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MARCH 1983**

EVALUATION OF DUST SOURCES AND CONTROL TECHNIQUES FOR CONVENTIONAL MINING VOL. II - GUIDELINES

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15. Abstract (Limit 300 words) <p>This report presents guidelines on methods of dust control in conventional coal mining operations. The normal mining cycle and equipment used in a room-and-pillar conventional section are described. Main ventilation, section ventilation, and face ventilation are discussed in detail. Proper installation of line brattice, maintenance of proper airflows at the face, and split ventilation are stressed. The effects of maintaining the end-of-the-line brattice near the face are described. The advantages and disadvantages of blowing and exhausting face ventilation are presented, and the use of water sprays on cutter bars and loading machines is described. The design of a nonclogging water spray system developed under a Bureau of Mines contract is presented. Other methods of reducing dust exposure are discussed and include alternative procedures for shot firing and administrative controls.</p>				
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FOREWORD

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The technical effort was conducted by MSAR under the direction of Mr. S.J. Rodgers.

Volume II presents guidelines on methods of dust control for conventional mining operations.

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1.0 INTRODUCTION

The 1977 Federal Coal Mine Health and Safety Act requires that each operator shall continuously maintain the average concentration of respirable dust in the mine atmosphere during each shift to which each miner in the active workings of such mine is exposed at or below 2.0 mg/m^3 (MRE equivalent). Compliance with the standard is determined by portal to portal sampling with man mounted dust samplers on individual people who engage in "high risk" occupations.

Currently one-fourth of the underground coal is produced from conventional mining sections. Conventional mining is defined as that cycle of operations which includes cutting the coal, drilling the shot holes, shot firing, loading the broken coal and installing the roof supports.

Respirable dust control studies have been conducted by the U.S. Bureau of Mines, Mine Safety and Health Administration, the coal industry and other organizations. These studies have addressed the problems of respirable dust control in both the coal and noncoal mining industries. Many of the earlier studies in coal mines were conducted in continuous mining operations. More recently, control of dust in longwall operations is being studied. Regardless of the type of mining, the technology of dust control can be transferred to conventional operations. This is particularly true with respect to continuous mining dust control practices since both continuous and conventional operations use room and pillar methods and thus require the same type of ventilation principles.

The guidelines presented herein are based on review of a number of dust control studies. Many of these studies report dust control effectiveness in terms of percentage dust reduction. Such information is relevant to the specific section being studied as well as the specific operation. Dust make is a function of a number of factors including the coal seam, seam height, inherent moisture content, type of equipment, rock partings and so on. The effectiveness of dust control techniques can vary from mine to mine and even section to section. Therefore, reference to percentage of dust reduction for a given technique is used infrequently in these guidelines. The mine operator, by implementing recommended procedures and making dust measurements, can establish the best methods or procedures for his particular dust control requirements.

2.0 CONVENTIONAL MINING

2.1 Background

Conventional mining operations offer a number of advantages over continuous and longwall operations. These include:

- Lower capital cost
- Simpler equipment to operate
- Lower equipment maintenance, repair and operating costs
- Improved operating efficiencies
- Higher equipment and sectional productivity
- Less production loss from equipment downtime
- Intermittent methane gas release
- Greater extraction safety
- Greater lump size variation

The capital cost of a continuous mining machine (~\$550,000) is not appreciably higher than that of a loader, cutter, and face drill (~\$500,000). However, the maintenance, repair and operating costs of conventional equipment are lower than those of continuous equipment. Furthermore, operational skills are less demanding with conventional versus continuous machines.

Productivity on conventional sections is comparable to that on continuous sections. Failure of a continuous mining machine halts all production on a section, while if one piece of equipment fails on a conventional section, the remainder of the section can continue to operate. The increased labor costs due to the higher number of miners required on a conventional section (11-12) as compared to a continuous section (8-9) are generally equalized by the higher productivity on a conventional section.

Conventional methods produce fewer fines and the lump size can be controlled with the drill hole patterns. Decrease in the quantity of fines results in reduced preparation plant costs. Shot firing results in a lower methane release. In addition, methane gas release is intermittent and the potential for ignition is reduced.

In spite of these advantages, the quantity of coal extracted by conventional methods has been decreasing due to:

1. Long wall development panels - 3 entry
2. Retreat mining - continuous preferable
3. Low coal of less than 42 in.

Currently, about 25% of underground production is by conventional methods. Although conventional mining appears to be on the decrease, the need to provide a healthy environment for the miners on conventional sections still exists.

2.2 Mining Cycle and Equipment

The conventional mining cycle consists of five distinct operations:

1. Cutting the face
2. Drilling the face
3. Hole loading and shot firing
4. Loading out the broken coal
5. Roof bolting

These operations are sequential and team work is required by all members of the section crew to maintain continuity of the operations.

Figure 1 shows a typical cutting machine. Cutter bars can be rotated from side to side to provide complete undercutting of the entry face. Nominal cutting depths are 8-10 ft. The cutter bar can be rotated also to permit side cutting and trimming of the rib. In some cases, a horizontal or vertical center face cut may be made. Water sprays on the cutter bar and bug dusters are standard dust control systems.

