

Safety in Mines Research Advisory Committee

Final Project Report

Design, construction and testing of underground seals.

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Executive summary

Research in the USA and Europe has shown that explosion proof seals can be made from a variety of materials and designs, but are generally built to suit availability of material, and are over designed, with actual designs based on trial and error. Explosion proof seals are generally defined as capable of withstanding pressures of 20 psi, but have been tested at pressures above 300 psi.

The US regulations concerning the construction of seals are based on the long-term explosion research programmes carried out by MSHA, and in particular the more recent work during the 1990's at the Lake Lynn facility.

Regulations state that a seal must withstand a static horizontal pressure of 20 psi and although there are construction details given, any alternative construction is permitted if it meets this pressure requirement, and is fire retardant.

In addition to the pressure requirement, MSHA have air leakage guidelines that a seal must withstand after an explosion, and recommend it should maintain its operation for a minimum of one hour after an explosion.

Approval of seals is by full scale explosion testing at Lake Lynn, where seals are exposed to explosions producing 20 psi (140 kPa), and then tested for leakage.

Australian approved standards for ventilation control do not address the structural design or material requirements for seals, but also require an overpressure of 140 kPa, and this within 24 hours of construction.

Approved systems for seal construction from MSHA are concrete blocks, Omega 384 foam blocks, cementitious foam seals and polymer foam seals. These all have approved methods of construction.

There are no effective small scale tests, or non destructive *in situ* tests for designs, materials or existing seals. Further work should be carried out to investigate small scale testing, and an evaluation method for existing seals.

The US definition of explosion proof seals is limiting, and ensures an effective one hour operation of a seal post-explosion. This needs to be further considered for South African application, and whether the seal must maintain the mine operations as well as provide escape time.

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Terminology and abbreviations

A great deal of the available literature is US sourced, or does itself contain reference to work and information when Imperial units were the normal standard. Although the accepted SA and SIMRAC practise is the use of SI units, the nature of the work reviewed here has made this impractical, so reference in the text of this report is given almost exclusively in imperial units. Where direct reference is made to SA conditions, the equivalent SI value is given in brackets.

The following abbreviations are used in this report.

psi	:pounds per square inch
kPa	:kiloPascals
m	:metres
"	:inches
'	:feet
kg	:kilogramme
w	:width (roadway)
h	:height (roadway)

As many units quoted are in Imperial units, these can be approximately converted to SI units with the following table, which has some of the commonly quoted figures.

conversion table

Imperial	SI (Approximate)
1 psi	6,895 kPa
20 psi	140 kPa
50 psi	350 kPa
1"	0,0254 m
6"	0,15 m
20"	0,50 m
1'	0,3 m
10'	3,0 m
15'	4,5 m
20'	6,0 m
200'	60 m

1 Introduction

Methane explosions in coal mines are fortunately not common occurrences. However, when they do occur, their effects can be devastating. Control measures to minimize their occurrence are for the most part in place in the mines. For an explosion to occur, three elements have to exist at the same time in the same place: a methane concentration of between 5 and 15%, sufficient oxygen and an ignition source. If sufficient coal dust is present the consequence of a methane explosion is raised by at least an order of magnitude.

In the working areas of a mine there are overlapping precautions in place to protect against each one of the above elements. There is a sufficient air supply to dilute methane emissions. There are monitoring instruments to warn against build-ups of methane. All equipment that is used in areas where there could possibly be methane is flameproofed. Open flame and hot spark generating objects are forbidden underground. Stonedusting is applied to inertize coal dust. There are precautions in place to prevent the existence at dangerous levels of each of the elements, and the probability of all of them existing at the same time at the same place are remote indeed.

However, large areas of the mines are sealed off. It is just not possible to operate a mine and keep all the workings ventilated and patrolled. Behind the seal walls, there is no or little active control over the atmosphere. If stonedusting had been correctly applied at the time of mining then there should not be a build-up of coal dust to dangerous levels because there no longer is a source of dust. However, in the absence of ventilation, methane that continues to emit from the coal pillars or even coal spillage where the pillars had been extracted, can build up into the explosive range. South African coals are characterised by lower methane contents and release rates than those in the USA and Australia and the atmosphere is then likely to contain an explosive mixture of methane and air for longer time periods than in those countries. Most of the potential ignition sources do not exist in sealed areas, but ignitions can still occur, such as by friction from falls of roof.

In contrast to the working sections of a mine, it is thus possible - even if not likely - for methane explosions to occur in sealed areas even when all the precautions have been taken. If it occurs, there are two possible hazards to which workers in the active areas of a mine may be exposed. Firstly, the explosion itself or at least the forces generated by it can extend into the workings and there cause bodily harm. If this does not happen it is still possible for the atmospheric by-products of the explosion, like lethal carbon monoxide, to filter into the workings through damaged seals.

The most practical protection against this possibility is to construct seals that are strong enough to withstand a possible explosion in the sealed area. This is a statutory requirement in South African coal mines.

There has not been any formal research carried out in South Africa into suitable construction methods and materials. This literature survey was done to find out how this is handled in other countries, mainly the USA and Australia with comparable mining conditions and mining methods.

It is concluded that although suitable materials and construction methods are available, the only methods of approval are full scale testing, which are costly and impractical. Research is required into the non-destructive and small scale testing of suitable designs and materials.

2 Explosion seal testing research

Seals have been exposed to full scale explosions in many parts of the world, and have been shown to withstand pressures of 319 psi however for design purposes the maximum pressure is usually quoted as 20 psi to 50 psi and sometimes to 70 psi. The USBM, the European Community for Coal and Steel (ECCS), the National Coal Board (NCB), and the Experimental Mine Company (EMC) in Germany, carried out most of the experimental work.

2.1 Materials

Explosion proof bulkhead materials have commonly been chosen for cost and availability rather than strength, with lack of strength being compensated for by an increase in mass.

2.1.1 Sandbags

A traditional sealing method, with a standard of $T = w/3 * h$. Girders must be used at the top of the seal to prevent shifting of the bags, and air leakage becomes excessive as the sand compacts.

2.1.2 Masonry

Either concrete or limestone blocks, with a wall thickness of 1,5 ft to 3 ft provides adequate explosion strength, this being further improved by keying into the walls and floor.

2.1.3 Concrete

Both plain and reinforced concrete have been used, with USBM tests showing that reinforcing is not necessary. Bulkhead thickness is $W/4$ or $H/4$ (whichever is the greater) for plain concrete and $W/10$ or $H/10$ for reinforced concrete.

