

# Chapter 69

## SYSTEM DESIGN ANALYSIS FOR EXPLOSION PROTECTION OF MINE FANS

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Abstract An explosion in an underground coal mine can have a devastating effect on the main fans used to provide mechanical ventilation. The Code of Federal Regulations, Title 30, Part 75.310 (CFR, 1992), specifies that each main mine fan shall be offset by at least 15 feet (4.6 m) from the nearest side of the mine opening unless an alternative method of protecting the fan is approved in the ventilation plan. Also, each main mine fan shall be protected by one or more weak walls or explosion doors. This paper presents venting and fan configuration designs which provide a comparable degree of safety for explosion protection. Design flexibility is enhanced and a means for consistency in safety judgments is afforded.

### INTRODUCTION

This paper provides engineering information to aid safety engineers and inspectors for judging the safety of fan installations. Some guidelines are given which provide fan protection beyond that required by Federal regulations.

An underground mine explosion may produce egress of air from a mine opening which is nothing more than a mild wind. Or, the discharge may be a violent blast of air or a shock or detonation wave. In the extreme case, the area surrounding a mine opening may be blown away causing damage beyond repair to the fan and housing. On the other hand, a violent explosion deep underground may produce little disturbance on the surface.

A main fan and its housing may sustain explosion damage from an explosion wind, from debris propelled by the wind or from a shock/detonation front. A study (Conn, 1992) examined potential damage to a fan from these effects before and after explosion vents are opened. This paper summarizes the practical aspects of the study.

### MINE FAN OFFSET

Ideally, a fan is offset 90' from its air course. An offset configuration of other than 90° is at times necessary due to terrain conditions. Also, rounded 90° offsets are used to reduce ventilation shock losses. Because of these varying factors, technical guidelines are needed for the design of a fan system. Although there can be no guarantee that any given configuration will prevent fan damage from all possible explosion forces, reasonable safety measures can be designed into the fan system.

The results of this study conclude that a comparable level of protection is offered by two offset angles which sum to 90° as by a single 90' offset. The fan must be placed far enough into the second offset to protect it from debris. The analysis is based on a comparison of a 45' and a 90' offset. With the vents closed, the 90' offset does not provide more significant protection than a 45' offset for explosion wind forces on the fan blades or for debris entering the fan duct. Fan blades are assumed to be the weak link of the system. Shock waves in both offset configurations will tend to break up at the offset angle and

reform downstream. With the vents opened, the 90° offset does not provide more significant protection than a 45° offset for explosion wind forces on the fan blades. For both configurations, a shock wave will exit through the opened vents. For debris which is not entrained in the air flow, a 90° offset provides better protection for the fan than a 45° offset. The reasons are (1) more energy is required to turn debris 90° rather than 45°, (2) more energy will be dissipated by an object being forced by the walls to turn 90° rather than 45° and (3) due to geometry and inertia, the probability is less for debris traveling in a straight line down an entry to be deflected off course at 90° rather than a lesser angle. Results (Conn et al., 1992) of limited Laboratory explosion tests in ducts indicate more debris goes through a 45° than a 90° configuration.

It is for these reasons that a mine fan offset with two angles which equal 90° provides about the same level of protection as a single 90° offset. As a general design criterion, the sum of the turned angles should be 90° (within 5°) between the center line of the air course and the fan. If the initial turned angle is 45° or more, then the second turned angle may be either toward or away from the mine opening. If the initial turned angle is less than 45°, then the second turned angle must be away from the mine opening. The fan must be placed far enough into the second offset to protect it from debris.

Figure 1 shows use of the criterion and placement of explosion vents. The required venting is the projected area shown; additional venting is advisable as shown by dotted lines. The sharp 90° offset design in figure 1a is taken as the standard by which all other configurations are judged for safety. The only configurations judged safer are those greater than 90°. The greater than or equal to 15 feet distance is the legal requirement for offsetting the fan from the nearest side of the mine opening. In practice the configuration in figure 1b is used to reduce ventilation shock losses. The fan is positioned out of direct line of debris entering the fan duct. The two configurations of figure 1c and 1d could be used where the terrain would obstruct a 90° turn.

