September 17, 2007

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Mine Safety & Health Administration
Office of Standards, Regulations and Variances
1100 Wilson Boulevard, Room 2350
Arlington, VA 22209-3939

RE: RIN 1219-AB52 – Sealing of Abandoned Areas, 72 Fed. Reg. 28,796 (May 22, 2007)

Dear Sirs:

The National Mining Association (NMA) submits these comments in response to the Emergency Temporary Standard (ETS) issued by the Mine Safety and Health Administration (MSHA) on May 22, 2007, (72 Fed. Reg. 28,796), for underground seals separating abandoned areas from active workings. NMA members operate underground coal mines and are directly affected by this rulemaking which changes requirements for the design, construction, maintenance and repair of seals as well as requirements for the sampling and controlling atmospheres behind seals.

Our comments consist of four parts which are described in detail below.

First, suggested revisions to the regulatory language with an accompanying explanation for the revisions.

Second, responses to the questions and requests for information contained in the preamble to the ETS.

Third, in direct response to MSHA's request, see 72 Fed. Reg. 45,358, we provide three technical evaluations of the National Institute for Occupational Safety and Health (NIOSH) final report on "Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines." The technical evaluations were performed by Dr. Martin Hertzberg, Packer Engineering, Inc. and Baker Engineering and Risk Consultants, Inc. These submittals, the later two which were submitted to NIOSH during the public comment period on their draft report, demonstrate that flaws in NIOSH's analysis resulted in the development of seal design criteria for conditions that have not been demonstrated in underground coal mines. More specifically, Dr. Hertzberg's conclusion, which is shared by the other reviewers, is that:

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> This critique and evaluation of the NIOSH report has shown that it is seriously flawed in two important aspects: first, in its contention that methane-air mixtures in those sealed areas will be uniformly mixed, and secondly, in its contention that the required seals should be able to withstand pressure forces from methane-air detonations. It is shown that the mixtures in those sealed area will not be uniformly mixed and that detonation propagation in those sealed areas is virtually impossible.

Fourth, a document entitled "Excerpts Taken from This Report on the 'Mitchell-Barrett' Solid-Concrete-Block Seal" which contains the results for tests conducted by NIOSH on the Mitchell-Barrett solid concrete block seal. Prior to publication of this ETS, Mitchell-Barrett seals (while not referenced by name but rather by construction design and material composition) were specifically recognized and accepted in agency's regulations as being sufficient to "protect miners from the hazards of sealed areas." We believe the deletion of this category of seals in the current ETS is not only unwarranted but, in fact, heightens rather than lessens the hazards of sealed areas to which miners are potentially exposed. The NIOSH document and the industry's historic and safe use of this type of seal substantiate our view that the agency's action lacks a sufficient basis in the record.

Fifth, comments responding to the letter from Congressman George Miller, Chairman, House Education and Labor Committee, to Secretary of Labor Elaine L. Chao dated July 24, 2007.

<u>Reliance on Mine Act § 101(b) for an Emergency Temporary Standard</u>

We do not believe MSHA has satisfied the standard under § 101(b) to bypass advance notice and comment rulemaking to change and amend existing standards. Thousands of mine seals have been constructed for many decades which have not and do not pose any danger, and certainly not a grave one. Moreover, we believe that the manner in which MSHA has proceeded by imposing new standards immediately without the benefit of public comment has produced a complex and confusing regime for the construction, approval and monitoring of seals.

MSHA has issued numerous documents regarding the management of seal design, construction and maintenance. Indeed, the agency has issued seven Program Information Bulletins culminating with the distribution of a massive document dated July 24, 2007 that seeks to "establish uniform procedures for the application of the . . . regulations regarding seals." It should be noted that these seven documents were accompanied by two "Seal ETS Compliance Assistance Questions and Answers" documents designed to provide further clarification to the regulated community of the agency's expectations.

Unfortunately, this wealth of information has only added confusion and inconsistent applications of the rules. Inconsistent decisions across MSHA districts, decisional delays and controversy have unfortunately been the rule rather than the exception since the agency's initial foray into this area on June 1, 2006. We believe this is due to the agency expanding what was, in large part, a narrowly defined problem into one comprising issues that were far removed from the issues identified during the Sago and Darby investigations.

The industry still faces inconsistent district interpretations and decisions in this area. For example, they are required to define "affected areas", when developing an action plan or when seeking, along with a seal manufacturer, approval of a seal design. This has resulted in mines throughout the country having to suspend operations (sometimes repeatedly) and withdraw miners far in excess of that assumed in the Regulatory Flexibility Analysis that accompanies the ETS. Not only has this caused confusion among operators as to the agency's expectations, miners and their families now question the safety of operations that have historically been considered to be some of the safest in the industry. Quite simply, these actions have resulted not from the identification of a safety consideration requiring immediate attention but rather from the agency's overly reactive approach that has resulted in each instance being categorized as presenting a "grave danger" when in fact they are nothing more than a condition that the company has successfully managed since installation of the seal.

NMA's Suggested Revisions

NMA's comments include suggested revisions to the ETS regulatory language that are intended to address the potential hazards that might arise within seal areas in a more concise, manageable and consistent manner. NMA's suggested language recognizes the need to conduct a risk-based analysis of the area behind seals both when considering what, if any, remedial actions are needed for existing installations as well as when designing, installing and monitoring new installations. It would replace the confusion and controversy that have become the hallmarks of the ETS with a system rooted in consistency and cooperation.

NMA appreciates the opportunity to submit comments on this rulemaking and stands prepared to continue to work with MSHA to develop appropriate standards.

Sincerely,

Bruce H. Watzman
Vice President, Safety, Health and Human Resources

Enclosures

PART 75--SAFETY STANDARDS FOR UNDERGROUND COAL MINES

1. The authority citation for part 75 continues to read as follows:

Authority: 30 U.S.C. 811, 863.

2. Revise Sec. 75.335 to read as follows:

Sec. 75.335 Seal requirements.

Seals shall be designed, constructed, and maintained to protect miners from hazards related to sealed areas. Seal designs and the installation of each seal shall be approved in accordance with Sec. 75.336.

(a) Seal strength requirements. Seals constructed on or after May 22, 2007 shall be designed, constructed, and maintained to withstand--

(1) 50 psi overpressure when the atmosphere in the sealed area is monitored and maintained inert in accordance with paragraph (b) of this section;

(2) 120 psi overpressure if the atmosphere is not monitored, and is not maintained inert, and the conditions in paragraph (a)(3)(i) through (iii) of this section are not present; or

(3) An overpressure greater than 120 psi if the atmosphere is not monitored and is not maintained inert and;

(i) The atmosphere in the area to be sealed is likely to contain homogeneous mixtures of methane between 4.5 percent and 17.0 percent and oxygen exceeding 17.0 percent throughout the entire area;

(ii) Pressure piling is likely due to opening restrictions near the proposed seal area; or

(iii) Other conditions are encountered, such as the likelihood of a detonation in the proposed seal area.

(iv) Where the conditions in paragraphs (a)(3)(i), (ii), or (iii) of this section are encountered, the operator must revise the ventilation plan to be submitted to the District Manager to address the potential hazards. The plan shall include seal strength sufficient to address the conditions.

(4) All pressure requirements are applied with a safety factor (SF) = 1.0 unless site specific requirements dictate a higher level.

(b) Sampling and monitoring requirements. **Effective May 22, 2007, a certified person as defined in §75.100 shall monitor atmospheres of sealed areas. For seals constructed prior to May 22, 2007 and for seals designed for 50 psi overpressure, mine operators shall develop and follow a protocol to monitor methane and oxygen concentrations, and to maintain an inert atmosphere in the sealed area. The protocol shall be approved in the ventilation plan.**

(1) A certified person shall sample atmospheres of sealed areas weekly when the seal is outgassing. At least one sample shall be taken at each set of seals. If a seal is ingassing during the weekly examination, a sample shall be collected during the next weekly examination. If the seal is ingassing for a second consecutive week a sample shall be collected at an alternative sampling location or with an alternative method of analysis, if available.

a. If the seal is ingassing during the second consecutive weekly examination, the operator shall examine that seal daily until the seal is outgassing. If the seal does not outgas an sampling plan shall be developed and submitted to the District Manager.

b. The District Manager may approve different sampling frequencies and locations in the ventilation plan or approve the use of atmospheric monitoring systems in lieu of weekly sampling. The mine operator shall revise the protocol, if repeated sampling indicates that a seal is not likely to outgas.

Rationale: Some seals will always ingas and there are limits to what an operator can do to get a seal to outgas, therefore, the District Manager should take this into consideration and if a seal always outgases then the seals in that seal line that outgas should be accepted as sampling points to demonstrate what is in the gob. It should be remembered that may mines are overmined or are very deep with harsh terrain; all of which prohibit the use of vertical boreholes. Operators need to be allowed to use alternative means (or methods) to establish that a gob is inert**.** If a seal changes with barometric changes then it should be examined and recorded. The intent of this is if there are several seals along a long seal line that are sampled that represent a gob and a percentage of less than one half are ingassing then the outgassing seals should be considered representative. Alternatively if there are inert seal sets on either side of a non-inert seal set, then the gob area should not be considered explosive.

The preamble (page 28,802) discusses MSHA's opinion that leakage into sealed areas as a result of barometric changes would not "significantly impact the atmosphere in a large portion of the sealed area but it may affect the atmosphere at a sampling location, when the seal is ingassing. Therefore, it is important that samples be representative of the atmospheric conditions in the larger portion of the sealed area rather than just the area immediately inby the seal."

As reflected in the above cited preamble language, the proposal acknowledges the need to review the entire sealed area, yet the action plans and sampling protocols ignore other data that can provide a clearer picture of the inertness of the entire sealed area. The recommendation will address this situation by permitting the use of sampling data from either one seal in a set of seals or other means of establishing the condition of the entire sealed area and not rely on an action plan based upon one seal set.

The introduction of boreholes into sealed areas that have methane present has the potential to cause pathways for lightning to travel into the sealed area and create another transition zone in the gob instead of only have one at the seal itself. While there may be instances when borehole sampling is appropriate, we believe our suggested regulatory language recognizing "an alternative sampling location" would permit such the use of a borehole without it being mandated for all applications as some have suggested.

(2) Certified persons conducting sampling shall be trained in the sampling procedures included in the protocol, as provided by paragraph (b)(5) of this section, before they conduct sampling, and annually thereafter. The mine operator must certify the date and content of training provided certified persons and retain each certification for one year.

Rationale: The industry applauds the agency's desire to develop a regulation for training of certified persons using a performance standard. The industry would like to clarify that this training is not part of Part 48 training and does not require a training plan submission.

(3) The atmosphere shall be considered inert when--

(i) The oxygen concentration is less than ~~10.0~~ **12.0** percent;

(ii) The methane concentration is less than ~~3.0~~ **4.0** percent; or

(iii) The methane concentration is greater than ~~20.0~~ **16.0** percent.

Rationale: MSHA's zone of what is inert is too restrictive. MSHA's inert zone is considered to be less than 3% and greater than 20%; the accuracy of hand monitors would allow the inert zone to be larger and to still have a safety factor. MSHA must also consider that these atmospheres are behind previously approved seals that offer some level of protection. Therefore, there is still a level of protection although the non-inert zone has been increased to 4.0% and greater than 16.0%. Allowable maximum oxygen according to the IC 7901 Determining the Explosibility of Mine Atmospheres is Maximum $O_2 = 5.0 + 7$ R. R value for methane which is the primary explosive gas is 1 therefore the maximum allowable oxygen is 12 percent.

The gas levels listed in the ETS mirror the gas levels used in the July 2006 PIB. While providing a safety factor for hand-held sampling is understandable, the failure to acknowledge a chromatograph reading to determine inert levels is not understandable. The regulation should allow for a narrowing of the safety factor when follow-up chromatograph samples are taken. This is how the system works for other gas readings taken by MSHA inspectors and should be provided for in this regulation. A chromatograph reading of oxygen below 12% levels on methane outside the 3% to 20% levels should be the "final decider" of the atmospheric levels for a sealed area.

(4) **When oxygen concentrations are 12.0 percent or greater and methane concentrations are from 4.0 percent to 16.0 percent in a sealed area, the mine operator shall take at least one additional gas sample within a 24 hour period. If the additional gas sample is from 4.0 percent to 16.0 percent and oxygen is 12.0 percent or greater then the operator may take a bottle sample to be analyzed by a gas chromatograph. The results will be plotted on the Zabetakis Nose Curve. If the atmosphere is inert with an R value outside the appropriate triangle the results will be recorded and no further action need to be taken. If the atmosphere is not inert with an R value inside the appropriate triangle, the following action plan will be implemented –** ~~When oxygen concentrations are 10.0 percent or greater and methane concentrations are from 3.0 percent to 20.0 percent in a sealed area, the mine operator shall take two additional gas samples at one-hour intervals. If the two additional gas samples are from 3.0 percent to 20.0 percent and oxygen is 10.0 percent or greater –~~

Rationale: Taking two additional samples at one hour intervals does not give the gob enough time to equalize after a barometric swing. A sampling period over twenty-four hours is much more reasonable. Should these additional samples show that the operator is still in the non-inert range then the operator at his discretion may take additional samples. These samples may be taken and analyzed using a gas chromatograph. Individual gases can be analyzed and the Zabatakis Nose Curve can be calculated and plotted to determine the true explosive nature of the gob. These calculations are outlined in IC 7901. Also, if chromatograph samples are taken then a comparison can be made to a handheld that reads CO2 and a correlation can be established as an indicator as to whether the atmosphere is inert or not even though the oxygen and methane are in the non-inert zone.

The industry agrees with the need for additional samples to verify an initial reading. The industry questions whether the time frame is sufficient when the sample reading is clearly an outlier from the previous samples accumulated as part of a baseline. In cases where the baseline has established a clear pattern of readings indicating an inert atmosphere, additional time should be accepted to allow for follow-up chromatograph sampling prior to implementing the action plan.

(i) ~~The mine operator shall implement the action plan in the protocol; or~~ **The mine operator shall implement the action plan in the protocol which will consider:**

(i) The size of the zone that has the 4-16.0% methane with oxygen above 12.0% or has a R value inside the appropriate triangle as determined by the Zabatakis Nose Curve then the size of the affected area and the action to be taken may be determined by one of the following methods:

(a) Evaluating the samples from the seals that have been examined to determine that the seal that is out of the inert zone is isolated to that one seal or seal set. A seal sample outside of the inert range will be recorded in the inspection book and re-sampled every 24 hours with a handheld monitor or chromatograph until it is determined to be inert.

(b) Should two adjacent seals or sets of seals be determined to be outside of the inert range, the internal nature of the gob will be examined by an alternative method, if available, to determine if the

internal part of the gob is inert. If the internal part of the gob is inert and the non-inert area is isolated and of limited size, then the designated affected area will limited to that seal.
(c) Should the non-inert gob area determined to be extensive, or a line of three or more adjacent seals or sets of seals be determined to be outside of the inert range, then immediate action will be taken to inert the atmosphere by implementing the section addressing this in the protocol as submitted to MSHA.
(d) Should inert seals exist adjacent to a non-inert seal, the internal nature of the gob will be considered inert; or
(e) Persons shall be withdrawn from the affected area, except those persons referred to in section 104(c) of the Act.

Rationale: There should be some tiered approach to what action the operator is required to take based on the size of the area that is in the non-inert range. Samples at times may swing in and out of the zone due to barometric highs and lows. Air changes to the mines ventilation system can impact the sampling results. This tiered approach gives the operator some time to respond without necessarily having to pull the people every time one or two samples may indicate that they are in the non-inert zone. Also, the size of the gob that is sealed in relation to the size of the non-inert zone must be considered and the non-inert zone must represent a small percentage of the sealed gob. This would apply particularly in large sealed areas along seal line fringe where leakage into the gob is a concern.

It must be accepted that the determination of what individuals should be withdrawn and the area of concern must be made on a case-by-case basis. The industry's historical use of properly constructed and maintained Mitchell-Barrett seals, which was prior to this regulatory proceeding, accepted and viewed as the gold standard has served the industry well. Mitchell-Barrett seals have little chance of failure and have repeatedly demonstrated, in tests conducted by the National Institute for Occupational Safety and Health at the Lake Lynn Experimental Mine, the ability to withstand explosive forces in excess of 50 psi. We urge the agency to consider their use when rendering withdrawal determinations.

