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For The
MINING EQUIPMENT TEST FACILITY

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MASTER

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ABSTRACT

The Department of Energy recently began the operation of its Mining Equipment Test Facility. One component at that facility is the highly sophisticated Mine Roof Simulator (MRS) for research and development of roof support equipment. Because of its previous experience, the University of Pittsburgh was contracted to assist the Facilities Manager by providing professional technical support services, principally for the MRS. This technical progress report briefly describes the services provided during the reporting period and planned for the next period. No significant technical disclosures of interest to those not associated with the MRS are contained herein.

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1. BACKGROUND AND OBJECTIVES

Experience in Europe over the past fifteen years has clearly demonstrated that the use of longwall mining methods with self advancing powered face and roadway supports can increase underground coal mine productivity while reducing accident rates on the face. Cost-sharing government demonstration projects and commercial operations in the United States which have utilized mechanized, powered roof supports report record production figures.

One factor which inhibits the growth in the number of mechanized longwall faces in the United States is the all or nothing aspect of the method. Well selected equipment can yield high continuous production; but support equipment unsuited for the particular geology or which lacks mechanical reliability can result in failure with abandonment of longwall face.

Longwall roof supports imported from Britian and Germany in the 1960's suffered from both inadequate support and stability. The coal seam thickness and roof and floor properties in the US mines are sufficiently different from those countries in which powered supports evolved that a direct transfer of technology was not applicable. Supports used on US faces have by trial and error grown in support capacity to from two to five times the capacities used in Europe. Characteristics other than capacity also seem to be diverging from those on longwall support faces worldwide. To meet this nations projected coal demand, longwall support technology tailored the US mining conditions and preferences must be developed and promoted. The Pittsburgh Mining Technology Center with its recently completed \$25 million Mining Equipment Test Facility (METF) is actively working to advance US longwall mining technology.

One of the four units of the US government owned METF is the Mine Roof Simulator (MRS). This unique \$10 million test facility was designed to simulate underground mine roof loads and motions. The MRS is a hybrid analog digital computer controlled closed loop electro hydraulic research device capable of applying either loads or displacements in the vertical and one horizontal axis. Its vertical capacity of 3,000,000 pounds can be applied over its 20 by 20 foot active test area. The horizontal load capacity is 1,600,00 pounds. It can simulate coal seam heights of up to 16 feet. Automatic data acquisition and real time display are provided. The most modern, sophisticated technology was used in its design and construction.

This above ground simulation of the underground environment is notably less costly than actual underground research. It does not tie up or endanger any coal reserves. It requires no preresearch mine

development and does not inhibit the commercial operations of nearby faces. It greatly reduces the hazards to research personnel while providing them a larger, more accessible, better lighted work area. Fire hazards, moisture, and dust do not inhibit the choice of research instrumentation or methods. Clearly above ground simulation is the most effective method to filter out unworkable concepts or unreliable devices. Above ground research also allows most of the "bugs", inevitable in all new equipment development, to be eliminated expeditiously prior to being installed in underground demonstration projects.

The MRS is operated by an Operating Contractor under the direction of the Facilities Manager. Operation began in October 1980. The capital and operations costs of this facility represent a large investment on the part of the federal government in the future of underground coal mining. With coordinated programming of research projects and efficient operation, this Mine Roof Simulator will return its investment many fold through the practical application of advanced roof support technology by US coal mining industry and equipment manufacturers. The end result should be a greater number of high production longwall mines in the United States.

It is imperative that such a heavily invested and important effort such as the MRS and its programs have technical support services from those experienced in this field to assure its best usage, economically, technically and professionally.

The Civil Engineering Department of the University of Pittsburgh has for several years been conducting mine roof support equipment research similar to that to be performed at the METF. Through this project, the expertise developed at the University of Pittsburgh will be provided as professional technical support services to assist the DOE in performing its mission of managing program tasks conducted at the Mining Equipment Test Facility, in particular to improve the effectiveness, timely and technical efficiencies, economy of the technical operation, development of pre-test specifications, and professional analysis of test results for the Mine Roof Simulator subfacility of the METF.

