CYCLES AREA THERE FOR SHIELD #";I
310     INPUT "NO. OF SHIELD CYCLES",Nocycles
320     FOR N=1 TO Nocycles
330     IF Ans$="A" THEN 350
331     PRINT LIN(5),"INPUT BEGINNING,ENDING RECORD FOR SHIELD #";I;" CYCLE #";N
340     INPUT "BEGINNING,ENDING CYCLE NOS",Begcyc,Endcyc
350     FOR J=Begcyc TO Endcyc-1
351     Dt=T(J+1)-T(J)
390     Dtsum(N)=Dt+Dtsum(N)
400     Dmag=(Mag(J+1)+Mag(J))/2
410     Dvert=(Vert(J+1)+Vert(J))/2
420     Dhorz=(Horz(J+1)+Horz(J))/2
430     Dloc=(Loc(J+1)+Loc(J))/2
440     Dang=(Ang(J+1)+Ang(J))/2
450     Magarea=Dmag*Dt
460     Vertarea=Dvert*Dt
470     Horzarea=Dhorz*Dt
480     Locarea=Dloc*Dt
490     Angarea=Dang*Dt
500     Summag(N)=Magarea+Summag(N)
510     Sumvert(N)=Vertarea+Sumvert(N)
520     Sumhorz(N)=Horzarea+Sumhorz(N)
```

```
530    Sumloc(N)=Locarea+Sumloc(N)
540    Sumang(N)=Angarea+Sumang(N)
545    NEXT J
550    Magavg(N)=Summag(N)/Dtsum(N)
560    Vertavg(N)=Sumvert(N)/Dtsum(N)
570    Horzavg(N)=Sumhorz(N)/Dtsum(N)
580    Locavg(N)=Sumloc(N)/Dtsum(N)
585    Angavg(N)=Sumang(N)/Dtsum(N)
591    Magsum=Magsum+Magavg(N)
592    Vertsum=Vertsum+Vertavg(N)
593    Horzsum=Horzsum+Horzavg(N)
594    Locsum=Locsum+Locavg(N)
595    Angsum=Angsum+Angavg(N)
610    NEXT N
611    Nummag=Magsum/(N-1)
612    Numvert=Vertsum/(N-1)
613    Numhorz=Horzsum/(N-1)
614    Numloc=Locsum/(N-1)
615    Numang=Angsum/(N-1)
620    PRINTER IS 7,1,WIDTH(160)
630    PRINT PAGE,TAB(40),"TIME WEIGHTED AVERAGE LOAD ANALYSIS"
640 PRINT TAB(50),"DATA FOR SHIELD #";I
650 PRINT LIN(2),"DATE DATA WAS TAKEN:",Date$
660 PRINT "FILE DESCRIPTION",Des$(I)
670 PRINT "NO. OF DATA POINTS",Nodtpt(I)
680    PRINT LIN(2),TAB(30),"MAG",SPA(8),"VERT",SPA(8),"HORZ",SPA(8),"LOC",SPA(8)
,"ANG"
690    FOR N=1 TO Nocycles
700    PRINT USING 710;"AVG(CYCLE #",N,")",Magavg(N),Vertavg(N),Horzavg(N),Locavg
(N),Angavg(N)
710 IMAGE 3X,11A,D,A,9X,M4D.DD,11X,M4D.DD,12X,M4D.DD,12X,M4D.DD,12X,M4D.DD
720    NEXT N
721    PRINT TAB(28);"______",SPA(6),"______",SPA(6),"______",SPA(6),"______",SPA
(6),"______"
722    PRINT USING 723;Nummag,Numvert,Numhorz,Numloc,Numang
723    IMAGE  25X,M4D.DD,11X,M4D.DD,12X,M4D.DD,12X,M4D.DD,12X,M4D.DD
724    PRINTER IS 16
730    NEXT I
1000   END
```