Shrinkage and slumping from the roof are disadvantages of concrete and this has resulted in its lack of favour in Europe.

To withstand 50 psi, plain concrete is suitable with the following standards:

$$\text{Thickness (T) > } \frac{\text{width (w)}}{10} \quad \frac{w}{8} \text{ (for soft coal)}$$

$$\text{Rib Recess (R) > } \frac{w}{10} \quad \frac{w}{5} \text{ (for soft coal)}$$

$T > 12$ inches for all bulkheads.

2.1.4 Fly ash cement

The availability of fly ash makes it a popular material, and it provides strength up to 100 psi. A slow minimum setting time of three days counts against it for emergency applications. Standard for use is $W/4$ or $H/4$ (whichever is the greater).

2.1.5 Gypsum products

Typical commercial products have setting times of 15 to 90 minutes, and provide strengths of 100 psi to 600 psi. An advantage of gypsum is that it deforms plastically before failure, so can withstand repeated explosions and ground movement.

2.1.6 Water bags

Testing in Europe showed that bag strength is a key feature for water bag barriers, and fire protection is required.

2.1.7 Composite construction

A common and relatively inexpensive method of using a filler material, such as waste or stone dust between two or more retaining walls.

Wooden walls do not provide adequate strength, but masonry walls do, as well as good air sealing.

2.1.8 Review of materials

Different research agencies and different countries have worked on similar construction materials, but produced slightly different results or guidelines, probably affected by local conditions, and varying test methods.

Tables 2.1 and 2.2 show some results for the standard construction materials.

Table 2.1 is from the US, and was produced following the Federal Coal Health and Safety Act of 1969, when further work was carried out on alternative materials and construction methods. The different materials were all considered suitable to withstand 50 psi if constructed to the minimum thickness shown.

Table 2.1 Minimum bulkhead thicknesses to withstand 50 psi

Material Type	Minimum Thickness
Concrete	$t/4$
Concrete, reinforced	$t/10$
Concrete blocks	16 inch
Fly ash	$t/4$
Gypsum	$t/4$
Rock, grouted	$w + h/2$
Rock, packed	$2t$
Sand bags	$wh/3$

Where : $t = w$ or h , whichever is greatest
 $w =$ average width of roadway
 $h =$ average height of roadway (plus depth of recess for concrete block and reinforced concrete bulkheads)

Similar work in Germany produced the expected pressure withstood by different seal types. The test findings are given in Table 2.2.

Table 2.2 Bulkhead construction and maximum pressure

Type	Construction	Pressure (psi)
Single masonry wall	20" to 30"	20 to 40
Double masonry walls, rockdust fill	20" walls, 15' fill	319
Cement, rock dust, water	19' thick, full setting time	57
Cement, rock dust, water	19' thick, 8 hours setting	28,5

2.2 Design techniques

Most development work has been by trial and error full scale testing, but some basic techniques have been developed for design.

There are four major categories of structure developed and tested, plugs, baffles, thin plate and thick plate.

2.2.1 Plug

Has thickness in the order of its width, and resists force by inertia and friction.

2.2.2 Baffle

Composite bulkheads are baffles, absorbing energy by reflection or deformation.

2.2.3 Thin plate

The thickness is less than one tenth of the width, characterised by bending with simple supports.

The thickness can be calculated, however this is very conservative, and most bulkheads have withstood pressures of 10 times the design.

$$T = 0,865 a(p/s_t)^{1/2}$$

Where:

T = thickness

a = maximum dimension

p = design pressure

s_t = tensile strength

2.2.4 Thick plate

The thickness is greater than one tenth of the width, and this induces arching superimposed on the bending.

The calculated thickness is approximated to:

$$T = 0,707 a(p/s_c)^{1/2}$$

Where:

s_c = compressive strength

2.3 Conclusions of full scale research

The main conclusions of these tests were that explosion proof bulkheads are generally over designed, are excessively massive, and prone to leakage after exposure to the explosion pressures.

Explosion pressures very seldom exceed 20 psi more than 200 feet from an explosion unless there is an excessive accumulation of coal dust, so bulkheads can be considered explosion proof if they withstand a pressure of 20 psi.

Most design work has been by trial and error, with full scale testing, and the guidelines that were developed for thin and thick plate seals are far too conservative to be practical.

More recent research work, carried out at the USBM Lake Lynn facility has been directed at practical construction and practical functioning of seals capable of withstanding 20 psi.

3 Requirements of seals

3.1 Minimum requirements

The Lake Lynn research was used in part to develop the present US regulations, and has identified the following requirements for seals:

- withstand a static pressure of 20 psi (regulation 30 CFR § 75.335 for all alternative seal methods or materials)
- control the gas-air exchanges between the sealed and open areas;
- prevent an explosion from propagating from one side to the other;
- continue to function for one hour when subjected to a fire test (ASTM E119-88)¹.

In Australia, the Queensland DME also stipulates that a seal should meet these same requirements within 24 hours of construction.

3.2 Leakage after explosion

To measure the control of gas-air exchange, MSHA have developed guidelines, additional to the regulations, for allowable air leakage across seals after exposure to a 20 psi explosion front. These are given in Table 3.1.

Table 3.1 Air leakage guidelines for post-explosion approval

Pressure differential (inches water)	Air leakage through seal (cfm)
< 1	< 100
< 2	< 150
< 3	< 200
> 3	< 250

4 Regulations

Present US regulations are based on research work carried out by MSHA at the Lake Lynn facility (Weiss et al, 1993), and these regulations form the basis of present seal specifications for coal mines.

In Australia the Queensland DME published Approved Standard for Ventilation Control Devices in 1996, with the same requirements as the US, but with the addition of meeting these requirements within 24 hours.

The US Code of Federal Regulation (CFR), Title 30, Part 75.335 is the regulation pertaining to the construction of seals, and is available at <http://www.msha.gov/REGS/FEDREG>.

¹ ASTM E119-88 constructs the seal as one wall of a test furnace and increases the furnace heat rapidly over an hour. The wall must not permit passage of flame, heat or gases hot enough to ignite cotton waste on the opposite side.

4.1 30 CFR § 75.335

Construction of seals.