2. SCOPE OF WORK

The professional technical support services will be provided on a continuing basis in timely correspondence to the needs that arise from the sequence of test programs to be undertaken at the METF. As will be requested by the METF Manager, the University will respond to technical needs over a broad range of disciplines including, mechanical function evaluations of the MRS rig and its specimens, structural analysis,

material behavior, rock mechanics, test instrumentation, control computer operation and data reduction . Within these disciplines, the actual technical services provided by this project are in four areas: assistance in planning the testing program, engineering analyses by the way of reviewing and improving the pre-test specifications to assure maximum and correct test results with definition of proper instrumentation and installation thereof, operation evaluation of the MRS tests including engineering analysis of test performance and data, and technology transfer by data processing and other assistance for preparation of publications.

3. TASK AREAS

Operation of the MRS in accordance with an approved Utilization Plan was underway and within the operating contractor staff training and system shakedown period when this project began. The Project Engineer, through a prior agreement, was involved in all test operation of the MRS todate. Some of the work covered herein is a continuation of tasks begun under the scope of work of the previous agreement.

3.1 Program Planning Assistance

3.1.1 Progress this Period.

During this period under this project, no modifications or additions to the Utilization Plan were made. Further, no assistance was requested from industry, academia, or other governmental agencies. concerning the use of the MRS subfacility.

Substantial interaction with BSI did occur during this period concerning the test requirements and test methods to be used on the Burrell Fibercrib tests. At the time of these tests, BSI staff had not yet received its strain gage training and their stock of displacement transducers had not yet arrived. BSI staff was guided as to how to set up the 450 Units for the strain gages and what type and precision bridge completion resistors would be required. Basic strain gage theory was also discussed. Sample gages of several types were loaned the BSI to familiarize them with the types they might expect the BOM to bring installed on the test cribs.

In addition to discussions and training provided BSI, a review of possible available displacement transducers at the University was made as a backup plan should the BSI ordered pots not arrive on time. The backup plan and the University transducers were not used as the BSI

transducers arrived two days prior to the tests.

A requirements document for the Kelastic Mine Beam (KMB) Post test was developed and submitted to J. H. Kelly of KMB and BSI for review and comment. Dr. Kelly's approval of the plan was obtained by phone. Dr. Kelly was also sent a No Cost Agreement for his signature and return. BSI had several objections to syntax in the RD which made them uncomfortable. A planning conference with Steve Litwin was held to resolve these. Also, after discussions with P.M. Yavorsky as to the responsibilities of the Project Engineer under this contract, all requests and deliverables related to manpower information were removed from the requirements document. The final redrafted RD was delivered to Yavorsky to transmit to BSI when Kelly's signed No Cost form is received. An unofficial copy was provided Steve Litwin of BSI, so that BSI could begin to develop their test plan.

A small amount of preliminary work was done this period toward the preparation of requirements documents for the Gullick Dobson Chocks owned by the METF. On site drawings for the GD Chocks were obtained and reviewed. These drawings contain no structural details. Hence, Gullick Dobson will have to be contacted for detailed structural drawings. The condition of the components for the 9 GD Chocks stored at the Bruceton site were examined. The units appear to be fairly sound structurally. Rustouts and broken components are primarily in non structural parts. All of the hydraulic lines will have to be replaced. Several of the hydraulic control valves are damaged or missing. Also several of the canopy capsules are missing. It should be possible for BSI to construct a sufficient number of usable specimens from the parts available. Most of the rebuilding work should be possible on site.

The remainder of the Requirements Document work efforts were directed to the evaluation of the capabilities of the MRS itself. The MTS Acceptance report was reviewed for vital data on the system capabilities. This report was to have verified the design specification, but does not. BSI will have to be directed to study and replot the acceptance data in the hope that it is possible to salvage some useful information from that extensive tests. It is more likely, however, that BSI will have to be directed to evaluate the capabilities from scratch.