```
1      REM ****************** PROGRAM NAME -- EMDISP ***************************
2      DIM Nodtpt(999),Vert(4,999),Horz(4,999),Vertdisp(4,999),Horzdisp(4,999),T(
4,999),Hforpct(999),Vforpct(999),Hdisppct(999),Vdisppct(999)
3      PRINTER IS 16
10     REM PROGRAM NAME -- EMDISP
20     PRINT PAGE,"THIS PROGRAM ANALYZES DATA USING THE FOLLOWING DISPLACEMENT MO
DEL"
30     PRINT LIN(1),"VERTDISP = .0064 * HORZ. FORCE - .0116 * VERT. FORCE"
40     PRINT "HORZDISP = .0074 * VERT. FORCE - .0340 * HORZ. FORCE"
41     PRINT LIN(5),"PUT RESULTANT LOAD FILE IN T15"
50     INPUT "INPUT DATE TO BE ANALYZED",Date$
60     F$=Date$[1,4]
70     F$=F$&Date$[6,6]
80     Sh1$="1"&F$
90     Sh2$="2"&F$
100    Sh3$="3"&F$
110    Sh4$="4"&F$
111    ASSIGN #1 TO Sh1$
112    ASSIGN #2 TO Sh2$
113    ASSIGN #3 TO Sh3$
114    ASSIGN #4 TO Sh4$
160    FOR I=1 TO 4
170    PRINT PAGE,TAB(55),"SHIELD #";I
180    PRINT LIN(5),"INPUT NO. OF DATA POINTS ON FILE FOR SHIELD #";I
190    INPUT "NO. OF DATA POINTS",Nodtpt(I)
200    FOR J=1 TO Nodtpt(I)
210    READ #I,J;I,J,T(I,J),Legf,Canf,Linf,Mag,Vert(I,J),Horz(I,J),Loc,Ang
220    Vertdisp(I,J)=.0064*Vert(I,J)-.0116*Horz(I,J)
230    Horzdisp(I,J)=.0074*Vert(I,J)-.0340*Horz(I,J)
231    Hforpct(J)=ABS(Horz(I,J))/(ABS(Horz(I,J))+ABS(Vert(I,J)))
232    Vforpct(J)=ABS(Vert(I,J))/(ABS(Horz(I,J))+ABS(Vert(I,J)))
233    Hdisppct(J)=ABS(Horzdisp(I,J))/(ABS(Horzdisp(I,J))+ABS(Vertdisp(I,J)))
234    Vdisppct(J)=ABS(Vertdisp(I,J))/(ABS(Horzdisp(I,J))+ABS(Vertdisp(I,J)))
240    NEXT J
241    PRINTER IS 7,1,WIDTH(160)
250    PRINT PAGE,TAB(40),"DISPLACEMENT ANALYSIS FOR SHIELD #";I
251    PRINT LIN(1),TAB(55),"DATE:";Date$,LIN(2)
260    PRINT USING 261;"RECORD #","HORZ. FORCE","VERT. FORCE","HORZ. DISP","VERT.
 DISP","HORZ.FORCE PCT","VERT.FORCE PCT","HORZ.DISP.PCT","VERT.DISP.PCT"
261    IMAGE 8A,4X,11A,4X,11A,4X,10A,4X,10A,5X,14A,3X,14A,3X,13A,3X,13A
270    FOR J=1 TO Nodtpt(I)
280    PRINT USING 290;J,Horz(I,J),Vert(I,J),Horzdisp(I,J),Vertdisp(I,J),Hforpct(
J),Vforpct(J),Hdisppct(J),Vdisppct(J)
290    IMAGE 2X,DDD,9X,M3D.DD,8X,M3D.DD,6X,MDD.DD,8X,MDD.DD,12X,MDD.DD,11X,MDD.DD
,9X,MDD.DD,10X,MDD.DD
300    NEXT J
301    PRINTER IS 16
310    NEXT I
320    PRINT PAGE,"PUT DISPLACEMENT TAPE IN T15"
330    PRINT LIN(5),"PRESS CONT AFTER INSERTING TAPE"
340    PAUSE
368    CREATE Sh1$,Noatpt(1),56
369    CREATE Sh2$,Nodtpt(2),56
370    CREATE Sh3$,Nodtpt(3),56
371    CREATE Sh4$,Nodtpt(4),56
409    ASSIGN #1 TO Sh1$
410    ASSIGN #2 TO Sh2$
```

```
411   ASSIGN #3 TO Sh3$
412   ASSIGN #4 TO Sh4$
430   FOR I=1 TO 4
440   FOR J=1 TO Nodtpt(I)
450   PRINT #I,J;I,J,T(I,J),Horz(I,J),Vert(I,J),Horzdisp(I,J),Vertdisp(I,J)
460   NEXT J
470   NEXT I
999 END
```

```
10    REM **************** PROGRAM NAME -- EMPLOT ****************************
20    COM X(999),Y(999),Xmin,Xmax,Ymin,Ymax,T(999),Totlegf(999),Netcanf(999),Tot
linkf(999),Mag(999),Vert(999),Horz(999),Loc(999),Ang(999),Hvratio(999)
30    COM Xlabel$[100],Ylabel$[100],Nodtpt,Hrs(999),Elphrs(999),Shno$,Date$
40    PRINTER IS 16
50    PRINT PAGE,"THIS PROGRAM PRODUCES PLOTS OF RESULTANT SHIELD LOAD DATA"
60    PRINT LIN(5),"PRESS CONT WHEN READY TO CONTINUE"
70    PAUSE
80    PRINT PAGE,"PUT RESULTANT LOAD VECTOR FILE TAPE INTO T15"
90    PRINT LIN(5),"PRESS CONT AFTER INSERTING TAPE"
100   PAUSE
110   INPUT "INPUT DATE DATA WAS TAKEN? mmddyy",Date$
120   F$=Date$[1,4]
130   F$=F$&Date$[6,6]
140   Sh1$="1"&F$
150   Sh2$="2"&F$
160   Sh3$="3"&F$
170   Sh4$="4"&F$
180   ASSIGN #1 TO Sh1$
190   ASSIGN #2 TO Sh2$
200   ASSIGN #3 TO Sh3$
210   ASSIGN #4 TO Sh4$
220   FOR I=1 TO 4
230   PRINT PAGE,TAB(25),"SHIELD #";I
240   INPUT "INPUT NO. OF DATA POINTS ON FILE",Nodtpt
250   FOR J=1 TO Nodtpt
260   READ #I,J;I,J,T(J),Totlegf(J),Netcanf(J),Totlinkf(J),Mag(J),Vert(J),Horz(J
),Loc(J),Ang(J)
261   Shno$=VAL$(I)
270   Tt=T(J)
280   IF Tt>=100000 THEN 320
290   Tim$=VAL$(Tt)
300   Tim$="0"&Tim$
310   GOTO 330
320   Tim$=VAL$(Tt)
330   Thh$=Tim$[1,2]
340   Hh=VAL(Thh$)
350   Hhsec=Hh*3600
360   Tmm$=Tim$[3,4]
370   Mm=VAL(Tmm$)
380   Mmsec=Mm*60
390   Tss$=Tim$[5,6]
400   Ss=VAL(Tss$)
410   Sssec=Ss
420   Seconds=Hhsec+Mmsec+Sssec
430   Hrs(J)=Seconds/3600
440   Hvratio(J)=Horz(J)/Vert(J)
450   NEXT J
460   Elphrs(1)=0
470   FOR N=2 TO Nodtpt
480   Elphrs(N)=Hrs(N)-Hrs(1)
490   NEXT N
500   PRINT LIN(1),TAB(25),"PRINTING OPTIONS"
510   PRINT LIN(1),TAB(5),"1.  RESULTANT MAGNITUDE VS TIME"
520   PRINT TAB(5),"2.  VERTICAL FORCE      VS    TIME"
530   PRINT TAB(5),"3.  HORIZONTAL FORCE    VS    TIME"
540   PRINT TAB(5),"4.  RESULTANT LOCATION  VS    TIME"
```