(a)(1) Each seal constructed after November 15, 1992, shall be--

(i) Constructed of solid concrete blocks at least 6 by 8 by 16 inches, laid in a transverse pattern with mortar between all joints;

(ii) Hitched into solid ribs to a depth of at least 4 inches and hitched at least 4 inches into the floor;

(iii) At least 16 inches thick. When the thickness of the seal is less than 24 inches and the width is greater than 16 feet or the height is greater than 10 feet, a pilaster shall be interlocked near the center of the seal. The pilaster shall be at least 16 inches by 32 inches; and

(iv) Coated on all accessible surfaces with flame-retardant material that will minimize leakage and that has a flame-spread index of 25 or less, as tested under ASTM E162-87, "Standard Test Method for Surface Flammability of Materials Using A Radiant Heat Energy Source." This publication is incorporated by reference and may be inspected at any Coal Mine Health and Safety District and Subdistrict Office, or at MSHA's Office of Standards, 4015 Wilson Boulevard, Arlington, VA, and at the Office of the Federal Register, 800 North Capitol Street, NW., Suite 700, Washington, DC. In addition, copies of the document can be purchased from the American Society for Testing (ASTM), 1916 Race Street, Philadelphia, Pennsylvania 19103. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552(a) and 1 CFR part 51.

(2) Alternative methods or materials may be used to create a seal if they can withstand a static horizontal pressure of 20 pounds per square inch provided the method of installation and the material used are approved in the ventilation plan. If the alternative methods or materials include the use of timbers, the timbers also shall be coated on all accessible surfaces with flame-retardant material having a flame-spread index of 25 or less, as tested under ASTM E162-87, "Standard Test Method for Surface Flammability of Materials Using A Radiant Heat Energy Source." This publication is incorporated by reference and may be inspected at any Coal Mine Health and Safety District and Subdistrict Office, or at MSHA's Office of Standards, 4015 Wilson Boulevard, Arlington, VA, and at the Office of the Federal Register, 800 North Capitol Street, NW., Suite 700, Washington, DC. In addition, copies of the document can be purchased from the American Society for Testing (ASTM), 1916 Race Street, Philadelphia, Pennsylvania 19103. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552(a) and 1 CFR part 51.

(b) A sampling pipe or pipes shall be installed in each set of seals for a worked-out area. Each pipe shall--

(1) Extend into the sealed area a sufficient distance (at least 15 feet) to obtain a representative sample from behind the seal;

(2) Be equipped with a cap or shut-off valve; and

(3) Be installed with the sampling end of the pipe about 12 inches from the roof.

(c)(1) A corrosion-resistant water pipe or pipes shall be installed in seals at the low points of the area being sealed and at all other locations necessary when water accumulation within the sealed area is possible; and

(2) Each water pipe shall have a water trap installed on the outby side of the seal.

[61 FR 9828, Mar. 11, 1996; 61 FR 29289, June 10, 1996]

4.2 Method of construction

Although the regulation states the method of construction (a)(1)(I)-(iv)², it allows for alternative methods and materials (a)(2), with the minimum requirement of withstanding the static horizontal pressure of 20 psi.

The standard method of construction, as described in the regulations is of solid concrete blocks, hitched, or keyed, at least four inches into the floor and ribs, and is shown in Figure 4.1.

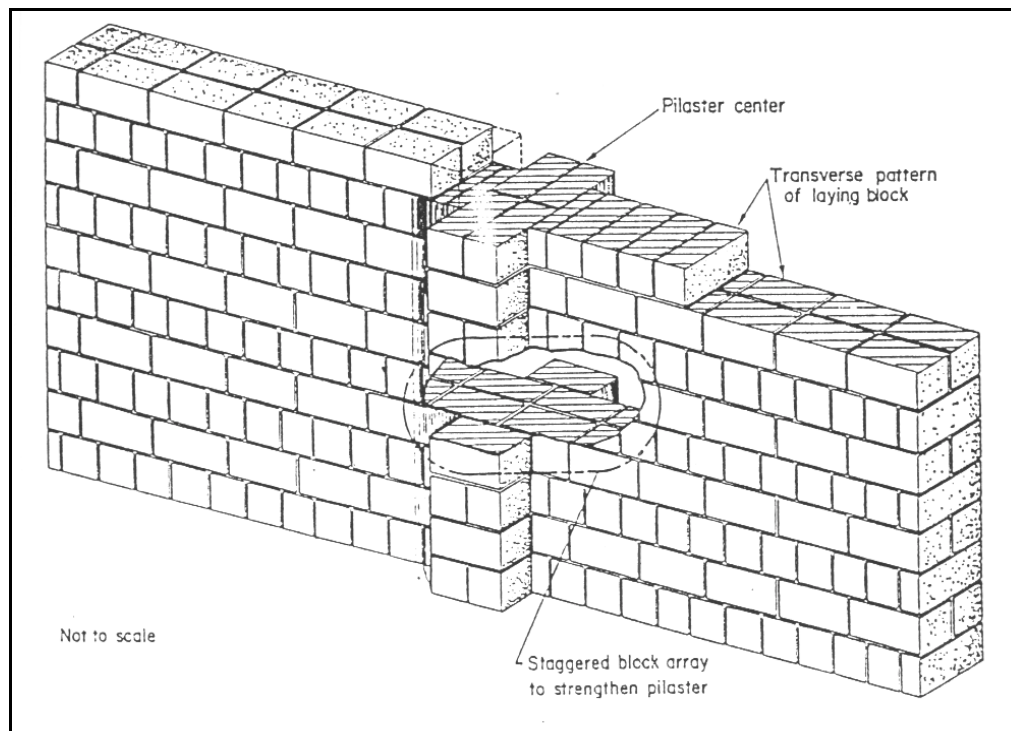


Figure 4.1 US regulation seal construction

² Numbers in parentheses refer to paragraphs in 30 CFR § 75.335.

5 Testing procedures

Full scale testing is considered to be the only satisfactory method of fully evaluating bulkheads, although small scale testing does provide some information to different loading rates. Some *in situ* testing of sidewall, roof and floor strata may be required to confirm adequate strength for recessing the walls.

5.1 Small scale tests

These are useful for qualitative observations in terms of bulkheads, but are required for site specific work in regard of anchoring and flashing and edge sealing materials, to ensure adequate rock strength for anchors and keying, and to ensure adequate bonding between the seals and the rock.

5.1.1 Bulkhead seal tests

Figures 5.1 and 5.2 show methods for testing the bonds between edge sealant and the rock and flashing materials, and Figure 5.3 for testing air leakage.

