THE NIOSH SHIELD HYDRAULICS INSPECTION AND EVALUATION OF LEG DATA (SHIELD) COMPUTER PROGRAM

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ABSTRACT

Longwall shields provide essential ground control in longwall mining, yet a high percentage of shields are operating at less than peak capacity and many at well below the rated support capacity due to defective hydraulic cylinders or malfunctions in other hydraulic components. Leg pressure data are currently collected on state-of-the-art longwall shields, but typically are not analyzed to evaluate shield performance. The National Institute for Occupational Safety and Health (NIOSH) Shield Hydraulics Inspection and Evaluation of Leg Data (SHIELD) program is a Visual Basic software system that is designed to analyze leg pressure data and identify shields that are not performing to rated specifications. The program analysis is configured to detect the following conditions: (1) loss of leg pressure, (2) imbalance in leg pressure, (3) low set pressure, (4) low yield pressure, and (5) full extension of the bottom stage. Other performance assessment measures include the percentage of the support capacity utilized (ratio of peak load to yield load), the percent of time that a shield operates at yield load, the ratio of the set load to the yield load, and the amount of support capacity that is lost due to leaking cylinders. Historical record keeping will allow the user to select a particular shield and review the performance record as developed by the program for that shield. In addition to these performance assessment measures, the software will include an animated description of shield hydraulic systems that will describe the operation and significance of each hydraulic component and the impact of component failures on the shield's capability to provide the required roof support. A general overview of the SHIELD program is provided in the paper together with an example analysis of a 2.5-year-old Australian longwall face.

INTRODUCTION

Longwall shields have grown in size, capacity, and operational capability since their introduction over 25 years ago. The quest for more powerful, more reliable, and longer lasting shields continues to this day. Despite the increased cost of the supports, the increased cost of downtime, and significantly greater difficulty in repairing the much larger and heavier shields fabricated from high-strength steel alloys, there has been relatively little effort to optimize either preventive maintenance, capacity requirements, or utilization of the available support capacity.

For the past decade, longwall shields have been equipped with pressure sensors that monitor leg pressures on every longwall shield. Modern shields may have control systems that allow these data to be collected and stored for analysis. However, with as many as 200 shields on a longwall face, the amount of data collected can become voluminous very quickly, making it impractical to organize and evaluate the data without the assistance of a computer and some sort of analysis program. The National Institute for Occupational Safety and Health (NIOSH) Shield Hydraulic Inspection and Evaluation of Leg Data or SHIELD program has been developed to provide this capability.

SHIELD is a software program developed to NIOSH specifications by NSA Engineering, Inc. in Golden, Colorado. This stand-alone program can take data from almost any modern longwall shield monitoring system, convert it into a standard format, analyze the data to detect leaking leg cylinders and several other performance assessment measures, and provide documented results in both tabular and graphical formats that makes assessing the operational status and support capability of the longwall shields easy and efficient for even the novice computer user. In addition to providing assessment of the shield data, the program provides practical information of how the hydraulic system and its various components function to provide the support capability, and what happens to this capability when the components fail.

Hydraulic failures that degrade the performance of longwall shields are more prevalent than most people would think. A recent survey of longwall operations in the USA indicated that over 60% of the longwall operations with shields in service for 4-6 years were having noticeable hydraulic problems (1). Many hydraulic problems go undetected since the leaks are internal and there are no visible signs of fluid loss associated with these events. In addition, there are misconceptions about the effect of these internal leakages (2), which adds to the poor conditions which exist on some longwall faces. Full extension of the bottom stage, which can occur naturally due to the operating height of the shield, or due to internal leakages, can degrade the setting force by as much as 50% and very little attention is paid to this condition by anyone. SHIELD will detect this condition and include it as part of the analysis of the shield performance. It is believed that mines which institute a good preventive maintenance program get the most use of their longwall shields. Failure to address problems as they occur reduces the useful life of the shield. SHIELD can provide the necessary information to institute a good preventive maintenance plan by identifying and tracking problems as they occur.

A shield responds to roof activity by developing additional loading after it is initially set against the mine roof and floor, and as such can provide valuable information about its effectiveness in controlling the ground on a longwall face (3, 4). Despite 25 years of use, many questions remain unanswered in terms of optimizing the design requirements and capacity utilization of a longwall shield. Is bigger really better? Does a higher setting pressure result in a higher final pressure regardless of the roof condition or geology? Is there an optimum setting pressure? What impact does the increased stiffness of higher capacity shields have on the shield response to the ground movements? Is there a maintenance advantage to having wider shields with fewer hydraulic cylinders? These are a few questions that SHIELD can provide some insight into by providing the capability to utilize the wealth of data currently not being analyzed to assess the performance capability of active longwall shields through their service life.

Finally, in terms of safety, it has become more and more difficult to repair longwall shields on an active longwall face. The equipment is bigger and heavier than ever before. Changing out a 400-mm leg cylinder on a 1,200-ton state-of-the-art longwall shield can be challenging and hazardous. Again, a good preventive maintenance plan whereby these failures are corrected during panel changes when spares parts can be interchanged in a more controlled environment, either underground or in a maintenance shop, can help to ensure the safety of those involved in doing this work.

The purpose of this paper is to provide an overview of the SHIELD program, describe its architecture and give examples of the outputs that can be generated to evaluate the condition of longwall shields. In this regard, an example analysis of an Australian longwall is included.

PROGRAM ARCHITECTURE

SHIELD is a Visual Basic program that is designed to operate on most personal computers. The program is a Windows-based architecture to facilitate easy use with anyone familiar with Window's operating systems. The program opens with a disclaimer window and a general introduction window that shows the program version number with a picture of a longwall shield.

The analysis begins with a window asking, "which analysis method you want to follow?" There are two options: either process the data manually, in which case the user must provide input regarding the configuration of the available raw shield data and the amount of data to be processed and analyzed, or use an automated option where the same shields are being monitored and the configuration of the shield data remains unchanged from the last analysis. In the automated mode, the program will process all available data since the last analysis was made. Neither option takes much time, but the Auto feature is the best option once the data configuration has been defined, and is ideal for periodic (daily or weekly) updates to the analysis of a particular set of shields.