```
550   PRINT TAB(5),"5.  RESULTANT ANGLE      VS     TIME"
560   PRINT TAB(5),"6.  LEG FORCE            VS     TIME"
570   PRINT TAB(5),"7.  CAPSULE FORCE        VS     TIME"
580   PRINT TAB(5),"8.  LINK FORCE           VS     TIME"
590   PRINT TAB(5),"9.  HORIZONTAL FORCE     VS     LEG FORCE"
600   PRINT TAB(5),"10. VERTICAL FORCE       VS     LEG FORCE"
610   PRINT TAB(5),"11. HORIZONTAL FORCE     VS     LINK FORCE"
620   PRINT TAB(5),"12. HORZ/VERT FORCE      VS     TIME"
630   PRINT TAB(5),"13. LOCATION             VS     CAPSULE FORCE"
640   PRINT TAB(5),"14. HORZIONTAL FORCE     VS     VERTICAL FORCE"
650   INPUT "SELECT A PRINTING OPTION: 1-14",Ptopt
660   IF Ptopt=1 THEN 800
670   IF Ptopt=2 THEN 890
680   IF Ptopt=3 THEN 990
690   IF Ptopt=4 THEN 1090
700   IF Ptopt=5 THEN 1190
710   IF Ptopt=6 THEN 1290
720   IF Ptopt=7 THEN 1390
730   IF Ptopt=8 THEN 1490
740   IF Ptopt=9 THEN 1590
750   IF Ptopt=10 THEN 1690
760   IF Ptopt=11 THEN 1790
770   IF Ptopt=12 THEN 1890
780   IF Ptopt=13 THEN 1990
790   IF Ptopt=14 THEN 2090
800   Xlabel$="ELAPSED FACE TIME, Hrs"
810   Ylabel$="RESULTANT MAGNITUDE, tons"
820   MAT X=Elphrs
830   MAT Y=Mag
840   CALL Minmax
850   CALL Plot
860   INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION? Y/N",Ans$
870   IF Ans$="N" THEN 2190
880   GOTO 500
890   Xlabel$="ELAPSED FACE TIME, hrs"
900   Ylabel$="VERTICAL FORCE, tons"
910   MAT X=Elphrs
920   MAT Y=Vert
930   INPUT "NO. DATA POINTS TO BE PLOTTED?",Nodtpt
940   CALL Minmax
950   CALL Plot
960   INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION? Y/N",Ans$
970   IF Ans$="N" THEN 2190
980   GOTO 500
990   Xlabel$="ELAPSED FACE TIME, hrs"
1000  Ylabel$="HORIZONTAL FORCE, tons"
1010  MAT X=Elphrs
1020  MAT Y=Horz
1030  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
1040  CALL Minmax
1050  CALL Plot
1060  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION? Y/N",Ans$
1070  IF Ans$="N" THEN 2190
1080  GOTO 500
1090  Xlabel$="ELAPSED FACE TIME, hrs"
1100  Ylabel$="LOCATION, inches from leg line"
1110  MAT X=Elphrs
```

```
1120  MAT Y=Loc
1130  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
1140  CALL Minmax
1150  CALL Plot
1160  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1170  IF Ans$="N" THEN 2190
1180  GOTO 500
1190  Xlabel$="ELAPSED FACE TIME, hrs"
1200  Ylabel$="ANGLE, degrees from vertical"
1210  MAT X=Elphrs
1220  MAT Y=Ang
1230  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
1240  CALL Minmax
1250  CALL Plot
1260  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1270  IF Ans$="N" THEN 2190
1280  GOTO 500
1290  Xlabel$="ELAPSED FACE TIME, hrs"
1300  Ylabel$="LEG FORCE, tons"
1310  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
1320  MAT X=Elphrs
1330  MAT Y=Totlegf
1340  CALL Minmax
1350  CALL Plot
1360  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1370  IF Ans$="N" THEN 2190
1380   GOTO 500
1390  Xlabel$="ELAPSED FACE TIME, hrs"
1400  Ylabel$="CAPSULE FORCE, tons"
1410  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
1420  MAT X=Elphrs
1430  MAT Y=Netcanf
1440  CALL Minmax
1450  CALL Plot
1460  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1470  IF Ans$="N" THEN 2190
1480   GOTO 500
1490  Xlabel$="ELAPSED FACE TIME, hrs"
1500  Ylabel$="LINK FORCE, tons"
1510  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
1520  MAT X=Elphrs
1530  MAT Y=Totlinkf
1540  CALL Minmax
1550  CALL Plot
1560  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1570   IF Ans$="N" THEN 2190
1580   GOTO 500
1590  Xlabel$="LEG FORCE, tons"
1600  Ylabel$="HORIZONTAL FORCE, tons"
1610  MAT X=Totlegf
1620  MAT Y=Horz
1630  INPUT "NO. OF DAT POINTS TO BE PLOTTED?",Nodtpt
1640  CALL Minmax
1650  CALL Plot
1660  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1670  IF Ans$="N" THEN 2190
1680  GOTO 500
```

