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Noise and Vibration Control for Surface Mines

Program Document

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NOISE AND VIBRATION CONTROL FOR SURFACE MINES

Program Document

By Bradley V. Johnson,¹ Richard J. Seibel,² and David E. Siskind³

ABSTRACT

This publication summarizes the in-house and contract research and development projects conducted since 1974 by the

Bureau of Mines for the control of noise and vibrations from surface mine blasting.

INTRODUCTION

Noise, ground vibration, and airblast-produced structure vibrations are unwelcome side effects of surface mining operations. Uncontrolled, these effects can result in an irritated public and in cracked walls or broken windows.

The Bureau's study of blast-produced ground vibrations dates back to 1930, when a study was initiated to determine the damage caused by ground vibration. Initial conclusions quantified ground vibrations and developed some predictive techniques for magnitude based on charge weight and distance to a structure.⁴ Statistical studies of structural response to both ground vibrations and airblasts were conducted in the late fifties and the sixties; research included analyses of data published by others and field tests and analysis of blasting vibrations at 25 quarries.

Areas of investigation consisted of seismic instrumentation, safe vibration levels for residential structures, generation and propagation of ground vibrations and airblasts, and prediction of ground vibration and airblast levels. For quarry blasting, relatively small blasthole diameters and charge weights are used. However, in surface coal mines, over a ton of explosives can be loaded into a hole over a foot in diameter. Coal mine blasts are often designed to fracture the rock in place rather than throwing it onto the pit floor. This can reduce airblast but at the risk of increased ground vibration. To make reasonable recommendations for surface coal mining, a new set of vibration data was needed. The Bureau began this study of surface coal mine blasting in 1974. Currently over 15,000 blast records are being analyzed and new recommendations are being formulated.

In 1978, the Bureau began a study of noise produced from sources other than blasting. This work initially gathered information on general noise abatement techniques and then listed major noise sources. Large haulage trucks have been found to be a major source of noise both in the mining pit and on public roads. Research is now being focused on controlling this noise.

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⁴Thoenen, J. R., and S. L. Windes. Seismic Effects of Quarry Blasting. Bureau of Mines Bull. 442, 1942, 83 pp.

PROGRAM GOALS

The goals of the Bureau's noise and vibration control program are to develop and demonstrate (1) proper mine blasting practices and (2) proper ground vibration and noise controls for surface mining operations. To accomplish these goals, the following objectives have been established:

1. To control blast noise from contour mining in Appalachia.
2. To determine the fatigue effect of repeated surface mine blasting on residential structures.
3. To develop blast designs that minimize airblast and ground vibration and to develop a handbook of blast design, all consistent with good blasting principles and fragmentation.
4. To apply precision blast initiation devices to control adverse

environmental impact and improve fragmentation.

5. To determine propagation and frequency characteristics in low-velocity geologic media.
6. To develop a simple weather assessment technique and criteria for adverse weather applicable to mines with potential airblast problems.
7. To develop remote monitoring methods.
8. To improve flyrock control.
9. To improve stemming techniques.
10. To identify, categorize, and rank surface mine noise sources.
11. To develop noise controls for large haulage trucks.

CURRENT STATUS

Adverse environmental effects from surface mining activities continue to be a major problem for the mining industry, the public living near mining operations, and the governmental agencies responsible for setting environmental standards. Congress, in recognizing this problem, passed the Surface Mining Control and Reclamation Act of 1977, which addresses many specific environmental effects, including the noise and vibrations from blasting and other mining operations.

Blasting in the mining, quarrying, and construction industries used 4 billion pounds of explosives in 1980. The necessity of blasting for most mineral production, or wherever rock must be excavated, has led to two sets of technical problems: environmental effects and design variables influencing fragmentation. Large surface coal mines have had to close because of widespread

complaints. Other mines have had to abandon many tons of previously purchased coal rights because of blasting vibration or have been required to agree to excessively strict vibration levels for their operating permits.