~~(ii) Persons shall be withdrawn from the affected area, except those persons referred to in section 104(c) of the Act.~~

(5) The protocol shall address--

(i) Sampling procedures, including equipment and methods to be used;

(ii) Location of sampling points;

(iii) Procedures to establish a baseline analysis of oxygen and methane concentrations at each sampling point over a 14-day sampling period. The baseline shall be established after the atmosphere in the sealed area becomes inert or the trend reaches equilibrium;

Rationale: The baseline should be used to establish the nature of the sampling point and an indication of what the internal nature of the gob is. These points should not be expected to never enter the non-inert zone because of changes in the mine or barometric swings. The majority of these baseline numbers should be inert, but it can be expected that there are times when they will be non-inert. (See action plan)

Industry would like MSHA to provide the agency's sampling protocol to be used by MSHA inspectors. This doesn't need to be part of a regulation, but should be made available to interested parties for comment. For example, will MSHA rely strictly on a hand-held sample or will a bag sample be used for confirmatory chromatograph readings? If a confirmatory sample is to be taken, what pump system does MSHA plan to use?

The Action Plan is to include affected area. Industry would expect that the affected area be based on more than a generalized "cookbook formula" and that mitigating systems be permitted to minimize the area. For example rockdust and/or water bags added to the active side of the seal can act to reduce explosion forces. These types of actions by an operator should be considered when establishing an affected area. We have heard of Districts stating that the entire mine is affected, yet the regulations clearly contemplate allowing for operating under an action plan.

(iv) Frequency of sampling;

(v) Size and conditions of the sealed area; and

(vi) Use of atmospheric monitoring systems, where applicable;

(vii) The protocol shall include an action plan that addresses the hazards presented and actions taken when gas samples indicate oxygen concentrations of ~~10.0~~ **12.0** percent or greater ~~for each of the following ranges of methane concentrations~~ **and methane of 4.0-16.0%**

Rationale: The non-inert zone has been narrowed and the actions are outlined above**.**

(A) 3.0 percent or greater but less than 4.5 percent; and
(B) 4.5 percent or greater but less than 17.0 percent; and
(C) 17.0 percent to 20 percent.

(6) The certified person shall promptly record each sampling result, including the location of the sampling points, and oxygen and methane concentrations. The results of oxygen and methane samples shall be recorded as the percentage of oxygen and methane measured by the certified person and any hazardous condition found, in accordance with Sec. 75.363.

(7) The mine operator shall retain sampling records at the mine for at least one year from the date of sampling.

(c) Welding, cutting, and soldering with an arc or flame are prohibited within ~~1~~50 feet of a seal **in the same air-course except when a plan is approved for such work by the District Manager**.

(d) For seals constructed after May 22, 2007, at least two sampling pipes shall be installed **the seals of greatest and least elevation** in each **set of** seal**s**. One pipe shall extend approximately 15 feet into the sealed area and another shall extend into the center of the first connecting crosscut inby the seal **and approximately 150 feet from the seal. A lesser distance or different location may be approved where location may be approved where local conditions preclude this straight-line distance.** Each sampling pipe shall be equipped with a shut-off valve and appropriate fittings for taking gas samples **and be identified as to location and length of pipe. The pipe in the lowest seal shall be approximately 12 inches above the highest anticipated water elevation.**

Rationale: The prohibition of burning and welding within 150 feet of a seal makes mining with a longwall in the west very difficult. The gob isolation stoppings will be within 150' of the tail drive of the longwall, and during a maintenance event, there will likely be times that burning and welding will be required. 75.1106 already addresses the safeguards needed to safely do this work, and a prohibition is not necessary, as long as proper procedures are followed.

The application of the prohibition of cutting and welding within 150 feet of a seal may not be enforceable or cause great interruption in some mines where the next entry or two entries over from the seal contains a pre-existing belt, belt drive, shop area, travel-way or track. There is no "grandfather clause" for these situations. If additional, new seals (as anticipated by the standard and being required in the new ETS plans) are to be built and there is not adequate space in front of existing seals, the new seals may be placed within the 150 feet of the existing areas listed above.

The standard where the 150-foot distance comes from (permissible zone near gob lines) is of a completely different nature from the seal situation. In the 150-foot gob scenario, the hazard is that there are generally no permanent ventilation structures between the gob and the permissible zone so that any of a number of incidents (gob reversal, low gob pressure, large roof fall pushing out gob air) could result in gob air carrying methane to come into the work area. In many areas around seals, there are definite air flow patterns separated by permanent ventilation devices that are designed to carry away any out-gassing from the seals.

(e) For each set of seals constructed after May 22, 2007, the seal at the lowest elevation shall have a corrosion-resistant water drainage system. Seals shall not impound water **except that adequate water may be impounded for the design operation of the water drainage system.**

3. Add Sec. 75.336 to read as follows:

Sec. 75.336 Seal design applications and installation approval.

(a) Seal design applications from seal manufacturers or mine operators shall be in accordance with paragraphs (a)(1) or (a)(2) of this section and submitted for approval to MSHA's Office of Technical Support, Pittsburgh Safety and Health Technology Center, P.O. Box 18233, Cochrans Mill Road, Pittsburgh, PA 15236.

(1) An engineering design ~~application~~ shall:

(i) Address gas sampling pipes, water drainage systems, air leakage, fire resistance, flame spread index, pressure- time curve, entry size, engineering design and analysis, material properties, construction specifications, quality control, design references, and other information related to seal construction;

(ii) Be certified by a professional engineer that the design of the seal is in accordance with current, prudent engineering practices; and

(iii) Include a Seal Design Table that discusses characteristics related to mine-specific seal construction.

(2) Each application based on full-scale explosion tests shall address the following requirements to ensure that a seal can reliably withstand the overpressures provided by Sec. 75.335:

(i) Certification by a professional engineer knowledgeable in structural engineering that the testing was done in accordance with current, prudent engineering practices and its applicability in a coal mine;

(ii) Technical information related to the methods and materials;

(iii) Proper documentation;

(iv) An engineering analysis to address differences between the seal support during test conditions and the range of conditions in a coal mine; and

(v) The application shall include a Seal Design Table that discusses characteristics related to mine specific seal construction.

~~(3) MSHA will notify the applicant if additional information or testing is required. The applicant must provide this information, arrange any additional or repeat tests, and notify MSHA of the location, date, and time of the test(s).~~

(3) (4~~) MSHA will notify the applicant, in writing, whether the design is approved or denied. If the design is not approved, MSHA will specify, in writing, the deficiencies of the application, or necessary revisions.~~ **Within 30 days, if the design is considered to be incomplete, MSHA will specify in writing, the items in paragraphs (a)(1) or (a)(2) which have not been addressed otherwise, the design will be accepted.**

~~(5) Once the seal design is approved, the approval holder must promptly notify MSHA, in writing, of all deficiencies of which they become aware.~~

(5) MSHA Tech Support will provide a selection of approved generic seal designs, constructed of commonly obtainable materials, complete with all design criteria and calculations, for use by the Operator and Professional Engineer in choosing a seal design applicable to the site(s) where the seal is to be constructed.

(7) In the case of MSHA designed seals, the operator must promptly notify MSHA, in writing, of all deficiencies of which they become aware.

Rationale: Once a professional engineer has certified that a design meets the required standard, and all required data has been attached to the submittal, the design should become effective immediately. MSHA should not have the ability to deny a design unless the application is not complete or the design methodology is flawed. It is the responsibility of the professional engineer to certify the design and it is the responsibility of the mine operator to employ a properly designed seal.

(b) The mine operator shall use an approved seal design provided its installation is approved in the ventilation plan. The mine operator shall--

(1) Retain the seal design approval information for as long as the seal is needed to serve the purpose for which it was built.

(2) ~~Designate a professional engineer to conduct or have oversight of seal installation.~~ ~~**A copy of the MSHA approval**~~ ~~and~~ ~~**applicable (if not an MSHA design)**~~ ~~certify that the provisions in the approved seal design specified in paragraph (a) of this section have been addressed. A copy of the certification shall be submitted to the District Manager with the information provided in Sec. 75.336(b)(3) and a copy of the certification shall be retained for as long as the seal is needed to serve the purpose for which it was built.~~ **Submit the information required in 75.336 (b)(3) to the District Manager and retain a copy of the submittal shall for as long as the seal is needed to serve the purpose for which it was built.**

Rationale: Once the seal design is approved by a professional engineer, there is no need for another professional engineer to get involved in the construction process. The original design should have a range of conditions under which the design would apply. The rest of the information requested in (b)(3) can be provided by mine personnel familiar with the construction site and mine specifics. To ask a professional engineer to certify that the construction was carried out in accordance with the plan is folly. For them to do that, they would have to be present the whole time the seals were under construction. That is unrealistic.

(3) Provide information for approval in the ventilation plan--

(i) The MSHA Technical Support Approval Number;

(ii) The mine map of the area to be sealed and proposed seal locations. This portion of the mine map shall be certified by a professional engineer;

(iii) Specific mine site information, including'

(A) Type of seal;

(B) Safety precautions taken prior to seal achieving full design strength;

(C) Methods to address site specific conditions that may affect the strength and applicability of the seal;
(D) The construction techniques;
(E) Site preparation;
(F) Sequence of seal installations;
(G) Projected date of completion of each set of seals;
(H) Supplemental roof support inby and outby each seal;
(I) Water flow estimation and dimensions of the water drainage system through the seals;
(J) Methods to ventilate the outby face of seals once completed;
(K) Methods and materials used to maintain each type of seal;
(L) Methods to address shafts and boreholes in the sealed area; and
(M) Additional information required by the District Manager.

4. Add Sec. 75.337 to read as follows:

Sec. 75.337 Construction and repair of seals.

(a) Prior to sealing, the mine operator shall--

(1) Remove **all known** insulated cables from the area to be sealed when constructing seals; and

(2) Remove metallic objects through or across seals, except water pipes, gas sampling pipes, and form ties approved in the seal design. **Metallic roof support materials, such as wire mesh need not be removed if the removal of the support material will expose miners to unnecessary hazards.**

(b) A certified person designated by the mine operator shall ~~directly supervise seal construction and repair and —~~

Rationale: A certified person conducts the required examinations and enters them in the proper record book. It is not necessary for this person to directly supervise the entire construction process. This requirement may unnecessarily delay important repairs or construction activities until a certified person can be notified. Trained, qualified persons should be permitted to repair or construct seals in accordance with the approved plan and the certified person can then conduct an examination to assure that the plan was followed.

(1) Examine each seal site immediately prior to construction or repair to ensure that the site is in accordance with the approved ventilation plan;
(2) Examine each seal under construction or repair during each shift to ensure that the seal is being constructed or repaired in accordance with the approved ventilation plan;
(3) Examine each seal upon completion of construction or repair to ensure that construction or repair is in accordance with the approved ventilation plan;
(4) Certify by initials, date, and time that the examinations were made; and
(5) Make a record of the examination at the completion of any shift during which an examination was conducted. The record shall include each deficiency and the corrective action taken. The record shall be countersigned by the mine foreman or equivalent mine official by the end of the mine foreman's or equivalent mine official's next regularly scheduled working shift. The record shall be kept at the mine for one year.

(c) ~~Upon completion of construction of each seal, a senior mine management official, such as a mine manager or superintendent, shall certify that the construction, installation, and materials used were in accordance with the approved ventilation plan. The mine operator shall retain the certification for as long as the seal is needed to serve the purpose for which it was built~~. **Upon completion of construction of each set of seals, a senior mine management official, such as a mine manager or superintendent, shall countersign the official seal record book**

Rationale: A senior mine official cannot certify that "the construction, installation and materials used were in accordance with the approved ventilation plan," unless he/she was present during the full period of time it took to complete the job. This is totally unrealistic and puts the senior manager in the position of certifying work they did not personally observe. The senior official should certify that the seal employed was designed by a professional engineer and that the certified foreman conducted the required examinations and entered them correctly in the book. In many cases, the quality control analyses are not available for several weeks after completion of the seal.

(d) The mine operator shall--

(1) Notify the local MSHA field office between two and fourteen days prior to commencement of seal construction;

(2) Notify the District Manager, in writing, within five days of completion of a set of seals; and

(3) Submit a copy of quality control results to the District Manager for seal material properties specified by Sec.75.336.

(e) Miners constructing or repairing seals, certified persons under paragraph (b) of this section, and senior mine management officials under paragraph (c) of this section shall be trained prior to constructing or repairing a seal. The training shall address materials and procedures in the approved seal design and ventilation plan. The mine operator must certify the date of training provided each miner, certified person, and senior mine management official and retain each certification for one year.

5. Add Sec. 75.338 to read as follows:

Sec. 75.338 Seals records.

(a) The table entitled “Seal Recordkeeping Requirements” lists the records the operator must maintain pursuant to Sec. Sec. 75.335, 75.336, and 75.337, and the duration for which particular records need to be retained.

Table to Sec.   75.338(a).--Seal Recordkeeping Requirements

Record	Section reference	Retention time
(1) Protocol to monitor methane and oxygen and maintain an inert atmosphere	75.335(b)............	Same ventilation plan requirements.
(2) Training of certified persons.	75.335(b)(2)..........	1 year.
(3) Gas sampling records......	75.335(b)(6)..........	1 year.
(4) Approved seal design......	75.336(b)(1)..........	As long as the seal is needed to serve the
(5) Certification of	75.336(b)(2)..........	As long as the seal is needed to serve the

(6) Record of examinations.... 75.337(b)(5)..........
1 year.
(7) Seal construction certification 75.337(c).............
As long as the seal is needed to serve the
(8) Certification of training. 75.337(e).............
1 year.

(b) Records required by Sec. Sec. 75.335, 75.336, and 75.337 shall be retained at a surface location at the mine in a secure book that is not susceptible to alteration. The records may be retained electronically in a computer system that is secure and not susceptible to alterations, if the mine operator can immediately access the record from the mine site.

(c) Upon request from an authorized representative of the Secretary of Labor, the Secretary of Health and Human Services, or from the authorized representative of miners, mine operators must promptly provide access to any record listed in the table in this section.

(d) Whenever an operator ceases to do business **or transfers control of the mine to another operator**, that operator must transfer all records required to be maintained by this part, or a copy thereof, to any successor operator who must maintain them for the required period.

6. Amend Sec. 75.371 by revising paragraph (ff) to read as follows:

Sec. 75.371 Mine ventilation plan; contents.

* * * * *

(ff) The sampling protocol as provided by Sec.75.335(b) and seal installation requirements provided by Sec. 75.336(b)(3). **The submitted copy of all records required to me maintained by the part, or copy thereof, will be maintained at all times by the District Office where the mine is located.**

* * * * *

Seal ETS Questions & Requests for Information

1. MSHA is interested in receiving comments regarding: (1) The economic and technological feasibility of monitoring and inerting sealed atmospheres; and (2) methods of inerting sealed atmospheres.

Response: As we understand the mechanics of sealed areas the most critical areas are in the transition zone at the seals due to constant atmospheric changes that occur with changing barometric pressures in this area due to in-gassing and out-gassing at different times of the day. To inert this area would serve as a significant safety factor to deplete any possibility of an ignition in this transition zone due to friction, lightning, or other means. We know of no published reports where explosions within sealed areas were generated from the rear areas of a gob and advanced to the areas where seals were installed.

2. MSHA requests comments from the mining community on the appropriateness of the strategy in this ETS for addressing seal strength greater than 120 psi.

Response: For pressures exceeding 120 psi (for example, due to anticipated pressure piling), still-larger seals are not the best answer. The handling of excessive pressures can be accomplished with existing technologies and innovative designs incorporating blast wave mitigation techniques such as using weak-wall structures or entry geometry modification located inby the seal. It is important to explore and develop concepts incorporating stacked or hanging rock dust bags and/or water-filled plastic tanks to provide blast-wave disruption and flame quenching in the region just inby the seal. These measures and techniques will serve to reduce the force and the extensiveness of an explosion before it encounters the mine seal. These are realistic approaches for mitigating these forces and can serve to address many of MSHA's concerns without the expense and uncertainty associated with addressing explosion pressures by seals alone.

For areas that would be down dip from the seal locations, introduction of water behind the seals to flood the area is the most effective way to not only rid the area of potential explosive gas accumulations but also to rid the area of oxygen as well. MSHA should reconsider not recognizing water as the most effective mine seal.

3. MSHA specifically solicits comments on the Agency's approach to the strength requirement for seals.

Response: Rather than increasing seal design requirements with arbitrary and/or clandestine safety factors embedded in the design and approval process, the full strength of the design should be made clear to engineers up front, without a safety factor expression. This will eliminate confusion to all involved. Furthermore, it is important for MSHA to consider the practicality and reasonableness of seal design, including recognition of the types of materials that are readily available in mines for the purposes of seal design and construction. To set standards that are out of touch with the reality of mining operations will only frustrate the ability of mine operators (particularly small operators) to comply with the ETS.

Deleted:

4. MSHA is also interested in receiving comments on the appropriateness of the three-tiered approach to seal strength in the ETS.