5.1.1.1 Bonding strength

Figure 5.1 shows a foam sealant bonded to a sheet metal flashing, and the strata sample. Measured force is applied to the flashing, and the displacement at x and y measured with increasing force.

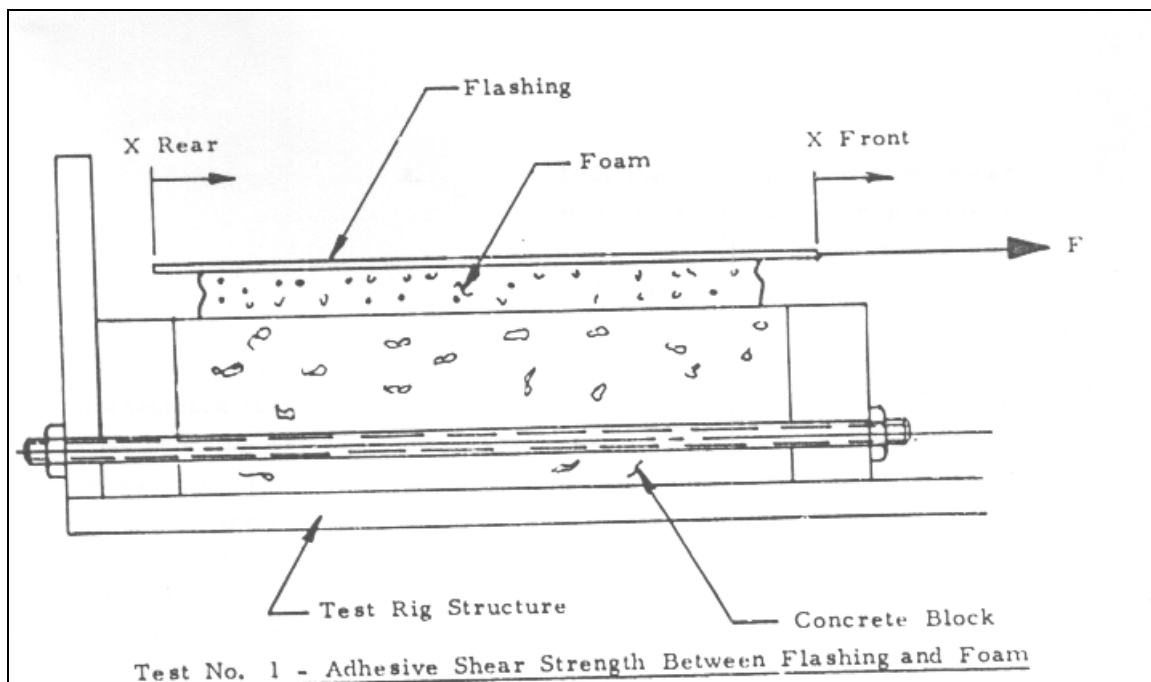


Figure 5.1 Small scale test for flashing to sealant bond

Figure 5.2 shows the same test but for bonding between the sealant and the strata. The force is applied to the sealant via a metal grid embedded in the sealant.

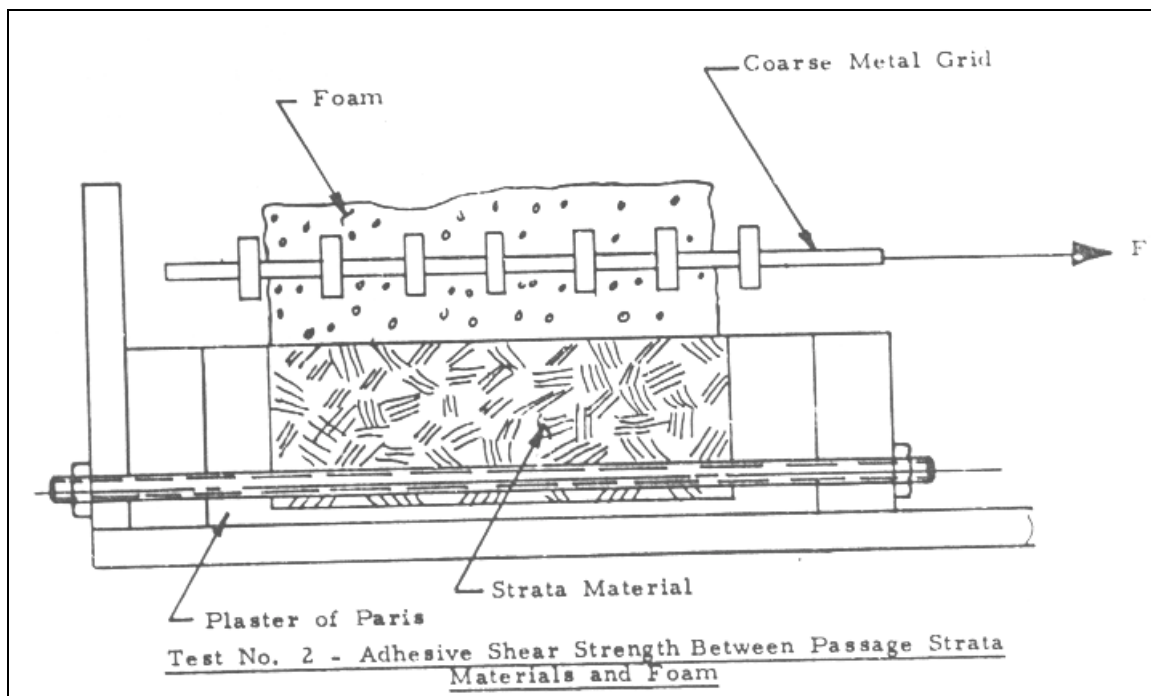


Figure 5.2 Small scale test for sealant to strata bond

5.1.1.2 Leakage

Air leakage tests are tested as shown in Figure 5.3. The flashing and sealant are bonded to a base (concrete or strata) and the pressure applied by means of a water bladder. Additional displacement is applied from an adjustable roof and bulkhead displacement.

After pressurising to 40 psi with the water bladder, the pressure is removed, and low pressure air flow applied across the system. Leakage rate across the seal is measured.