```
1690  Xlabel$="LEF FORCE, tons"
1700  Ylabel$="VERTICAL FORCE, tons"
1710  MAT X=Totlegf
1720  MAT Y=Vert
1730  INPUT "NO. OF DAT POINTS TOP BE PLOTTED?",Nodtpt
1740  CALL Minmax
1750  CALL Plot
1760  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1770   IF Ans$="N" THEN 2190
1780   GOTO 500
1790  Xlabel$="LINK FORCE, tons"
1800  Ylabel$="HORIZONTAL FORCE, tons"
1810  MAT X=Totlinkf
1820   MAT Y=Horz
1830  INPUT "NO. OF DAT POINTS TO BE PLOTTED?",Nodtpt
1840  CALL Minmax
1850   CALL Plot
1860  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1870  IF Ans$="N" THEN 2190
1880  GOTO 500
1890  Xlabel$="ELAPSED FACE TIME, hrs"
1900  Ylabel$="HORZ/VERT"
1910  MAT X=Elphrs
1920  MAT Y=Hvratio
1930  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
1940  CALL Minmax
1950  CALL Plot
1960  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
1970  IF Ans$="N" THEN 2190
1980  GOTO 500
1990  Xlabel$="CAPSULE FORCE, tons"
2000  Ylabel$="LOCATION, inches from leg line"
2010  MAT X=Netcapf
2020  MAT Y=Loc
2030  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
2040  CALL Minmax
2050  CALL Plot
2060  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
2070  IF Ans$="N" THEN 2190
2080  GOTO 500
2090  Xlabel$="VERTICAL FORCE, tons"
2100  Ylabel$="HORIZONTAL FORCE, tons"
2110  MAT X=Vert
2120  MAT Y=Horz
2130  INPUT "NO. OF DATA POINTS TO BE PLOTTED?",Nodtpt
2140  CALL Minmax
2150   CALL Plot
2160  INPUT "DO YOU WANT TO SELECT ANOTHER PRINT OPTION?",Ans$
2170  IF Ans$="N" THEN 2190
2180  GOTO 500
2190 NEXT I
2200  PRINT PAGE,"DO YOU WANT TO SELECT ANOTHER DATA SET? Y/N"
2210  INPUT Ans$
2220  IF Ans$="Y" THEN 110
2230  END
2240  SUB Minmax
2250  COM X(999),Y(999),Xmin,Xmax,Ymin,Ymax,T(999),Totlegf(999),Netcapf(999),Tot
linkf(999),Mag(999),Vert(999),Horz(999),Loc(999),Ang(999),Hvratio(999)
```

```
2260  COM Xlabel$[100],Ylabel$[100],Nodtpt,Hrs(999),Elphrs(999),Shno$,Date$
2270  Xmin=X(1)
2280  Ymin=Y(1)
2290  Xmax=X(1)
2300  Ymax=Y(1)
2310  FOR I=1 TO Nodtpt
2320  IF X(I)<Xmax THEN 2340
2330  Xmax=X(I)
2340  IF X(I)>Xmin THEN 2360
2350  Xmin=X(I)
2360  IF Y(I)<Ymax THEN 2380
2370  Ymax=Y(I)
2380  IF Y(I)>Ymin THEN 2400
2390  Ymin=Y(I)
2400  NEXT I
2410  PRINT PAGE,"THE MINIMUM/MAXIMUM DATA VALUES ARE AS FOLLOWS",LIN(2)
2420  PRINT USING 2440;"XMIN = ",Xmin,"XMAX = ",Xmax
2430  PRINT USING 2440;"YMIN = ",Ymin,"YMAX = ",Ymax
2440  IMAGE 15X,7A,MD.DDE,5X,7A,MD.DDE
2450  INPUT "ARE THESE VALUES SATISFACTORY FOR AXIS SCALING? Y/N",Ans$
2460  IF Ans$="Y" THEN 2490
2470  INPUT "INPUT SCALING FACTOR FOR X-AXIS: XMIN,XMAX",Xmin,Xmax
2480  INPUT "INPUT SCALING FACTOR FOR Y-AXIS: YMIN,YMAX",Ymin,Ymax
2490  SUBEND
2500  SUB Plot
2510  COM X(999),Y(999),Xmin,Xmax,Ymin,Ymax,T(999),Totlegf(999),Netcanf(999),Tot
linkf(999),Mag(999),Vert(999),Horz(999),Loc(999),Ang(999),Hvratio(999)
2520  COM Xlabel$[100],Ylabel$[100],Nodtpt,Hrs(999),Elphrs(999),Shno$,Date$
2530  PLOTTER IS "GRAPHICS"
2531  P$="CRT"
2540  DEG
2550  GRAPHICS
2560  Xminorig=Xmin
2570  Yminorig=Ymin
2580  Xmaxorig=Xmax
2590  Ymaxorig=Ymax
2600  Rescale$="N"
2601  PEN 2
2602*MISSING ROM
2610  LOCATE 25,115,25,95
2620  SCALE Xmin,Xmax,Ymin,Ymax
2630  LINE TYPE 1
2640  FRAME
2650  AXES (Xmax-Xmin)/25,(Ymax-Ymin)/25,Xmin,Ymin,5,5
2660  GRID (Xmax-Xmin)/5,(Ymax-Ymin)/5,Xmin,Ymin,1,1
2670  FOR I=1 TO Nodtpt
2680  IF (X(I)<Xmin) OR (X(I)>Xmax) THEN 2710
2690  IF (Y(I)<Ymin) OR (Y(I)>Ymax) THEN 2710
2691  PEN 1
2700  PLOT X(I),Y(I)
2710  NEXT I
2711  PEN 2
2720  LORG 5
2730  LDIR 90
2740   FOR Xlabel=Xmin TO Xmax STEP (Xmax-Xmin)/25*5
2750  MOVE Xlabel,Ymin-.13*(Ymax-Ymin)
2760  IMAGE MD.DDE
2770  LABEL USING 2760;Xlabel
```