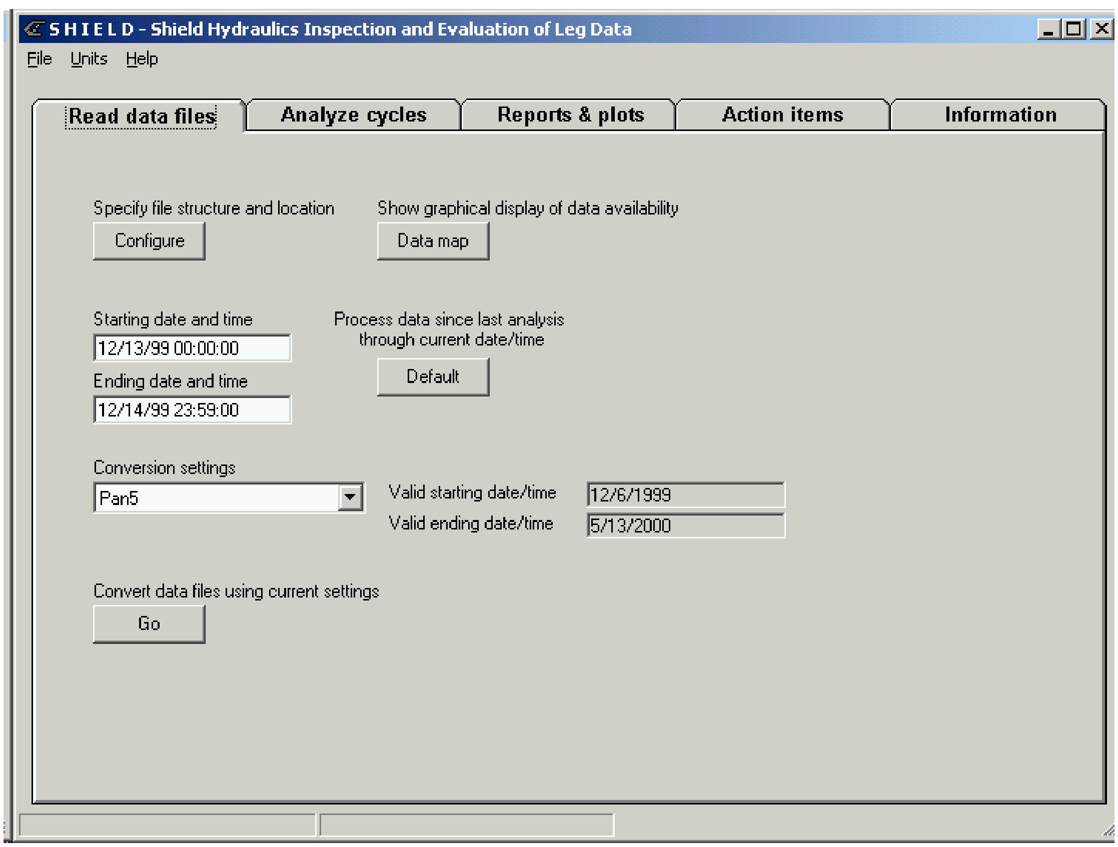

Figure 1. Main window showing various tabs that control the overall operation of the SHIELD program. In this example, the Read Data Files tab is activated.

Data File Configuration

The first time the program is used, the Manual analysis option must be chosen to set up the raw data configuration files and several other parameter thresholds to facilitate the analysis of the shield performance. This process begins with the main window shown in figure 1 by pressing the *Configure* button, which brings up the file conversion window shown in figure 2. It is expected that the raw shield data (leg pressures from hydraulic sensors on individual leg cylinders) collected from the underground shield computer control system will be stored and/or downloaded to a surface computer for subsequent processing by the SHIELD program. One of the requirements then is to define the path (*Set Path* button) where the raw data files are stored, so that the SHIELD program can access them. The program is designed with flexibility to accommodate different data file structures making the program compatible with most shield data collection systems. In general, the format of the raw data files needs to be defined so that SHIELD can convert these raw data files into a standard format for processing. This is done with the *Field Definitions Setup* button located toward the bottom of the *Configure File Conversion* window (figure 2). The field definition for the raw shield data defines what each item refers to in the data stream so the program will have the necessary information to extract the date-time, shield number, leg position (headgate or tailgate) and associated leg pressure data. It is assumed that file configurations are constant for a given panel. A subwindow is included to designate the defined configurations, which are typically referenced by panel name. These configurations are saved to file for later use. The user can provide starting and ending dates and time to help identify and control the analysis period.

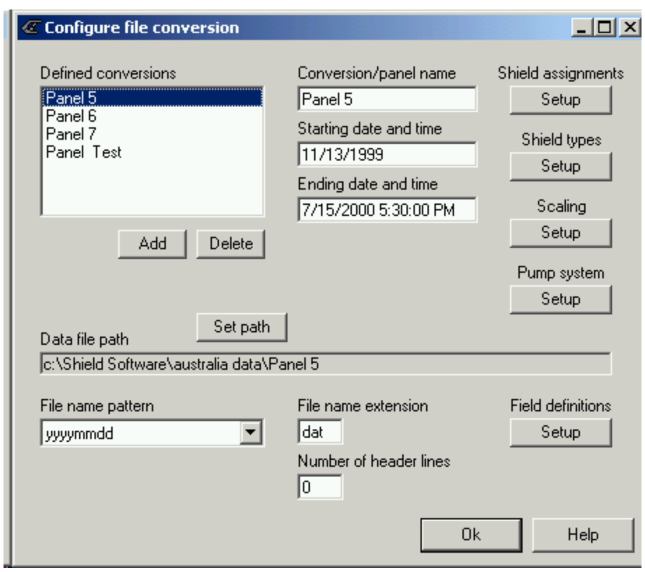

Figure 2. This window is used to define file parameters for the raw data acquired from an active longwall face.

There are four buttons on the right side of the *Configure File Conversion* window to provide information on what shields are being monitored and the shield specifications. These are labeled: (1) *Shield assignments*, (2) *Shield types*, (3) *Scaling*, and (4) *Pump system*. *Shield assignments* allows the user to define which shields have data available for processing, descriptive information including the serial number, purchase date, and date of the last rebuild for the shields being examined, and a few setup indices to define the shield numbering nomenclature. The *Shield Type* menu, which can also be edited from the *Shield Assignments* window, can be used to provide information on the shield size, capacity, and leg cylinder specifications that will be used to evaluate the shield performance. *Scaling*, which can also be edited from the *Shield Assignments* window, designates the unit measurements for the shield leg pressures in either psi, bar, or MPa. Information on the pumping system can also be included by activating the *Pump System* button (see figure 2).

File Conversion

Once the data file and shield assignments are defined, the raw shield data are converted to a standard file format (daily binary files) using the designated conversion settings by executing the ***Go*** button on the *Read data files* tab (figure 1) . The raw data files (*.dat files) and converted data files (*.dtb) are stored in a folder designated by the user-defined path selection. The formation of both the raw data and converted data files are designated on a data map which can be viewed by executing the *Data map* button (figure 1).

Data Analysis

Data analysis is also executed from the main window using the *Analyze Cycles* tab(see figure 1). The initial function of this part of the program is to evaluate the leg pressure data and define the loading cycles from this data set. Before the analysis begins, the user can configure the cycle detection parameters by executing the *Configure* button. These parameters set thresholds which help to define data limitations that are useful in identifying shield loading cycles from the raw data set. The starting and ending date and time can be set to include either a complete or a partial set of the available shield data. The analysis is done by executing the *Go* command on the *Analyze Cycles* tab. The analysis examines the loading pattern of each shield cycle and determines which shield cycles have characteristics which would suggest that the shield capability is being degraded by leaking hydraulic cylinders, low setting pressures, full extension of the bottom stage, yielding at less than the yield rating, or an imbalance in leg pressures on the same shield. The loading characteristics for all shields are also analyzed including measures of setting pressure, peak pressure, time weighted average pressure, and change in pressure after setting. Averages, as well as maximum and minimum values, are computed for most performance assessment parameters. The path for storing or viewing the listing of analyzed (*.cyc) files is chosen from the *Data map*.

Description of analysis parameters and leg cylinder conditions

1. **Leaking cycles** - Cycles are detected in which the leg pressure decreases after the support is set against the mine roof and floor. The amount of time that the pressure is decreasing during a cycle is calculated and expressed as the percent of total cycle time to measure the severity of the leak.

2. **Cycles at full extension** - Full extension of the bottom stage of the hydraulic cylinder is determined by the characteristic flat-line leg pressure curve following the setting pressure, whereby the pressure in the bottom stage does not increase beyond a nominal amount until the top stage pressure overcomes the setting force developed in the bottom stage (2). A check is made to see if the pressure does increase after 10 minutes, suggesting that there is indeed roof loading occurring to justify the full extension determination as opposed to a condition where there is simply no roof loading. It is possible that full extension would not be detected on a leaking leg

if the leak caused a drop in pressure immediately after the support was set against the mine roof and floor.

3. **Set pressure** - The start of the cycle normally is the first sample after the end of the previous cycle (pressure drop more than the threshold). The set pressure is the first sample taken once the set pressure threshold is reached. If the pressure does not reach the set pressure threshold within 10 minutes, the maximum reading is taken as the set pressure. If the set pressure is attained somewhere within the first 10 minutes of the cycle, the start time for the cycle is adjusted accordingly. The minimum, average and maximum set values are calculated for all cycles within the reporting period. Other assessments made relative to the setting pressure include:

   - **Percent time less than set pressure** - This is a measure of how long (what percent of the cycle time) the leg pressure was less than the intended setting pressure. It is useful in judging whether a positive set operation was successful in achieving full setting pressure on non-leaking legs, or the effect of leaks on shields which have leaking cylinders.