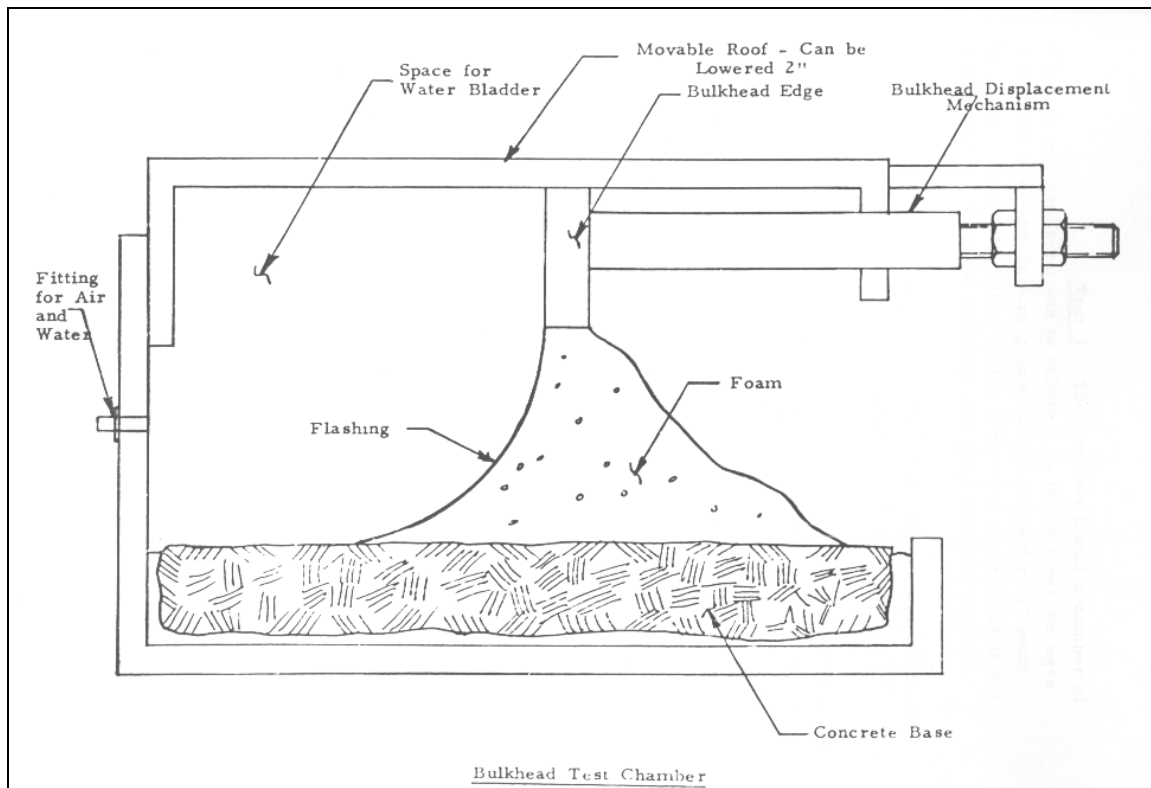


Figure 5.3 Small scale leakage test

5.2 Full scale tests

All tests for compliance with the regulations of MSHA guidelines are carried out in the full scale explosion galleries at lake Lynn. The galleries and procedures are well documented in literature, and in the Appendix to this report, and will only be reviewed briefly here.

The galleries are shown in Figures 5.4 and 5.5, with Figure 5.5 showing the configuration for an explosion test, with the ignited gas zone isolated by a diaphragm. This gas is ignited and the explosion is contained within Drift C by the seals being tested, and a bulkhead positioned across Drift E.

During an explosion the seals constructed in the crosscuts must prevent the passage of flame from Drift C to Drift B.

The test configuration for the subsequent air leakage tests is shown in Figure 5.6 and 5.7. Air pressure is maintained in Drift C and the leakage measured through the seals by means of a second seal with a small open window, as shown in Figure 5.7