Response: The three-tiered approach to seal strength embraces, to some degree, a risk-based determination which we support. We believe however, that rather than establishing fixed strength thresholds the industry and miner safety would be better served by establishing a mechanism to permit case-by-case determinations of the seal strength requirements necessary to protect the environment where miners normally work or travel. Unfortunately, the proposed rule while a step in the right direction does not embrace this concept fully and will result, in some instances, of operators being unnecessarily required to install seals not reflective of the potential hazard of the environment.

5. MSHA seeks comments on the feasibility of including in the final rule a requirement that existing seals be removed and replaced with a higher strength seal.

Response: MSHA appropriately recognizes that replacing existing seals is impractical and may create severe safety hazards. Seals do not need to be universally remediated. Instead, an assessment of risk should be undertaken to determine whether the existing seals should be remediated to insure effective operation. Any such risk assessment should be based on location of the seals, their proximity to active work areas, the nature of the atmosphere concentrations inby the seals, and the overall condition of the seals, potential sources of ignition (frictional, lightning, etc.).

To the extent that an existing seal must be remediated, how do we deal with the 10-foot requirement for anchorage and hitching? A degree of flexibility and discretion is required when making these adjustments to remediate existing seals. In many cases, there is not adequate space to step out a row of pillars to re-seal an area.

6. Commenters are encouraged to submit information and supporting data regarding new technologies to reinforce seal strength.

Response: A seal that has no ch4, low oxygen and not up to 50 psi or greater overpressure has no significant impact on the health and safety of anyone. To remediate this type of seal by reinforcement is a waste of valuable resources that can better be spent on other safety and health priorities.

7. The agency is particularly interested in comments concerning sampling, and the sampling frequency, including sampling only when a seal is outgassing. The agency requests comments on whether another sampling approach is more appropriate for a final rule, such as when the seal is ingassing.

Response: Sampling frequency should be based upon history established at seal sets. When an area is stable and inert a weekly sampling regiment is unnecessary. When a sealed area is in transition a more frequent sampling regiment may be needed. MSHA's states that sampling approach in the "ETS will yield results that reflect a reasonable representation of the atmosphere in a sealed area," is inaccurate. The approach MSHA is using assumes that a sample at a 15' pipe can be used to determine the content of an extensive sealed area's atmospheric content. If there are additional boreholes available, they should be used to help evaluate the totality of the sealed area.

Sampling error is a major concern even when sampling for an out-gassing seal. To contemplate sampling an in-gassing seal or a seal that is in barometric pressure transition is a recipe for inaccurate sampling. MSHA should not consider requiring in-gassing seals to be sampled.

There are many reasons why a sealed area may continually in-gas. The preamble implies that a borehole or inerting or pressure balancing may be required. This is not needed in most cases where in-gassing is occurring. The preamble does not discuss the more obvious reasons for in-gassing, such as ridge top mining with a blowing system etc.

8. MSHA requests comments on the "action plan" and whether it provides adequate protections for miners.

Response: Once the affected area is determined by the operator, effective protection can be provided up to and including withdrawal of miners. There needs to be an immediate mediation process of when the affected areas determined by the operator differ from the enforcement agencies with a mandatory meeting or hearing before and ALJ in the event the disagreement is not resolvable on the local level.

9. The agency requests comments concerning the establishment of a baseline, including sampling, only when a seal is outgassing and whether it is appropriate to sample the atmosphere in sealed areas during ingassing.

Response: If appropriate provisions, such as extended sampling pipes, have been provided then a representative sample at the areas just inby seals can be obtained. Sampling in all of these cases is only a representative sample of the area of the transition zone around the seals from ingassing/outgassing changes.

10. MSHA is requesting comments on the appropriateness of the ETS requirement regarding open flames associated with welding, cutting and soldering activities within 150 feet of a seal and the feasibility of this requirement.

Response: Prohibiting cutting and welding within 150 feet of a seal may not be enforceable or cause great interruption in some mines where the next entry or two entries over from the seal contains a pre-existing belt, belt drive, shop area, travel-way or track. There is no “grandfather clause” for these situations. If additional, new seals (as anticipated by the standard and being required in the new ETS plans) are to be built and there is not adequate space in front of existing seals, the new seals may be placed within the 150 feet of the existing areas listed above.

The standard where the 150-foot distance comes from (permissible zone near gob lines) is of a completely different nature from the seal situation. In the 150-foot gob scenario, the hazard is that there are generally no permanent ventilation structures between the gob and the permissible zone so that any of a number of incidents (gob reversal, low gob pressure, large roof fall pushing out gob air) could result in gob air carrying methane into the work area. In many areas around seals, there are definite air flow patterns separated by permanent ventilation devices that are designed to carry away any out-gassing from the seals.

11. MSHA requests comments regarding the appropriate number and location of sampling pipes for a final rule.

Response: With respect to monitoring, we question the value of a second sampling pipe in every seal as described in section 75.335(d). The agency states that it has included this new provision in the ETS “so that the operator can obtain a more representative sample of the sealed area.” What is the basis for this assertion? Is there any guarantee that a second (3rd, 4th, etc.) sampling pipe will provide the assessment of the atmosphere that MSHA intends? What is the basis for MSHA’s belief that a second pipe will provide a representative sample of the entire sealed area? A sampling tube going to the first crosscut makes the most sense. In addition, a tube in the highest (seal at the roof) and lowest (near the top of the projected high water mark) elevations makes more sense because it will help determine that there IS stratification of the methane and there is not a homogeneous mixture of methane behind the seals.

12. MSHA request comments on the ETS requirement for water drainage systems for seals.

Response: The “drainage system” requirement to prevent impounding and accumulations of water at the seals is vague. Under the definitions and descriptions, it may be impossible to guarantee that there will be no water at a seal. Since an “accumulation” to MSHA inspectors may be as little as an inch in depth in a puddle near a seal, there is impossible to guarantee no such puddle will exist. Already we have heard that the “P” traps must be countersunk into the bottom to reduce the number of inches of water that is impounded by a seal. Digging holes in the bottom at the lowest point invites water pooling in some mines. In addition, mines with water in the hundreds or thousands of gallons per minute flowing through seal structures cannot prevent such accumulations or seals impounding some minimal amount of standing water. All structures require some energy, in the form of “head” or accumulated water, to function.

Again, water in a sealed area is an ally when down dip from the seals. It increases the safety factor of this area as opposed to decreasing it. Even if one has to design a bulkhead suitable to impound water it displaces the ability of explosive gas to accumulate and become a problem.

AN EVALUATION AND CRITIQUE OF THE NIOSH REPORT: "EXPLOSION PRESSURE DESIGN CRITERIA FOR NEW SEALS IN U. S. COAL MINES"

Prepared for the National Mining Association

by Dr. Martin Hertzberg, Consultant

July, 2007

On June 22, 2007, Mr. Bruce Watzman, Vice President for Safety, Health, and Human Services for the National Mining Association (NMA) contacted this consultant and forwarded a copy of the 91 page NIOSH report by Zipf, Sapko, and Brune entitled "Explosion Pressure Design Criteria for New Seals in U. S. Coal Mines" The report was written in order to provide an engineering-science basis for new regulation requirements for seals that isolate gobs, abandoned, or mined our areas of underground coal mines. Mr. Watzman also forwarded the 145 pages of "Reviews and Responses" to that report by some thirty reviewers. A week later this consultant was retained by the NMA to perform an independent evaluation and critique of the aforementioned report and the accompanying reviews and responses.

This evaluation and critique will discuss the following issues considered in the NIOSH report and in the reviews and responses solicited by the authors of the report:

I. The extent to which the composition within a sealed area is expected to be uniformly mixed or not, and specifically whether methane layering can occur within such sealed areas.

II. The issue of whether a methane air detonation is possible within such a sealed area and whether the probability of the occurrence of such a detonation is sufficient to justify the design of seals to withstand such a detonation.

I. METHANE LAYERING IN SEALED AREAS.

Several reviewers (Beerbower, Lusk, and Watzman) have indicated that since the density of methane is about half that of air, methane would tend to accumulate in roof layers and that accordingly, the NIOSH assumption of a constant, stoichiometric composition being present in a sealed area is an inappropriate basis for the design criteria for seals. The NIOSH authors standard response to the issue of methane layering is as follows (pp 19-20 of their report):

" A common misconception exists that methane layering will develop within the still air of a sealed area......in the completely still air within a sealed area, diffusion processes will dominate over buoyancy effects, which will lead to development of a homogeneous methane-air mix within a few days or less." They quote the diffusion coefficient for methane in air as being D = 0.157 square cms / sec. They describe the Loschmidt apparatus with pure methane in the upper half of a tube 50 cm long and pure air in the lower half. When the separating boundary is remove (very carefully!) it takes 55 minutes for the mixture to achieve a uniform composition. That is consistent with theory, which gives the characteristic diffusion time as:

t = l (squared) / D.

For the Loschmidt experiment described above, the diffusion distance l is 25 cm, which gives t = 3,890 sec = 66 minutes, which is the correct order of magnitude for pure diffusion mixing.

For a typical mine roof height, l = 2.1 meters and the characteristic mixing time would be 3 ¼ days, which is somewhat larger than the NIOSH estimate of 21 hours.

However, it is well established that pure diffusion mixing is almost never achieved in the real world. That is because even the most trivial temperature gradients in a region cause convective currents that result in much more rapid mixing than pure diffusion mixing. Thus even NIOSH's estimate of mixing times are unrealistically long. Does that not only further support the NIOSH position on p. 20 of their report, that "In summary, contrary to common misconceptions about methane layering, the completely still air within a sealed area will develop a fairly uniform mixture of methane and air within a matter of days after sealing. Diffusion processes dominate buoyancy effects, and the mixing process is only enhanced by any convective mass transfer."?

Regrettably, the misconception is NIOSH's, for the methane layering problem is not a *static* one in which a fixed quantity of less dense methane is introduced above a fixed quantity of still air in a sealed system. Instead, the problem is a *dynamic* one. Consider the case they considered of diffusion of a roof layer in a 2.1 meter high mine entry. Taking their relatively rapid diffusion mixing time of 21 hours, their misconception of the problem is most clearly revealed by asking the simple question: how much additional methane is added to their sealed area during that 21 hours? Consider, for example a sealed area of moderate size in a moderately gassy mine. Let the sealed area volume be 6 million cubic feet, and let the methane emission rate be 1.5 million cubic feet per day. During the 21 hours that the diffusional mixing was taking place, an additional 1.3 million cubic feet of fresh methane from the roof and ribs would have entered the sealed volume and initially concentrated below the roof. That additional methane would occupy some 22 % of the sealed area volume, and require much more additional time for it to mix with the air, even as more and more methane is added to the system. <u>It is clearly a misconception to view the problem from a *static* perspective, when in the real world the problem is a *dynamic* one.</u>

It has long been known that the tendency for a methane layer to form is quantifiable in terms of the dimensionless Layering Number, L, which is given by:

L − U / 37 x cube root of (Q / w), where

U is the air velocity (ft/min) under the layer, Q is the methane flow (cfm), and w is the width of the entry (ft). [Bakke and Leach, "Principles of Formation and Dispersion of Methane Roof Layers and Some Remedial Measures" Institution of Mining Engineers, U. K. Vol 121, No. 22 pp. 645-658 (1962)].

In a level entry methane layers are dissipated by the flow velocity of the ventilating air if the Layering Number is greater than 5. Below a layering number of 5 methane layers will increase in length as the Layering Number decreases. If the entry is not level, there is a greater tendency for layering to occur in the elevated portions of the entry.

Note that the Layering Number is an expression of the *dynamic* balance between the magnitude of the air velocity, U, which tends to cause turbulent mixing, and the emission rate of the lighter gas, Q, whose accumulation in a lower density roof layer insulates it from the mixing. The Layering Number is a modified form of the Richardson Number which expresses the magnitude of the atmospheric wind velocity that is needed to disrupt an atmospheric inversion layer that contains warm, less dense air above, and colder, more dense air below.

Clearly, the determination of the air velocity in a sealed area that is leaking slowly through strata or seals is difficult to determine quantitatively; however it is quite clear that contrary to the NIOSH's misperception, a static condition in which the velocity, U, is low results in a *greater* tendency for layering.

<u>But why speculate?</u> The NIOSH report on p.15 and in Fig. 5 describes the tube bundle systems for continuous monitoring of gas compositions in the sealed areas of Australian coal mines. They state:

"Typical tube bundle systems will monitor from 20 to 40 points or more, with about half located in the active mining areas and half in sealed areas". <u>So what does the Australian data show?</u> Do the data show uniform methane concentrations everywhere within the sealed areas, or do they show considerable higher methane concentrations in roof areas or in the highest points of a dipping seam?

It should be noted that Mr. Brian Lyne (on p. 78 of the Comments and Responses) asks the question: "How about a mine where traces of methane are only found (up to 3 % layers)?"

Regrettably, the NIOSH authors seem more interested in answering questions theoretically than in observing what actually happens in the real world. They were so convinced of the correctness of their position on methane layers that they didn't bother to request clarification of Mr. Lyne's reference to " 3% layers".

II. THE POSSIBILITY OF METHANE-AIR DETONATIONS IN SEALED AREAS.

An equally egregious example of the NIOSH authors preference for abstract theory over real world observations is displayed in their treatment of the possibility of detonations occurring in sealed areas. Over the years, researchers have performed thousands of explosion tests in methane - air mixtures in test apparatus ranging in size from tenths of a meter to full scale mine dimensions of several meters. In all of those tests, there is virtually no documented evidence of a fully developed detonation having been observed in methane - air mixtures. It is no coincidence therefore that researchers whose main interest is the study of gaseous detonations will not use methane for their studies but will use other, detonable fuels such as hydrogen or acetylene.

The NIOSH analysis on pp 20 - 29 of their report deals with the mechanism by which subsonic deflagrations transit into supersonic detonations. The analysis is seriously flawed. For example, the profiles depicted in Fig. 9 that purport to delineate the pressure development during the deflagration to detonation transition are incorrect in the deflagration stage. While the feedback loop depicted in Fig. 10 correctly depicts the mechanism by which turbulence causes a deflagration to transit into a detonation, its application to flame propagation in a constant volume, sealed system is flawed.

Here is how the typical transition from deflagration to detonation is described by Hertzberg and Cashdollar in "Introduction to Dust Exposions", pp. 5 - 32 in *Industrial Dust Explosions* , ASTM STP 958 (1987):

" The effect of turbulence is pronounced and devastating when the flammable volume is *partially* confined in a tube or corridor, with one end *open* and ignition at the other closed end (Fig 4a) (italics added). The flame front is depicted at some time, t, propagating toward the open end as the burned gases behind the flame front expand and push the still unburned mixture outward toward the open end. For typical flame speeds and tube diameters beyond a few centimeters, the Reynolds number of the unburned mixture flow in the tube or corridor rapidly exceeds the critical value for the generation of turbulence. A turbulent flow appears ahead of the wave, and as the flame propagates into that turbulent flow, it accelerates. This increases the flow velocity ahead of the wave, which increases the turbulence level, which further accelerates the flame front, and so forth. The process is self-accelerating and if the tube is long enough and wide enough, it eventually leads to a supersonic detonation."

It is essential to note that this mechanism for acceleration to turbulent flow occurs only for ignition at the closed end of a tube. It is only under that boundary condition that the unburned mixture is free to flow unrestrained through the open end of the tube. By contrast, if ignition occurs at the open end of a tube, propagation remains laminar and stable without acceleration as the flame propagates in a steady state toward the closed end of the tube. Under that boundary constraint, the unburned gas remains essentially stationary as the flame flows into it, and there is no turbulent acceleration.

What then should one expect to happen in the first case if instead of propagating from the closed end to an open end, the flame ignited at the closed end is constrained to propagate toward another closed end? That boundary constraint requires that the unburned gas velocity at that closed end remain at zero throughout the course of the flame propagation within the tube. Under that boundary constraint the opportunity for the development of turbulence is so severely limited that the likelihood of a transition from deflagration to detonation is negligible.

The data in that regard was clearly cited in the comment by Watzman on p. 136 of the Comments and Responses:

"Experiments that examined methane in air were carried out by Bartknecht in 1971 and reported in the Gas Explosions Handbook [Bjerketveldt, 1992]. The tests were done at 1 atmosphere pressure in a 1.4 meter diameter 40 meter long pipe with test conditions of one end closed and both ends closed. Two ignition point scenarios were used, one (with ignition) at the closed end and one (with ignition) at the open end of the pipe. Tests were done with the pipe open at one end and closed at both ends, a case similar to the scenarios depicted in Figure 8 (actually Figure 9)of the NIOSH Report. The experiment found that the highest flame speed was achieved when the ignition was at the closed end of the pipe and the other end was open. When the pipe was closed at both ends, the flame accelerated at first, but after 15-20 meters started to decelerate….".