After the face has been cut, the next operation is drilling. Drilling may be done with handheld or tire mounted drills (Figure 2a). The number and location of holes are dictated by seam height, coal hardness, desired size of product and so on (Figure 2b). The use of hollow steel drills reduces the amount of dust make during drilling.

Charging the holes and shot firing follow the drilling operation. Dust concentrations in the entry being shot, as well as downstream entries, are high during shot firing, but dust is rapidly dissipated if proper ventilation techniques are used. Wet stemming will significantly reduce the amount of dust generated during shot firing.

Once the coal has been shot, then it must be loaded out. Figure 3 shows a typical loading machine. Water sprays on the gathering arms and the chain conveyor are used to minimize dust generation. Wetting of the coal pile prior and during loading operations will also reduce dust make.

The final operation in a conventional mining cycle is roof bolting. Dust levels during roof bolting can be minimized with the use of dust collectors, or wet drills.

Other dust sources on a conventional section are the haulageway and the section dump point. Water and calcium chloride can be used to control dust on the shuttle car runways. Water sprays at the dump point will reduce dust levels in those locations.

2.3 Room and Pillar Mining

The room and pillar method is employed in conventional mining operations. Approximately 30-40% of the coal is removed during room and pillar

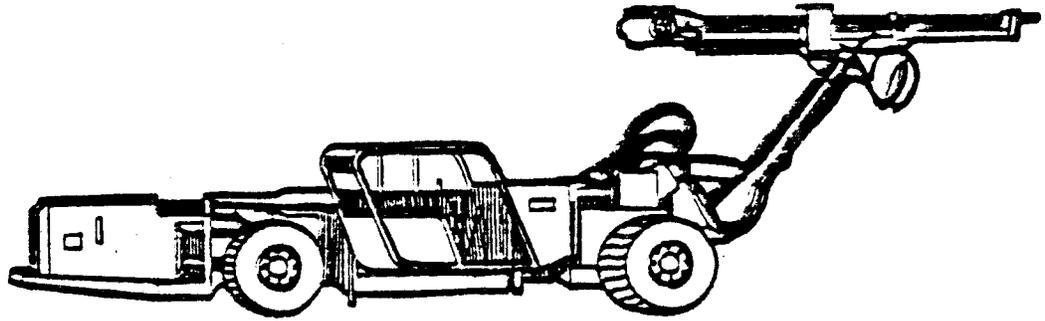


FIGURE 2a. - Tire mounted drilling machine

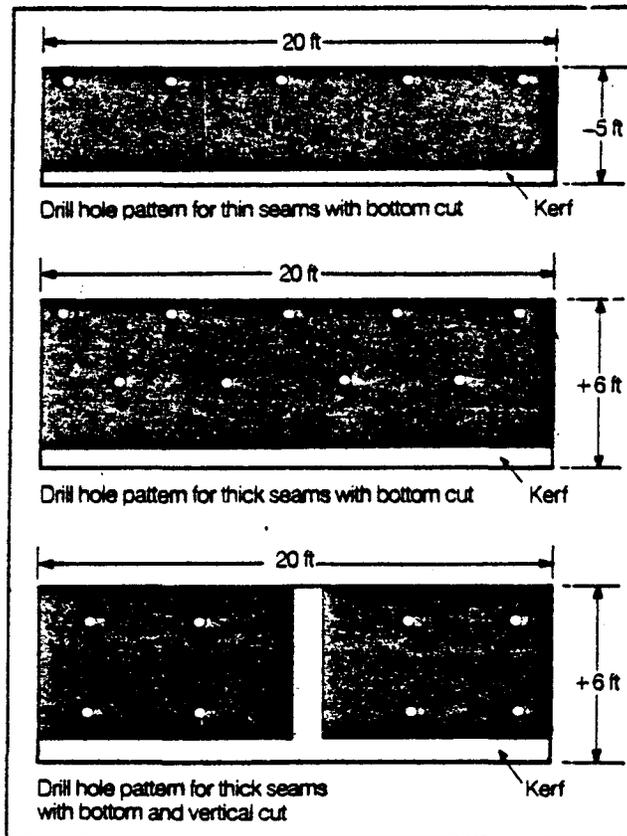


FIGURE 2b. - Drill hole patterns

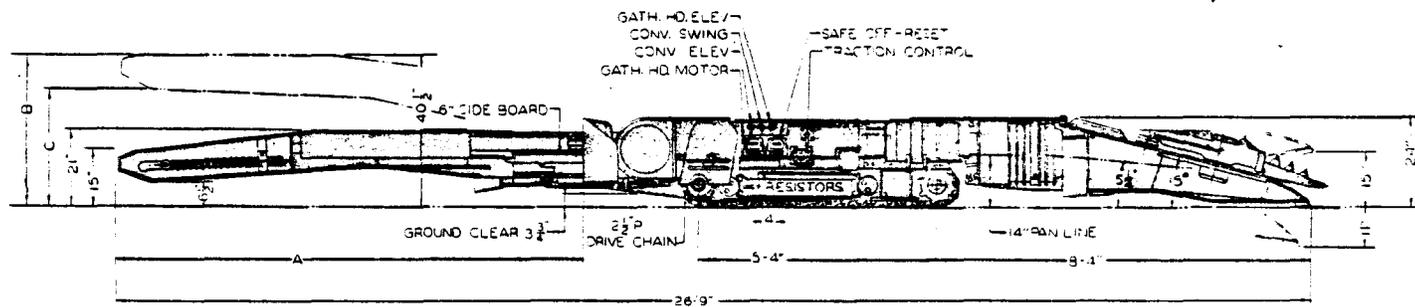
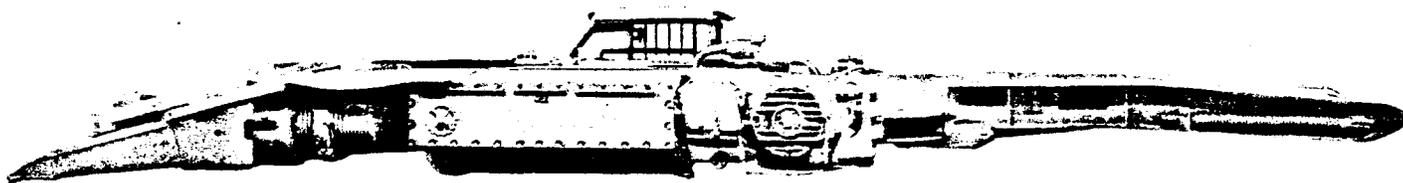
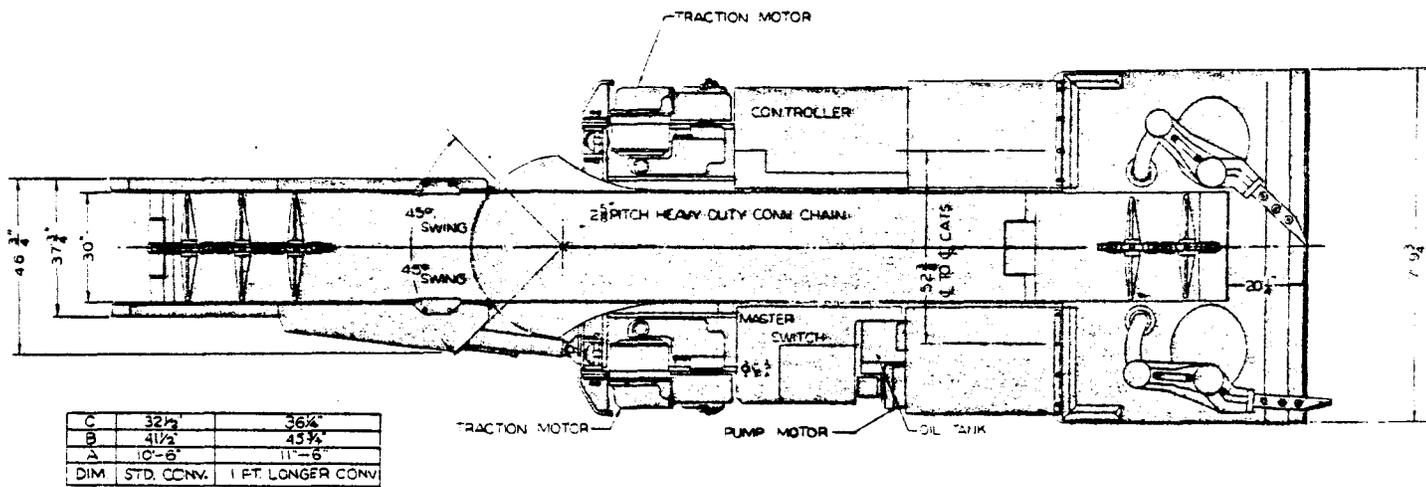