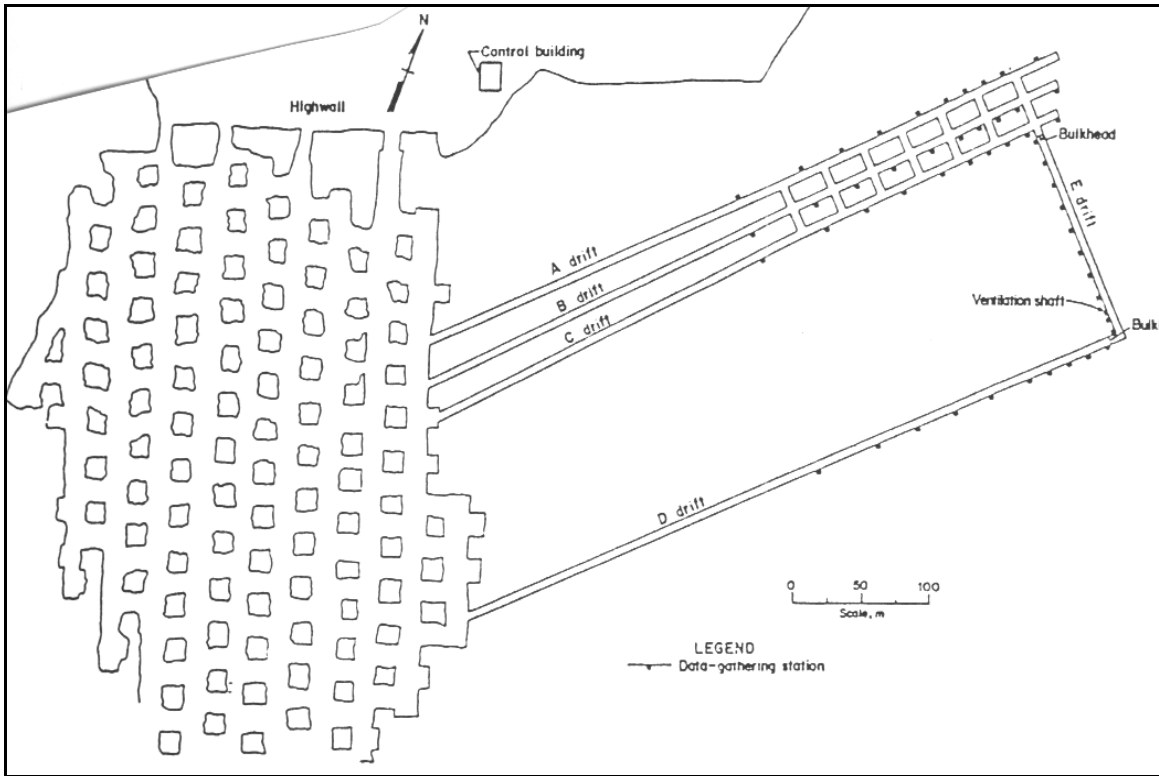


Figure 5.4 Lake Lynn explosion test facility

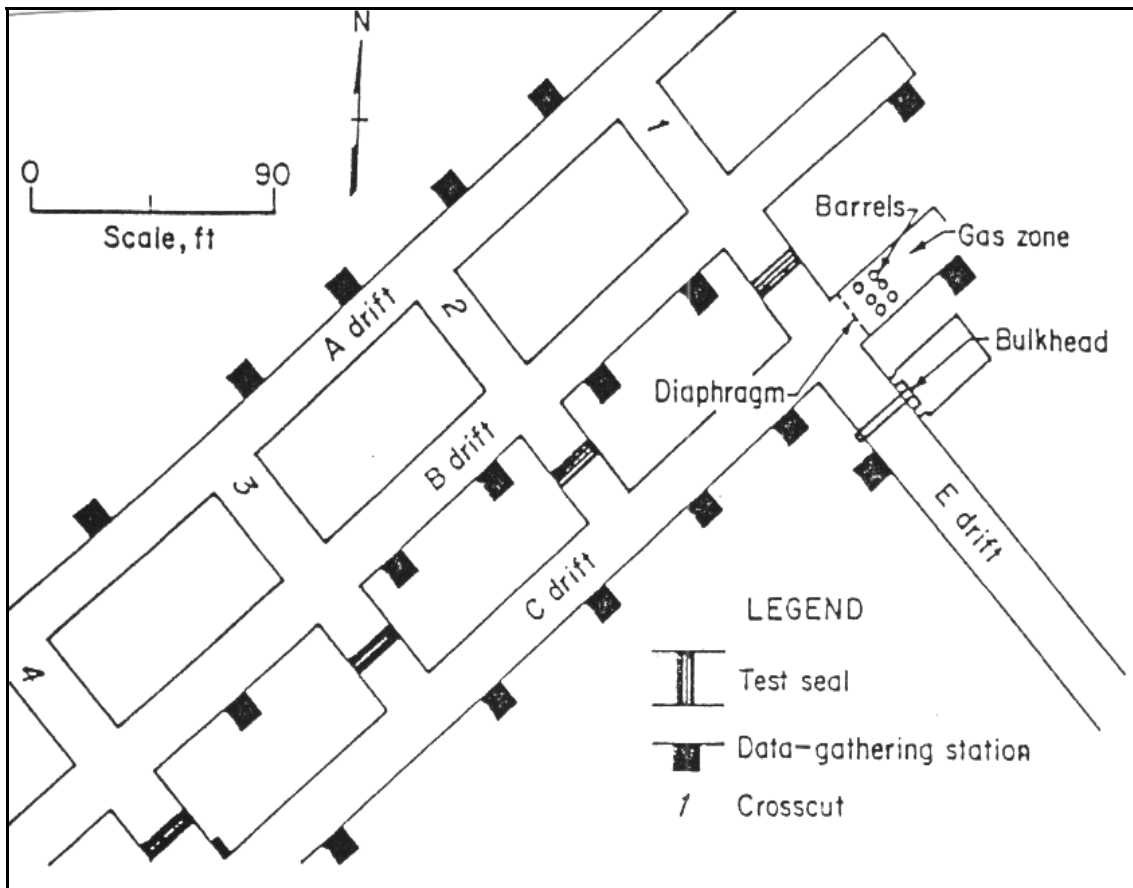


Figure 5.5 Explosion test setup

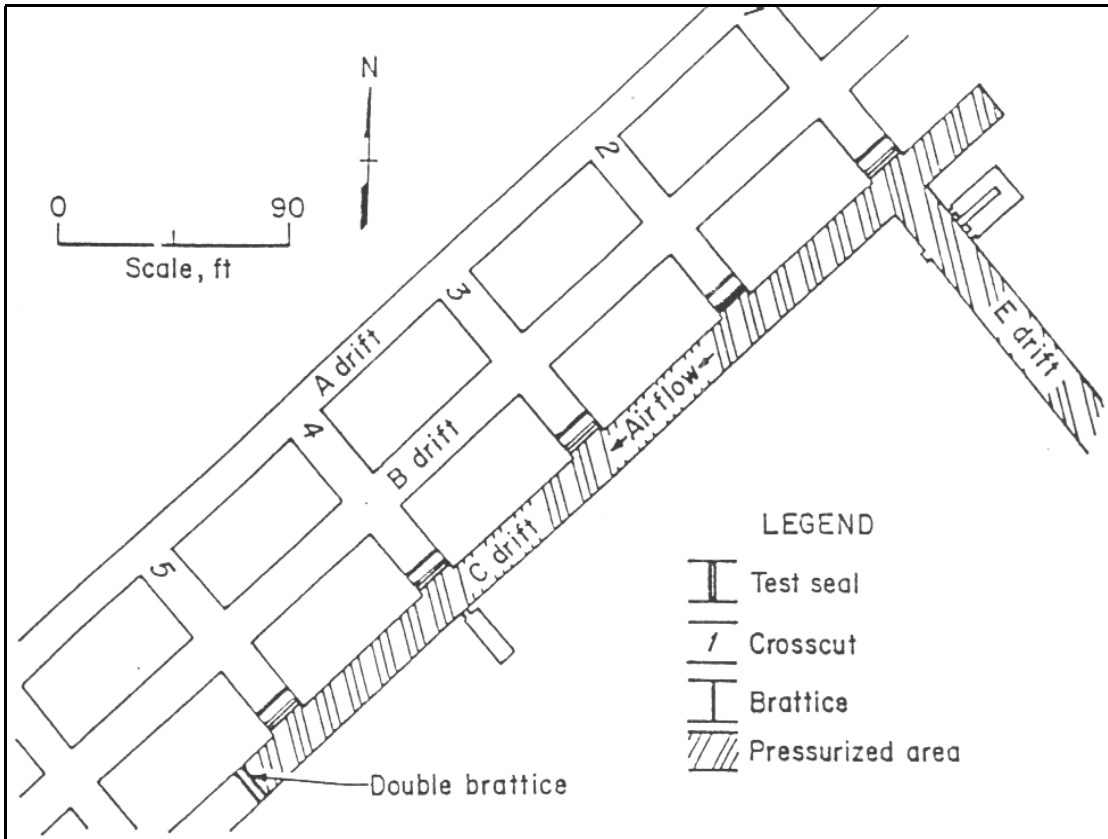


Figure 5.6 Lake Lynn air leakage set up

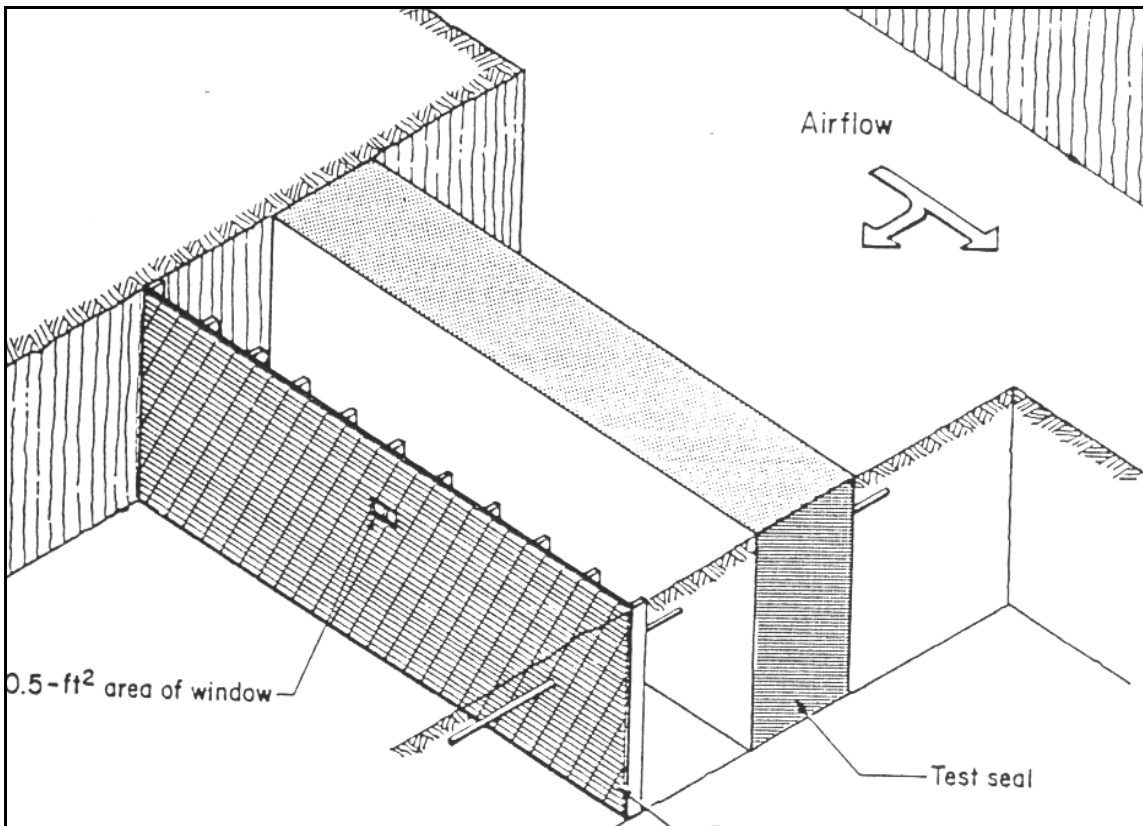


Figure 5.7 Seal air leakage test

5.3 *In situ* strength tests

The roof, floor and ribs must be sufficiently strong to support the wall, depending