```
2780  NEXT Xlabel
2790  LDIR 0
2800  FOR Ylabel=Ymin TO Ymax STEP (Ymax-Ymin)/25*5
2810  MOVE Xmin-.1*(Xmax-Xmin),Ylabel
2820  LABEL USING 2760;Ylabel
2830  NEXT Ylabel
2840  MOVE Xmin+(Xmax-Xmin)/2,Ymin-.32*(Ymax-Ymin)
2850  LABEL Xlabel$
2851  MOVE .80*(Xmax-Xmin),.97*Ymax
2852  LABEL "SHIELD #";Shno$;"//";Date$
2860  LDIR 90
2870  MOVE Xmin-.24*(Xmax-Xmin),Ymin+(Ymax-Ymin)/2
2880  LABEL Ylabel$
2881  IF (P$="9872A") AND (Sc$="N") THEN 3010
2890  INPUT "DO YOU WANT TO CHANGE SCALING FACTORS?",Sc$
2891  IF Sc$="N" THEN 2960
2900  IF Rescale$="N" THEN 2910
2901  Xmin=Xminorig
2902  Ymin=Yminorig
2903  Xmax=Xmaxorig
2904  Ymax=Ymaxorig
2905  GCLEAR
2906  GOTO 2600
2910  Rescale$="Y"
2920  DIGITIZE Xmin,Ymin
2930  DIGITIZE Xmax,Ymax
2940  GCLEAR
2950  GOTO 2610
2960  INPUT "DO YOU WANT TO DUMP GRAPHICS ON 9872",Ans$
2970  IF Ans$="N" THEN 3000
2980  PLOTTER IS "9872A"
2981  P$="9872A"
2990  GOTO 2600
3000  DUMP GRAPHICS
3010  GCLEAR
3020  EXIT GRAPHICS
3060  SUBEND
```

```
1     REM ********************  PROGRAM NAME -- DELTA ***********************
5     COM Xmin,Xmax,T(999),H(999),V(999),Hdisp(999),Vdisp(999),Beg,Last,X(999)
10    REM -- PROGRAM NAME--DELTA
20    PRINTER IS 16
30    PRINT PAGE,"THIS PROGRAM COMPUTES MAX/MIN VALUES FOR VARIOUS DATA PARAMETERS"
40    INPUT "INPUT DATE TO BE ANALYZED",Date$
50    F$=Date$[1,4]
60    F$=F$&Date$[6,6]
70    Sh1$="1"&F$
80    Sh2$="2"&F$
90    Sh3$="3"&F$
100   Sh4$="4"&F$
110   ASSIGN #1 TO Sh1$
120   ASSIGN #2 TO Sh2$
130   ASSIGN #3 TO Sh3$
140   ASSIGN #4 TO Sh4$
160   FOR I=1 TO 4
161   L=0
170   PRINT "INPUT BEG/END RECORD # FOR SHIELD #";I;"  CYCLE #";L+1
171   INPUT Beg,Last
180   L=L+1
181   FOR J=Beg TO Last
190   READ #I,J;I,J,T(J),H(J),V(J),Hdisp(J),Vdisp(J)
200   NEXT J
210   Hset(L)=H(Beg)
220   Vset(L)=V(Beg)
230   MAT X=H
240   CALL Minmax
250   Hmax(L)=Xmax
260   Hmin(L)=Xmin
270   Delh(L)=Hmax(L)-Hmin(L)
280   MAT X=V
281   CALL Minmax
290   Vmax(L)=Xmax
300   Vmin(L)=Xmin
310   Delv(L)=Vmax(L)-Vmin(L)
320   MAT X=Hdisp
321   CALL Minmax
330   Hdispmax(L)=Xmax
340   Hdispmin(L)=Xmin
350   Delhdisp(L)=Hdispmax(L)-Hdispmin(L)
360   MAT X=Vdisp
361   CALL Minmax
370   Vdispmax(L)=Xmax
380   Vdispmin(L)=Xmin
390   Delvdisp(L)=Vdispmax(L)-Vdispmin(L)
400   INPUT "ANY MORE SHIELD CYCLES TO ANALYZE?",Ans$
410   IF Ans$="Y" THEN 170
420   PRINTER IS 7,1,WIDTH(160)
430   PRINT PAGE,TAB(50),"ANALYSIS FOR SHIELD#";I
440   PRINT LIN(1),TAB(55),"DATE:";Date$
450   PRINT LIN(2),SPA(30),"HORIZONTAL",SPA(37),"VERTICAL",SPA(6),"HORZ. DISP";SPA(3),"VERT. DISP"
460   PRINT USING 470;"CYCLE #","SET","MIN","PEAK","DELTA","SET","MIN","PEAK","DELTA","DELTA","DELTA"
470   IMAGE 4X,7A,6X,3A,7X,3A,7X,4A,6X,5A,12X,3A,7X,3A,6X,4A,5X,5A,12X,5A,9X,5A
```