The regulatory agencies have been asked to close down "irresponsible blasters." Public interest groups have claimed widespread damage from airblasts, ground vibrations, and flyrock. Conflicts abound at the State and local level concerning environmental regulation of these effects, permit granting, hearings, and lawsuits. Even prior to the 1977 Surface Mining Act, 17 States had regulations on blasting vibrations based on Bureau research, and in 1974 blast noise standards were proposed in Illinois that threatened to halt all blasting in the State.

The Bureau completed four major studies of blast effects from coal and other types of surface mining in 1980.⁵ These studies identified the major factors in the design of production blasts that influence airblast and ground vibration levels. They also determined levels of ground vibration and airblast that correspond to acceptable structure response and damage potentials, and made a comprehensive analysis of measurement systems. Results were needed by the mining industry and the regulatory agencies for realistic, technically based, and defensible criteria for allowable blast-induced ground vibrations and airblasts.

The Bureau's research program emphasizes improved minerals production and the establishment of essential and realistic environmental, health, and safety guidelines. For blasting in particular, there have been efforts to determine safe-level criteria for ground vibration and airblast. These criteria should provide the basis for realistic, technologically established, and defensible regulatory levels, and also for practical blast design for the industries that use explosives.

The work on noise control is not as advanced. An annotated bibliography on noise abatement techniques has been

established. Under existing contract JO100001, "Technology for Environmental Noise Control in Surface Mines," the Bureau is investigating the sources and relative levels of noise from surface mines. One of the sources identified has been the large haulage trucks used in the surface mines. Because they are built for off-highway use they are not designed to meet EPA noise criteria. Most of the techniques used to protect the workers have taken the form of special cabs which, while they protect the driver from excessive noise, do not reduce the noise radiated to the surrounding areas. A follow-on contract will use recommendations from contract JO100001 to develop techniques for reducing the noise from large haulage trucks. Prototype techniques will be applied to trucks and demonstrated under actual operating conditions.

Comprehensive blast design work is continuing. One important parameter, delay timing, is now being researched with the goal of developing a precise blast initiation system to insure proper blast delay intervals. A system is now undergoing laboratory development, with field tests scheduled for 1983.

The fatigue effect of repeated blasts is not known. The Bureau of Mines has built a full-scale test structure to study this and other effects, such as settlement, at the Ayshire Mine near Evansville, Ind. Field data are now being gathered, and analysis will begin soon.

Future work will also include a study of the effects of blasting on hydrology and fugitive dust generation. Another aspect is the human response to blast noise and vibrations.

Determination of safe technical criteria is only one factor in the establishment of environmental control. To insure that recommended controls are practical for the mining industry, the social, legal and economic effects of a control must also be considered.

⁵Siskind, D. E., V. J. Stachura, M. S. Stagg, and J. W. Kopp. Structure Response and Damage Produced by Airblast From Surface Mining. BuMines RI 8485, 1980, 111 pp.

Siskind, D. E., M. S. Stagg, J. W. Kopp, and C. H. Dowding. Structure Response and Damage Produced by Ground Vibration From Surface Mine Blasting. BuMines RI 8507, 1980, 74 pp.

Stachura, V. J., D. E. Siskind, and A. J. Engler. Airblast Instrumentation and Measurement Techniques for Surface Mining. BuMines RI 8508, 1981, 53 pp.

Stagg, M. S., and A. J. Engler. Measurement of Blast-Induced Ground Vibrations and Seismograph Calibration. BuMines RI 8506, 1980, 62 pp.

The end results of the program will be a comprehensive set of operating parameters that, when followed, will help guard against environmental damage while

enabling mines to supply the country with the necessary minerals in an economical manner.

RESEARCH APPROACH

The Bureau of Mines is in continual contact with the mining industry and other Federal agencies. The Bureau learns of current mining problems through interactions at mining symposia and through visiting and working in mining operations. The industry makes numerous requests for Bureau information and receives additional data through Bureau publications and presentations. The Bureau also has a close working relationship with both State and Federal agencies that have programs relevant to the Bureau's concerns.