In discussions with BSI concerning the crib tests of Burrell it was evident that some of the safety procedures applied in these tests would be highly counterproductive if applied on other research projects. While on business unrelated to this project, the Project Engineer had the opportunity to spend an hour with the monitor for safety of the BSI contract. He seems to appreciate the special nature of research and the need on occasion to take some personnel risks provided the hazards are minimized and tests are carefully and independently reviewed for

potential hazards. Additional formal meetings with the possible attendance by the University staff would be necessary to develop a set of standards for safety during tests in the MRS. The development of a standard which specifies several classes of test operation and their personnel hazard levels is strongly suggested.

Information pertinent to planning and scheduling is obtained by the Project Engineer by his participation in the monthly BSI progress reviews and the weekly meetings between C. Goode (PMTC) and Steve Litwin.

3.1.2 Tasks Planned for Next Month

There are no plans to work on the Utilization Plan in the near future. Until the basic capabilities of the MRS can be defined and the performance problems with the unit are cured, further long range planning is not possible. The Utilization Plan in hand is more than adequate for the short term. The several literature studies underway and described below will impact on the next edition of the Utilization Plan. With the shift to internal R & D, posts, props, jacks, arches, and ATRS devices may all be greatly expanded in the MRS Utilization Plan.

The Fibercrib third set of tests and the KMB Post tests are both anticipated for next month. Because of a reluctance on the part of Burrell to complete the tests as planned, additional planning conferences will probably be required for that job.

Work on requirements documents for the GD Chock and the capabilities evaluation will continue next month.

The only other externally sponsored job currently in hand is the BOM-ATRS tests. The requirements document for this job will be developed with the BOM and their University of Pittsburgh Contractor (C P Manglesdorf) probably some time in August. The delay in this job is due to the desire to perform some simpler jobs on the MRS first. The simpler jobs were delayed by the MRS operational problems, MTS repair and calibration of the major operational loops of the MRS, and BSI training. Hopefully, these problems will not delay this job beyond August.

3.2 Engineering Analysis

3.2.1 Progress this period.

The Operating Contractor submitted no analyses for review under this project during the reporting period.

A preliminary photo log from the May 15, 1981 Burrell concrete crib test was provided by BSI and reviewed for completeness. The photos were sharp, well formatted, and adequately documented. Overall they are of good technical quality and in the fullest compliance with the Burrell Test RD, except that no photo coverage was provided for specimen one. Also, the submittal would have been more useful for DOE publicity use if some additional action shots had been taken. Both Burrell and the BOM were also taking photos. We requested copies from both, but to date none have been recieved. Action shots may be obtainable from them.

Essential to the ability of the University to plan productive tests and evaluate Operating Contractor analyses adequately is an accurate easily accessed finite elements package. The SOLID SAP package developed by E L Wilson for the BOM was available to the Civil Engineering Department and a copy was acquired prior to this project. Also prior the this project, a free format small machine sub set version of this package(called FEP2) with only plane elements was created and partially documented by R C Garson.

The Research Analyst by simple practice examples has become completely familiar with all the operational aspects of the SOLID SAP sub set program FEP2. A planar analysis of the Burrell solid crib is currently being performed. Several analysis models will be compared. Also several crib aspect ratios will be examined to determine the best specimen size for future solid crib studies. A crude fracture study will also be simulated.

The SOLID SAP package is more than adequate for all the elastic analysis needs of the MRS required of this project.

3.2.2 Tasks Planned for Next Month

The SAP program familiarization by the Research Analyst will continue for at least another two months. During the next month, a straight line segment stress contour plotting program will be written specifically for the Burrell solid crib models. A good part of the aspect ratio study

will also be done.

The second and last familiarization example, to be undertaken next month, will be a planar analysis of the axial loads and bending moments in a Joy Shield.