```
471   PRINT
480   FOR N=1 TO L
490   PRINT USING 495;N,Hset(N),Hmin(N),Hmax(N),Delh(N),Vset(N),Vmin(N),Vmax(N),
Delv(N),Delhdisp(N),Delvdisp(N)
495 IMAGE 7X,D,6X,MDDD.DD,3X,MDDD.DD,3X,MDDD.DD,3X,MDDD.DD,9X,MDDD.DD,3X,MDDD.DD
,3X,MDDD.DD,3X,MDDD.DD,9X,MDDD.DD,7X,MDDD.DD
500   NEXT N
501   NEXT I
502   PRINTER IS 16
503   INPUT "DO YOU WANT TO ANALYZE MORE DATA",Ans$
504   IF Ans$="Y" THEN 40
599   END
1000  SUB Minmax
1010  COM Xmin,Xmax,T(999),H(999),V(999),Hdisp(999),Vdisp(999),Beg,Last,X(999)
1020  Xmin=X(Beg)
1030  Xmax=X(Beg)
1040  FOR M=Beg TO Last
1050  IF X(M)<Xmax THEN 1070
1060  Xmax=X(M)
1070  IF X(M)>Xmin THEN 1090
1080  Xmin=X(M)
1090  NEXT M
1100  SUBEND
```

```
1      REM ****************** PROGRAM NAME -- DELTA *****************************
5      COM Xmin,Xmax,T(999),Mag(999),Loc(999),Ang(999),Beg,Last,X(999)
6      DIM L(999),C(999),Lk(999),Horz(999),Vert(999)
10     REM -- PROGRAM NAME--DELTA
20     PRINTER IS 16
30     PRINT PAGE,"THIS PROGRAM COMPUTES MAX/MIN VALUES FOR VARIOUS DATA PARAMETE
RS"
40     INPUT "INPUT DATE TO BE ANALYZED",Date$
50     F$=Date$[1,4]
60     F$=F$&Date$[6,6]
70     Sh1$="1"&F$
80     Sh2$="2"&F$
90     Sh3$="3"&F$
100    Sh4$="4"&F$
110    ASSIGN #1 TO Sh1$
120    ASSIGN #2 TO Sh2$
130    ASSIGN #3 TO Sh3$
140    ASSIGN #4 TO Sh4$
160    FOR I=1 TO 4
161    L=0
162    PRINTER IS 16
170    PRINT "INPUT BEG/END RECORD # FOR SHIELD #";I;"  CYCLE #";L+1
171    INPUT Beg,Last
180    L=L+1
181    FOR J=Beg TO Last
190    READ #I,J;I,J,T(J),L(J),C(J),Lk(J),Mag(J),Vert(J),Horz(J),Loc(J),Ang(J)
200    NEXT J
210    Magset(L)=Mag(Beg)
220    Locset(L)=Loc(Beg)
225    Angset(L)=Ang(Beg)
230    MAT X=Mag
240    CALL Minmax
250    Magmax(L)=Xmax
260    Magmin(L)=Xmin
270    Delmag(L)=Magmax(L)-Magmin(L)
280    MAT X=Loc
281    CALL Minmax
290    Locmax(L)=Xmax
300    Locmin(L)=Xmin
301    IF (Locmax(L)<0) AND (Locmin(L)>0) THEN 315
302    IF (Locmax(L)>0) AND (Locmin(L)<0) THEN 315
303    IF (Locmax(L)>0) AND (Locmin(L)>0) THEN 310
305    Locmax(L)=Xmin
306    Locmin(L)=Xmax
310    Delloc(L)=Locmax(L)-Locmin(L)
311    GOTO 320
315    Delloc(L)=Locmax(L)+Locmin(L)
320    MAT X=Ang
321    CALL Minmax
330    Angmax(L)=Xmin
340    Angmin(L)=Xmax
350    Delang(L)=Angmax(L)-Angmin(L)
400    INPUT "ANY MORE SHIELD CYCLES TO ANALYZE?",Ans$
410    IF Ans$="Y" THEN 170
420    PRINTER IS 7,1,WIDTH(160)
430    PRINT PAGE,TAB(50),"ANALYSIS FOR SHIELD#";I
440    PRINT LIN(1),TAB(55),"DATE:";Date$
```