   - **Average amount less than set pressure** - This is a measure of how low the achieved setting pressure was relative to the intended setting pressure. It is calculated as the difference between the intended set pressure and the average of all measured leg pressures which were less than the intended setting pressure.

4. **Time-weighted average pressure (TWAP)** - The time-weighted-average pressure is a measure of the average loading on the shield during a particular cycle. These are then averaged to produce an average TWAP for a leg cylinder for all the measured cycles. The minimum and maximum TWAP averages for all cycles are also calculated. The TWAP is used in various analyses whereby one condition is compared to another using the TWAP as the indicator of the shield loading.

5. **Maximum pressure** - The maximum pressure is the peak pressure recorded during a loading cycle. These are then averaged for all cycles to produce an average maximum pressure for each leg cylinder. The minimum and maximum of these maximum pressures for all cycles are also documented.

6. **Yielding** - Yielding is determined when the shield loading reaches a peak near the rated capacity of the support, and the pressure drops to about 10% of the yield pressure as the yield valve closes after expelling fluid from the cylinder cavity. Performance analysis associated with yielding include:

   - **Percent of time yielding is occurring** - This is a measure of how long the shield was in a state of yielding. It is determined as the number of pressure samples that were equal or greater than the yield pressure specified in the *Shield types* screen, divided by the cycle length and expressed as a percent.

   - **Average amount greater than yield pressure** - This is an average of the leg pressures minus the rated yield pressure for all leg pressure measurements greater than yield pressure. It is intended to show when the yield setting is greater than the rated specifications for the shield.

7. **Average pressure difference between legs** - This value is calculated only for shields that have pressure data for both legs. The signed difference of pressures of the headgate leg minus the tailgate leg are summed for each sample and are reported only for the headgate leg. The signed difference is listed for individual legs; however most displays (and the sorting order) consider the absolute value of the difference.

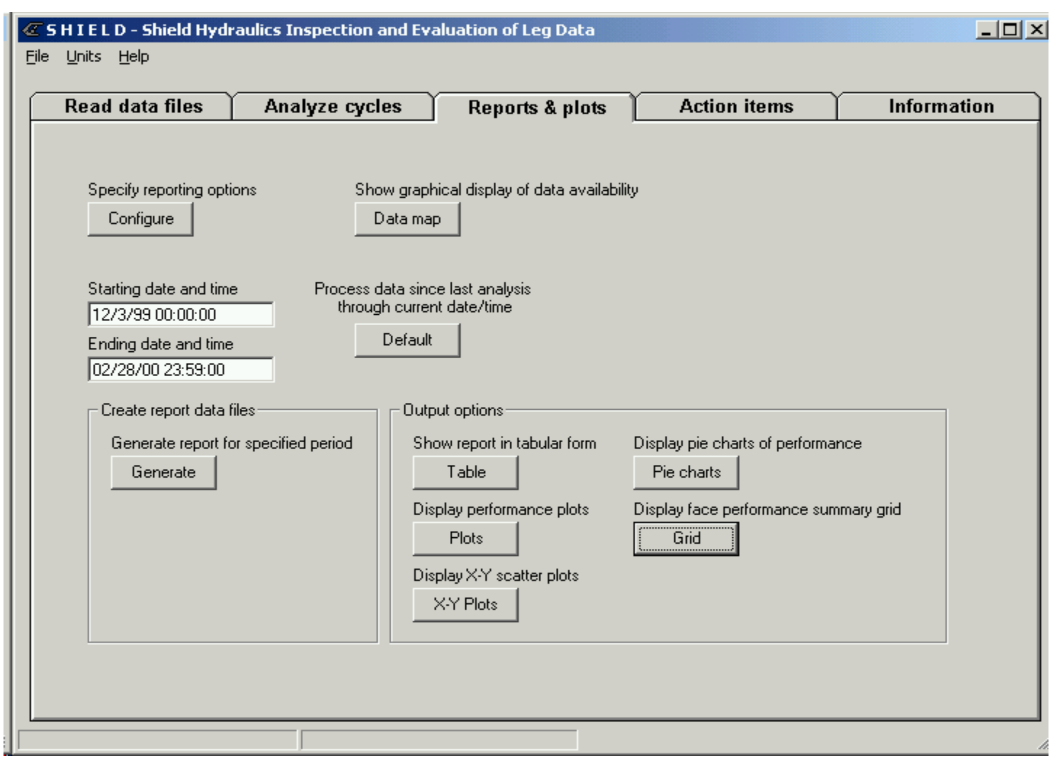

Figure 3. Once the data is analyzed, performance and problem reports can be generated from this window.

Data reports and plots

Reports and plots of the analyzed data are made in the *Reports & Plots* tab of the main window (figure 3). Again, the starting and ending date and time can be entered to allow the user to control the set of data to be included in the report. A *Default* button is also included to allow the user to generate a report of all data since the last analysis was conducted. The report is generated by activating the *Generate* button. Once the report is generated, the information can be displayed in five different formats as indicated on the right side of the window (see figure 3): (1) Table, (2) Plots, or (3) X-Y Plots, (4) Pie charts, and (5) Grid.

Tables

The *Report Table* is divided into two basic sections. At the top of the window several options are available to select the type of information to be displayed in tabular format in the box immediately below. At the bottom of the window is a histogram of a particular performance parameter chosen for analysis. Figure 4 shows an example of the *Report Table* window with an overall face summary displayed in the text box and a histogram showing the distribution of leaking leg cylinders.

- **Action items** - This selection groups the data into various problem categories and sorts each group to show the most numerous problems first. For example, in the leaks section, the legs having the greatest percentage of leaks are shown first. Typically, items in this section will be included in this list only if more than 10% of the shields experienced the condition being described.

- **Overall face summary** - This format shows summaries and averages of the various performance parameters calculated for the entire face.

- **Individual shield summary** - All data for each leg are shown and can be sorted, based on any of the calculated parameters. To reduce the amount of data shown, the list can be reduced to show only the shield number, leg, and data for the selected sort parameter. When a sort parameter is selected, the histogram is synchronized to show the same data.