That is precisely what one should expect as the flame propagates toward a boundary which is constrained to v = 0 at that boundary. Instead of simply acknowledging what the data by Bartknecht and many others who proceeded him show; namely, that acceleration by turbulence is severely limited in propagation towards a closed end, the NIOSH authors really go off the deep end in their response to Watzman's comment. Their response is:

"Bartknecht shows a deflagration in a smooth wall pipe without DDT (deflagration to detonation transition). In a deflagration, the flame speed slows as it approaches the closed end where the gases are precompressed. Unfortunately, Bartknecht did not include the corresponding sharp increase in the closed end as the mixture burns the pre-compressed unburned gases. For example, at 1 atmosphere pressure, the pressure due to combustion is about 9 atm. Subsequently, if the gases at the end of the tube are precompressed to about 2 atmospheres before the flame reaches and ignites, then local, short lived side-on overpressure would approach about 18 atmospheres. (2 x 9atm = 18 atm)."

So again, according to the NIOSH authors, theory triumphs over data! We are left wondering how it is possible that such a distinguished researcher as Wolfgang Bartknecht could have missed detecting a pressure of 18 atm (265 psi) in his experiments? Surely it must be so if the NIOSH author's theory says so. So even though a detonation was never observed by Bartknecht, we are told that he should have seen detonation-like pressures as a result of "pre-compression" One wonders why the NIOSH authors limited the pre-compression to only 2 atm? If, at the time that about 90% of the flammable mixture had been burned, the end of the tube would have been precompressed to about 8 atm, then according to their logic, "local, short lived side-on overpressures would approach" 8 x 9atm. = 72 atm (1,058 psi). How could Bartknecht have possibly missed seeing his apparatus blown to smithereens?

The NIOSH calculation which estimates the effect of pre-compression is fallacious. They use the constant-volume explosion pressure of 9 atm., which is valid only for the *complete* combustion of the entire system volume, to improperly characterize the combustion of only a portion of the system volume.

A similar mistake is seen in Fig. 9 of the NIOSH paper. As indicated earlier, the two pressure profiles for the slow deflagration wave and the fast deflagration wave are in error. For the slow deflagration wave, the figure shows a pressure of about 135 psi at the ignition end of the tube, but the burned gas volume depicted is about 1/12th of the total tube volume. Hence the unburned volume from which the burned gas volume was generated is only about 1 % of the total unburned gas volume. For slow, subsonic combustion, the pressure throughout the tube should therefore be fairly uniform at (0.01) (135 psi) = 1.4 psi. The profiles shown in Fig. 9 for that case starts at 135 psi and drops to about 70 psi between the wave front and the "pressure wave front". They are clearly too high by orders of magnitude.

Similarly, the fast deflagration profile grossly overestimates the pressure behind the combustion wave and the pressure wave front. There, the burned gas volume is about 1/3rd of the total tube volume, and hence it represents about 1/20th of the total unburned gas volume. The average pressure in the system should therefore be about (0.05) (135 psi) = 7 psi. For the fast deflagration case, the pressure may no longer be so uniform throughout the tube but the 135 - 210 psi depicted behind the wave front and the 70 psi just behind the pressure wave front are clearly much too high.

It speaks volumes about the NIOSH author's preconceptions that the profiles shown in Fig. 9 are closer representations of what would be expected for the direct initiation of a detonation than they are for the profiles to be expected for the deflagration to detonation transition. The authors are clearly "hooked" on detonations despite the fact that there is virtually no evidence that a methane-air detonation has ever occurred in an operating mine.

Not only is there virtually no evidence of such a detonation in an operating mine, but the existence of methane layers and concentration gradients in the methane accumulations in sealed areas should have a profound effect on flame propagation within that sealed area. D. C. Bull in "Fuel-Air Explosions", University of Waterloo Press, Study No. 16,(1982), pp 139 – 155, reports on detonation experiments through concentration gradients and concludes "Propagation of detonation(s) through a cloud of fuel/air in varying concentrations is extremely difficult". That conclusion applies to easily detonable fuels such as hydrogen or acetylene. For a methane air mixture with the varying concentrations present in a sealed area, detonation propagation should be virtually impossible.

III. CONCLUSION.

MSHA is in process of developing criteria for the strength of seals that isolate gobs, abandoned, or mined-out areas of underground coal mines within which methane can accumulate, from the operating areas of a mine that are well ventilated and contain normal, breathable, non-explosive air. The issue involves the design of such seals so that they will withstand the pressure forces from any accidental explosions behind those seals. The NIOSH report, "Explosion Pressure Design Criteria for New Seals in U. S. Coal Mines", was written in order to provide an engineering-science basis for those regulations.

This critique and evaluation of that NIOSH report has shown that it is seriously flawed in two important respects: first, in its contention that methane-air mixtures in those sealed areas will be uniformly mixed, and secondly, in its contention that the required seals should be able to withstand pressure forces from methane-air detonations (256 to 653 psia). It is shown that the mixtures in those sealed areas will not be uniformly mixed and that detonation propagation in those sealed areas is virtually impossible. Accordingly, it is concluded that an adequate margin of safety is provided by seals that are designed to withstand normal, and much lower explosion pressures.

Dr. Martin Hertzberg
Teacher and Consultant, Science and Technology

Combustion Research, Basic and Applied Gas and Dust Explosion Prevention Fire Research Industrial Safety Detection Systems Instrumentation Environmental Sciences Education in Science

P. O. Box 3012 Copper Mountain, CO 80443
Phone: 970-968-2091 email: ruthhertzberg@msn.com
Cell phone: 970-333-7878 web site: www.explosionexpert.com

EDUCATION Ph. D. Chemistry, 1959, Stanford University, Stanford, California
BA, cum laude, 1949, New York University, Heights Campus, Bronx, New York
Certificate in Meteorology, 1954, U S Naval Postgraduate School, Monterey, California

HONORS Fulbright Professor of Science, American University in Bulgaria, 1992
Meritorious Service Award, U S Department of the Interior, 1991. Foreign Visiting Scholar, National Center for Scientific Research (CNRS), Orleans, France, 1988
Phi Beta Kappa, 1949 Phi Lambda Upsilon, 1957

EXPERIENCE

1993-2007 . University of Northern Colorado, Aims Community College, Colorado Mountain College, Vail Valley, and Squaw Valley Academies: Instructor of chemistry, physics, math., french, and german. Penn State-Mont Alto, and Lock Haven University: taught mechanics, and laboratory courses in physics and chemistry. Independent consultant on fire and explosion accident prevention and investigation.

1992 Fulbright Professor of Science, American University in Bulgaria. Taught courses in environmental science, physics, and began a cooperative research program.

1970 – 1992 Supervisory Research Chemist, GS - 14, U S Bureau of Mines, Pittsburgh Research Center, Fire and Explosion Prevention. Group Supervisor for explosion testing and evaluation of mineral and industrial dusts and gases. Research results were of basic interest and were widely published. They were also used in evaluating hazards involved in mining and other industries. Served as consultant to the Electric Power Research Institute, the Department of Energy, and the National Academy of Sciences on nuclear reactor safety issues. Consultant for the Mine Safety and Health Administration on fire and explosion prevention. Supervised complementary research on thermal pyrolysis mechanisms related to coal combustion technology.
Internationally recognized expert on combustion, flames, explosions, and fire research with papers in the 15th, 16th, 18th,19th,20th,21st,22nd,23rd,24th, and 25th Symposia (International) on Combustion.Co-editor of ***Industrial Dust Explosion***, ASTM STP 958, 1987. Patents on ionization smoke detection and infrared temperature sensing. Senior

member, interagency panel for evaluation of the Bureau's research program on disaster prevention in mines.

1964 - 1970 Principal Research Scientist, Atlantic Research Corporation, Alexandria, VA. Research on solid propellant combustion, mass spectrometric studies of exothermic compounds, infrared flare radiometry, ignition, flammability, and chemiluminescence.

1961 - 1964 Physical Chemist, Republic Aviation Corporation, Farmingdale, N. Y. High power and chemical lasers, spectroscopy, optics, and space technology.

1956-1961Senior Research Scientist, Lockheed Research Laboratory, Palo Alto, CA. Honors cooperative student at Stanford, mass spectrometry for satellites, chemical kinetics of ion-molecule reactions, atmospheric composition, ionization processes.

RESEARCH INTERESTS AND CAPABILITIES

Combustion Science and Technology: Flame propagation in heterogeneous systems such as pulverized coal, metal dusts, gas/dust mixtures, propellants, and explosives; fire and flame structure; flammability limits; extinguishing fires and explosions; thermal pyrolysis of solids; ignition; spontaneous combustion; optical pyrometry; and fire detection systems.

Development and Engineering: Fire and explosion prevention in mines, power plants, cement plants, and other industries - mineral, chemical, petroleum, agriculture, fuels, and transportation; hazard analysis for prevention, detection and extinguishment; instrument design and development; ionization smoke detection; mass spectrometry; optics, lasers, and infrared systems design; control of combustion generated pollutants; environmental sciences; meteorology; energy resources, and global climate issues.

Publications: Senior author of over 100 publications and many patents: a detailed list is available, as are reprints for study and evaluation.

Foreign Travel: Extensive travel experience in France, England, China, Israel, Poland, Bulgaria, Russia, Scandinavia, and Germany; conversant in French and understand German.

Review of NIOSH Analysis

Packer Engineering File Number 500879

Submitted by:

Submitted to:

Mr. Bruce Watzman
National Mining Association
101 Constitution Avenue, NW
Suite 500 East
Washington, DC 20001

March 13, 2007

P.O. Box 353 (60566-0353)
1950 N. Washington St. (60563-1366)
Naperville, IL
630.505.5722 Fax: 630.505.1986
www.packereng.com

6700 Alexander Bell Drive
Suite 100
Columbia, MD 21046
443.545.2000 Fax: 443.545.2001
www.packerend.com

1050 Highland Drive,
Suite B
Ann Arbor, MI 48108-2262
734.786.5000 Fax: 734.786.5001
www.packereng.com

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General Review of Combustion Issues for NIOSH Draft Report: Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines

Prepared by:

Christopher F. Schemel
Vice President, Packer Engineering, Inc., Columbia, Maryland, USA

Vincent Van Brunt, Ph.D., P.E.
Professor of Chemical Engineering
University of South Carolina, Columbia, South Carolina, USA

Noah L. Ryder, P.E.
Senior Staff Engineer
Packer Engineering, Inc., Columbia, Maryland, USA

Additional NIOSH Report Review Comments:

Jose L. Torero, Ph.D., C. Eng.
University of Edinburgh, BRE Center for Fire Safety Engineering,
Edinburgh, Scotland, UK

REVIEW SUMMARY

The NIOSH Report relies upon four basic assumptions in its attempts to justify its proposed design criteria. These assumptions are highly idealized and are based on theoretical calculations and experimental conditions that do not accurately reflect the actual conditions in coal mines. These assumptions are:

1. Combustion of stoichiometric (~10%) methane-air in a closed volume raises the pressure from 101 kPa to 908 kPa (14.7 psi to 132 psi).
2. Combustion of fuel-rich coal dust and air mix in a closed volume raises the absolute pressure from 101 kPa to about 790 to 890 kPa (115 to 129 psi) which is only slightly less than combustion of methane-air mix.
3. If a detonation occurs in an ideal methane-[dry] air mix at 1 standard atmosphere, the detonation pressure developed is 1.76 MPa or 256 psi (CJ detonation pressure).
4. A methane-air detonation wave reflects from a solid surface at a pressure of 4.50 MPa (653 psi).

The pressures stated in the above assumptions are total pressures, atmospheric pressure + pressure rise form an explosion.

The methane concentration throughout a mine varies temporally and spatially thus, assuming a constant stoichiometric homogeneous mixture as the basis for a design criteria is inappropriate. The assumptions used by NIOSH and the corresponding recommendation derived from those assumptions failed to include highly relevant information that can greatly impact the calculations of constant volume overpressures. The issues include:

- Flammable cloud size potential;
- Methane-air mixing based on known methane-air behavior;
- Realistic vapor cloud concentration gradients within sealed volumes based on mixing characteristics;
- Accounting for the effects of moisture in the air on combustion;
- Effects of geometry on mixing, potential flammable volumes, and combustion characteristics; and
- Effect of existing explosion mitigation mechanisms in place in coal mines.

The NIOSH Report also presents design criteria for high overpressures from methane-air detonations. This assumption of a methane-air detonation does not take into account a large body of research that questions the ability of a methane-air mixture to detonate. In addition, the conditions required for any potentially detonatable gas mixtures to transition from a low speed deflagration to a detonation are not addressed in appropriate detail in the NIOSH analysis. The requirement set in the NIOSH Report for seal designs to protect from a detonation in a sealed area of a coal mine is not justified given the superficial level of analysis the NIOSH Report provides and the referenced literature in this review.

Finally the NIOSH Report does not adequately outline the input parameters used in the Computational Fluid Dynamics (CFD) models and incorrectly assumes that the calibration of the model that was necessary to achieve agreement with the experiments is generally applicable to larger scale scenarios with alternative geometries, concentration profiles, and blockage ratios.

INTRODUCTION

The NIOSH Draft Report: *Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines* (NIOSH Report) describes an analysis of combustion processes and an approach for seal design that applies to abandoned areas of coal mines. This report provides a review of several issues addressed in the NIOSH Report from a combustion and process safety perspective.

The seals addressed in the NIOSH Report are used as part of an engineered system intended to: lower the probability of an explosion in an abandoned area of a mine; prevent an explosion in an abandoned area of a mine from impacting a working area; and prevent propagation of an explosion form an active area into a sealed area. The current regulatory design criterion for alternative seals requires a seal to be able to withstand a 20 psi overpressure during an explosion by remaining intact and not allowing the atmosphere from one side of the seal to pass to the other. This requirement was increased to 50 psi by the Mine Safety and Health Administration in 2006.

The NIOSH Report addresses explosion seal overpressure design criteria by developing a set of three prescriptive criteria for seals to withstand overpressures and impact loading. The report examines the types of explosion scenarios that the NISOSH Report authors feel present a threat to mine seals.

The focus of this review is to examine the four assumptions developed in the NIOSH Report. These facts presented in Section 3 of the NIOSH Report are the driving ideas behind the new seal design criteria from a combustion and safety perspective.

One of the threats presented in the NIOSH Report is a detonation of methane in an abandoned area of a mine. In the NIOSH Report, the assumption is made that a methane-air detonation in a coal mine could occur. Little or no experimental data exists to support the concept that a methane-air detonation could occur in an underground coal mine environment. Historical experience in coal mines does not lend support that an underground coal mine environment can develop a detonation. Studies suggest that a methane-air detonation is not achievable at standard pressures in the absence of other combustible gases. Studies on methane-air explosion systems are presented in this review to provide some perspective on the idea of a methane-air detonation in a coal mine and provide a perspective on the risk of detonation and deflagration in a sealed area.

Baker Engineering and Risk Consulting, Inc. provided a review of the NIOSH Report for Packer Engineering, Inc. Sections of this report that reference Baker Risk's comments are noted as Baker Risk, 2007. The Baker Report is provided as an attachment to this report.

REVIEW OF KNOWN MINE SEALED AREA EXPLOSIONS

The NIOSH Report reviews known explosions in sealed areas of U.S. coal mines from 1993-2006. This provides a perspective on the type of consequences that have been experienced in explosions. The review also discusses ignition sources and a stated cause for each incident. A summary of this information is provided in Table 2 of the NIOSH Report.

The incident review section of the NIOSH Report describes a number of events in some detail, but there is no attempt to provide a correlation between the seal characteristics and the magnitude of each explosion. Seals are described within the Report as a constructive element that reduces the potential for explosion, thus a key issue in the prior incident review is if the seals failed or if they did not. Seal failure leads to an estimation of the specific overpressure and no attempt is made to relate the seal failure to any other cause.

There is no analysis in the NIOSH Report of the past explosion incidents and how seal type, their location in the mine and geometry of the area affected the development of the explosion. Faulty construction leading to seal failure in explosions has also been sited by the Mine Safety and Health Administration. From a damage prevention and safety analysis perspective, an analysis of data provided by the past incidents is essential because it is necessary to consider all variables of this problem in order to develop an analysis that correctly addresses it in the most effective manner. The Report fails to do this.

SEAL DESIGN PRACTICES IN THE U.S., EUROPE AND AUSTRALA

The conclusion of Section 2.1 of the NIOSH Report is that the 20 psi (140 kPa) requirement does not originate in the need to make a seal explosion proof, but more to avoid leakage. This is based on the work of Mitchell that is referenced in the NIOSH Report; nevertheless this conclusion is not consistent with the rest of the text. The text indicates that Mitchell (Line 361) established that an explosion seldom exceeds 20 psi (140 kPa). There is no clear description of what issues lead to such pressure increases and what measures need to be taken to guarantee that an explosion will not exceed 20 psi (140 kPa).