```
450   PRINT LIN(2),SPA(30),"MAGNITUDE ",SPA(33),"LOCATION",SPA(19),"ANGLE      "
460   PRINT USING 470;"CYCLE #","SET","MIN","PEAK","DELTA","SET","MIN","PEAK","D
ELTA","SET","MIN","PEAK","DELTA"
470   IMAGE 4X,7A,6X,3A,7X,3A,7X,4A,6X,5A,8X,3A,7X,3A,6X,4A,5X,5A,8X,3A,7X,4A,6X
,5A
471   PRINT
480   FOR N=1 TO L
490   PRINT USING 495;N,Magset(N),Magmin(N),Magmax(N),Delmag(N),Locset(N),Locmin
(N),Locmax(N),Delloc(N),Angset(N),Angmin(N),Angmax(N),Delang(N)
495 IMAGE 7X,D,6X,MDDD.DD,3X,MDDD.DD,3X,MDDD.DD,3X,MDDD.DD,5X,MDDD.DD,3X,MDDD.DD
,3X,MDDD.DD,3X,MDDD.DD,5X,MDDD.DD,3X,MDDD.DD,3X,MDDD.DD,3X,MDDD.DD
500   NEXT N
501   NEXT I
502   PRINTER IS 16
503   INPUT "DO YOU WANT TO ANALYZE MORE DATA",Ans$
504   IF Ans$="Y" THEN 40
599   END
1000  SUB Minmax
1010  COM Xmin,Xmax,T(999),Mag(999),Loc(999),Ang(999),Beg,Last,X(999)
1020  Xmin=X(Beg)
1030  Xmax=X(Beg)
1040  FOR M=Beg TO Last
1050  IF X(M)<Xmax THEN 1070
1060  Xmax=X(M)
1070  IF X(M)>Xmin THEN 1090
1080  Xmin=X(M)
1090  NEXT M
1100  SUBEND
```

```
1  REM ********************** PROGRAM NAME -- EMHORZ **************************
2 DIM T(4,100),Totlegf(4,100),Netcanf(4,100),Totlink(4,100),Mag(4,100),Vert(4,10
0),Horz(4,100),Loc(4,100),Ang(4,100)
3 DIM Nodtpt(100),Shht(4),H(100),Legang(100),Capang(100),Horzleg(4,100),Horzcan(
4,100),Delhorz(4,100),Horzvert(4,100),Legres(4,100),Ag(100)
4 DIM Capangv(100),Legangv(100)
5 DEG
10     REM ANALYSIS OF HORIZONTAL SHIELD LOADING
20     PRINTER IS 16
30     PRINT PAGE,"THIS PROGRAM SUBTRACTS HORIZONTAL COMPONENT OF LEG FORCE AND C
ANOPY CAPSULE FORCE FROM RESULTANT HORIZONTAL SHIELD LOAD"
40     PRINT LIN(5),"INSERT ENGINEERING UNITS TAPE INTO T15"
45 PRINT LIN(2),"PRESS CONT WHEN READY TO CONTINUE"
46 PAUSE
50     INPUT "DATE DATA WAS TAKEN? mmddyy",Date$
60     F$=Date$[1,4]
70     F$=F$&Date$[6,6]
80     Sh1$="1"&F$
90     Sh2$="2"&F$
100    Sh3$="3"&F$
110    Sh4$="4"&F$
120    ASSIGN #1 TO Sh1$
130    ASSIGN #2 TO Sh2$
140    ASSIGN #3 TO Sh3$
150    ASSIGN #4 TO Sh4$
160    FOR I=1 TO 4
170    READ #I,3;Nodtpt(I)
180    READ #I,4;Shht(I)
190    NEXT I
200    PRINT PAGE,"INSERT SHIELD GEOMETRY TAPE INTO T15"
210    PRINT LIN(5),"PRESS CONT WHEN READY TO CONTINUE"
220    PAUSE
230    ASSIGN #5 TO "GEOFIL"
240    READ #5,1;Nogeom
250    FOR I=1 TO Nogeom
260    READ #5,I+1;Hh,Xx0,Yy0,Xx1,Yy1,Xx2,Yy2,Xx3,Yy3,Xx4,Yy4,Xx5,Yy5,Xx6,Yy6,Xx7
,Yy7,Xxr3,Yyr3,Xxr4,Yyr4,Xxr6,Yyr6,H1,V1,H4,V4,Ag(I),Lega,Capa,Lina
270    H(I)=Hh
280    Legang(I)=Lega
290    Capang(I)=Capa
300    NEXT I
310    FOR I=1 TO 4
320    FOR K=1 TO Nogeom
330    IF INT(Shht(I)+.5)<>INT(H(K)+.5) THEN 360
340    Legangv(I)=Legang(K)
350    Capangv(I)=Capang(K)
360    NEXT K
370    NEXT I
380    PRINT PAGE,"INSERT RESULTANT LOAD VECTOR FILES INTO T15"
390    PRINT LIN(5),"PRESS CONT WHEN READY TO CONTINUE"
400    PAUSE
401 ASSIGN #1 TO Sh1$
402 ASSIGN #2 TO Sh2$
403 ASSIGN #3 TO Sh3$
404 ASSIGN #4 TO Sh4$
410    FOR I=1 TO 4
420    FOR J=1 TO Nodtpt(I)
430    READ #I,J;I,J,T(I,J),Totlegf(I,J),Netcanf(I,J),Totlink(I,J),Mag(I,J),Vert(
I,J),Horz(I,J),Loc(I,J),Ang(I,J)
```