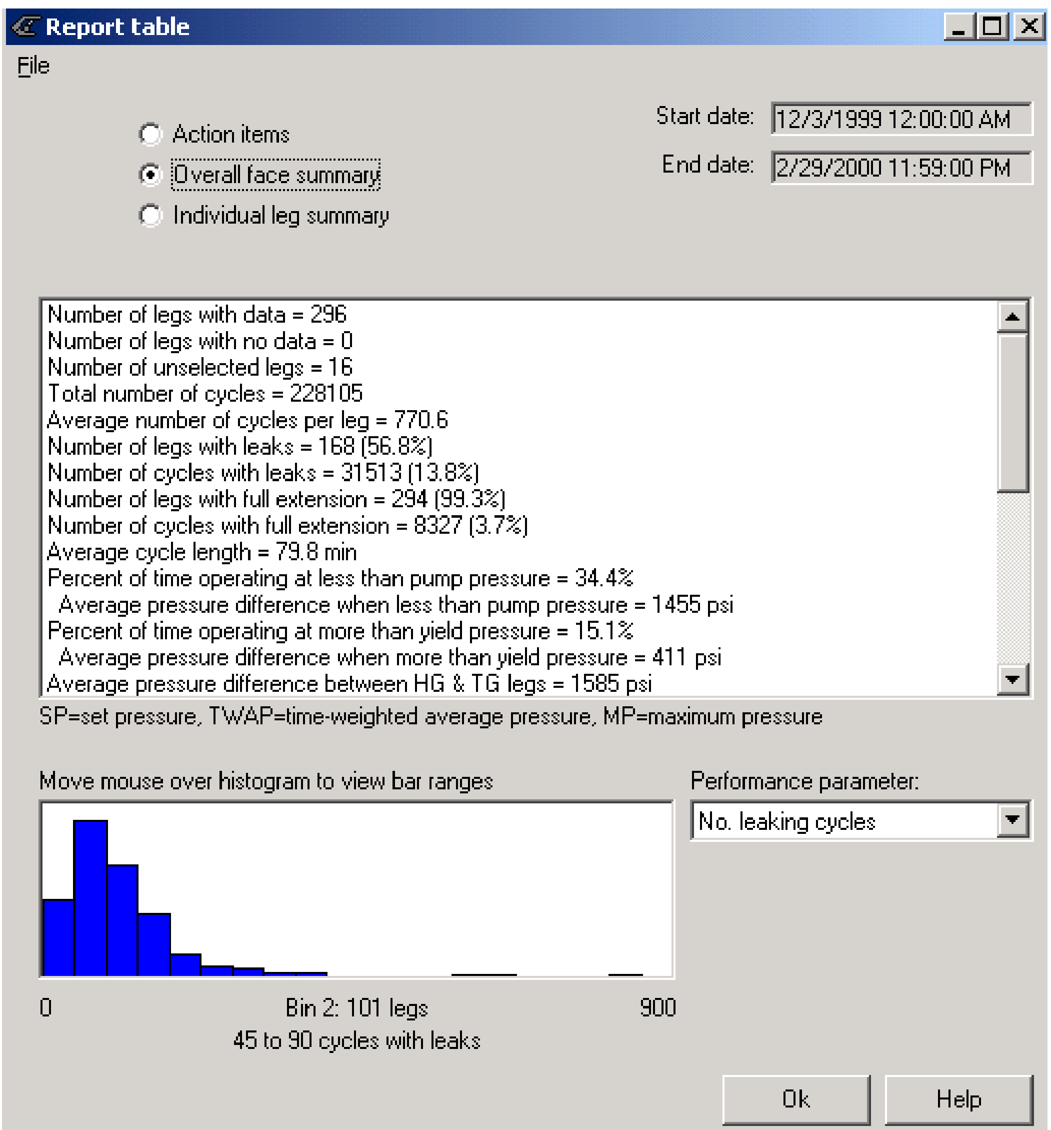

Figure 4. Report table showing overall face summary and histogram of leaking cylinders.

- **Histogram** - For the selected parameter, the data for all shields are sorted into 20 bins covering the range of data. The height of the bars corresponds to the number of items (legs or cycles) assigned to that bin. Moving the mouse over the histogram will display the bin number, the X-axis range of the bin (bin width), and the number of items in the bin (see figure 4). The histograms can be used to assess the variability of the data.

Plots

This window shows graphical plots of various calculated parameters and can also show leg pressures for specific cycles. The display can be zoomed to a larger or reduced time scale. Performance values for individual shields for a selected cycle and averages for several cycles are also shown. This display is useful to evaluate variation of shield loading over time, load distributions along the face, comparison of a specific shield with its neighbors, and detailed analysis of shields not performing to specifications. The plot colors can be changed by pressing the *Colors* button. The minimum and maximum Y-axis value for each parameter can be changed to adjust the plot scaling. Three main types of plots can be shown:

Cycles for individual shields (figure 5) – This screen plots the selected parameter values for a particular shield for the designated reporting period and documents the parameter values for selected cycle numbers and averages during the reporting period. The X-axis initially corresponds to the entire reporting period, but can be zoomed to display shorter time intervals. The Y-axis shows either pressure or a percentage (%) value, depending on the parameter chosen to view. The shield number can be selected by entering the number and pressing *Enter* or using the adjacent small scroll control. When a shield is selected, all cycles for that shield (for both legs) are read and the nearest cycle to the currently selected time are displayed. The current time can be changed by entering a cycle number, scrolling the cycle number, or entering an evaluation time directly (which finds the nearest cycle). Selecting a cycle for one leg will automatically adjust the other leg to show the nearest cycle. Selecting the display parameter from the combo box will update the plot and show the values for the currently selected cycles as well as the average values for each leg over all cycles.

Cycle distribution for entire face (figure 6) – Utilizes the same basic format as the individual cycle screen except now the data is shown for all shields. The X-axis initially corresponds to the shield number for all shields installed on the face, but can be zoomed to show groups of fewer shields. For the selected time period, the nearest cycle for all legs is determined and the values of the selected parameter are plotted. This plot shows the difference between shields and generalized loading characteristics along the face (areas of greatest and least loading, etc.). The vertical cursor represents the currently selected shield and can be moved by clicking on the plot or entering a different shield number. The selected time can be entered directly, in the text box, or indirectly by changing the cycle number, for either the headgate or tailgate leg.

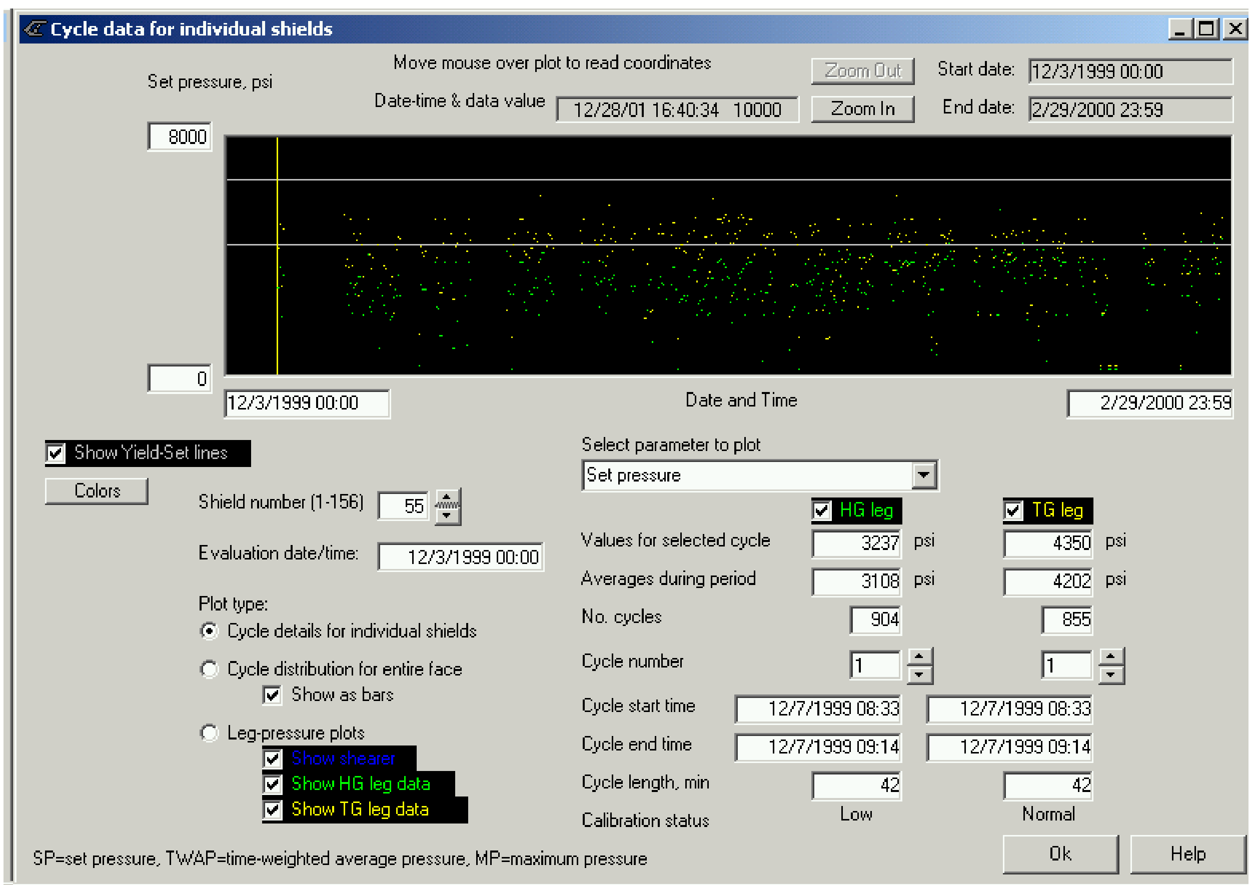

Figure 5. Plot can be generated which show a selected individual shield performance relative to a selected analysis parameter. The example here shows the setting pressures over the 3 month reporting period for shield number 55.