It is through these continual interactions that the Bureau identifies mining problems and their priorities; such interactions are also essential for technology transfer. Formal vehicles for technology transfer include presentations at mining symposia, Bureau publications, open industry briefings, technology transfer seminars, journal articles, technology demonstrations, films, and exhibits at professional and industrial meetings.

The process cycle typically involves--

1. Industry interaction.

2. Problem identification.
3. Problem prioritization and Government interaction.
4. Research.
5. Problem solution.
6. Evaluation and feedback.
7. Technology transfer through industry interaction, briefings, presentations, and publications.

This cycle is made possible through expertise gained under a strong in-house research program. If personnel is limited, portions of set 4 in the cycle are contracted out. The result is an integrated program that is responsive to the needs of the mining industry and of the Nation.

Technology transfer seminars on Ground Vibrations and Airblast Control were presented on November 5, 1980, in Chicago, Ill.; on December 3, 1980, in Denver, Colo.; and on December 17, 1980, in Washington, D.C.

IN-HOUSE RESEARCH⁶

Assessment of Damage from Blast-Induced Ground Vibrations

This project determined the thresholds of damage for cyclic repetitions of low vibration levels as well as for single exposures to high levels of vibration. Existing or new structures were subjected to blast-induced vibrations at levels that actually produced observable damage. Also small structures were

subjected to many repetitions of simulated blast vibrations on large-scale shaking tables, with the results correlated to previous studies and field tests on similar structures.

Airblast Assessment and Control

The project determined the important variables for controlling the generation and propagation of noise from blasting, developed techniques for minimizing noise levels, and established noise and damage

⁶Dates and funding appear in appendix A.

thresholds for use in developing regulations. The initial task was a survey of the literature to determine the important variables for controlling airblast. Field tests were designed, using this information, to evaluate the instrumentation available for impulsive noise level measurement, to determine the effects of generation and propagation variables on noise levels, and to establish safe noise level criteria.

Evaluation of Current Methodologies for Ground Vibration Measurement

Increased interest by all sections of industry and Government in ground vibration problems necessitated a standardized methodology for determining ground vibration levels. The Bureau of Mines, in an unbiased capacity, evaluated existing instrumentation, methods, and measurement criteria to produce a reasonable standardized measurement system. This will permit efficient planning for new mine monitoring systems and help insure compliance with environmental statutes.

Collection and Analysis of Ground Vibration Data From Surface Mine Blasting

This project determined ground vibration levels for surface coal mine blasting that will permit economical mining yet will minimize damage from blasting. Experimental work measuring vibrations from actual mine blasts was combined with previous blast vibration work to achieve guidelines that will include effects of structural fatigue damage as well as damage from single shots.

Evaluation of Noise-Measuring Devices for Airblast Transients

This project examined techniques for the measurement of blast noise overpressures and evaluated the performance of commercially available impulse precision sound level meters and carrier-type systems designed for sonic boom studies. Using recorded blast signals, measurement

methods such as peak, root mean square, linear or flat, and C-weighted were investigated. Recommendations were made on instrumentation and measurement techniques for airblast noise measurement at surface mines.

Determination of Criteria for Ground Vibration Damage From Surface Mine Blasting

Damage caused by ground vibrations from surface coal mine blasting is a serious problem for both mine operators and governmental agencies responsible for regulating these adverse environmental effects. Appropriate permissible levels for blast-produced ground vibrations will be determined, permitting economical mining while minimizing damage to nearby residences. Field measurements from coal mine blasts will be combined with previous blast vibration work and response spectra analysis techniques to develop safe levels that will include effects of repeated blasting damage as well as damage from single shots.