Nonlinear, creep, and fracture analysis capabilities will be needed at the MRS both for prototype evaluation where destructive tests have been performed, or to analytically develop specimen loading which simulates true roof behavior underground. The finite element method of stress analysis has been shown to be far superior to all previous analysis techniques, and is recommended for the analysis at the MRS. This method has an excellent history in mining, including the longwall mining method, with a few noted exceptions. Problems in its use have occurred with its application with incorrect rock data or when used by inexperienced engineers. The BOM, DOE, and several other federal agencies have developed specialized finite element codes well suited to the needs of this project, BSI, the METF, and the other projects and programs of the PMTC and the Bruceton Research Center. One or more of these should be acquired and brought up on the DOE and/or METF computers. The University of Pittsburgh CE Department, through this project, can provide its experience and knowledge in the conversion of accessible software to the on-site computers, and where necessary assist BSI in the preparation of subset packages for the METF computers. Niel Styler, part time DOE Mining Engineer and Pitt Professor, is working along these lines on another project. A coordination of efforts could be very productive.

No work on the acquisition of advanced finite elements packages will be undertaken without prior approval of the METF Manager. We do, however, feel that this type of software is urgently needed not only by the METF but the whole Bruceton Research Center.

3.3 Test Operation Evaluation

3.3.1. Progress this period.

No tests were conducted during the employment of the Project Engineer under this project and no data from prior tests was evaluated during this period.

3.3.2 Tasks planned for next month

A review of the "Fibercrib" data report for the second and third days of testing is expected to occur next month. The KMB Post will hopefully also be performed next month and result in raw data requiring a review. BSI has a data base from their training period which may contain information vital to project planning for the MRS or useful in publications. It is hoped that the METF Manager can make that data available for review in the upcoming period.

3.4 Technology Transfer

3.4.1 Progress this period.

Todate, no publications have been generated, no conferences attended, and no special industry problems requiring the support of the University through this project solved.

On May 6 and 15, BSI performed concrete crib tests for Burrell, and additional tests are planned. BSI also used a wooden crib as part of their personnel training program.

A Journal literature search was begun by the Research Analyst for any recent wood or concrete crib data. This search was limited to the period from 1970 to present. Todate it has produced almost nothing in the way of published data!

The Research Analyst then conducted a retro search using published books available at the University of Pittsburgh and Carnegie Library. Though many books have sections on roof support which describe posts, cribs, packs, arches, and the like, almost no capacity, design or other technical data is provided. To evaluate the quality of the search being done by the Research Analyst, the Project Engineer did a full retro search of the books at Pitt. The Analyst had done a very careful and exhaustive search. No significant published book data exists at that library. Two recent sources with some data are Peng's book on Ground Control(1978) and the SME Handbook (1973).

The absence of recent journal and retro book data makes it necessary to perform a retro search for roof support data in the journals. This will be a very time consuming task. Because of his greater experience in retro searching technical topics in old journal abstracts, and his better understanding of the relevance of data to the needs of the MRS, this search will primarily be performed by the Project Engineer. The

search will cover all forms of ground support except those which employ tension such as bolts, trusses, pegs, and grouting. The topic of tunnel liners will also be skipped, but not the topic of roadway supports. This search will be performed as time permits over a period of at least a year.

This absence of crib data in the recent literature is a clear sign of an area where substantial data generation at the MRS may be required.

Large mining companies will certainly have test data to support their cribbing practices. Prior to undertaking a program of tests in the MRS, an effort to obtain private data should be undertaken.

An English language study was performed on the subject of strain and displacement recording transducers. Its principal objective was to discover if in the last few years any new or unique methods of measurement had been developed to a cost effective stage sufficient for application at the MRS. As a secondary objective, the literature was examined for information on trends in the well established techniques.