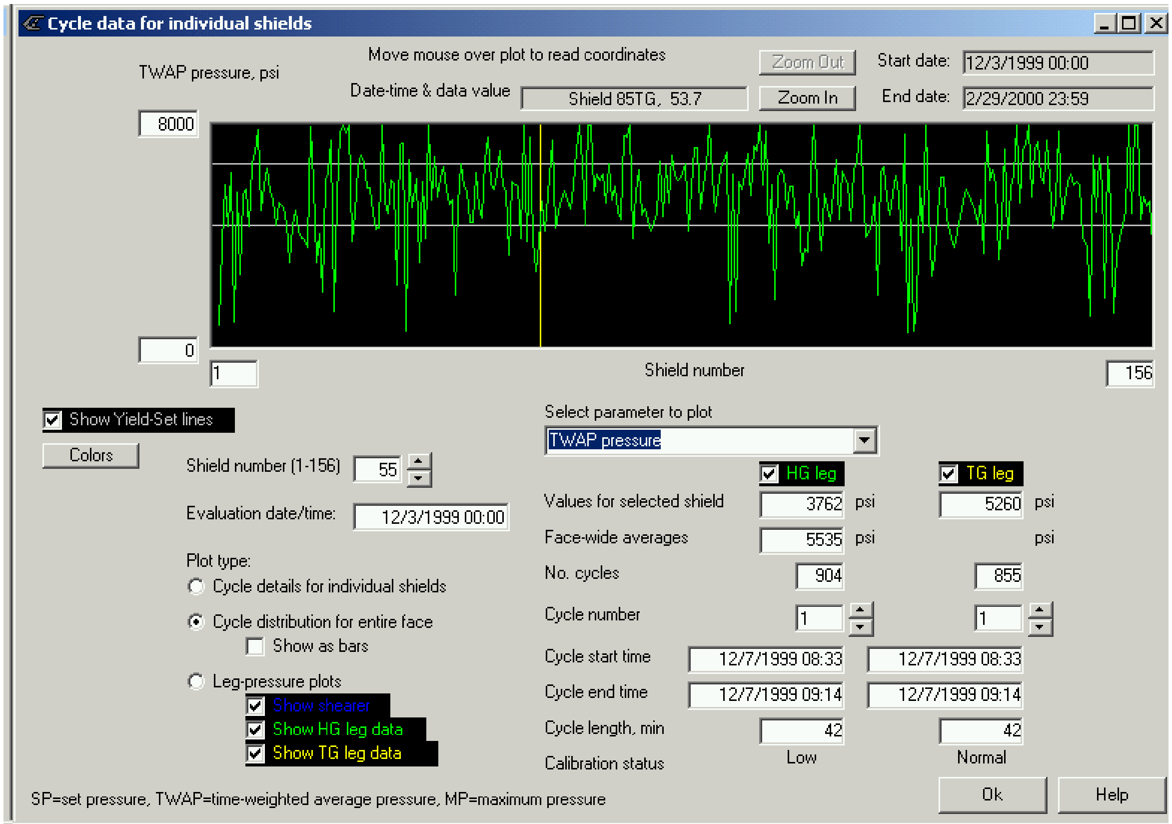

Figure 6. The distribution of a particular parameter for all shields across the longwall face can also be shown. The example shows the distribution of Time Weighted Average Pressure (TWAP) for all 156 shields. The values for a selected shield (shield 55) are also shown in the window.

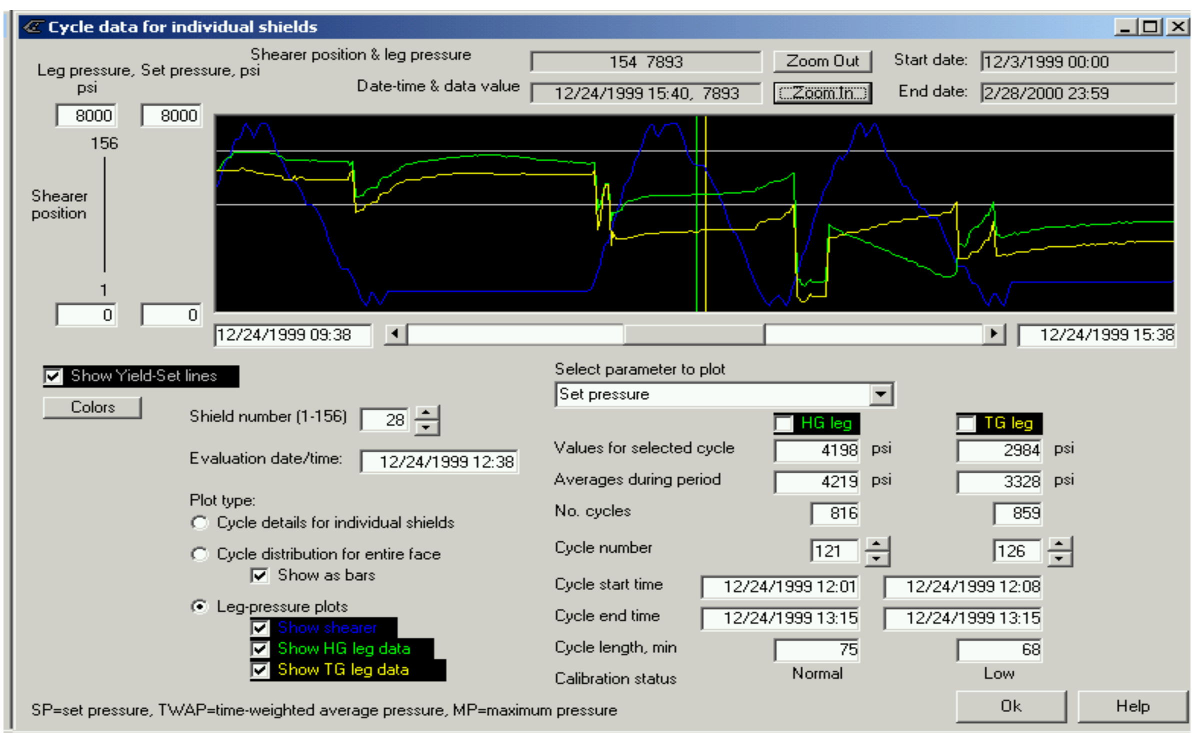

Figure 7. Leg pressure profiles can be plotted for any shield with shearer positions if this data is available. The example shows leg pressure cycles for shield 28 on 12/24/99. The performance for a specific cycle (in this case cycle No. 816) relative to a designated performance parameter (in this case setting pressure) can also be shown in the window and on the graph if desired.

Leg pressure plots (figure 7) – In this screen, the full pressure profile is shown for selected shields. The X-axis initially corresponds to a time period of 1 day - ½-day before to ½-day after the selected evaluation time (currently selected cycle). The X-axis can also be zoomed to show a shorter time period. This plot is similar to the above *Cycle Plot* but has leg pressures superimposed on the cycle data and optionally, the shearer position.

X-Y Plots (Scatter Diagrams)

This window produces scatter plots that show correlations between the following performance parameters: (1) set pressure (SP), (2) time-weighted average pressure (TWAP), (3) maximum pressure (MP), (4) average change in pressure after setting (TWAP - SP), and, (5) total change in pressure after set (MP - SP). Figure 8 provides an example where the average change in pressure (TWAP - SP) as a function of setting pressure is displayed. Filters are provided to remove leaking legs and miscalibrated legs from the data set.

Pie Charts

Pie charts can also be displayed to provide an overview of the performance of the shields. Parameters included in the pie charts are: (1) setting force showing the achieved setting force and deficiency in setting force relative to the full setting force based on the available pump capacity, (2) leaking legs showing the percentage of leg cylinders that are leaking compared to those that are not, and (3) an assessment of the shield capacity utilization showing the amount of the available capacity that was used, how much is lost due to leaking cylinders, and the remaining or unused available support capacity. Examples of the pie charts are shown in the example analysis of the Australian longwall following this section.