Control of Blast Noise and Vibration From Contour Mining of Coal in Appalachia

Airblast and ground vibration effects on structures from the contour mining of coal in Appalachia will be determined. Many complaints on record for the Appalachian Coal Region indicate that the particular topography and mining method may generate abnormal levels of airblast and ground vibrations. The applicability of blasting criteria developed for midwestern surface coal mining will be evaluated, and if required, specialized criteria will be developed for Appalachian mining.

Fatigue and Structural Damage From Repeated Surface Mine Blasting

Fatigue damage to structures from repeated blasting is an often-posed problem to the mining industry and the governmental agencies responsible for regulating these adverse environmental

effects. Appropriate criteria will be recommended, incorporating the results of this long-term single-structure with data from concurrent fatigue model tests and the peak-level criteria developed from previous short-term studies.

Application of Abatement Technique
to Mine Environmental Noise Problems

The objective of this project was to determine and promote the application of noise abatement techniques to the solution of fugitive mine noise problems. Noise emissions were identified, characterized, and quantified, and cost-effective abatement technology was described. Changes necessary in mining systems to provide isolation of noise sources were identified.

Blast Design To Minimize Airblast
and Ground Vibration

The objective of this project is to develop blast design criteria to minimize airblast and ground vibrations and still permit effective blasting programs at surface mines. Past work will be integrated with new data on delay intervals and use of decking. Other blast design parameters will also be considered for research as needed.

CONTRACT RESEARCH⁷

Control of Vibration and Blast Noise
From Surface Coal Mining (J0255022)

(Wiss, Janney, Elstner
and Associates, Inc.)

The objective of this work was to determine the extent of adverse environmental effects of airblast and ground vibrations from surface coal mine blasting and to develop blasting techniques to minimize these effects. The project was divided into three phases covering

Analysis and Technical Clarification
of Ground Vibration and
Airblast Standards

In developing criteria for control of damage and annoyance levels of airblast and ground vibration and associated measurement methods (descriptors), both the National Academy of Science-sponsored Committee on Hearing and Bioacoustics (CHABA) and the Army Corps of Engineers have supplied support to the International Standards Organization, American National Standards Institute, the U.S. Department of Housing and Urban Development, and U.S. Environmental Protection Agency. Their recommendations will be analyzed and critiqued for applicability to blasting. This will involve participation in working group meetings, an effort that has already been initiated. Although none of the criteria proposed so far include any blasting data, they are often more stringent than the Bureau's well-founded recommendations for airblast and ground vibration.

Feasibility of the Development
of a Precious Blast
Initiation System

Current delay blasting systems will be studied, and alternatives to pyrotechnic delay caps analyzed. Experimental prototypes will be built and tested in the laboratory, and a feasibility and cost analysis will be done.

2 years work. The contract has been completed.

Survey of Blast Damage to Water Supplies
in Appalachia (J0285029)

(Philip R. Berger and Associates)

The objective of this contract was to determine possible adverse environmental effects of blasting on ground water supplies in close proximity to contour coal mining operations in Appalachia. Ground vibrations associated with surface coal mine blasting are a

⁷Dates and funding appear in appendix B.

major problem to homeowners near the mine sites. Not only can the vibrations cause damage to the residences, as shown in a number of Bureau studies, but a number of complaints exist in contour strip mining areas concerning loss of, or damage to, water wells caused by blasting. The final report will be available in 1982.

Human Response to Blast Noise and Ground Structure Vibrations (J0206009)

(Bolt, Beranek and Newman)

This study will determine, by field surveys and field tests, levels of surface-mine-blasting-induced ground vibrations and airblast that are perceptible, annoying, or intolerable to humans.

Standards on the Measurement of Human Acceptability of Blast Noise and Ground-Transmitted Vibration and Shock (J0205020)

(Acoustical Society of America)

This contract provides for administration of the national and international standards committees for which the Acoustical Society of America holds

coordinating responsibility, specifically in the technical areas of human and structural tolerance and measurement of noise and vibration.

Technology for Environmental Noise Control in Surface Mines (J0100001)

(ORI, Inc.)