```
440    NEXT J
450    NEXT I
460    FOR I=1 TO 4
470    FOR J=1 TO Nodtpt(I)
480    Horzleg(I,J)=Totlegf(I,J)*SIN(Legangv(I))
490    Horzcan(I,J)=Netcanf(I,J)*COS(Capangv(I))
500    Delhorz(I,J)=Horz(I,J)-Horzleg(I,J)-Horzcan(I,J)
510    Horzvert(I,J)=Horz(I,J)/Vert(I,J)
520    Legres(I,J)=Horz(I,J)/Horzleg(I,J)
530    NEXT J
540    NEXT I
550    PRINTER IS 7,1,WIDTH(160)
560    PRINT PAGE,TAB(50),"ANALYSIS OF HORIZONTAL SHIELD LOADING"
570    PRINT USING 580;"HORZ.RES.FORCE","TOT.LEG FORCE","HORZ.LEG FORCE","NET CAN
.FORCE","HORZ.CAN.FORCE","RES.HORZ.FORCE","HORZ/VERT","HORZ.LEG.FORCE/HORZ"
580    IMAGE 14A,3X,13A,3X,14A,3X,13A,3X,14A,3X,14A,3X,8A,3X,19A
590    FOR I=1 TO 4
595 PRINT LIN(2),TAB(60),"DATA FOR SHIELD #",I
600    FOR J=1 TO Nodtpt(I)
610    PRINT USING 620;Horz(I,J),Totlegf(I,J),Horzleg(I,J),Netcanf(I,J),Horzcan(I
,J),Delhorz(I,J),Horzvert(I,J),Legres(I,J)
620 IMAGE 3X,MDDD.D,12X,MDDD.D,10X,MDDD.D,8X,MDDD.D,11X,MDDD.D,10X,MDDD.D,10X,MD
.DD,10X,MD.DD
630 NEXT J
640 NEXT I
999 END
```

APPENDIX E.--LINEARLY ELASTIC SHIELD DISPLACEMENT MODEL

As previously indicated, observations of shield behavior have indicated that a vertical (roof-to-floor) convergence produces both a vertical and a horizontal support reaction. The vertical reaction is intuitively obvious. The primary source of the horizontal load reaction is the horizontal component of the leg force, resulting from the inclination of the leg cylinder, and the connection of the canopy to the base structure by the caving shield-lemniscate system.

Conceptually, the shield can be thought to behave as a linear elastic truss with two degrees of freedom. Vertical and horizontal load reactions can then be related to vertical (roof-to-floor) and horizontal (face-to-waste) displacements by the following mathematical relationship:

$$F_v = K_1\delta_v + K_2\,\delta_h \qquad \text{(E-1)}$$

$$F_h = K_3\delta_v + K_4\,\delta_h \qquad \text{(E-2)}$$

where F_v = vertical support resultant load,

F_h = horizontal support resultant load,

δ_v = vertical (roof-to-floor) shield displacement,

δ_h = horizontal (face-to-waste) shield displacement,

and

K_1, K_2, K_3, K_4 = stiffness coefficients.

Vertical and horizontal shield loading can then be determined if the shield displacements (δ_v and δ_h) are known. Inverting equations E-1 and E-2 enables determination of shield displacements from known resultant shield loading as described in equations E-3 and E-4 below. Both solutions require knowing the shield stiffness parameters (K_1, K_2, K_3, K_4).

$$\delta_v = \frac{1}{K_1K_4 - K_2K_3} * \left[K_4F_v - K_2F_h\right]. \qquad \text{(E-3)}$$

$$\delta_v = \frac{1}{K_1K_4 - K_2K_3} * \left[-K_3F_v + K_1F_h\right]. \qquad \text{(E-4)}$$

The shield stiffness parameters (K_1, K_2, K_3, K_4) shown in table E-1 were determined with the aid of the Bureau's mine roof simulatutor (MRS). By commanding the MRS to maintain a fixed horizontal displacement of the lower platen, the shield is subjected to pure vertical convergence. Terms $K_2\,\delta_h$ and $K_4\,\delta_h$ of equations E-1 and E-2, respectively, then become zero, leaving $F_v = K_1\,\delta_v$ and $F_h = K_3\,\delta_v$. The resultant reaction of the shield to the applied vertical displacement (δ_v) is measured by the MRS force required to produce this displacement (F_v) and the constraining force (F_h) required to maintain fixed horizontal displacement of the platens. Therefore, knowing the vertical displacement and the associated reactive forces of the shield, the vertical stiffness parameters (K_1 and K_3) can be calculated: K_1 being equal to the ratio of resultant vertical shield load to the vertical displacement, and K_3 being equal to the ratio of the resultant horizontal load to the vertical displacement. Likewise, subjecting the shield to pure horizontal (face-to-waste) displacement permits determination of stiffness parameters K_2 and K_4 as terms $K_1\,\delta_v$ and $K_3\,\delta_v$ of equations E-1 and E-2, respectively, become zero.

TABLE E-1. - Shield stiffness parameters

Shield configurations	Linear model stiffness parameters, kips/in			
	K_1	K_2	K_3	K_4
78 in, active capsule........	585	174	157	203
78 in, inactive capsule......	633	268	228	229
58 in, active capsule........	666	505	328	505
58 in, inactive capsule......	715	517	430	378

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