The NIOSH Report provides a review of the standards established by established by a few countries when sealing abandoned areas of mines. The standards in the United Kingdom, Germany, Poland and Australia are summarized in Table 3 of the NIOSH Report. The United Kingdom, Germany and Poland all require a 72 psi rated seal. These three countries are reported as never having recorded a seal destroyed in an explosion. All four countries have at least some requirements on inerting and monitoring of the sealed areas under some circumstances.

COMBUSTION AND EXPLOSION ASSUMPTIONS DEVELOPED IN THE NIOSH REPORT

The NIOSH Report addresses the fundamentals of explosions and detonations. NIOSH uses a series of experimental results to establish what potential overpressures can be attained. The focus is on the idealized version of the calculations and experiments and not on the parameters that influence the predicted overpressure. The NIOSH Report references both constant volume combustion tests and pipe/tube combustion tests, but no emphasis or analysis is made on what the necessary conditions are to attain the reported overpressures in these referenced tests. There is no link illustrating how the test conditions compare to real mine conditions and the resulting possible explosion scenarios are not developed at any point in the NIOSH Report.

The NIOSH Report states that there are two possible explosion scenarios. The first explosion scenario is an explosion involving a large volume of flammable gas mixture covering a long stretch of the mine entry. This scenario is intended to address the possibility of an ignition creating a flame front capable of ramping up to a strong turbulent deflagration or, given enough flame travel distance (e.g., 50 meters or more), undergoing a deflagration-to-detonation transition (DDT). [Baker Risk, 2007]

The second explosion scenario consists of a flammable mixture being formed directly behind or in front of the mine seal as a result of leakage through the seal. In this scenario, it is unclear how much flammable volume would be created due to seal leakage. [Baker Risk, 2007]

The NIOSH Report in Figure 3 presents three different potential explosive volumes to be considered when designing seals. This description of methane volumes assumes that the filling volume is uniform and creates a homogenous methane-air mixture. Methane is lighter than air and has mixing characteristics that would lead to concentration gradients within the mixture. Concentration gradients would create different combustion characteristics of the methane-air mixture and affect the magnitude of pressures created in the confined space. Thus, it is inappropriate to assume that the response mechanisms envisioned by the Report’s authors, even if one were to accept them, could be applied universally throughout the underground coal mining industry given the range of potential applications

Review of NIOSH Report assumptions:

Assumption 1: ***Combustion of stoichiometric (~10%) methane-air in a closed volume raises the pressure from 101 kPa to 908 kPa (14.7 psi to 132 psi).***

Assumption 2: ***Combustion of fuel-rich coal dust and air mix in a closed volume raises the absolute pressure from 101 kPa to about 790 to 890 kPa (115 to 129 psi) which is only slightly less than combustion of methane-air mix.***

The chemical equation presented by NIOSH for methane combustion is a simplistic approximation; methane combustion is a very complex phenomenon which has many intermediate steps [Glassman, 1987]. An example of issues from an over simplified approximation is the statement in the Report "the [chemical] energy content of 1 m^3 of ideal methane-air mix is about the same as 0.75 kg of TNT." This statement is offered by NIOSH to design engineers as guidance when evaluating hazards. However, in application vapor clouds convert a small amount of the chemical energy to kinetic energy during an explosion. Therefore, factors like confinement and obstructions are far more important influences on explosion magnitude more than fuel values in the cloud [CCPS, 1994]. This is one example of why understanding the entire system when evaluating explosion hazards is important.

A stoichiometric mixture of methane-dry air combusted under ideal experimental conditions can result in a pressure increase of ~120 psi. The NIOSH analysis does not address the assumptions that are involved in this calculation as they apply to a sealed area of a coal mine. The NIOSH Report asserts that a worst case is considered; however, real effects in coal mine atmospheres should be considered. Both carbon dioxide and water vapor, usually at saturation, will considerably narrow the flammability and detonability limits [Zabetakis, 1965] and additionally, may significantly reduce the probability for mixtures to transition from deflagrations to detonations. In addition, experiments with atmospheres containing both water and carbon dioxide need to be conducted. The addition of these species on deflagration and detonation characteristics needs to be verified before a tight three tiered prescriptive regulation can be considered.

The NIOSH Report does not consider the effect of water vapor on the combustion of the methane-air system or on a dust cloud. Underground mines usually have high humidity levels and this parameter will affect the energy created during combustion of a vapor cloud in a mine. Idealized treatment of explosion chemistry and physics can lead to some conclusions that cannot be realized in real methane-moist air systems. This fact may lead to misrepresentations of some phenomenon and an over estimation of the risks that are present in coal mines.

The NIOSH Report assumes that the methane filling process is homogenous throughout the entire sealed area. This assumption is not valid as methane is less dense than air and will stratify in stagnant conditions, thus creating a vertical gradient within the sealed area. The Nagy, 1981 Explosion Hazard in Mining report that the NIOSH Report references, reports on experiments that indicate methane layering lowers the overpressures realized during an explosion. The assumption that stoichiometric conditions will prevail is also incorrect as the filling process is temporal and spatial in nature. There is only one segment in time during which stoichiometric conditions will exist at any given location throughout the mine. If ignition occurs before or after time the pressures will decay quickly. Extensive literature exists on methane filling and the pressure variation resulting from ignition of various mixtures. [Eltschlager, 2001, Cashdollar, 2000, Cote].

It is known that the naturally evolving methane from the coal seam will fill the volume of the sealed area, replacing air with methane. The methane volume will accumulate over time to a percentage in the air so that the mixture is not flammable. For a methane-air system, the flammable limits by percent volume are 5.0-15.0% [Glassman, 1987]. It is recognized that during the methane filling process a time period exists where the methane-air mixture in the abandoned area will be flammable and if ignited could explode. Common thinking in the mine industry is that this filling process takes anywhere from several days to several weeks.

It has been well documented that gradients will exist in a quiescent environment in which a gas is introduced based on its relative density in comparison to air. This implies that it is unrealistic to expect a homogeneous mixture to exist within the sealed area. Thus the location of the ignition source relative to the mixture is important.

A more valid approach to this problem would be to generate risk curves based on the volume of the space and a range of liberation rates to determine estimates of overpressure as a function of time (based on the mixture fraction in the space). This could further be refined by introducing stratification and horizontal gradients.

Assumption 3: If a detonation occurs in an ideal methane-[dry] air mix at 1 standard atmosphere, the detonation pressure developed is 1.76 MPa or 256 psi (CJ detonation pressure).

A detonation depends on three conditions; confinement, mixture ratio and ignition source [Glassman, 1987]. Detonations come about in two ways, by a large ignition source like a high explosive, or by detonation to deflagration transition (DDT), resulting from turbulence induced mixing and reaction acceleration in the run-up distance [CCPS, 1994].

Some uncertainty exists whether methane can in fact detonate in air [Glassman, 1987]. The NIOSH Report references literature that a methane-air detonation was realized in an experimental mine during a set of experiments [Cybulski, 1967]. The methods for determining the maximum pressures observed are in most of the cited cases *back-calculated* from observations and empirical correlations that may or may not be realistic or applicable. Few of the tests showed pressures and velocities representative of a detonation and those that claimed to have shown a detonation were not based on values obtained with measurement devices, but rather were determined based on damage done to objects that were then further extrapolated to infer a specific pressure. Cybulski's use of electric blasting caps, black powder and dynamite as ignition sources is unrealistic in its relation to most underground coal mining. Cybulski concludes that differences exist between the tests conditions and the assumed amounts of methane accumulations expected in actual operation regarding both flammable volume and methane layering. A more in depth analysis should be undertaken to ascertain if or when detonations can arise in a mine scenario.

The issues of distance and flammable volume are not clearly separated in some portions of the NIOSH Report. Although the Report does classify and identify the potential of methane detonations, the use of distance can be misleading with regards to implementing distance as a safety factor or criteria. The explosion energy is determined by the flammable gas mixture volume and concentration, rather than by the length of the flammable gas column. The rate at which this energy is released, for a given fuel mixture, is controlled by boundary conditions and geometry (degree of congestion and level of confinement). Severe confinement and or congestion can lead to detonations. [Baker Risk, 2007]

In the case of tunnels, a one dimensional (1D) analysis is justified since the length to diameter ratio (or equivalent hydraulic diameter) is normally large (i.e., an L/D ratio of 30 or more). This 1D approach can utilize a “run-up” distance concept to determine the potential for a DDT. The tunnel lengths that the flammable mixture is present in impacts both the explosion strength and the potential to “run-up” or DDT. [Baker Risk, 2007]

No known work exists examining detonations in rectangular geometries. The applicability of tunnel geometry for the analysis of mine geometry needs to be examined. The sealed areas of mines represent complex geometries consisting of linked tunnels and cross cuts. These areas can span several miles. How one dimensional analysis relates to this geometry should be analyzed.

To categorize the explosion scenarios by lengths alone can be misleading, as there are optimum situations which promote DDT. For example, some tunnels may be more congested than others or have more favorable boundary conditions that would promote DDT. The “run-up” distances are dependent on the boundary condition in congested environments. Better criteria for explosion strength categorization may be the tunnel L/D ratio. [Baker Risk, 2007]

The energy required for ignition of a deflagration is on the order of 10^{-4} Joules. The energy required to ignite a detonation is on the order of 10^{6} Joules [CCPS, 1994]. The ignition sources in sealed areas are limited by the active removal of known, man made ignition sources. Rock falls may be the most credible source of sparking that could provide the minimum ignition energy required for the ignition of a deflagration in a methane-air system. Some research in this general area has been done for machine tools contacting rock [Blickensderfer, 1975, Ward, 2000] and frictional contact [Ward, 2005].

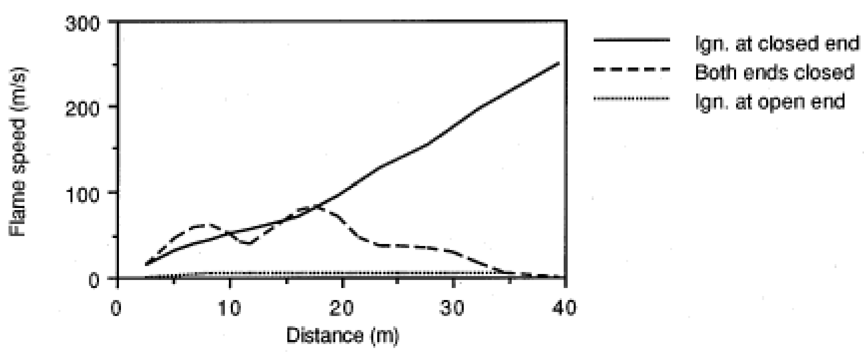
Some of the explosions in the incident summary provided in the NISOH Report stated that lightning was the ignition source. Lightning as an ignition source in an actively isolated sealed area of a mine is not a greatly researched area. One study stated that lightning could be transferred to an underground sealed area and act as an ignition source for methane [Novak, 2001]. The implication of the report was that the energy transfer was not at a high energy level when transferred through rock strata. This issue requires more research to develop a better understanding of the hazard.

An important concept the NIOSH Report used in establishing the seal design criteria for a detonation is the cell size required for detonation. NIOSH uses the cell size to create the parameter referred to in the NIOSH Report as the run-up length to a detonation. Cell size is a characteristic for a detonation of a given gas mixture and is based on the equilibration velocity of the wave and the corresponding cell size needed to complete chemical reactions. The minimum cell sizes for a given gas system usually exist at the most detonatable mixture of the gases and are representative of the sensitivity of a mixture. The NIOSH Report gives a methane detonation cell size of 300 mm which is consistent with other references [Glassman, 1987, Knystautas, 1986].

Methane is particularly insensitive to detonation compared to a corresponding cell size of ~ 535 mm for other alkanes (ethane, propane, etc.) [Glassman, 1987, Lee, 1984].

A literature search conducted as part of this review was not able to find experiments where a successful methane-air detonation was established. Two projects were found that conducted experiments in semi-confined spaces where no methane-air detonations were achieved [Bull, 1979, Inaba, 2004]. It is important to note that these two tests were **not** performed in tunnels and had only partial confinement of the explosive mixture, but the studies do provide some insight into the difficulty of achieving a methane detonation. One paper reported that based on the model developed from the experimental data, 22 kg of tetryl (a highly explosive compound) would be needed to initiate a methane-air detonation [Bull, 1979].

Experiments that examined methane in air were carried out by Bartknecht in 1971 and reported in the Gas Explosion Handbook [Bjerketvedt, 1992]. These tests were done at 1 atmosphere pressure in a 1.4 meter diameter 40 meter long pipe with test conditions of one end closed and both ends closed. Two ignition point scenarios were used, one at the closed end and one at the open end of the pipe. Test were done with the pipe open at one end and closed at both ends, a case similar to the scenarios pictured in Figure 8 of the NIOSH Report. The experiment found that the highest flame speed was achieved when the ignition was at the closed end of the pipe and the other end was open. When the pipe was closed at both ends, the flame accelerated at first, but after 15-20 meters started to decelerate. This testing did not have obstructions in place in the pipe. The graph below illustrates the experiments findings.



Flame speed in a 1.4 m diameter pipe with methane-air. (Bartknecht 1971) [Bjerketvedt, 1992]

Research conducted by [Knystautas, 1986] examined several hydrocarbons in air to understand detonations. This research was conducted in confined tubes with obstructions in the diameter and confirmed that critical values of flame velocity exist for deflagration to detonation transitions.

Obstructions in the flow field of the explosion gases are very important because the methane-air (or any fuel-air) mixture interacts with the obstructions to create turbulence which accelerates the flame fronts during the propagation along the length of the geometry. Knystautas did not get methane-air mixtures to detonate and found that the flame speeds propagated in the obstruction fields for all tests were below the Chapman-Jouget (C-J) predictions. In short, the Knystautas research indicates that a high degree of obstruction is required in a closed tube (on the order of 0.43 fraction of the diameter) to propagate any of the tested hydrocarbons to a DDT. At no time during these tests was methane accelerated to near DDT velocities.

Assumption 4: A methane-air detonation wave reflects from a solid surface at a pressure of 4.50 MPa (653 psi).

NIOSH states that any seal with a tunnel run-up of 50 meters or more requires a seal capable of withstanding an explosion overpressure load of 640 psi. The idea of an explosion containment system designed to withstand a detonation that is made of a single element, such as one big mine seal, may not be a very effective strategy. A detonation overpressure containment seal would have to be built to standards that may not be attainable, reliable or a cost effective use of safety resources given the real risk presented by a methane-air detonation in a mine.

Inherently, gas explosions are not the same as condensed phase explosions (e.g. TNT). A good discussion of the differences is found in Baker, W.E. et al. Explosion Hazards and Evaluation, Elsevier, New York, (1983) [Baker, 1983]. Baker discusses several significant factors that are not considered in the Report. First, the difference between constant pressure energy addition and constant volume-isentropic expansion is discussed in detail including how the combustion wave spreads.

The transition from a three dimensional source wave to one with reflected pressures is a complex issue. Baker, 1983, makes clear that reflected pressures are extremely geometry dependent and the effects from a non-spherical explosive source that is not a high explosive need to be evaluated. The simple formula presented in section 3.6 (line 793) gives only one such limit. Using a single equation to estimate the pressure of a reflected wave is extremely misleading. Rather, as Baker et al. point out, the effects of the specific impulse from an explosion need to be considered. Using a single equation to express reflected wave characteristics implies that Fact 4 (lines 801, 802) may not, in fact be valid.

The NIOSH Report uses explosion pressure and explosion pulse, not the terms used in the bulk of explosion literature, i.e. peak side-on overpressure and impulse. The NIOSH Report should make it clear what is being calculated or measured. For example, Figures 20-22 are given with explosion pressures on the axes. This term "explosion pressure" is not clearly defined in the NIOSH Report. Explosion pressure (see Lines 1817, 1823, and 1829) is not a term normally found in the literature and this complicates analysis of the Report.

MODELING OF EXPLOSIONS

The NIOSH Report provides a summary of the different model packages that are available to analyze explosions. The model runs that simulate the Lake Lynn Experimental Mine provide a degree of validation to both model codes and their application to understanding overpressures in mine configurations.

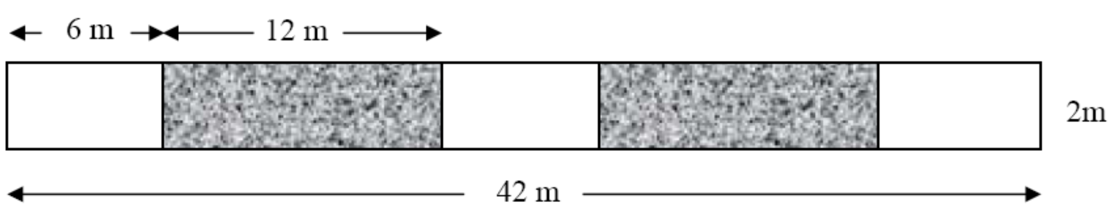
These models can provide valuable information if used appropriately in designed studies to develop configuration and scenario specific seal evaluations. Different design concepts can be evaluated using these programs to help understand the mine and sealed area specific configuration elements that govern the potential overpressures.