Work under this contract will identify the environmental noise problems associated with mining operations, develop techniques for monitoring such noise, and identify and recommend technology for abatement of noise problems.

Technology for Control of Environmental Noise From Off Road Haul Trucks (J0218020)

(Woodward Associates)

This contract supports the development of cost-effective techniques for reducing the sound radiated from large haulage trucks without significantly reducing the efficiency of the trucks. Prototype techniques will be applied to trucks and demonstrated under actual operating conditions.

APPENDIX A.--IN-HOUSE BUREAU RESEARCH PROJECTS

Research Area: Minerals Environmental Technology
 Research Program: Noise and Vibration Control From Surface Mine Blasting
 Research Center: Twin Cities

Project	Starting date	Expected completion	Funding, thousand dollars								
			FY 75	FY ¹ 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	
Assessment of Damage From Blast-Induced Ground Vibrations.	FY 75--7/1/74	Completed	60	175	-	-	-	-	-	-	-
Airblast Assessment and Control.	FY 75--7/1/74	Completed	100	125	120	130	-	-	-	-	-
Evaluation of Current Methodologies for Ground Vibration Measurement.	FY 77--10/1/76	Completed	-	-	35	-	-	-	-	-	-
Collection and Analysis of Ground Vibration Data From Surface Mine Blasting.	FY 77--10/1/76	Completed	-	-	175	-	-	-	-	-	-
Evaluation of Noise-Measuring Devices for Airblast Transients.	FY 77-10/1/76	Completed	-	-	35	-	-	-	-	-	-
Determination of Criteria for Ground Vibration Damage From Surface Mine Blasting.	FY 78--10/1/77	Completed	-	-	-	100	-	-	-	-	-
Control of Blast Noise and Vibration From Contour Mining of Coal in Appalachia.	FY 78--10/1/77	Completed	-	-	-	-	120	90	130	-	-
Fatigue and Structural Damage From Repeated Surface Mine Blasting.	FY 79--10/1/78	9/30/84	-	-	-	100	100	75	70	160	-
Application of Abatement Techniques to Mine Environmental Noise Problems.	FY 79--10/1/78	9/30/83	-	-	-	-	20	30	65	-	-
Blast Design To Minimize Airblast and Ground Vibration.	FY 79--10/1/78	9/30/85	-	-	-	-	50	90	120	130	-
Analysis and Technical Clarification of Ground Vibration and Airblast Standards.	FY 80--10/1/79	9/30/83	-	-	-	-	-	20	20	50	-
Feasibility of the Development of a Precise Blast Initiation System.	FY 81--10/1/80	9/30/87	-	-	-	-	-	-	-	50	100
Total.....			160	300	365	330	290	305	455	440	

¹Includes transition quarter.

APPENDIX B. - CONTRACT BUREAU RESEARCH PROJECTS

Research Area: Minerals Environmental Technology
 Research Program: Noise and Vibration Control From Surface Mine Blasting

Project	Starting date	Expected completion	Funding, thousand dollars								
			FY 75	FY ¹ 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	
J0255022--Control of Vibration and Blast Noise From Surface Coal Mining.	1975	Completed	535	-	-	-	2	-	-	-	
J0285029--Survey of Blast Damage to Water Supplies in Appalachia.	1978	1982	-	-	-	267	-	31	-	-	
J0206009--Human Response to Blast Noise and Ground Structure Vibrations.	1980	1982	-	-	-	-	-	202	121	-	
J0205020--Standards on the Measurement of Human Acceptability of Blast Noise and Ground Transmitted Vibration and shock.	1980	1982	-	-	-	-	-	10	10	-	
J0100001--Technology for Environmental Noise Control in Surface Mines.	1980	Completed	-	-	-	-	-	76	-	-	
J0218020--Technology for Control of Environmental Noise From Off Road Haul Trucks.	1981	1983	-	-	-	-	-	103	-	-	
Total.....	-	-	535	-	-	267	2	422	131	-	

¹Includes transition quarter.