FIGURE 3. - Loading machine

advance mining. Permanent stoppings must be maintained within three open crosscuts of the face. The minimum quantity of air required by law at the last open crosscut is 9000 cfm, and the minimum quantity of air required by law at the face is 3000 cfm. The proper use of check curtains, line curtains and regulators will assure that these air quantities are achieved.

Details on the proper use of check curtains and line curtains are given in a later section entitled "Ventilation." However, it is worth noting at this point that improved methods of installing and sealing permanent stoppings are being studied under U.S. Bureau of Mines sponsorship. The improved methods have led to more effective use of air available on-section, and has resulted in a reduction of power requirements. Power savings is a noteworthy benefit in these days of increased power costs.

3.0 VENTILATION

3.1 Introduction

Ventilation is the most important dust control procedure which can be used in underground coal mining operations. It has been suggested that the use of water alone, without ventilation, would be incapable of controlling dust levels to the current standards. Ventilation air serves two purposes with regard to dust control -- it carries away dust that is generated and also dilutes the dust that is present in the working place. Ventilation also maintains methane concentration at safe levels.

There are two basic methods of directing ventilation air to the face:

1. Line brattice
2. Auxiliary fans or tubing

Approximately 80% of the underground mines use line brattice. Each mine operator must submit a dust control plan, and the type of ventilation and ventilation rates must be specified in the plan. In addition, Federal regulations stipulate that the maximum respirable dust concentration for intake air is 1 mg/m³.