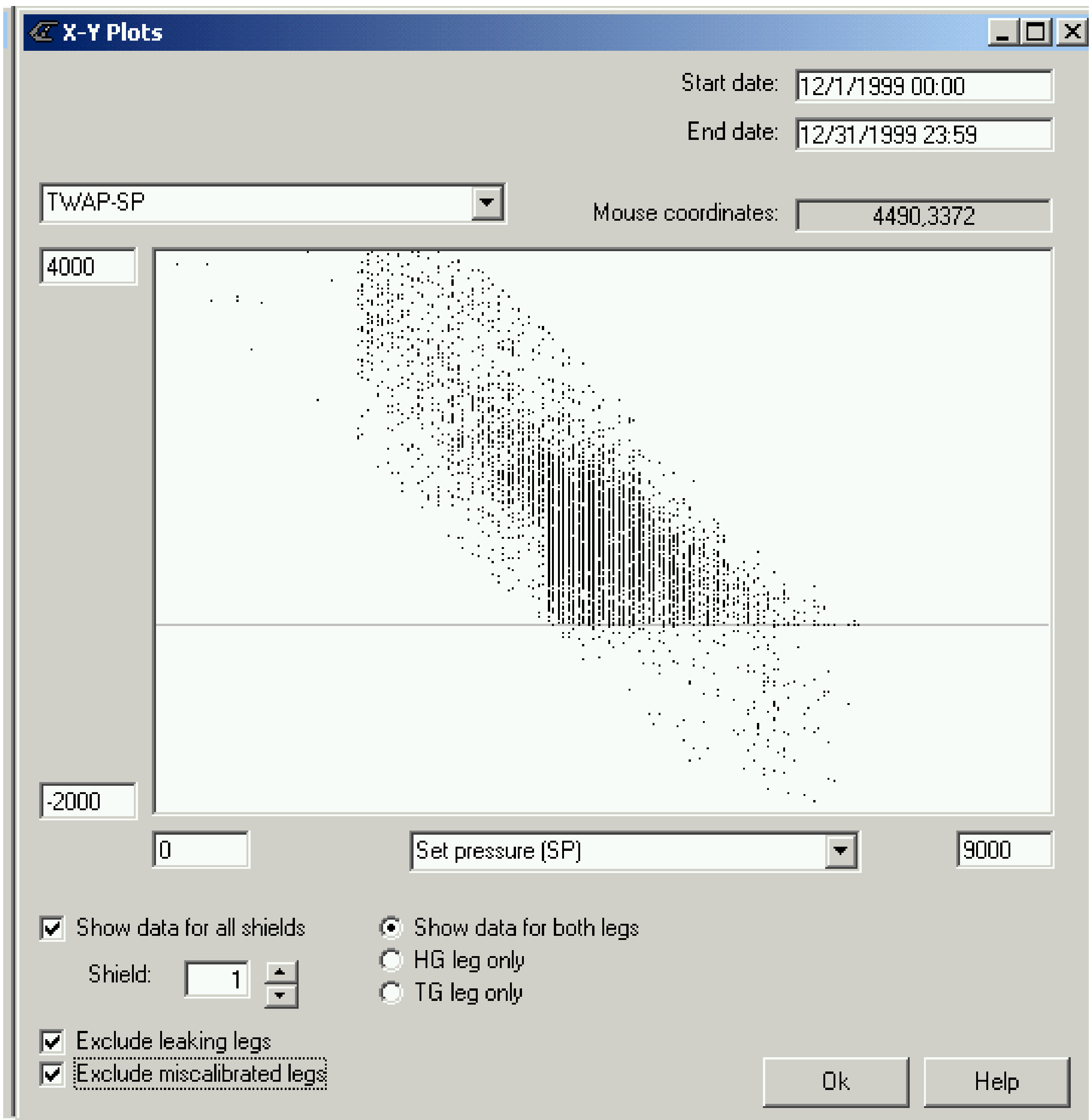

Figure 8. A scatter diagram for several of the loading parameters can also be displayed to show the parameter correlations. Example here shows change in support loading after setting as a function of setting pressure.

Grid Display

An overview of the performance of entire longwall system of shields can be displayed in a color coded grid (figure 9). The grid shows each shield employed on the longwall face in groups of 10, with a color to indicate legs that are performing properly and legs that are leaking. Legs for which there are no data are also indicated. Several other performance measures can be displayed in grid format as well.

Action Items

When an analysis is complete, this tab accessed from the main window will list the major findings, problems and statistics for the last report generated. These data are grouped into various problem categories and each group is sorted to show the most serious problems first. For example, in the leaks section, the legs having the greatest percentage of leaks are shown first.

Information

The Information module accessed from the main window is designed to provide information on how the shield hydraulic system and leg cylinders in particular function to provide the roof supporting capability. Photos, diagrams, and graphic animations are included to help explain each component and the impact of failure of that component in terms of degrading the capacity of the shield. Figure 10 is one example, showing information pertaining to the staging valve, and figure 11 is an example of an animation showing extension of the leg cylinder and subsequent roof loading that causes pressure changes in both stages of the cylinder.

Figure 9. A grid can be displayed which also provides an overall summary of the complete face. In this case, shields with and without leaking cylinders are identified.

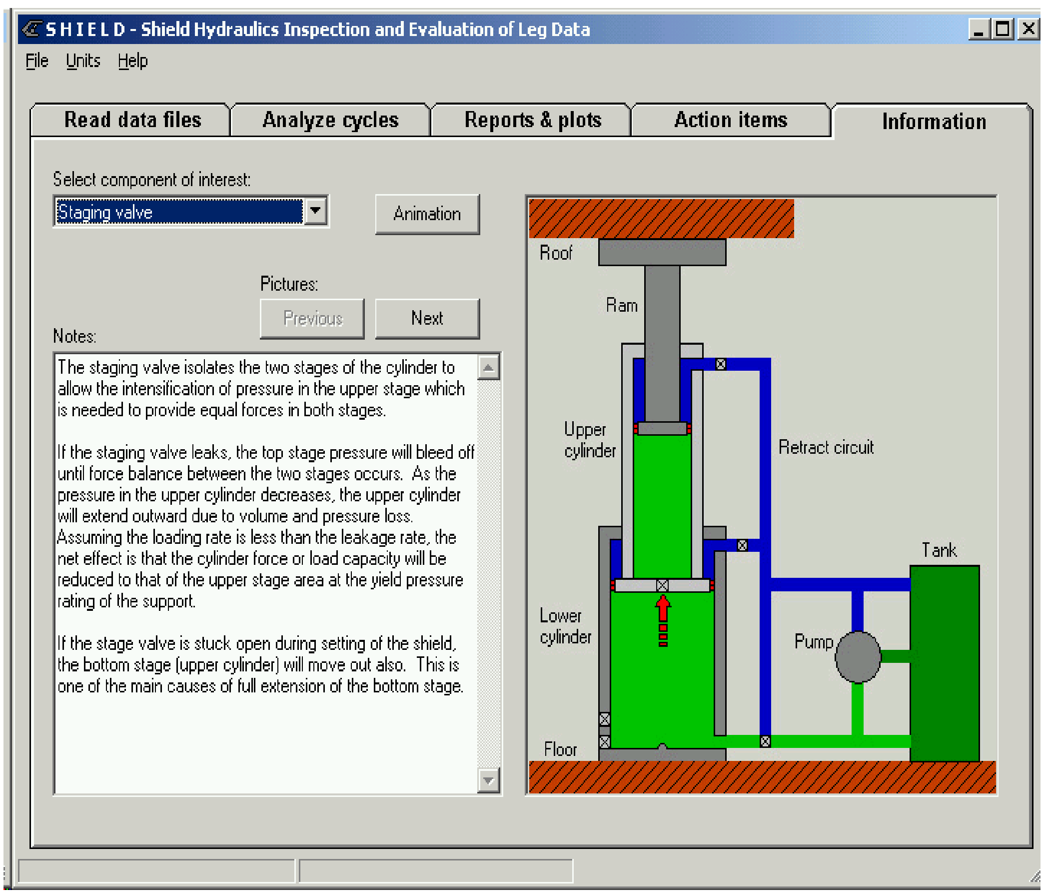

Figure 10. Component diagrams are also included which describe how a particular component works and what impact failure of the component will have on the supporting capability of the shield.