on the design used. Some *in situ* tests can be carried out, these depending on the design of the wall.

An example of this is given in Figure 5.8, showing a shear strength test for floor strata. For trenching it is recommended this is a minimum of 160 psi, and typical SA conditions of shale/siltstones have strength of 220 psi (1500 kPa).

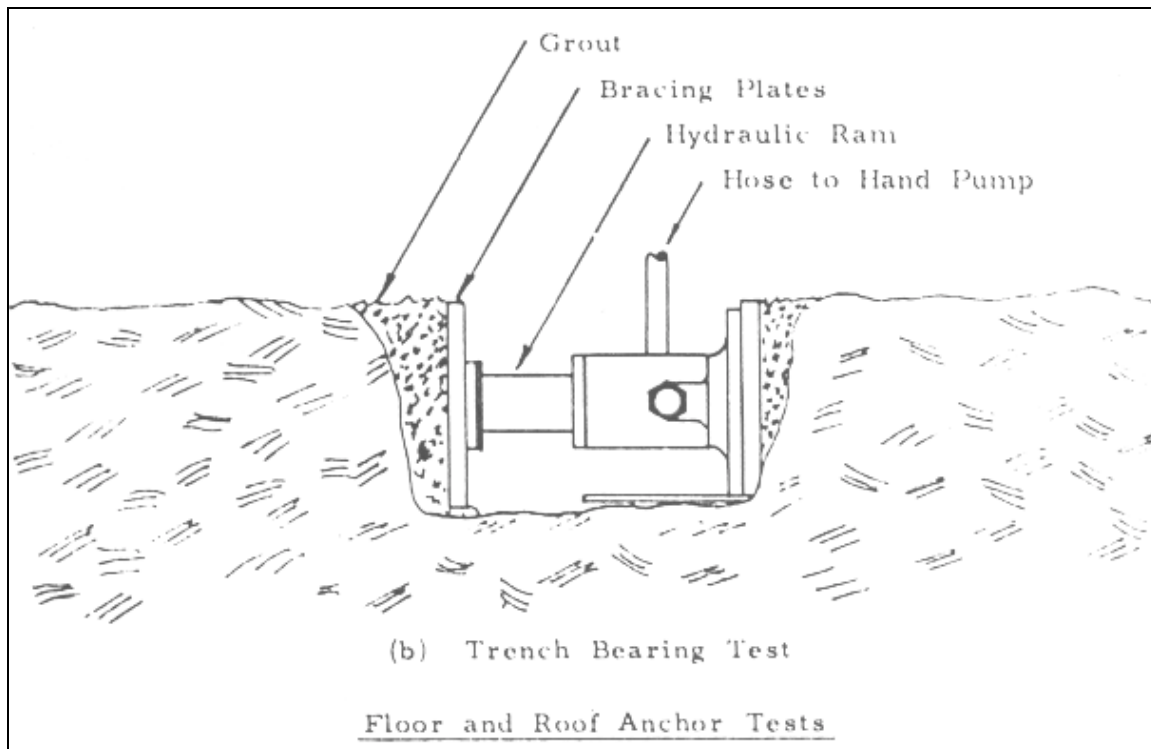


Figure 5.8 Roof and floor shear strength test.