This section addresses the three areas of mine ventilation: main ventilation, section ventilation and face ventilation. Main ventilation originates from the outside of the mine (the mine portals or fans) and extends to the section dump location. There is little that can be done with this part of the ventilation system by section personnel. Section ventilation on the other hand not only has a significant impact on production but can and is controlled by the people on the section. Face ventilation is the area in by the last open crosscut or in the case of pillaring in the block of coal being mined. In all of these areas three aspects are discussed, namely what to install (materials, etc), how to install the ventilation device, and where to install the device. This latter aspect includes a brief review of the pertinent laws, a discussion of why it is required and, more importantly, when to install it as part of the face cycle.

3.2 Main Ventilation System

Primary air is supplied to all areas of the mine through the use of large fans located on the surface. The primary fan may operate in either a blowing or exhausting mode, but most fans are operated in the exhausting mode. The air is directed to working sections, worked out sections and gob areas through the use of stoppings and regulators. The mine ventilation engineer is responsible for developing the underground air distribution and determining that each underground area is properly ventilated.

Good practices are required to assure that each working section is properly ventilated. Sufficient air must be directed from the primary

ventilation system to assure that Federal regulations are met, that the mine ventilation plan is adhered to, and that safe levels of dust and methane are maintained.

Regulators control the quantity of air used on section, and stoppings prevent the mixing of intake and return air. Line brattice which will be discussed in the following section provides a sweep of clean air to the face.

Stoppings provide the means for directing air flow throughout the mine. Generally these have a life expectancy of years although there are situations where they may be used for only a month or so. The various materials and types of construction are included in Table 1. When deciding which type of stopping to use the following must be considered:

1. How much air loss is acceptable?
2. What are the legal requirements?
3. How much time is available to construct the stopping?
4. What is the expected life of the stopping?

The only occasion a check would be installed is when a permanent stopping has been damaged and is awaiting replacement or repair. Usually when this happens, the main ventilation in a mine is interrupted and emergency action is required. Typically such a stopping would have been crushed out or destroyed by a roof fall or damaged by a haulage accident.

Estimates of air losses through a stopping are listed in Table 2. Values in the table are for a pressure differential of 1 inch water gauge, and while doubling the pressure does not double the loss of air, the loss does increase substantially. It is not unusual for a fan to operate against 6 to 8 inches of water gauge which would be the pressure against those stoppings.

Normally, a wet wall stopping with a coating of mortar, stoppit or similar material would be used for brattices in the mains. For brattices in the panels, dry wall stoppings with a coating of mortar or similar material are ordinarily used. To reduce leakage or quick repair of damaged stoppings, very thin plastic (4 mil or so) can be placed over any of these stoppings. On short panels the Kennedy stoppings are not only quickly and easily installed but also reusable, that is they can be recovered for use in another location. For temporary stoppings heavy plastic attached to wood frames or concrete blocks laid up dry are commonly used. These stoppings would typically be used while repairing other stoppings or for rerouting the air as when constructing overcasts or seals.

Overcasts are used to:

1. Carry return (or intake) air across belt entries, neutral entries or track entries to other return (or intake) entries

TABLE 1. - Stopping characteristics

<u>Type of Installation</u>	<u>Material Used</u>	<u>Normal Life</u>
Stopping	Concrete Block & Mortar Wet	Permanent
Stopping	Concrete Block & Mortar Dry	Permanent or Temporary
Stopping	Concrete Block & Stoppit Wet	Permanent
Stopping	Concrete Block & Stoppit Dry	Permanent or Temporary
Stopping	Sheet Metal Kennedy Stopping	Temporary
Stopping	4 mil Plastic & Wood Frame	Temporary
Stopping	Very Thin Rolls of Metal Foil	Temporary
Stopping	Wood	Permanent and Temporary
Check Stopping	Brattice Cloth	Temporary
Overcast & Undercasts	42+ in. Diameter Metal Culvert	Temporary
Overcast & Undercasts	4+ in. Diameter Pipe	Temporary
Overcast & Undercasts	Standard Size HVAC Ducts	Temporary
Overcast & Undercasts	4 in. to 6 in. H-Beams	Permanent
Overcast & Undercasts	25+ lb Railroad Rail & Corrugated	Permanent
Overcast & Undercasts	Sheet Metal With Foams	Permanent
Overcast & Undercasts	Sheet Metal With Concrete	Permanent
Overcast & Undercasts	Sheet Metal Kennedy Overcasts	Temporary
Overcast & Undercasts	Pre-Cast Concrete Slabs	Temporary

TABLE 2. - Air losses through typical stoppings
made with different materials

<u>Type of Stopping</u>	<u>Air Loss/100 ft² at 1 in. H₂O (cfm)</u>
Hollow Core Gravel Blocks Dry Wall	900
Hollow Core Gravel Blocks Dry Wall Mortar Coated	5
Hollow Core Gravel Blocks Wet Wall	55
Hollow Core Gravel Blocks Wet Wall Mortar Coated	5
Brattice Cloth (Burlap)	35,500
Brattice Cloth (Burlap) Asphalt Coated	40
Brattice Cloth (Nylon)	5

2. Isolate belt entries
3. Keep the track, intake and return entries isolated
4. Equalize the returns (one of the primary uses most often neglected)
5. Bleeding or ventilating an area directly to the returns.