The practice of calibrating a model based on small scale experiments and applying the same baseline conditions for different scenarios can be problematic. The calibration process typically involves adjusting various properties and model parameters that will affect turbulence, temperatures, pressures, and speed of the flame front. These adjustments are valid for a specific set of conditions but may not be generally applicable. Thus, the results predicted by the models that are not supported by any experimental/literature values must be treated extremely cautiously if they are based on calibrated baseline conditions.

The simulation codes are continuously under development as new information is found and better representations of physics and chemistry is included in them. FLACS, AutoReaGas, NASA-Lewis, and the Wall Analysis Code all have version numbers and dates of release. These need to be included in the report as an appendix. As the Report presently reads, there is no means of comparing results with any additional information about geometry, temperature and concentration gradients, etc. For each code the version and date needs to be specified. For each application run for comparison purposes, the full initial decisions, assumptions, and conditions need to be provided. If new information is obtained, no comparison with the results from these simulations can be obtained. This is the bare minimum needed for each simulation. Detailed output from each case simulated would be a part of any proper and careful analysis.

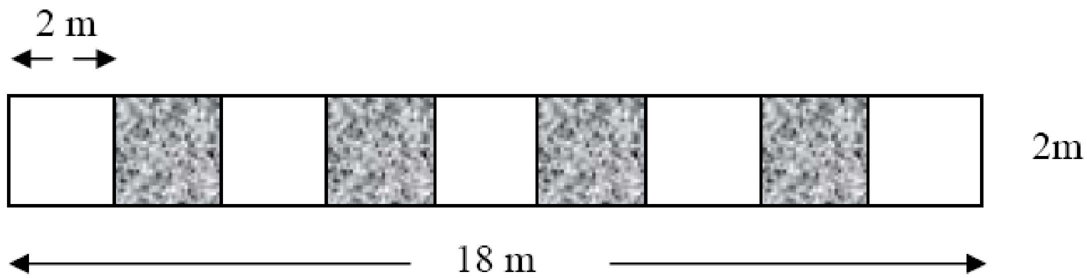
The following analysis is extracted from the Baker Risk report to Packer. The full Baker Risk report is an attachment to this review.

The models assumed for the AutoReaGas and FLACS trials are based on the Lake Lynn layout. This layout, if a 2 meter tunnel height is assumed, has a blockage ratio of about 0.57 and essentially consists of a rectangular cross section with three venting shafts and two pillars (see figure below). [Baker Risk, 2007]

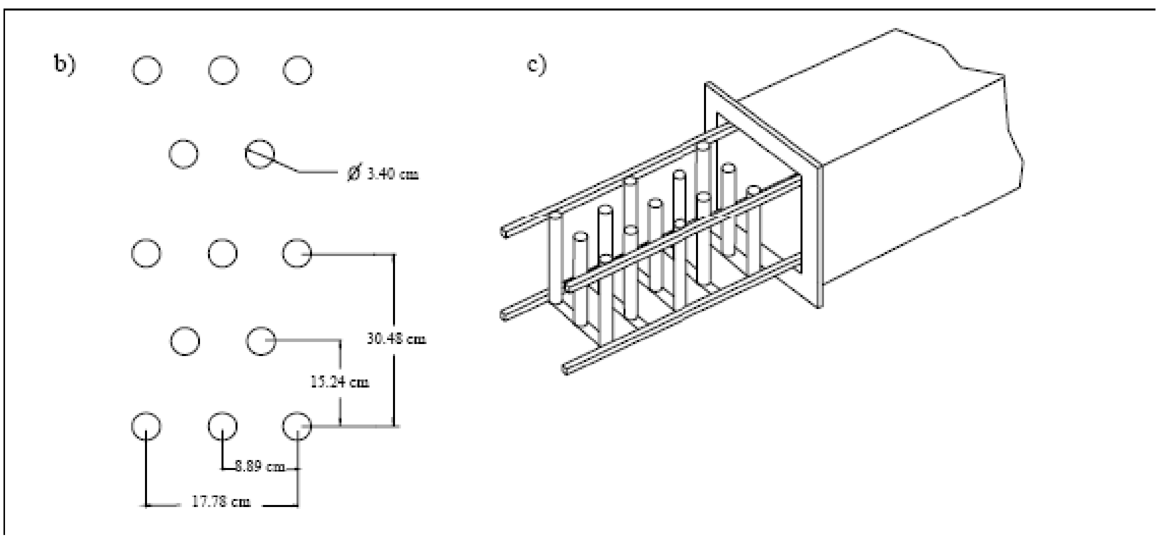


Conversely, the tunnel designs and layouts illustrated in Figures 1A and 1B of the

NIOSH Report contains more obstacles and a blockage ratio of about 0.44 (see figure below). [Baker Risk, 2007]



The differences between these arrangements can have a significant impact on the potential for a DDT. For example, in methane air tests carried out at McGill University by Chao, 1999, with tubes of square cross sectional areas, the obstacle arrangement consisted of a staggered array of 3x2 cylinders. The blockage ratio used was 0.41 and the layout can be seen in the figure below. [Baker Risk, 2007]



Previous experiments carried out by Knystautas, R., and Lee, J.H.S., in round cross sectional tubes with a blockage ratio of 0.43 and orifice plates as obstacles did not exhibit the high flame velocities that the square tube tests revealed. The results of these tests showed that the steady state flame velocities for the circular tube were all below the speed of sound, whereas significant portion of the velocities for the square tube achieved a state of "quasi-detonation" (i.e., above the speed of sound). The tests concluded that although both tubes had similar blockage ratios, the obstacle array of staggered cylinders yielded more flame acceleration than the orifice plates. [Baker Risk, 2007]

CONCLUSIONS

This review provides an analysis of the NIOSH Report and raises questions about each of the design assumptions that NIOSH used to justify the pressure requirement for the seals. The NIOSH Report does not present a convincing argument for providing a prescriptive seal standard that is many times in excess of successful standards in other countries throughout the world. It uses a theoretical homogeneous methane-air (dry) combustion conditions to represent the stratified methane combustion in the moist conditions in coal mines. This assumption is used in spite of data indicating that both of these conditions will significantly reduce the flammable mass and severity of combustion. Furthermore, the NIOSH Report uses the pressure obtained in ideal explosion conditions in narrow tube geometries to approximate the conditions in mine tunnels and entries. This method of developing design criteria is not appropriate for this application. Before a prescriptive regulation that is so much greater than the international standards is applied more analysis and data is needed.

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Baker Engineering and Risk Consultants, Inc.
BAKERRISK 3330 Oakwell Court, Suite 100 ◆ San Antonio, TX 78218-3024 ◆ PH: (210) 824-5960 FX: (210) 824-5964

March 8, 2007

Christopher F. Schemel
Vice President
Packer Engineering, Inc.

-- VIA EMAIL --

Re: ***Draft of Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines***
BakerRisk Project 01-01743-001-07

Dear Mr. Schemel:

On February 22, 2007, Packer Engineering requested the support of Baker Engineering and Risk Consultants, Inc. (BakerRisk) in the review a NIOSH draft report on the Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines. This memorandum provides BakerRisk's commends on the NIOSH draft report along with references to further documentation in support of these comments.

1. BACKGROUND

In response to several coal mine related explosions, and the recent Sago mine explosion, the 2006 MINER Act requires the MSHA to amend the current 20 psi explosion pressure design load on mine seals to a higher design load by the end of 2007. NIOSH engineers have produced a report outlining the necessity to approach mine seal design using a three-tiered explosion pressure design criteria for possible mine explosion scenarios.

2. BAKERRISK COMMENTS

2.1 General Comments

The NIOSH report basically states that there are two possible explosion scenarios. The first explosion scenario is an explosion involving a large volume of flammable gas mixture covering a long stretch of mine shaft. This scenario is intended to address the possibility of an ignition creating a flame front capable of ramping up to a strong turbulent deflagration or, given enough flame travel distance (e.g., 50 meters or more), undergoing a deflagration-to-detonation transition (DDT).

The second explosion scenario would consist of a flammable mixture being formed directly behind, or even in front of, the mine seal as a result of leakage through the seal. In this scenario, it is unclear how much flammable volume would be created due to seal leakage.

The issues of distance and flammable volume are not clearly separated in some portions of the NIOSH report. Although the report does properly classify and identify the potential of methane detonations, the use of distance can be misleading with regards to implementing distance as a safety factor or criteria. The explosion energy is determined by the flammable gas mixture volume and concentration, rather than by the length of the flammable gas column. The rate at which this energy is released, for a given fuel mixture, is controlled by boundary conditions and geometry (degree of congestion and level of confinement).

In the case of tunnels, a one dimensional (1D) analysis is justified since the length to diameter ratio (or equivalent hydraulic diameter) is normally large (i.e., an L/D ratio of 30 or more). This 1D approach can utilize a “run-up” distance concept to determine the potential for a DDT. The tunnel lengths that the flammable mixture is present in impacts both the explosion strength and the potential to “run-up” or DDT.

To categorize the explosion scenarios by lengths alone can be misleading, as there are optimum situations which promote DDT. For example, some tunnels may be more congested than others or have more favorable boundary conditions that would promote a DDT. The “run-up” distance are dependent on the boundary condition in congested environments. A better criteria for explosion strength categorization may be the tunnel L/D ratio.

2.2 Specific Comments

The following are specific comments regarding the NIOSH report.

i. The discussion relating to the phenomenon of spontaneous combustion given at the top of pages 6 and 7 may merit additional discussion. Coal is known to undergo spontaneous ignition but under very specific conditions. It is not clear how probable such scenario is?

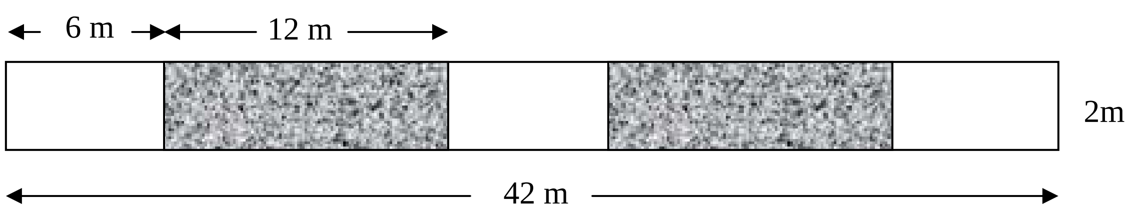
ii. Reference is made on page 8, line 157, about several hundred meters of open entry to be likely behind the seals and later on line 159 reference is made to potentially having 3-4 kilometers of open entries. These distances do not speak to how much flammable volume may actually exist in these open spaces and the order of magnitude difference between the two open entry distances is noteworthy and can make significant impacts to the blast loads produced. The duration of the pressure pulse associated with a detonation is a function of the gas column length, with a longer column length yielding a longer duration pressure pulse.

iii. On page 10, the reference to coal oxidation indicates a release of carbon dioxide in the atmosphere of the abandoned mine section, but no discussion is provided of expected carbon dioxide concentrations. This may be relevant in that the presence carbon dioxide, or any other inert gas species, will increase the detonation cell width of the mixture and hence make it less like to undergo a DDT.

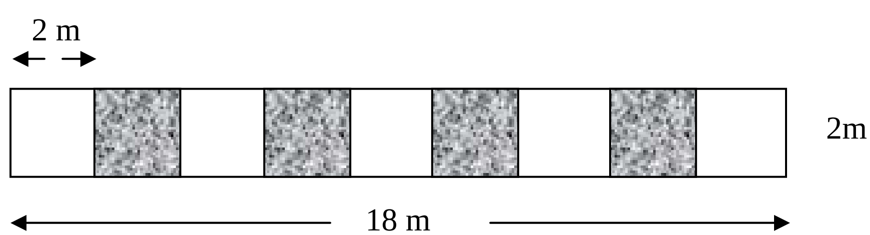
iv. Page 27 has a reference to 0.75 kg of TNT as having an energy equivalent to a cubic meter of methane-air flammable mixture. This reference is misleading to the industry. Although the potential energy is equivalent in this two examples, the energies are released at an entirely different rate. The cubic meter of gas, if placed in an uncongested and unconfined volume, will simply burn out as a flash fire causing a rush of hot air, but no real overpressure. Conversely, a 0.75 kg mass of TNT will detonate and create a 8 psig side-on load at a distance of 10 feet (approximately 19 psig reflected load).

v. The reference on page 35 states that detonation propagation in an elongated confined environment can occur when the diameter of the confinement (tunnel or pipe) is approximately 5 times the detonation cell size. The bulk of the technical literature on this topic would support that a stable detonation can occur in a pipe with a diameter equal to about 3 times the detonation cell width; in the case of methane, this would imply a diameter of less than 1 meter (about 90 cm). Furthermore, unstable detonations can occur in a pipe with a diameter equivalent to roughly one cell width.

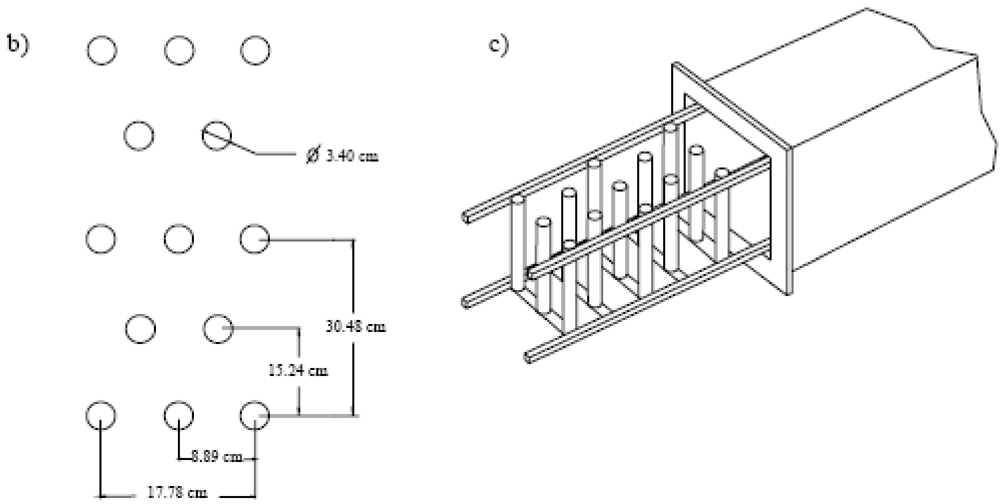
vi. The models assumed for the AutoReaGas and FLACS trials are based on the Lake Lynn layout. This layout, if we assume a 2m tunnel height, has a blockage ratio of about 0.57 and essentially consists of a rectangular cross section with three venting shafts and two pillars (see figure below).



Conversely, the tunnel designs and layouts illustrated in Figures 1A and 1B of the NIOSH report contain more obstacles and a blockage ratio of about 0.44 (see figure below).



The differences between these arrangements can have a significant impact on the potential for a DDT. For example, in methane air tests carried out at McGill University by Chao, J., Kolbe, M., and Lee, J.H.S., (*Influence of Tube and Obstacle Geometry on Turbulent Flame Acceleration and Deflagration to Detonation Transition* presented at the 1999 ICDERS symposium in Heidelberg, Germany) with tubes of square cross sectional areas, the obstacle arrangement consisted of a staggered array of 3x2 cylinders. The blockage ratio used was 0.41 and the layout can be seen in the figure below.



Previous experiments carried out by Knystautas, R., and Lee, J.H.S., in round cross sectional tubes with a blockage ratio of 0.43 and orifice plates as obstacles did not exhibit the high flame velocities that the square tube tests revealed. The results of these tests showed that the steady state flame velocities for the circular tube were all below the speed of sound, whereas significant portion of the velocities for the square tube achieved a state of "quasi-detonation" (i.e., above the speed of sound). The tests concluded that although both tubes had similar blockage ratios, the obstacle array of staggered cylinders yielded more flame acceleration than the orifice plates.

3. CLOSURE

This letter report has been a review of the NIOSH report on Explosion Pressure Design Criteria for Mine Seals. BakerRisk looks forward to hearing from you after you and other members of the review committee have had an opportunity to review the comments provided in our letter report. BakerRisk remains eager to develop a path forward in the near future that will serve Packer Engineering's needs.

Please feel free to contact me if you have any questions or comments on this matter.