If a fan installation design cannot meet the criterion of 'energy dissipation of a 90° bend', then additional venting and/or fan protective screening

should be provided. Figure 2 shows the required vent area, the fan screen and the fan offset at least 15 feet from the nearest side of the mine opening. Although a sharp 90° bend is shown, some rounding of the inside corner would normally be made to reduce ventilation shock losses. In Fig. 3, a 90° single turn cannot be reasonably made because of the high wall configuration. Therefore, added vent area is shown and a second fan screen. The second screen should be of heavy duty construction and located 1.5 m (5 ft) or more in by the first screen. Either the added vent area or a second screen is satisfactory but the use of both would be better.

Figures 4 and 5 show "standard" shaft installations. The double 90° turn and the optional venting in Fig. 4 should provide excellent fan protection from all debris. In practice, the bends would be rounded. Figure 6 shows a 45° shaft installation. Because a 90° turn was not made, a second heavy duty fan screen is added to protect the fan. Figure 7 shows a less than 45° shaft installation. In addition to the added screen, a large grid deflector grate is shown to prevent large size debris from entering the fan entry. Figures 6 and 7 are for existing systems. New fan systems should not be this type of design.

Where additional venting is shown in the figures, about 1/3 to 1/2 of the original vent area should be added; it depends upon the geometry of a given installation. The idea is to provide debris with an exit before it reaches the fan.

#### VENTING

Two requirements are given in 30 CFR Part 75, for explosion protection of a mine fan by venting: (1) vent area (projected) equal to or greater than the connection entry and (2) that area be in direct line with possible explosion forces. Also for a diversion entry, the cross-sectional area of the fan entry should be no greater than the pressure entry (preferably less).

Venting beyond that required by regulation is often advisable because it is a simple and inexpensive way to protect the fan in the event of an explosion. The greater the vent area to vent explosions, the lower is the probability of damage to the fan and its housing. Location of additional

venting should normally be along the outby wall of the fan entry to allow as much debris as possible to be forced to the outside rather than into the fan screen. Additional venting located on the inby wall of the fan entry will aid in pressure reduction on the fan blades but probably not help much in venting debris.

Vent closures of 0.005 m (3/16 in) thick steel or less should be considered rather than a concrete block weak wall because of much faster opening during an explosion. Several vent panels covering a given vent area will react faster to explosion forces than a single large panel and are therefore preferable. When vent closure fasteners are used, they should release at 0.002 Pa (0.3 psi; 8.3 inches of water) or less. If this goal can not be met for some positive pressure systems or for high wind regions, then venting beyond that required by MSHA regulation is strongly recommended. Non-hinged vent panel covers should be tethered to prevent flying panels from causing damage or injury and to allow immediate replacement. Several vent panel fastening methods are described in NFPA 68 - Venting of Deflagrations, (NFPA, 1988).

If a concrete block weak wall system is used, then the bottom row of block should rest on a greased steel sill so that the entire wall moves easily as a single unit. There should not be mortar between the blocks; plaster, rather than surface bonding mortars, should be used to control ventilation leakage.

#### DISCUSSION

In the planning and design of a main mine fan system, consideration must be given to restoration of the system as soon as possible, should an explosion occur. Since it is vital that ventilation be restored if disrupted by an explosion, the fan entry ducting and the venting system should be capable of quick repair or replacement. Lumber, plywood and brattice cloth may serve for immediate, temporary repair of the duct/venting system in an emergency. Consideration of fan repair facilities should be planned ahead of time.

Consideration should also be given to (1) good housekeeping of the first 150 m (500 ft) inby the fan, and (2) use of several vent closure panels for a given vent area. Debris in the first 150 m (500 ft) inby which is large enough to break through the fan screen

should be removed. This may allow vent closures to open fully before large debris beyond 150 m (500 ft) reaches the mine opening. Due to inertia, smaller vent closure panels open more quickly than larger (heavier) panels. Calculation also show that during the initial opening of vents, 0.005 m (3/16 in) steel panels are far more effective, by several times, than concrete block weak walls for slowly developing explosion winds.