Typically a normal overcast is constructed of the same material a stopping is with the addition of rails or H-beams providing support for the floor of the overcast. Usually belts go over the track entry which is across the top of the overcast while the track goes under the overcast. Intakes, since they are often travelways, also go under the overcasts while returns go on top of the overcasts. Overcasts are devices constructed by taking top (if necessary) whereby the bottom is left at its normal mining elevation. Undercasts are areas constructed by taking bottom and leaving the top in its normal mining elevation. Except in very high coal (9 ft or so) these overcasts or undercasts always require some top and/or bottom. Kennedy overcasts can be used for new panels since they are reusable and most of these overcasts are removed when the panel is completed.

A typical culvert overcast would enclose a conveyor and could be made with half of a 6 ft to 8 ft diameter pipe isolating the belt from returns, intakes and neutral entries. Often these belt overcasts offer little restriction to the flow of air and can be very quickly and inexpensively constructed.

Pipes can be used to carry air from one area to another, e.g., from a set of seals to the returns across belt entries. In most cases sufficient air must be carried so that a perceptible movement of air is seen which probably requires 400 to 500 cfm. This would require approximately one sq ft of opening which is roughly the equivalent of 1-12 in. pipe, 2-10 in. pipes, 3-8 in. pipes, 5-6 in. pipes, 12-4 in. pipes or an 8 in. x 12 in. rectangular duct.

Equalizing overcasts can be constructed of 3 ft or 4 ft diameter metal overcasts. The overcasts used for panels can also often be used for equalizing overcasts when the panel is abandoned.

Regulators can be constructed of concrete blocks with sliding wood doors or simply partially constructed stoppings with concrete blocks added or removed as required. The doors have the advantage of allowing travel in the returns with permissible equipment while the stoppings are less expensive, quicker and easier to build.

Doors can be constructed of wood or made by hanging pieces of belt the full height of the entry. Where rubber tired (trackless) equipment is used, double doors are normally used. Where truck is installed, single doors are normally used.

Seals normally are constructed from 8 in. x 8 in. x 16 in. solid concrete blocks except when a high head of water is expected. Wet seals are provided when it is desired to seal off the air supply but it is not desired to impound water. Dry seals are used when no water is to be allowed through the seal.

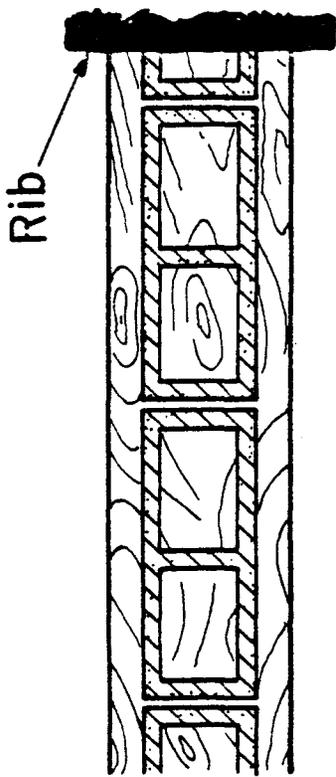
Construction practices determine the effectiveness and expected lifetime of air diversion devices. The determining factor when deciding which construction method or material to use is the expected life of the device; obviously when building for a life of 30 years more time and money is justified than for a life of six months.

The first thing to do when building a stopping is to select the location and avoid pot holes, humps in the floor, wide places and uneven ribs. Also try to avoid building where the stopping will go into a hole in the roof or will be under a roof bolt. Locate the stopping in an area of smooth level bottom where the length will be minimized and where the top is smooth and competent. When building along belts, build as close to the belt entry as possible as this minimizes the area that must be rock dusted. When building along track entries, build as far from the track entry as possible because rock dusting along tracks is the easiest to do. These crosscuts are also then available for supply, storage and manholes.

