Miller, Diane M. (CDC/NIOSH/EID)

From: lusk@engr.uky.edu
Sent: Thursday, March 08, 2007 9:14 AM
To: NIOSH Docket Office (CDC)
Cc: Doyle, Glenn (CDC/NIOSH/EID); Chen, Jihong (Jane) (CDC/NIOSH/EID) (CTR)
Subject: 100 - mineseal Comments

Name
Braden Lusk

Organization
University of Kentucky

Email
lusk@engr.uky.edu

Address
234-D Mining and Mineral Resources Bldg
Lexington, Kentucky 40506-0107
USA

Comments
I have prepared technical comments regarding the Draft Report titled "Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines."
First and foremost I would like to commend the efforts of the research team in preparing a document that shows at great length the efforts undertaken to ascertain proper loading requirements for seals in underground coal mines. The technical comments that follow are in no way intended to degrade the value of the research described in the report.
The findings described are well thought out, and supported with validation in most cases. For the most part, the document provides solid scientific information that will be an excellent tool for evaluating and designing seals in the future. Several serious problems do exist, however, if the recommendations are adopted by MSHA immediately. The mining industry (and technology advancement in general) is in no way prepared to handle the design requirements suggested in the report. The following paragraphs cite specific examples of how current technology does not allow for immediate implementation of the recommendations.
The most appropriate format for referring technical comments is by line or section within the report. Each comment is derived as response to specific portions of the report. Every effort has been taken not to take the portions out of context. A logical step for reviewing the document is to begin with the Executive Summary.
Major concern arises when the recommended code for analyzing the performance of seal structures is not commercially available. The Wall Analysis Code (WAC) from the U.S. Army Corps of Engineers is not available for unlimited distribution. This already puts mining operations at a disadvantage when attempting to secure a proper seal design. While the use of other structural analysis programs is deemed appropriate, a design safety factor of 2 or more is recommended. Guidance should be provided as to how this safety factor should be applied. In later sections of the report, safety factors are addressed, but a solid recommendation for how to apply the safety factor is not provided. Later comments will address problems that could be encountered when applying such a factor.
There are many advantages to separating seal types by their location within a mining system. Section 1.3 outlines four seal applications. It is certainly appropriate to assume different possible loading dependent upon location and orientation. When such classifications are made, it is important to address the event that a seal location may not match one
described explicitly in the report. Some seal applications may not fall
within the described categories, and thus provisions would need to be established for gaining approval. The report does not provide information to be used when sealing areas outby previously sealed areas. In this case, monitoring of previously approved 50 PSI seals may not be reasonable. Provisions need to be addressed for redundant seal configurations.
Section 1.4 outlines three types of explosive gas accumulation associated with sealed areas. The report and modeling does not address the natural effect of gas layering. The natural bedding of gases within a sealed area should at the very least be topically addressed. When discussing the first type of explosive

gas accumulation on Line 218, a situation is described where accumulated gas would have no possibility of venting.

There is no basis for believing that a large sealed area could act as a pressure vessel and not allow for any venting. Even experimental data shows that after some relatively short amount of time, a sealed area would return to its typical or undisturbed pressure. The concept seems overly pessimistic to assume that an explosive mixture could be created in an entire large sealed area. This feat is difficult to create in a laboratory setting, much less an ever changing mining environment.

The possibility of 100% filling of a sealed area with no layering of gases is unlikely at best. This is supported by the fact that typical seal designs for 20 psi have not been damaged in explosions. The use of Omega block seals has likely accounted for the vast majority of failures. A review of failures associated with alternative seal designs since 1992 is advisable to determine seal designs most likely to cause failures. Table

2 shows that seals were destroyed, but does not describe the type of seals in place prior to the explosions.

A reference to "static horizontal pressure" in Line 386 is evidence that the authors of this report understand the need to update and further define the terminology associated with dynamic pressure loading. Previous criteria do a poor job of defining the loading that should be designed for. The information provided in Section 3 is the most comprehensive explanation of pressure loading associated with methane and coal dust explosions available to the mining industry to date. The authors should be commended for providing this much needed tool to the industry. There are many methods available for calculating resultant pressures from gas detonations. The use of the Chapman-Jouguet (CJ) pressure is appropriate for estimating worst case detonation pressures. It should however be noted that there is limited understanding for the actual processes involved with the process of detonation. A more distinct explanation is needed for the difference between the free field or steady state pressures estimated through CJ calculations (Section 3.5), and the reflected pressures calculated using Landau and Lifshitz (Section 3.6). These pressures are completely different in nature, and should not be characterized as two different pressure criteria. The reflected pressures are dependent upon the orientation of the seal structure to the propagating detonation wave. The angle of incidence is the driving factor for reflected pressure with 90 degrees from the direction of propagation as the worst case. This factor is not addressed within the report, but could be an additional criterion for the design of seals.

Line 964 states that "at the extremely high pressures that could occur in a mining explosion, the models are not correct;..." While the validation process for lower pressures is outstanding, the use of these models for creating design pulses at higher pressures is not advisable. The codes were used to create the high pressure (640 psi) design pulse described in detail beginning in Line 1053. This decision is questionable when considering that a pressure of 450 psi is the highest pressure cited with experimentally produced or recorded data. Thus, citing a design pulse at 640 psi seems over-conservative. Also, a clear distinction was not established concerning the nature of the 450 psi measurement. It is important to know whether the measured pressure was reflected or side-one.