Offsetting the fan from the mine opening and providing venting in direct line of explosion forces are good fan protection measures. Flexibility of design and consistency of safety judgements are provided by the drawings presented in this paper.

#### REFERENCES

- Code of Federal Regulations (CFR), 1992, "Part 75, Mandatory Safety Standards, Underground Coal Mines, Subpart D, Ventilation," Title 30, p. 515.
- Conn, J. W., 1992, "Explosion protection of Mine Fans", internal technical report, U. S. Department of Labor, MSHA, 62 pp.
- Conn, J. W., Murtaugh, S. M. and McCord, W. M., 1992, "Explosion Protection of Mine Fans - Laboratory Tests", internal technical report, U. S. Department of Labor, MSHA, 32 pp.
- NFPA 68, 1988, "Description of Deflagration Vent5 and Vent Closures,11 Chapter 9, Guide for Venting of Deflagrations, National Fire Protection Association, Quincy, Massachusetts, pp. 42-46.

## TOP VIEWS

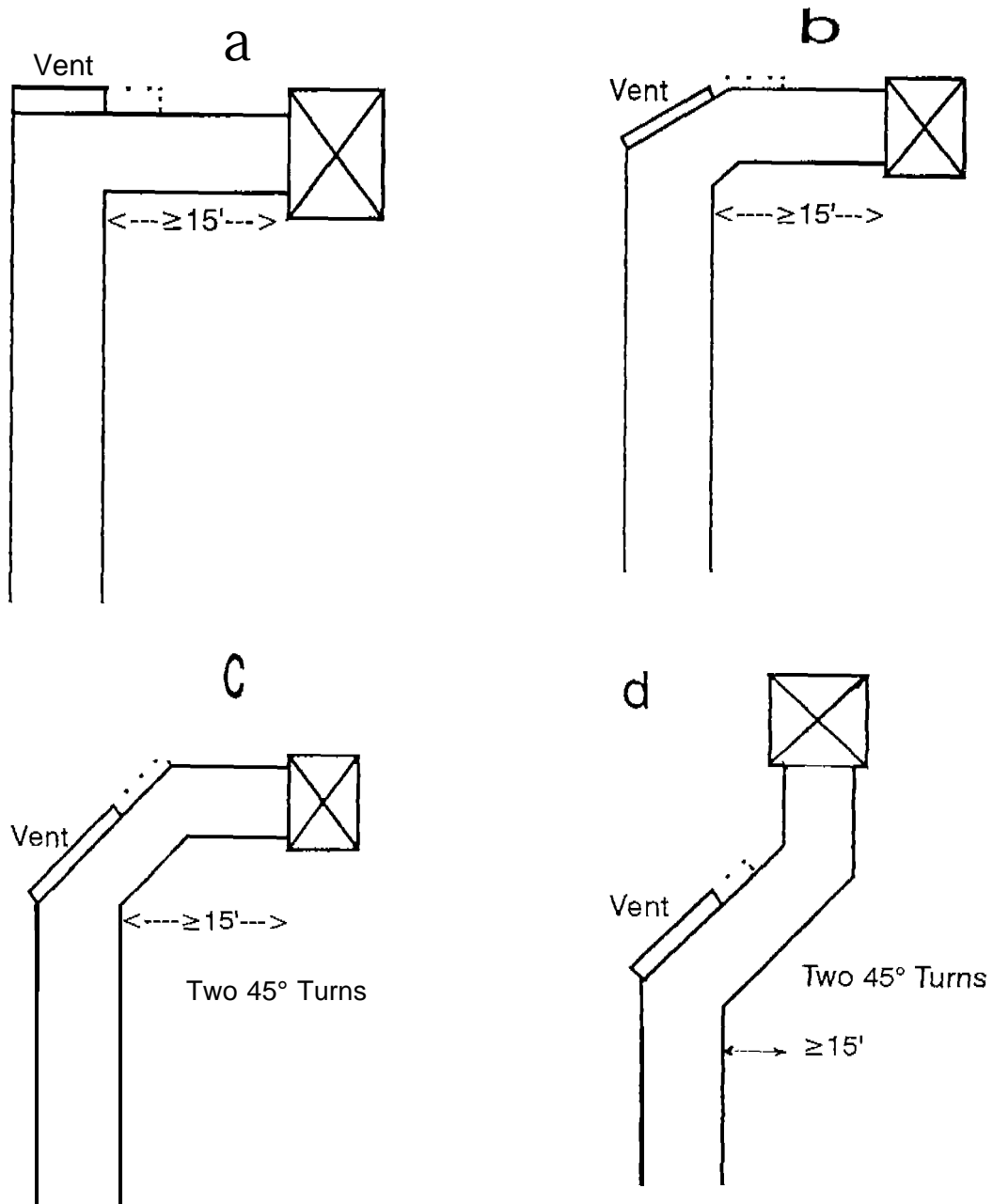


Figure 1. CONFIGURATIONS OF COMPARABLE SAFETY FOR FAN PROTECTION WHEN THE VENTS ARE OPEN

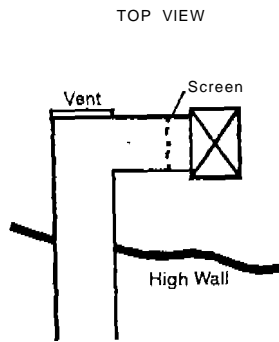


Figure 2. A 'STANDARD' 90° INSTALLATION

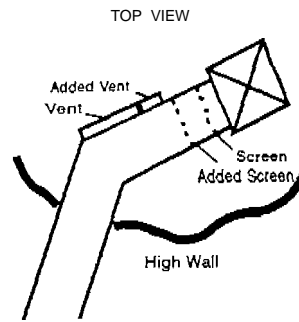


Figure 3. A SINGLE 50° ANGLE INSTALLATION WITH ADDED VENT AND ADDED SCREEN

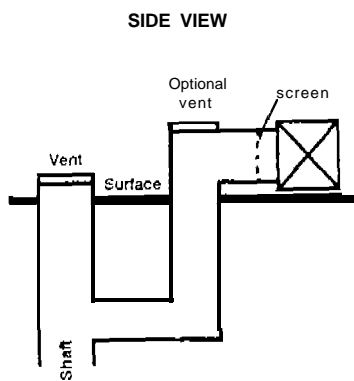


Figure 4. A 'STANDARD' 90° SHAFT INSTALLATION WITH AN OPTIONAL VENT

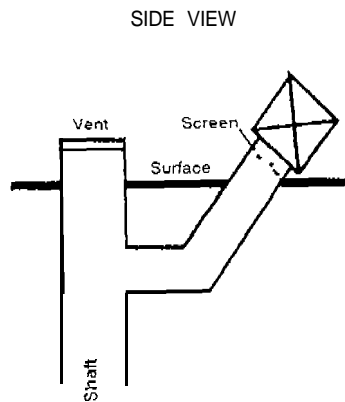


Figure 5. A 'STANDARD' 90° SHAFT INSTALLATION

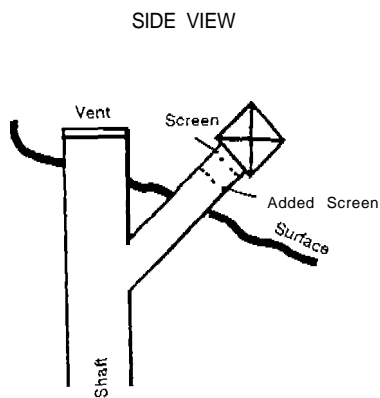


Figure 6. A SINGLE 45° SHAFT INSTALLATION WITH ADDED SCREEN

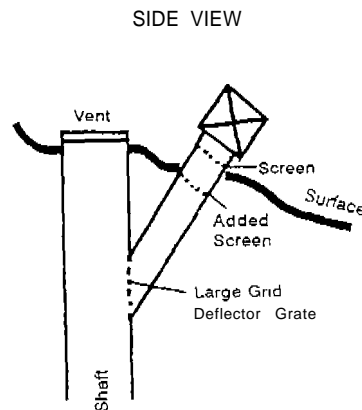


Figure 7. A LESS THAN 45° SHAFT INSTALLATION WITH ADDED SCREEN AND DEFLECTOR GRATE