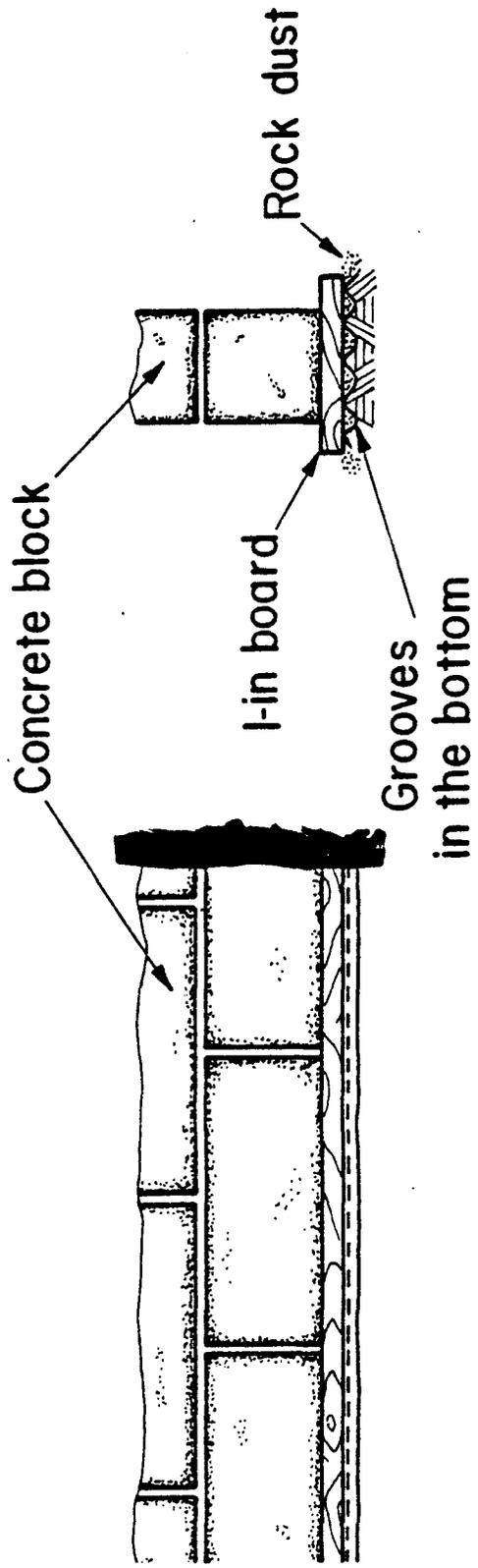
The secret to a good stopping is the foundation. A smooth level surface for laying the blocks is essential. If the bottom is hard and reasonably level, rock dust can be spread on the bottom and leveled off to provide a smooth level surface to lay the blocks on. Another method is to lay a 1 in. board on the bottom (or on the rock dust) and then start laying blocks on this board. Laying the blocks on the wood allows the wood to yield thereby preventing crushing of the blocks if a small amount of bottom hooving occurs (see Figure 4).

If a more substantial footing is required, one inch boards can be used to make a form for pouring concrete. Such a footing is generally 6 in. wider than the blocks being used and is shown in Figure 5. If the bottom is soft it may be necessary to dig a trench 6 to 10 in. deep, 12 to 18 in. wide. Generally it is not necessary to form the sides unless the bottom is not level. The trench which is shown in Figure 6 is then filled with concrete, leveled and finished off. A minimum of 24 hours and preferably 2 or 3 days should be allowed before laying up the blocks. In any event the footing must be able to support the blocks as the stopping is built.

Before raising the stopping, the ribs should be scaled of loose material. If rib sloughing is a problem and a long life is anticipated it may be necessary to dig back into the ribs 2 to 6 inches, thereby "hitching" the stopping in the rib. The blocks should be staggered as is typical of brick work everywhere. If the stopping is layed up dry, no mortar is used between any of the joints. If the stopping is layed up wet, mortar is used between all joints. The blocks are cut or "chipped off" as required to assure a reasonably close fit with the rib and top. If the stoppings are to be removed soon the mortar can be weakened by adding rockdust to the mix.