Sincerely,

Massimiliano Kolbe
Project Consultant

Approval:

Kelly Thomas, Ph.D.
Blast Effects Manager

Notice

Baker Engineering and Risk Consultants, Inc. (BakerRisk) made every reasonable effort to perform the work contained herein in a manner consistent with high professional standards.

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EXCERPTS TAKEN FROM THIS REPORT
ON THE
'MITCHELL-BARRETT' SOLID-CONCRETE-BLOCK SEAL

Experimental Study of the Effect of LLEM Explosions on Various Seals and Other Structures and Objects[1]

Kenneth L. Cashdollar, Eric S. Weiss, Samuel P. Harteis, and Michael J. Sapko

National Institute for Occupational Safety and Health
Pittsburgh Research Laboratory
Pittsburgh, PA

February 2007

[1] This report details work performed at the request of the Mine Safety and Health Administration and the West Virginia Office of Miners' Health, Safety, and Training in support of their investigations into the Sago mine explosion. This report has not undergone external peer review.

Experimental Facilities and Instrumentation

The full-scale explosion tests were conducted in the LLEM [Mattes et al. 1983; Triebsch and Sapko 1990], which is shown in the plan view of figure 1. This is a former limestone mine, and five new drifts (horizontal passageways in a mine) were developed in 1979-1980 to simulate the geometries of modern U.S.A. coal mines. The mine has four parallel drifts - A, B, C, and D. D-drift is a 1710-ft long single-entry that can be separated from E-drift by an explosion-proof bulkhead door. In order to simulate room and pillar workings, drifts A, B, and C can be used; and they would be separated from E-drift by an explosion-proof bulkhead door located near the C- and E-drift intersection (fig. 1). The A-, B- and C-drifts are each approximately 1710 ft long, with seven crosscuts at the inby end. Drifts C and D are connected by E-drift, a 500-ft long entry which simulates a longwall face. The current explosion tests were conducted in the multiple entry area of A-, B-, and C-drifts. The entries are about 20 ft wide by about 6½ ft high, with cross-sectional areas of 130-140 ft^2. The LLEM is designed to withstand explosion pressures of 100 psi.

Each LLEM drift has ten data-gathering (DG) stations inset in the rib wall at the locations shown in figures 1 and 2. Each DG station houses a strain gauge transducer to measure the explosion pressure and an optical sensor to detect the flame arrival. The wall pressure is perpendicular to the gas flow and is the pressure that is exerted in all directions. Nagy [1981, p. 58] calls this omnidirectional pressure the "static pressure" to differentiate it from the dynamic pressure, although the "static pressure" does vary with time during the explosion. The dynamic or wind pressure is directional. The total explosion overpressure is the sum of the omnidirectional pressure and the wind or dynamic pressure. Other instruments may also be installed at various locations in the LLEM during an explosion test.

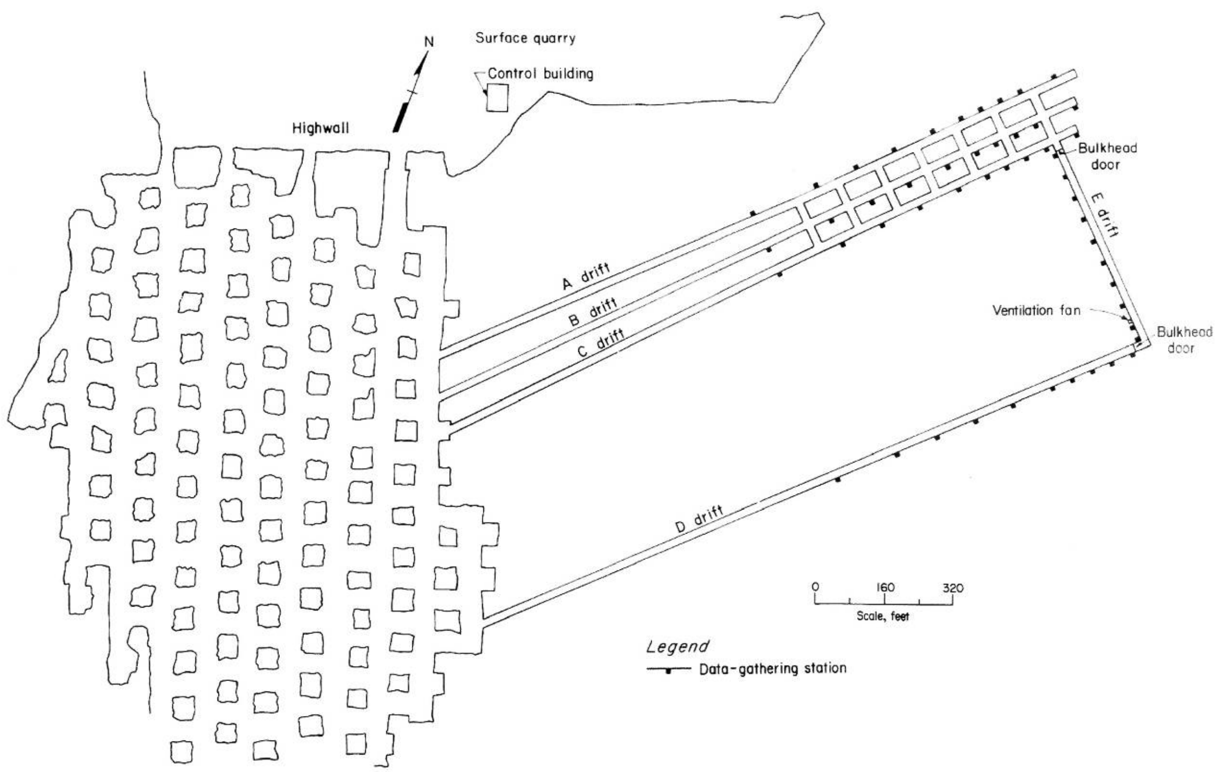

Figure 1 - Plan view of the Lake Lynn Experimental Mine (LLEM)

During the normal course of underground coal mining, it sometimes becomes necessary to install seals to isolate abandoned or worked out areas of a mine. Since 1992, 30 CFR 75.335 required a seal to ". . . withstand a static horizontal pressure of 20 pounds per square inch." This regulation formed the basis for previous PRL evaluations [Stephan 1990a; Stephan 1990b; Greninger et al. 1991; Weiss et al. 1993a; Weiss et al. 1993b; Weiss et al. 1993c; Weiss et al. 1996; Weiss et al. 1997; Weiss et al. 1999] of explosion-resistant seals at the LLEM. During the 1990s, PRL and MSHA jointly evaluated the capability of various seal construction materials and designs to meet or exceed the requirements of the CFR.

Fig. 2 is a close-up plan view of the seal test area in the multiple-entry area of the LLEM. In this example, there are seals in the first four crosscuts from the face or closed end of C-drift. Note that, at the LLEM, the first crosscut is the one nearest the face. The flammable methane-air gas zone is at the face (closed end) of C-drift. The gas zone is confined on the outby end by a plastic diaphragm. The bulkhead door is closed between C-drift and E-drift before the test. For an explosion test, the gas is ignited and the explosion pressure travels out C-drift.

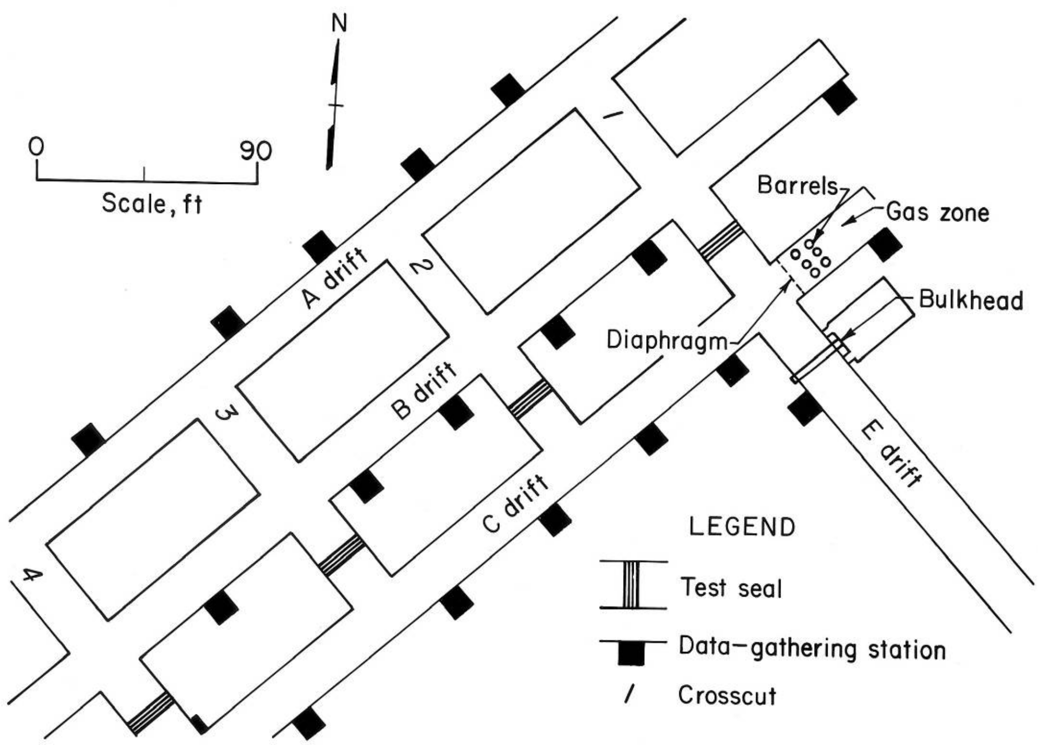

Figure 2 - Seal test area in the LLEM.

Examples of pressure transducers in front of a seal are shown in figure 3. For the later tests (LLEM #503-506), there were generally at least two pressure transducers in front of each seal – one mounted horizontally to face the incoming pressure wave and one mounted vertically to be perpendicular to the incoming pressure wave. Behind each seal was a linear variable differential transducer (LVDT) as shown in figure 4. The LVDT measures the movement of the seal [Weiss et al. 1999, pp.5-6]. Also shown in figure 4 are the horizontal and vertical yellow breakwires used to measure the time of seal failure. During the explosion tests, a high-speed, PC-based National

Instruments[2] (NI) data acquisition system collected the data from the various instruments at a sampling rate of 1,500 per sec. The reported data were normally averaged over 10 ms (15-point smoothing). For some of the tests, a second Kinetic Systems (KS) data acquisition system collected the data at 5,000 samples per second.

Figure 3 - Front view and side view of pressure transducers in front of seals.

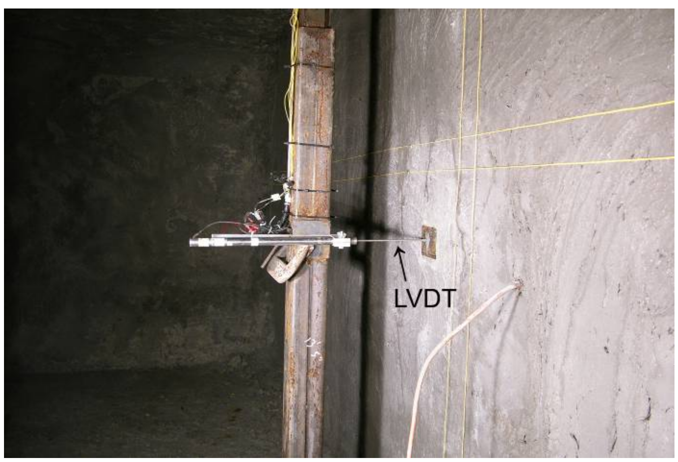

Figure 4 - LVDT mounted behind seal to measure movement.

Explosion Tests Summary

Test 6, LLEM test #506, October 19, 2006

For the sixth and final test of this series, the seal in X-2 that had survived from the previous LLEM explosion tests and was left in place. A new solid-concrete block seal was installed in X-3. This new 16-in thick solid-concrete block seal with a 32-in thick center pilaster was constructed in a similar manner as the solid-concrete block seal in X-1 for Test 1, except the X-3 seal used Type S mortar (not BlocBond) and was coated on both sides with Quikrete's B-Bond sealant. Additional details on the construction of this seal are in the "Seal Construction Description" of Appendix B6. A seal (not a solid-concrete-block seal) was installed in C-drift at about 320 ft from the face.

[2] Mention of any company name or product does not constitute endorsement by NIOSH.

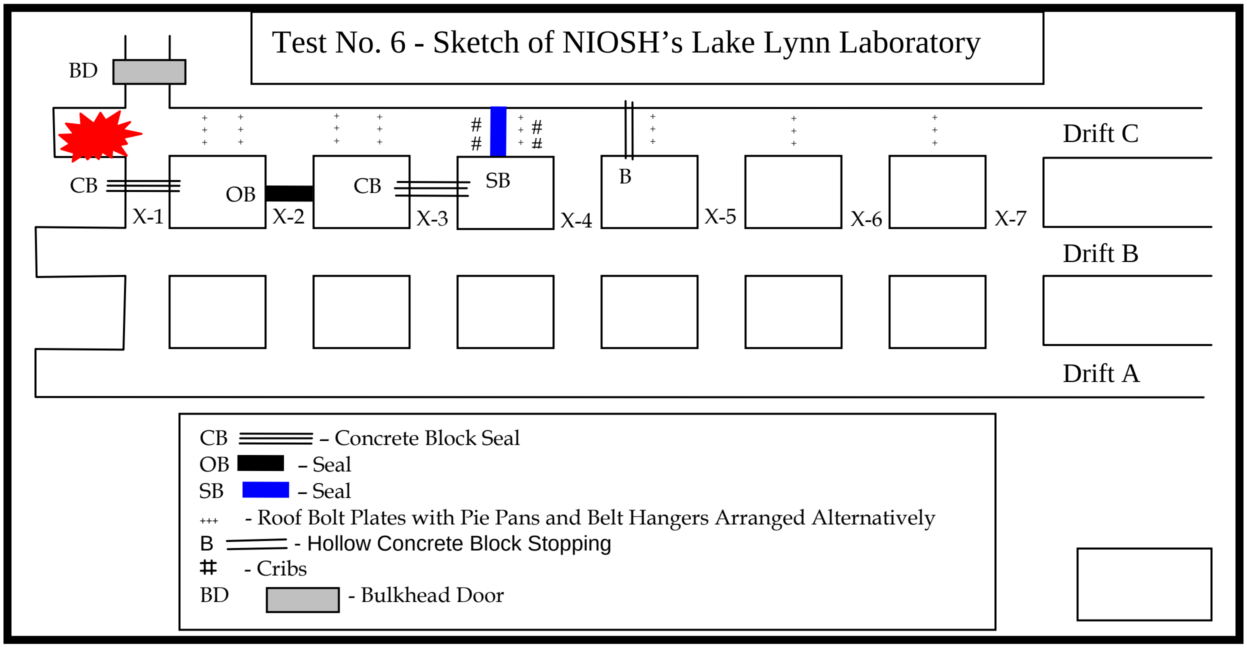

Figure 58 – Test set-up for Test No. 6 (LLEM #506).

For Test 6 (LLEM #506), a longer 71-ft gas ignition zone was used at the face of C-drift in order to generate higher pressures than those for Test 5. In this test the plastic diaphragm used to confine the gas mixture was located just outby X-1. The 71-ft long ignition zone was filled with 1265 ft^3 of natural gas to give a mixture of ~10% CH_4 in air. Although this zone was only ~50% longer than the ignition zone for Test 5, the flammable gas volume was ~90% greater. This was due to the additional volume in X-1 between the seal and the bulkhead door leading to E-drift, as shown in figures 2 and 58. The methane-air zone was ignited at the face of C-drift and the pressure pulse propagated out C-drift past the seals in crosscuts X-2 and X-3 to the seal in C-drift. The seals in the crosscuts experienced the side-on pressure and the seal in C-drift experienced the head-on pressure of the explosion. Because the flammable gas zone was much larger, the resulting pressures were much higher than those in Test 5.

Figure 60 shows the pressures and LVDT displacement data at the X-3 solid-block seal, along with the pressure at the wall of C-drift inby the seal at 234 ft. The pressure transducers at the seal were located near the middle front of the seal at 256 ft from the face of C-drift. There were two pressure transducers at the seal – one mounted horizontally and one mounted vertically, as shown in figure 3. However, the vertical transducer did not operate properly during this test, and its data are not shown. All of the graph data were averaged over 10 ms. The seal survived both the outgoing pressure pulse of ~44 psi and the later reflected pulse of ~49 psi shown in figure 60. The peak pressure reading from the NI raw data at 1500 Hz was ~82 psi, but it lasted less than 1 ms. The maximum LVDT movement during the explosion was 0.14 in. Since the solid-block seal in X-3 did not fail, there was no change in the breakwire signals.