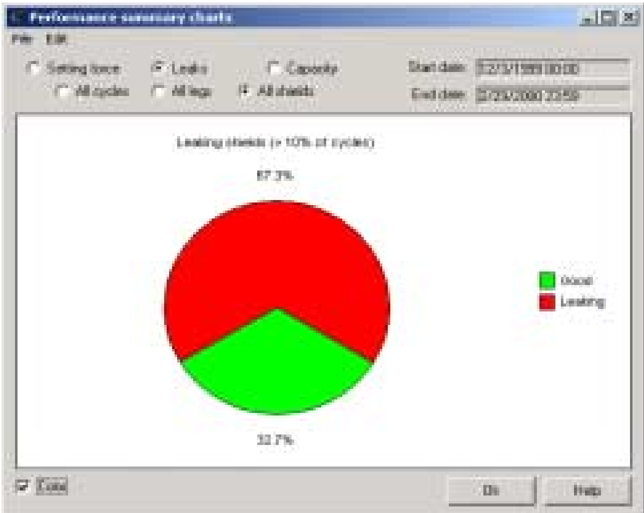

Figure 12b. As seen in this pie chart, 67.3 pct of the shields had one or more leaking cylinders.

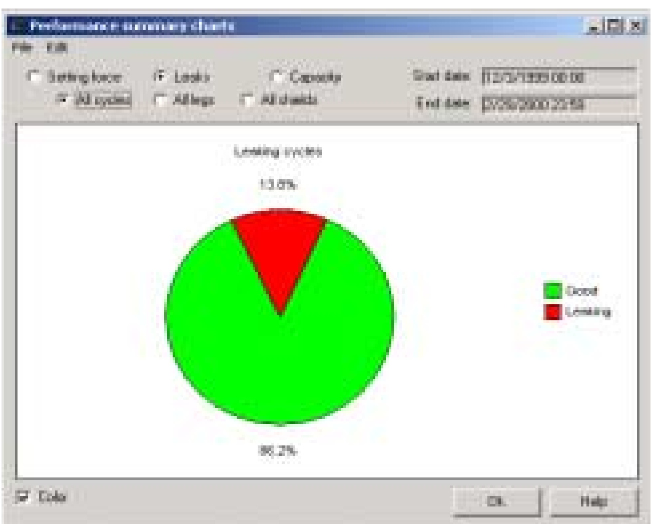

Figure 12c. The pie chart shows that 13.8% of all loading cycles had leaking cylinders.

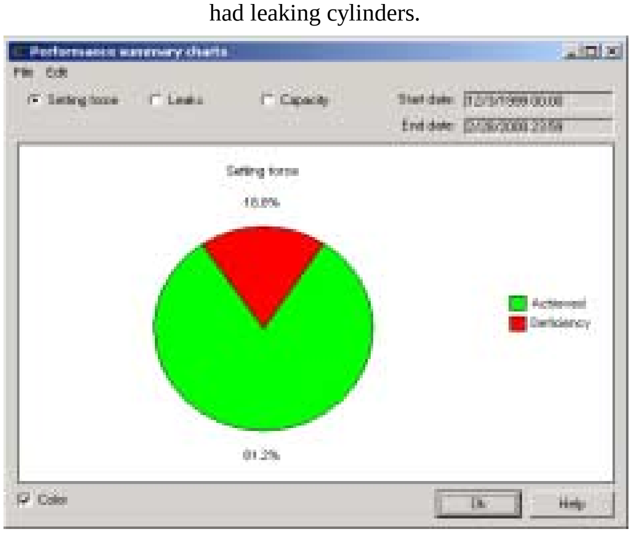

Figure 13. Illustration of how much setting force is lost due to leaking cylinders and low setting pressures.

SHIELD - SHIELD HYDRAULICS INSPECTION AND EVALUATION OF LEG DATA

Table 1. Overall face summary.

Start date: 12/3/1999 12:00:00 AM
End date: 2/29/2000 11:59:00 PM

Number of legs with data = 296
Number of legs with no data = 0
Number of unselected legs = 16
Total number of cycles = 228105
Average number of cycles per leg = 770.6
Number of legs with leaks = 168 (56.8%)
Number of cycles with leaks = 31513 (13.8%)
Number of legs with full extension = 294 (99.3%)
Number of cycles with full extension = 8327 (3.7%)
Average cycle length = 79.8 min
Percent of time operating at less than pump pressure = 34.4%
Average pressure difference when less than pump pressure = 1455 psi
Percent of time operating at more than yield pressure = 15.1%
Average pressure difference when more than yield pressure = 411 psi
Average pressure difference between HG & TG legs = 1585 psi
Average Set pressure = 3993 psi
Average Twap pressure = 4862 psi
Average Maximum pressure = 5717 psi
Minimum pressure = 202 psi
Maximum pressure = 8953 psi
Average SP/MP = 69.8%
Average SP/TWAP = 82.1%
Average TWAP/MP = 85.1%
Average (TWAP-SP)/(MP-SP) = 50.4%
Average TWAP-SP = 869 psi

Another approach in analyzing the performance of a longwall panel might be to conduct an analysis periodically to see what the trend in performance is as a function of increased time. For example, the shield data can be analyzed monthly and the output data plotted to observe trends. The SHIELD program facilitates this effort by allowing the user to conduct automatic analysis using new data since the last analysis was made. Figure 14 is an example using the Australian mine data to show the increasing trend in leaking cylinders on a monthly basis over a full panel extraction period of 7 months. In this figure, it is seen that the percentage of leaking cylinders increases from 9.6 to 14.1 during the panel extraction period.

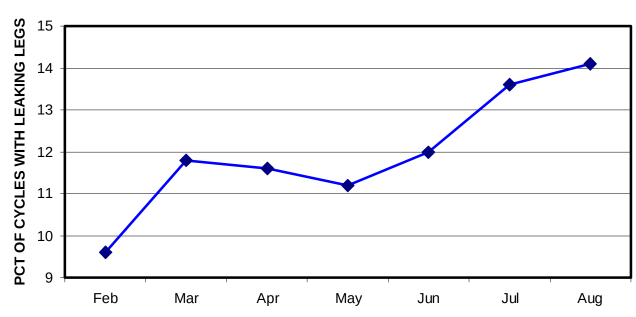

Figure 14. Trend of increasing leg cylinder leakage occurring during the extraction of a single longwall panel.

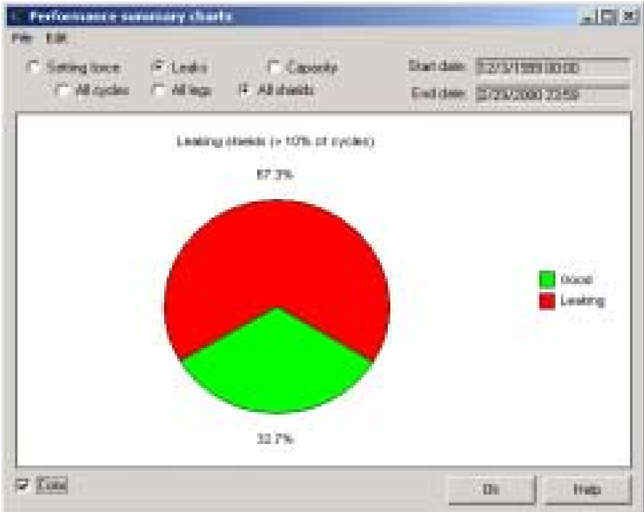

Figure 12b. As seen in this pie chart, 67.3 pct of the shields had one or more leaking cylinders.