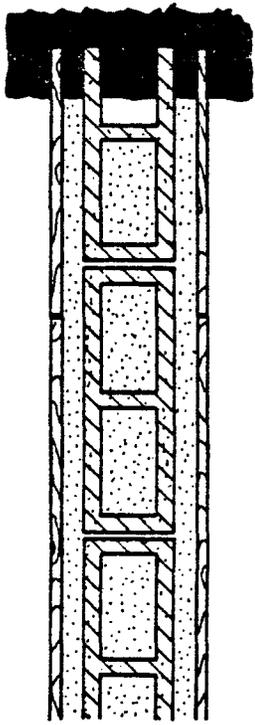
PLAN VIEW



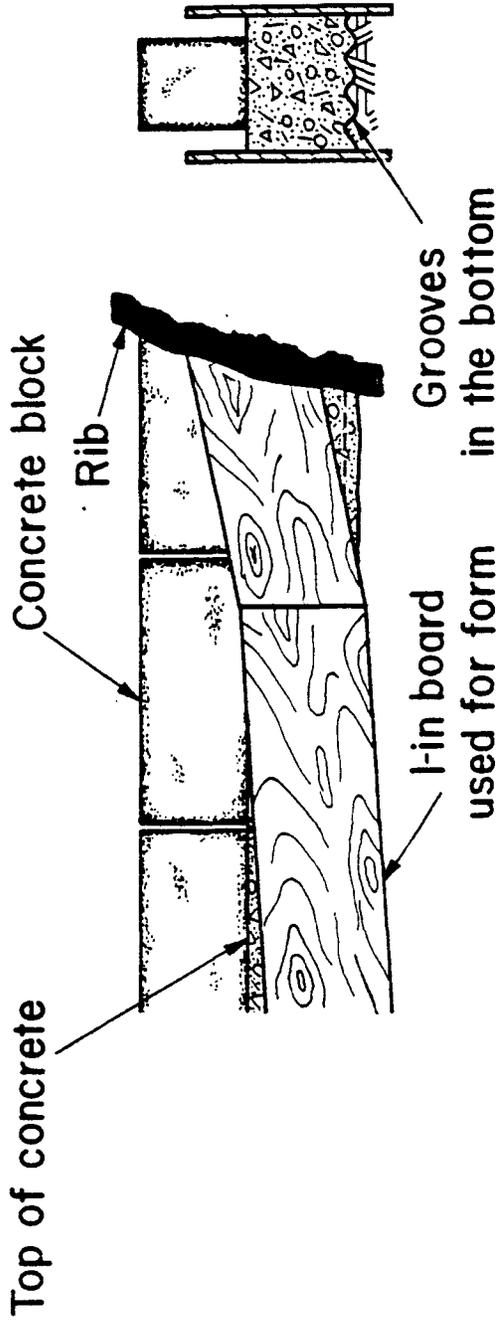
FRONT ELEVATION

SIDE ELEVATION

FIGURE 4. - Conditioning of bottom for stopping installation

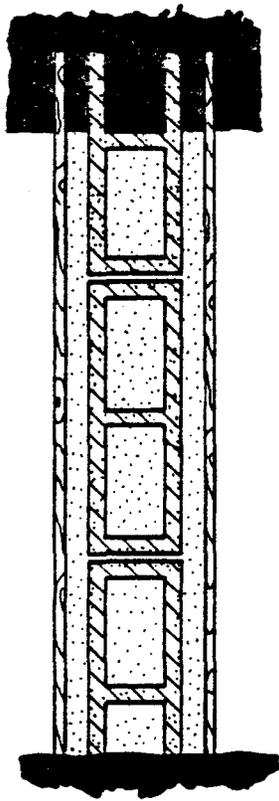


PLAN VIEW

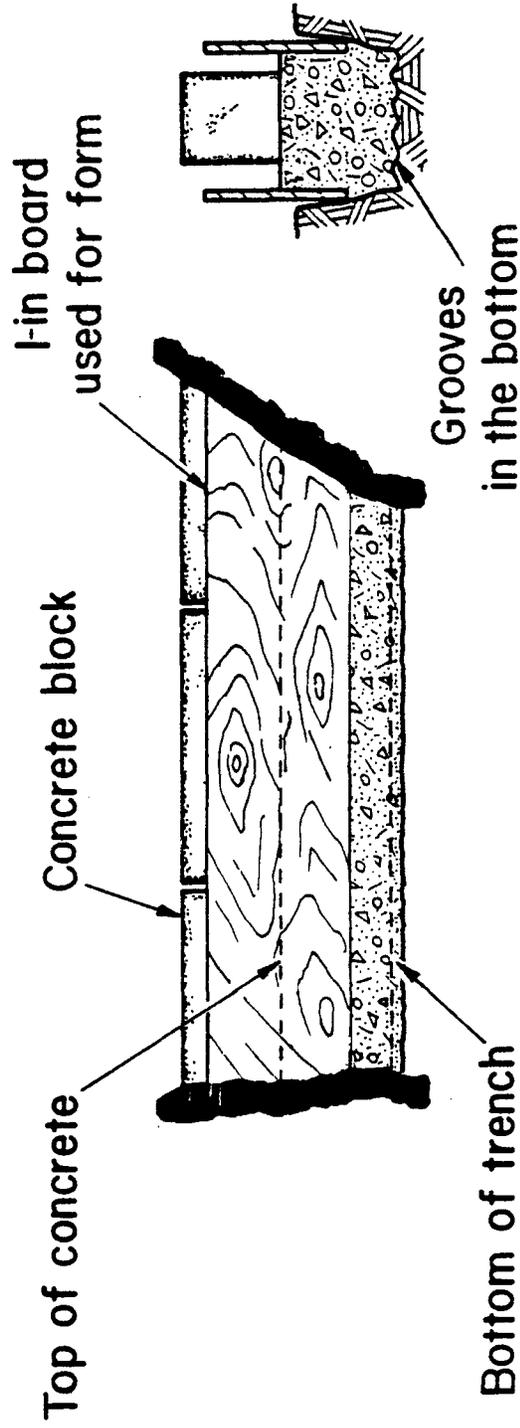


FRONT ELEVATION SIDE ELEVATION

FIGURE 5. - Concrete footer for stoppings



PLAN VIEW



FRONT ELEVATION

SIDE ELEVATION

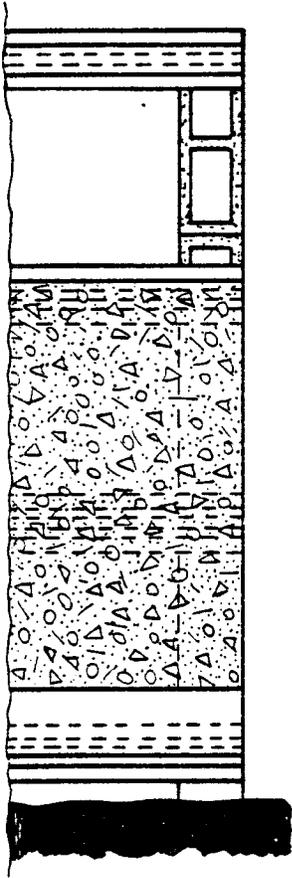
FIGURE 6. - Trench for concrete footer

When the top is reached the stopping should be wedged to hold it in place especially if it is a dry wall stopping. The small crevices and spaces along the top should be filled with pieces of block or mortar. If the stopping is to have a coating of mortar, this should be applied to the high pressure side. Man doors can be as simple as a piece of brattice or belt nailed to the top of the opening or a metal frame with a door attached. These doors are frequently available from local suppliers. For low coal, a 4 in. thick block can be used; for coal over 4 ft high a 6 or 8 in. thick block should be used.