The peak pressures and rise times for the remaining two design pulses seem appropriate; however, the constant pressure condition following the initial pulse may not accurately reflect the loading of a seal due to a methane explosion. The design pulses are vitally important to proper seal design. The natural frequency of the structure is directly related to the seals effectiveness in sustaining integrity following a blast event. Even if pulse durations are much greater than natural frequencies of designed seals, harmonics of the seals motion may be affected by the duration of the pressure loading.

Requirements for monitoring starting on Line 1133 are not well defined.

Currently, there is not a proven system for administering such a monitoring program in the U.S. The report describes systems currently in use in Australia, but these applications may not be sufficient for all applications in U.S. mining systems. Such requirements are subject to interpretation and should be well defined prior to implementation.

Section 6 includes the most concerning portions of the research described in the report. Line 1168 addresses an item of deep concern stating that "a general design for a mine seal is not possible." While this is a true statement, the consequences of mandating individual seal designs are serious. The mining industry does not have access to a great number of engineers capable of designing seals for dynamic response to blast events.

Commercial finite element software is prohibitively expensive, most government codes are not available commercially at any cost, and engineers capable of performing the analyses are few and far between. With the current process for design submittal, the process would be overly backlogged, and timely approval is not a possibility. The scientific community is responsible for providing data which will allow mining companies to increase the safety of miners exposed to the risks associated with sealing. This report shows that pressures created by methane explosions in underground coal mines are much higher than previously expected. With this in mind, the mining companies are ultimately responsible for responding to and mitigating an increased risk to miners and this is an important task that is of utmost importance.

As stated in Line 1175, the recommended design approaches "only demonstrate two possible failure modes which are both dependent on the structural reactions of the surrounding strata." Later in the section (Line 1376), it is recommended that all other failure modes be addressed in seal designs, but no guidance is provided for how to accomplish this.

If the nation's premier institute for mining research does not provide designs that factor all failure modes, how can the mining industry be expected to do so on a regular basis. The mining companies should be charged with developing these standards, but time must be allowed for technology development and transfer. Immediate compliance with higher design pulses could create an unreasonable burden to the mining industry.

For this reason, interim rules are advisable until adequate designs can be developed and validated.

It should be noted that the design pulses described in Lines 1198-1201 completely ignore any effects of reflected pressure. While this is an assumption that could be made, it may not accurately depict real situations.

Line 1240 states that "The design engineer will need to verify that this (rigid contact with the roof, ribs and floor with no movement) assumption holds true before proceeding with this WAC analysis." Again, no guidance is given regarding how this verification should be accomplished.

Furthermore, WAC is not available for unrestricted distribution. Another code such as SBEDS could be used, and should be suggested in the report due to its availability.

When considering arching failure, one-way arching is considered more conservative, but two-way arching would provide more accurate results.

When applying safety factors, the most accurate calculations should be used, and safety factors applied later in the process.

Line 1269 should be clarified to describe how scaling the computed minimum seal thickness by a factor of 2^1/2 effectively doubles the applied load on the structure.

Line 1315 begins describing a design methodology for choosing between failure mechanisms. The methodology advises that WAC analysis should be performed when thickness to height ratios are less than ¼. Plug analysis should be used when that ratio exceeds 1. This becomes a problem when minimum thicknesses are calculated using WAC and then a safety factor is applied to that thickness. Raising the thickness of an arching seal could expose that seal to other failure mechanisms that were not designed for.

Line 1338 describes additional recommendations for the reinforcement of seal designs that already incorporate a safety factor of 2. This suggests that NIOSH engineers recommend a safety factor of well over 2.

Furthermore, the effects of the additional reinforcement should be considered in the overall design of the seal rather than as an afterthought.

Line 1367 mentions the use of a "simple explosion-proof valve."

Specifications and suppliers of these valve should be provided with the recommendation.

Overall, the development of design pulses was well outlined and supported by review of literature and validation. The issues cited above should be considered prior to implementation of the required design pulses.

Nevertheless, the research described in this report characterizing pressure time curves associated with methane explosions in underground coal mines is important and will stand as a quality first step in dealing with the problem at hand. More serious concerns are raised when discussing the design of seals to withstand the loading environments possible. Currently the mining industry is ill prepared to handle these designs. A rush to judgment and implementation of final rules by MSHA at this point would be an egregious error. A limited number of engineers nationwide are adequately trained to handle dynamic analysis of seals, and the mining industry does not have regular access to these engineers.

Technology transfer plans need to be addressed immediately. The future research outlined in Section 7.3 should be completed prior to final rulemaking. Legislative pressures and mandates should not overcome the need to create policy that is substantiated by quality scientific findings. Interim policies could be implemented to bridge the gap between the antiquated 20 psi standard and future design standards.

When final rules are promulgated, additional factors should be considered.

MSHA must either provide standard design options, or accept designs that are approved by Professional Engineers at the liability of the approving Engineer.

I would like to stress the fact that I believe this NIOSH report is of superior quality. The research performed is essential to the protection of miners. Nevertheless, the mining industry must proceed with caution in order to avoid creating standards that will become quickly outdated once further research is performed. It is certainly much easier to pick apart someone else's work rather than perform original research. It is hoped that the technical comments listed here will be used to add to the quality scientific work described in this report. The results of the report will no doubt increase safety for underground

coal miners exposed to the risks of sealing.