6 MSHA approved seal construction methods

Solid concrete blocks, Omega 384 foam blocks and cementitious foams are all approved by MSHA for seal construction, but only with specific design and construction criteria. Note that MSHA do not endorse any of the specific named brand products, only the type of material or construction method.

6.1 Solid concrete blocks

Must be constructed to standard according to 30 CFR § 75.335. i.e. 16 inches thick wall of solid concrete blocks staggered and mortared, a centre pilaster and keying at the floor and ribs.

6.2 Omega 384 foam blocks

Four construction methods are approved for these low density fibreglass blocks. Blocks must be staggered and a surface bonding mortar applied to both sides of the wall. The wall must be keyed to the floor and ribs.

Walls are either 24 or 32 inches thick with either a centre pillaster, or two pillasters at equal one-third spacings.

6.3 Cementitious foam seals

Approved for foams of compressive strength 200 psi, and a seal thickness of 4 feet and 8 feet. The seal is not necessarily keyed to the floor and ribs.

6.4 Polymer foam seals

Two polymer foam seals are approved, with and without aggregate. These are for a 20" thick, 580 lb/yd³ foam core with no aggregate, between dry stacked concrete block walls; and for a 16" 450 lb/yd³ foam with an aggregate of 1300 lb/yd³ density four tenths to three quarter inch stone, between dry stacked concrete block walls.

6.5 Not approved

Wooden block seals all failed the air leakage tests.

Water traps constructed as industry norms did not prevent the passage of flame and gases from one side of a seal to the other.

7 Conclusions

The definition and requirements of explosion proof seals as applied in the USA and Australia may not meet with South African requirements. The seals are defined to meet requirements as relatively short life post explosion, and may not necessarily remain operational in terms of maintaining the operating functions of the mine, after the shorter term life saving requirements.

7.1 Requirements

As defined by MHSA, an explosion proof seal must:

- withstand a static pressure of 20 psi.
- control the gas-air exchanges between the sealed and open areas;
- prevent an explosion from propagating from one side to the other;
- continue to function for one hour when subjected to a fire test

7.2 Testing methods

The only effective way of proving explosion proof stoppings is by full scale testwork, using methane/air or coal dust explosions.

Small scale tests can provide some qualitative evaluations of seals, however small scale testing should be restricted to determining the bond strengths between edge seals and flashing and sidewall materials. There is some limited use of small scale tests for determining air leakage between the seal and the strata afetr being exposed to pressure.

There are no effective non-destruction means of testing, or means of *in situ* tests for existing seals.

7.3 Research work

Research prior to 1970 in the USA and Europe concluded that explosion proof bulkheads can withstand pressures in excess of 300 psi, but are generally impracticably massive and over designed.

More recent work has been directed at the practical construction of seals capable of withstanding a pressure of 20 psi. However this definition has limitations.

7.4 Regulations

Present regulations in the US and Australia considers the limits of practicality of construction and of function for seals. These have been developed from testwork carried out by the USBM and MSHA at the Lake Lynn facility, and stipulate withstanding a pressure of 20 psi, based on this being the maximum pressure at 200' from an explosion. In Australia requirements must be met within 24 hours of construction.

7.5 Construction

Seal construction is by concrete blocks, as described in the US regulations, or by any other method that satisfies the criteria.

Approval of other types of seals is obtained from MSHA by full scale explosion testing at Lake Lynn, where a seal must meet the MSHA guidelines for air leakage as well as the regulated 20 psi. There is present discussion as to the cost and necessity of such full scale testing requirements for seals in the US.

Four different alternative construction methods and materials have been approved to date, these being concrete blocks, Omega foam blocks, cementitious foam and polymer foam.

8 Recommendations

The requirements of an explosion proof seal for the South African industry must be defined. For short operational life post-explosion, the US requirements of withstanding 20 psi with limits on air leakage is adequate. However the objective of these seals is to maintain an adequate fire and gas seal for one hour after exposure, to ensure adequate escape time for the workforce. This may not ensure the long term operational life of the mine and workings.

A suitable testing method is required. Compliance for construction, and alternative means of construction or materials can only be given by full scale explosion testing, and at present these procedures are designed around the existing MSHA facility. This is expensive and impractical for the SA industry. Methods for consideration should include not only large scale tests but also develop non-destructive test methods for *in situ* evaluation of existing seals, and small scale tests to provide at least initial evaluations.

Any construction method approved by the USBM, as complying with the US requirements is acceptable for seal construction to ensure one hour of post explosion operation, however to ensure post-explosion operation of the mine, the traditional methods of over design in construction are still required.

Bibliography

Due to the amount of information contained within some of the documents, particularly regarding bulkhead calculations, articles consulted in the compilation of this report are not referenced directly in the text, so are included as a bibliography for further reading.

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APPENDIX I Definitions from US regulations.

30 CFR § 75.301

Definitions

Noncombustible Structure or Area. Describes a structure or area that will continue to provide protection against flame spread for at least 1 hour when subjected to a fire test incorporating an ASTM E119-88 time/temperature heat input, or equivalent. The publication ASTM E119-88, "Standard Test Methods for Fire Tests of Building Construction and Materials" is incorporated by reference and may be inspected at any Coal Mine Health and Safety District and Subdistrict Office, or at MSHA's Office of Standards, 4015 Wilson Boulevard, Arlington, VA, and at the Office of the Federal Register, 800 North Capitol Street, NW., Suite 700, Washington, DC. In addition, copies of the document can be purchased from the American Society for Testing Materials (ASTM), 1916 Race Street, Philadelphia, Pennsylvania 19103. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552(a) and 1 CFR part 51

Noncombustible Material. Describes a material which when used to construct a ventilation control results in a control that will continue to serve its intended function for 1 hour when subjected to a fire test incorporating an ASTM E119-88 time/temperature heat input, or equivalent. The publication ASTM E119-88, "Standard Test Methods for Fire Tests of Building Construction and Materials" is incorporated by reference and may be inspected at any Coal Mine Health and Safety District and Subdistrict Office, or at MSHA's Office of Standards, 4015 Wilson Boulevard, Arlington, VA, and at the Office of the Federal Register, 800 North Capitol Street, NW., Suite 700, Washington, DC. In addition, copies of the document can be purchased from the American Society for Testing Materials (ASTM), 1916 Race Street, Philadelphia, Pennsylvania 19103. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552(a) and 1 CFR part 51.