This search revealed that the conventional transducers have changed very little in capability, continued to increase significantly in cost, and appear to be improving slightly in reliability and ruggedness. The advent of the microprocessor has lead to a complete revolution in data acquisition systems now offered. Neither of these observations appear to have a significant impact on the planned activities for the MRS testing but may impact on the kind of systems considered for underground tests.

The laser, fiberoptic, and ultrasonic new instrumentation appear to be about a year or two still away from nonexperimental use in strain and displacement measurement. ultrasonic thickness measurement is now quite precise and the units are reasonably priced. Because of the possible danger to the MRS from possible bolt fracture, the acquisition of an ultrasonic unit is suggested. When not in use for MRS maintenance and inspection, its possible application to support testing can be investigated.

The quality of fiberoptic selflighted viewsopes appears to have increased significantly. Their combination with video recording camera will permit the observation of internal movement and deformation of roof support parts, or other circumstances where lack of access or personnel hazard exist. A viewscope with sufficient magnification to allow crack identification and measurement should be purchased for the MRS. It will permit the examination of supports for cracks while under severe loads without personnel having to crawl on or under the supports.

Under a previous contract, a literature search for data on hydraulic

powered supports was begun. It identified all the significant English language journal articles on face supports from 1965 through the first quarter of 1980. A significant number of these were skimmed for their applicability to the proposed utilization of the MRS at that time. The articles were sorted as primary, secondary, and no interest to the MRS programs. Because of a substantial shift in the scope of the use of the MRS, this literature effort will have to be reexamined and expanded to include more data on non hydraulic and other than face supports. The bibliography maintained will contain articles with technical information on support or ground behavior. Nontechnical papers, and papers devoted to applications and economics of supports will not be maintained.

A literature source search, also under previous contract, was performed, which covered the years from 1970 to mid 1980, to identify articles on the application of Finite Elements to ground control in mining. Its principal purpose was to identify possible software sources.

Both of these searches were updated by a source search from 1980 through the first quarter of 1981.

3.4.2 Tasks planned for Next month

The principal efforts next month will be devoted to retro searching of journals to identify article sources on passive supports and mechanical jacks. Some skimming and classification of articles will probably also be done. Selected readings are not likely to occur this next month of any of the passive support papers.

A review of recent magazines will be performed to examine the adds, notes, and nontechnical articles for details on the activities of other research facilities and for trends and changes in equipment and methods of support. The magazines planned for this type of review are Coal Age (American), Colliery Guardian (UK), and Gleuckauf (German).

A search of the BOM-Oakland library card catalog for passive support literature will be performed. This will be supplemented by an index search of the abstracts of the publications of the BOM from 1910 through 1960.

The retroactive journal literature search for crib and prop test data will be continued for the next several months. A nonexhaustive search for rigid and yieldable mine roadway arches will be done at the same time from 1970 back. A formal search for roadway arch data from 1974 to present may also be performed. The degree of emphasis on arches will depend on whether the Youngstown Arch specimens are provided to the MRS

for test in the near future.

4. MANPOWER EFFORT THIS MONTH

The Project Engineer (R C Garson) worked the equivalent of 22 days. His efforts were distributed as follows:

- 28.9% Administration and report preparation.
- 26.9% Work on the KMB Post RD and work towards the GD Chock testing. Also includes a review of the preliminary photo album for the Burrell tests.
- 26.1% Literature searches for powered support data, crib data, and prop data. Information on the application of Finite Elements to mining problems and availability of software was also sought.
- 10.8% Meetings with DOE and BSI
- 7.3% Supervision of Research Analyst

The Research Analyst worked the equivalent of 22 days for the month of June. This effort was distributed as follows:

- 60.9% Familiarization with the use of the SOLID SAP Finite Element program, including a variety of simple examples. Also practiced with the use of the UPDATE text editor and the UARC tape library routines.
- 21.8% Literature search for crib data
- 11.5% Preliminary modeling of solid Burrell concrete crib for analysis by SOLID SAP program.
- 5.8% Supervision meetings and lecture on shield testing.