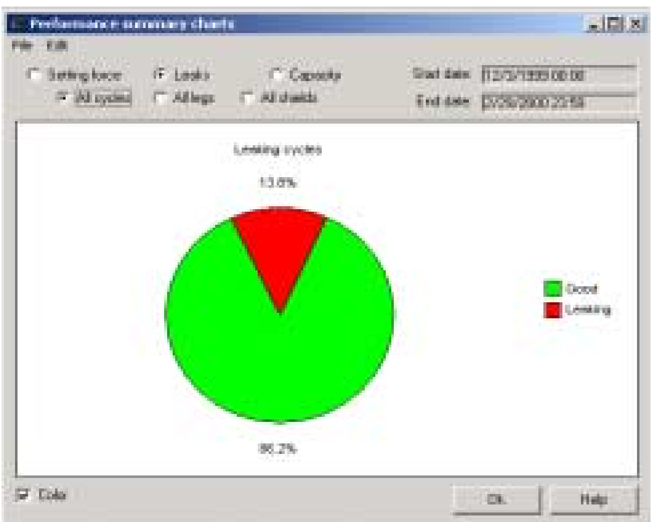

Figure 12c. The pie chart shows that 13.8% of all loading cycles had leaking cylinders.

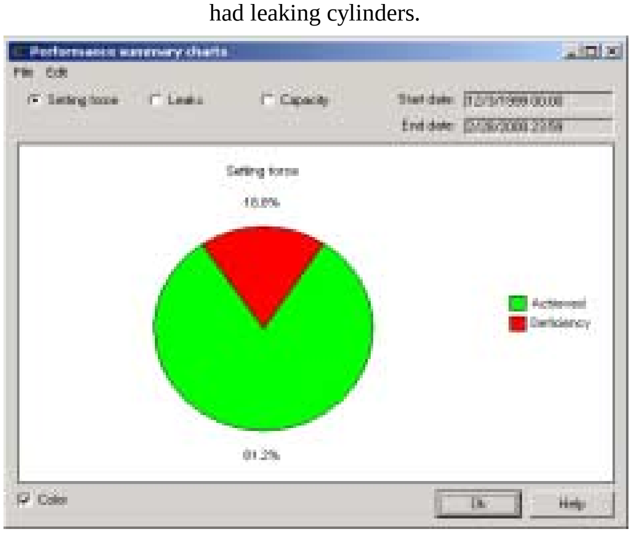

Figure 13. Illustration of how much setting force is lost due to leaking cylinders and low setting pressures.

SHIELD - SHIELD HYDRAULICS INSPECTION AND EVALUATION OF LEG DATA

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Number of legs with leaks = 168 (56.8%)
Number of cycles with leaks = 31513 (13.8%)
Number of legs with full extension = 294 (99.3%)
Number of cycles with full extension = 8327 (3.7%)
Average cycle length = 79.8 min
Percent of time operating at less than pump pressure = 34.4%
Average pressure difference when less than pump pressure = 1455 psi
Percent of time operating at more than yield pressure = 15.1%
Average pressure difference when more than yield pressure = 411 psi
Average pressure difference between HG & TG legs = 1585 psi
Average Set pressure = 3993 psi
Average Twap pressure = 4862 psi
Average Maximum pressure = 5717 psi
Minimum pressure = 202 psi
Maximum pressure = 8953 psi
Average SP/MP = 69.8%
Average SP/TWAP = 82.1%
Average TWAP/MP = 85.1%
Average (TWAP-SP)/(MP-SP) = 50.4%
Average TWAP-SP = 869 psi

Another approach in analyzing the performance of a longwall panel might be to conduct an analysis periodically to see what the trend in performance is as a function of increased time. For example, the shield data can be analyzed monthly and the output data plotted to observe trends. The SHIELD program facilitates this effort by allowing the user to conduct automatic analysis using new data since the last analysis was made. Figure 14 is an example using the Australian mine data to show the increasing trend in leaking cylinders on a monthly basis over a full panel extraction period of 7 months. In this figure, it is seen that the percentage of leaking cylinders increases from 9.6 to 14.1 during the panel extraction period.

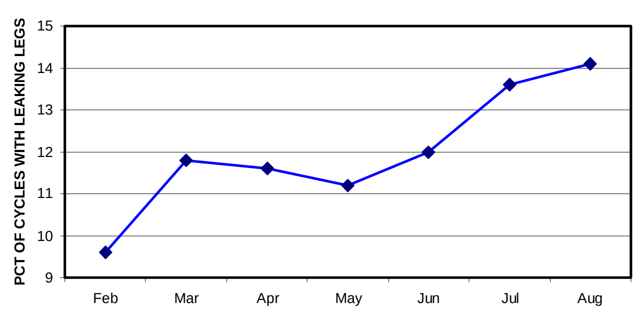

Figure 14. Trend of increasing leg cylinder leakage occurring during the extraction of a single longwall panel.

SUMMARY

Shields play a vital role in achieving successful, safe, and productive longwall mining. Although shield design has improved considerably through the years, hydraulic leakages and other problems that degrade the support performance are still prevalent, particularly on aging supports that have been in service for several years. The purpose of the NIOSH Shield Hydraulics Inspection and Evaluation of Leg Data (SHIELD) Computer Program is to help operators detect and track these failures and institute a good maintenance program that will help to preserve the full capability and life expectancy of the supports while achieving optimum ground control. By having a historical record of failures in terms of operating hours and loading, a reasonable preventive maintenance plan could be executed to allow repairs or rebuilds to be made to the hydraulic system before they become problematic.

In addition to providing useful maintenance information, the SHIELD program can monitor the use of the available support capacity on every loading cycle. This can provide insight into the utilization of the available support capacity and help to measure a ground reaction curve for the face area that may lead to more accurate requirements for support capacity, more efficient use of the available support capacity, how significant setting pressures are on the ground response, and in general how well the shield is controlling the ground. For the first time, this type of information can be collected and analyzed in a systematic and scientific method. Ultimately, such analyses may lead to improved shield design or utilization.

SHIELD is a stand-alone program that is designed for use with any support system provided that leg pressure data from the active longwall shields can be stored in a file that can be accessed by a personal computer. The program is designed to be flexible in handling various data formats to ensure that it is compatible with the different support types and computer control systems that are currently in use. As such, the program should provide a means to utilize the vast amounts of data that are available from modern shield installations, in a format that is easy to use, with the capability to maintain a continual record of the performance of every shield on a longwall face. It's modular architecture will allow the program to be expanded as needed to include other types of analyses.

Finally, a goal of the program is to help educate and inform people involved in various degrees with longwall shields on how the support, and its hydraulic system in particular, functions to provide the desired roof support. For example, learning and understanding how the setting force is reduced by as much as 50% when the bottom stage is fully extended, and when and why the bottom stage reaches full extension, can heighten awareness of how shields work, and what steps can be taken to improve ground control and shield performance.

REFERENCES

1. Barczak, T.M. Examining Longwall Shield Failures from an Engineering Design and Operational Perspective. Proceedings, New Technology for Coal Mine Roof Support, NIOSH, IC 9453, 2000, pp. 223-245.

2. Barczak, T.M. and Gearhart, D.F. Safety and Performance Considerations in Hydraulic Roof Support Systems. Proceedings, 17th International Conference on Ground Control in Mining, Morgantown, WV, 1998, pp. 176-187.

3. Peng, S.S. What Can a Shield Leg Pressure Tell Us? Coal Age, March 1998, pp 54-57.

4. Stafford, J., Mahoney, S., Conover, D.P. and DeMarco, M.J. Shield Monitoring to Forecast Severe Face Weighting at the South Bulga Colliery, NSW, Australia. Proceedings, 18th International Conference on Ground Control in Mining, Morgantown, WV, 1999, pp. 164-175.