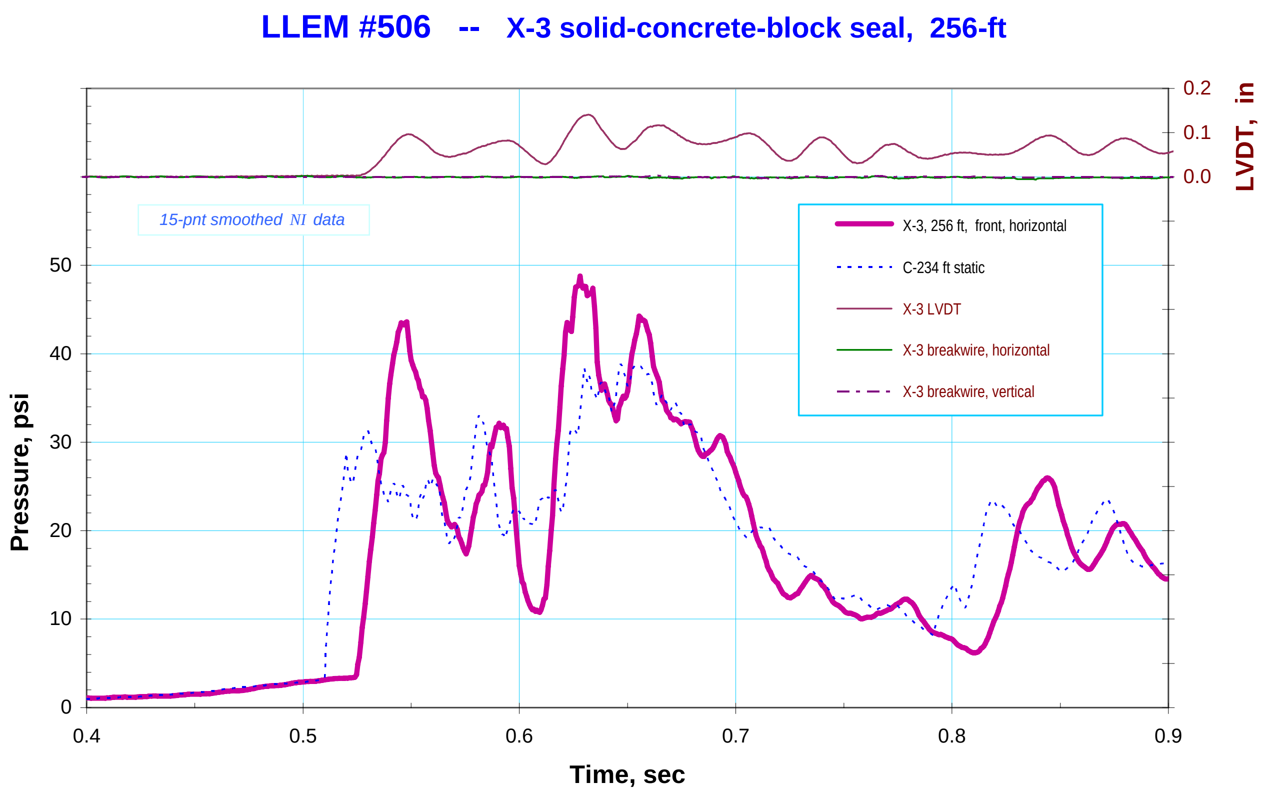

Figure 60 – Pressures and LVDT displacement at the X-3 seal during Test 6.

Pressure, LVDT displacement, and breakwire summary data for the seals in X-2, X-3, and C-drift during Test 6 are listed in table 11. The maximum pressures at the seals are listed for the two data acquisition systems – NI for National Instruments and KS for Kinetic Systems. The data were averaged over 10 ms for the listed pressure values. The breakwire time is from the NI raw data. The maximum smoothed pressure from the horizontal transducer at the middle of the solid-block X-3 seal was 48.8 psi from the NI and 48.4 psi from the KS, and the seal survived.

Table 11 - Pressures and LVDT displacement at the seals during Test 6 (LLEM #506)

C-Drift Pressure & Break-Wire Data at Seals

Seal or Stopping		**Seal Pressures** psi, NI	psi, KS	LVDT Deflection in	mm	Break Time, sec
X-2 BC	*H*	50.7	49.2	0.06	1.6	
156 ft						
		seal survived				
X-3 BC	*H*	48.8	48.4	0.14	3.6	--
256 ft	*V*	-	-			--
		seal survived				

Seal or Stopping		**Seal Pressures** psi, NI	psi, KS	LVDT Deflection in	mm	Break Time, sec
Wood Cribs	*A*					0.561
	B					0.562
		cribs destroyed				
C-drift	*rib*	99.2	99.3	>6	>150	
	H,e	92.3	92.6			
320 ft	*H*	91.1	89.0			0.578
	V	90.1	89.2			0.575
		seal destroyed,				
C-drift	*H*	7.5	7.6			0.790
384 ft		*stopping destroyed,*				

Table 12 lists pressure and flame sensor data at the various DG-panels on the walls of B- and C-drifts during LLEM #506. The positions of the seals in the crosscuts and C-drift are depicted by the blue and green shading. On the left part of the table are the maximum B-drift wall pressures and on the right are the maximum wall pressures in C-drift. The C-drift pressures were relatively constant from 84 ft out to 234 ft. The pressure increased significantly out to ~320 ft as the pressure pulse was confined by the C-drift seal. After the seal broke, the pressures beyond the seal were much lower – 7.5 psi at the stopping at 384 ft, ~4.6 psi at 403 ft, and ~3 psi at 501 ft, etc. The last two columns of table 12 list the flame signal and arrival time at each of the DG-panels. For this test the flame went past the 234-ft panel but did not reach the 304-ft panel. Therefore, the interpolated flame travel distance was about 240 ft. Based on the initial gas zone length of 71 ft, the expansion ratio would be about 3.4.

Table 12 - Wall pressures and flame travel during Test 6 (LLEM #506)

Pressure & Flame Data								
B-Drift Static Pressures				**C-Drift Static Pressures**			**Flame Signal**	
distance, ft	psi, NI	psi, KS		distance, ft	psi, NI	psi, KS	volts	sec, NI
				3	42.4	42.5		
10	5.6		1	13	-	-	>5	0.227
			X-1					
108	4.4		2	84	36.6	36.7	>5	0.415
158	~4		3	134	34.7	35.0	>5	0.454
			X-2					
211	--		4	184	37.6	37.6	>5	0.510
257	2.4		5	234	38.9	38.9	>5	0.572
			X-3					
329	2.7		6	304	89.5	88.1	~0	
			X-4					
427	3.2		7	403	4.6	4.7	~0	
			X-5					
526	3.3		8	501	3.2	2.7	~0	
			X-6					
626	3.1		9	598	3.0	3.1	~0	
			X-7					
782	3.0		10	757	3.0	3.0	~0	
			11	1506	2.3	2.2		

The seal in X-2 and the solid-block seal in X-3 survived the explosion during Test 6 (LLEM #506). The air-leakage data are in table C10 in Appendix C. Both seals passed the leakage test. The seal in C-drift was destroyed during the test and was therefore not measured for air leakage.

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APPENDIX B

Seal Construction Descriptions

By Cynthia A. Hollerich, Eric S. Weiss, and Michael J. Sapko

Appendix B6

Mitchell-Barrett Solid-Concrete-Block Seal in Crosscut 3
Construction Date – September 11-15, 2006
NIOSH-MSHA-WVOMHS&T Seal Testing - Test No. 6 Protocol

On September 11-15, 2006, a 16-inch thick Mitchell-Barrett solid-concrete-block seal with an interlocked center pilaster was constructed by personnel from Ki (NIOSH contractor) in crosscut 3 between B- and C-drifts within the Lake Lynn Experimental Mine.

- Average crosscut dimensions at seal location – 18.6 ft (223 inches) wide by 6.8 ft (82 inches) high.
- The seal was constructed approximately 6-7 ft into the crosscut (as measured from the C-drift side) on a small concrete foundation that tapered from 0- to 3-in thick on top of an 8-in thick reinforced concrete floor designed to assist in the leveling of the first course of block.
- The crosscut (roof, ribs, and floor) at the seal location was washed, using a garden hose, just prior to the start of the construction.
- The crosscut (roof, ribs, and floor) at the seal location was washed, using a garden hose, just prior to the start of the construction.
- The 6 inch x 8 inch x 16 inch solid-concrete-blocks used for the construction of this seal were purchased in April 2002 from Klondike Block & Masonry Supplies, Inc. in Uniontown (724-439-3888). These blocks were stored within the LLEM.
- The Type S mortar was packaged in 70 lb bags manufactured by Brixment (purchased in August 2006 from Stone & Company Concrete & Builders Supplies in Connellsville, PA; 724-628-2200). Each batch of mortar consisted of 2 parts masonry sand and 1 part Type S mortar. This Type S mortar and sand mixture was then mixed with water according to the manufacturer's recommendations to obtain the proper consistency.
- The Type S mortar mix (~3/8-inch thick bed) was applied to the concrete floor as the each block was laid.
- The dry solid concrete blocks were laid in the wet Type S mortar mix to begin seal construction. Using full wet-bed construction, the Type S mortar mix was applied to all vertical and horizontal dry block joints (figure B6-1). The vertical and horizontal joints were nominally 3/8 inch. The blocks were laid in a transverse pattern (refer to attached photographs).
- Construction of the first row (front course, C drift side) consisted of thirteen, 6 inch x 8 inch x 16 inch block (16 in block dimension parallel with C-drift) and two partial block cut to fit within ½ inch of each rib. Construction of the first row (back course, B-drift side) was similar except the blocks were offset to result in a staggered joint pattern (to the previously laid block). A total of 26 full blocks and 4 partial blocks were required to complete this first bottom course. The blocks were laid in a similar manner for courses 3, 5, 7, 9, 11, and 13 (although some courses required fewer partial blocks to complete the closure to the rib).
- For the second course, 27 full blocks and 2 partial blocks were installed with the length of the block parallel with to the crosscut ribs (see attached photographs). Courses 4, 6, 8, 10, and 12 were laid in a similar manner (although some courses required only 1 partial block to complete the closure to the rib).
- The blocks used to construct the 16 inch x 32 inch pilaster were interlocked to the 16 inch thick main wall at the center of the seal (see attached photographs). The 32 inch pilaster dimension was oriented in the C- drift to B-drift direction.
- On the 13th and final course, each of the blocks was cut and laid to result in a gap of approximately 1 to 2 inches between this top course and the mine roof (figure B6-2).

- The gap between the top course of block and the mine roof was completely filled with mortar throughout the entire width and length of the seal (figure B6-3). No wedges were used in the construction of this seal.
- Approximately 364 full blocks (6 inch x 8 inch x16 inch) and 23 partial blocks were used to construct this seal; 6 half block (4 inch x 8 inch x 16 inch) were used at the mine roof.
- Rib and floor hitching (keying) was used on this seal. The hitching was simulated by bolting 6 inch x 6 inch x ½ inch thick steel angle to the both ribs on each side of the seal and on the floor on each side. This angle was secured by 1 inch diameter by 9 inch and 12 inch long Hilti Kwik bolts III spaced at approximately 18 inch centers. A total of 22 bolts were installed on each side; 4, 12 in long bolts on each rib and 14, 9 inch long bolts on the floor. The steel angle on the floor was installed in 3 sections on each side of the seal; a 16 inch section was anchored to the floor against the pilaster (1 bolt on each end of this angle section) and 2, ~103 inch sections were anchored against the seal on the floor to either side of the pilaster (6 bolts on each section). Type S mortar mix was used to fill any gaps between the steel angles and seal and the steel angles and ribs (figure B6-4).
- 14.5 bags (or 1,015 lb) of the Type S mortar (subsequently mixed with sand and water) were required for the block construction of this seal and an additional 2 bags (140 lb) of Type S mortar (mixed with sand and water) to fill in the gaps between the steel angles and the seal and the steel angles and the strata interface.
- Both faces of the seal were subsequently coated with an approximately ¼-in coating of Quikrete B-Bond; 4 bags of B-Bond on each side.
- Construction of the seal took approximately 22 hours (79 worker-hours); this included approximately 23 worker-hours to install the steel angle on the ribs and floor on both sides of the seal. This does not include the time required to spot the construction materials to the site.

Figure B6-1.-Full wet-bed construction on all horizontal and vertical block joints.

Appendix B6

Figure B6-2.-Installing cut block to on top course.

Figure B6-3.-Completely filling the gap between the top block course and the mine roof with mortar; the block were not wedged.

Figure B6-4.-Mortar filling any gaps that exist between the steel angle hitching and the block along the floor and ribs.

APPENDIX C

Air-Leakage Data for Seals

Table C9.- Air leakage measurements before the sixth explosion test (No. 506)

Location	Air leakage rates, cfm, at pressure differential of --			
	0.8 in H_2O	1.5 in H_2O	2.3 in H_2O	4.2 in H_2O
Seal in crosscut 1	104.4	130.5	182.7	243.6
Seal in crosscut 2	0	0	4.8	7.4
Seal in crosscut 3	17.4	24.4	33.1	43.5
Seal across C-drift (C-320)	0	5.2	8.3	11.3

Table C10.- Air leakage measurements after the sixth explosion test (No. 506)

Location	Air leakage rates, cfm, at pressure differential of --			
	0.6 in H_2O	1.3 in H_2O	2.2 in H_2O	3.9 in H_2O
Seal in crosscut 1	87	130.5	174	226.2
Seal in crosscut 2	0	<4.4	5.2	8.7
Seal in crosscut 3	17	20	29.1	45.7
Seal across C-drift (C-320)	seal destroyed			

Comments on the letter of Congressman George Miller, Chairman, House Education and Labor Committee to Elaine L. Chao, Secretary of Labor, dated July 24, 2007.

In general the comments reflect a lack of understanding regarding the design, installation and maintenance of seals and, without foundation, imply that the thousands of existing installations are “potentially catastrophic” in nature. Contrary to this characterization, we believe the thousands of existing installations demonstrate that seals can, and have, performed as designed and do protect miners from the hazards that could result if they had not been installed. Two isolated and unrelated events should not call into question the industry’s seal design and installation program and result in unfounded distrust in the sealing of abandoned areas in underground coal mines. It is this premise, we believe, that underlies many of the positions reflected in Chairman Miller’s submittal.

Included in the National Mining Association response to the Emergency Temporary Standard are three technical evaluations of the National Institute for Occupational Safety and Health final report on “Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines” prepared by Dr. Martin Hertzberg, Packer Engineering, Inc. and Baker Engineering and Risk Consultants, Inc. Many of the issues contained in Chairman Miller’s submittal are addressed in these submittals.

Going beyond the NIOSH report however, we believe that certain recommendations in the letter are without foundation, do not reflect the realities of the underground environment and may diminish rather than enhance the safety of underground coal miners. For example, the letter recommends “keeping methane concentrations above 50% could be considered a significant insurance policy that it will not forseeably fall into the 5-15% explosive range.” This recommendation ignores the practical realities of methane production in underground coal mines. Relatively few mines produce methane at these liberation rates and the recommendation implies the introduction of additional flammable or explosive gas into a sealed area that may, over time, result in a catastrophic failure of either the seals or the handling of the mixtures internally. This is an ill-advised scheme which has the potential to increase the risk.

Similarly, the letter recommends that seal construction not be completed until MSHA inspects the seal. Mandating that MSHA inspect every seal prior to completion creates a situation where there could easily be severe disruptions to the seal construction process both before and at closure. This could actually create situations where MSHA, by their absence, could create extremely unsafe or hazardous situations for which the mine operator would be responsible. While we are sympathetic to the desirability to have thorough inspections conducted during the construction phase, we must not jeopardize miner safety as might well occur if the recommendation is adopted without condition.

In closing we are concerned that many of the comments and recommendations contained in the letter lack a complete understanding and appreciation of the multitude of factors that are considered during and after the sealing process. Contrary to the belief of some, many mines do not liberate methane and consequently there will never be an accumulation or an explosive mixture behind sealed areas. In these situations there is no risk. Consequently, considerations of what actions are required during the seal process, including the curing period, are far different for these seals than for those in others setting and should be based on a complete risk analysis of the area to be sealed rather than a one-size fits all approach as the letter envisions.

Sealing has proven to be a highly successful means to prevent miners from exposure to deteriorating ground conditions. Sealing is not only the best viable option for dealing with deteriorating ground conditions, it provides the greatest margin of safety for all involved when constructed with proper materials and workmanship. Past history demonstrates the need for a dynamic program that provides operators the tools to design, construct and maintain seals suited for the particular environment within which they will be installed. Unfortunately many of the recommendations contained in Chairman Miller's letter will diminish this ability and may inadvertently diminish rather than enhance miner safety.