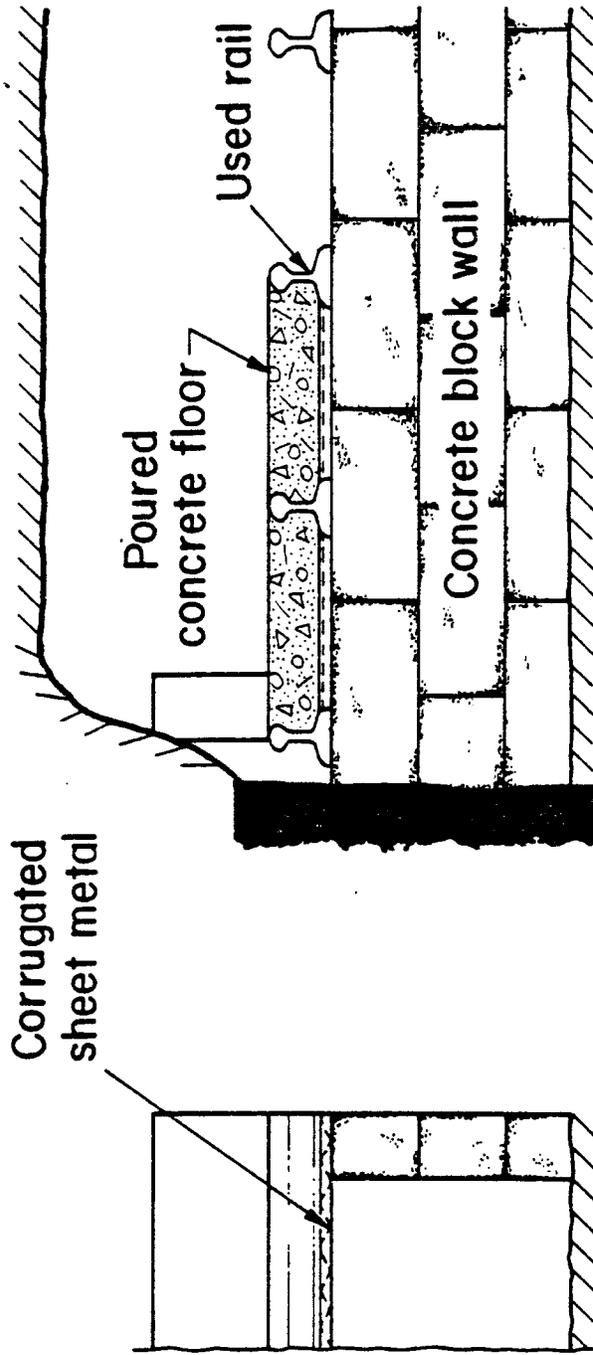
Overcasts require higher quality work than stoppings. For example, footings must be more substantial and laid out more accurately than for stoppings. Similarly the walls must be raised absolutely vertical since they will be supporting the floor of the overcasts. Actually construction of an overcast takes place before mining activity begins. If the location is known before the coal is mined, then the top can be removed (mined) before it is roof bolted. For example, when the mining method is continuous mining and cycle mining is being used, it is possible to mine and load out the coal then back up and cut down the top of the depth of that lift. The roof bolter can then come in and roof bolt this lift. If the crosscut can be driven from one entry across the entry with the overcast, then a smooth top is possible. Normally approximately 60 ft of top in a crosscut must be cut down to provide a good graduated smooth top for adequate air flow. This procedure only works when the top is soft enough to be cut, however, by using this method the mine does not have to come back later and cut out roof bolts as well as the top.

The top of the walls should be even and smooth for the rails or H-beams to rest on. A bearing plate across the top of the walls of 1/4 in. x 6 in. iron strap the length of the wall is desirable but not usually necessary. Wingwalls from this main wall to the rib should be built with and tied into the main wall as it is raised. The floor of the overcast can be laid with specially shaped precast concrete blocks, poured concrete, reinforced poured concrete, stopping blocks, etc. This floor is then covered with a 2 in. to 6 in. layer of concrete, unless it is a poured concrete floor. The floor or forms for poured concrete can be plywood or corrugated sheet metal as shown in Figure 7. In the latter method the corrugation is laid between supports on 2 ft spacings. After the floor is poured, walls are raised to the roof from the floor to finish the separation of the air courses.

Overcasts are often the greatest source of air leakage and are usually the most difficult to repair so extra care during their construction is justified. After the overcast is completed it is desirable to fill in the area behind the walls with rock or other noncombustible material if it is available. Usually this material is available from mining the overcast in the first place. There are two advantages to backfilling. First, the grading reduces the turbulent motion of the air with resulting pressure losses and second, the material reduces air losses through the walls. When backfilling is not possible, especially in high overcasts, a ladder should be provided on each side to assist men when traveling the returns. Figure 8 shows backfilling on one side, a ladder on the other side.



PLAN VIEW



SIDE ELEVATION

FRONT ELEVATION

FIGURE 7. - Initial preparation for an overcast

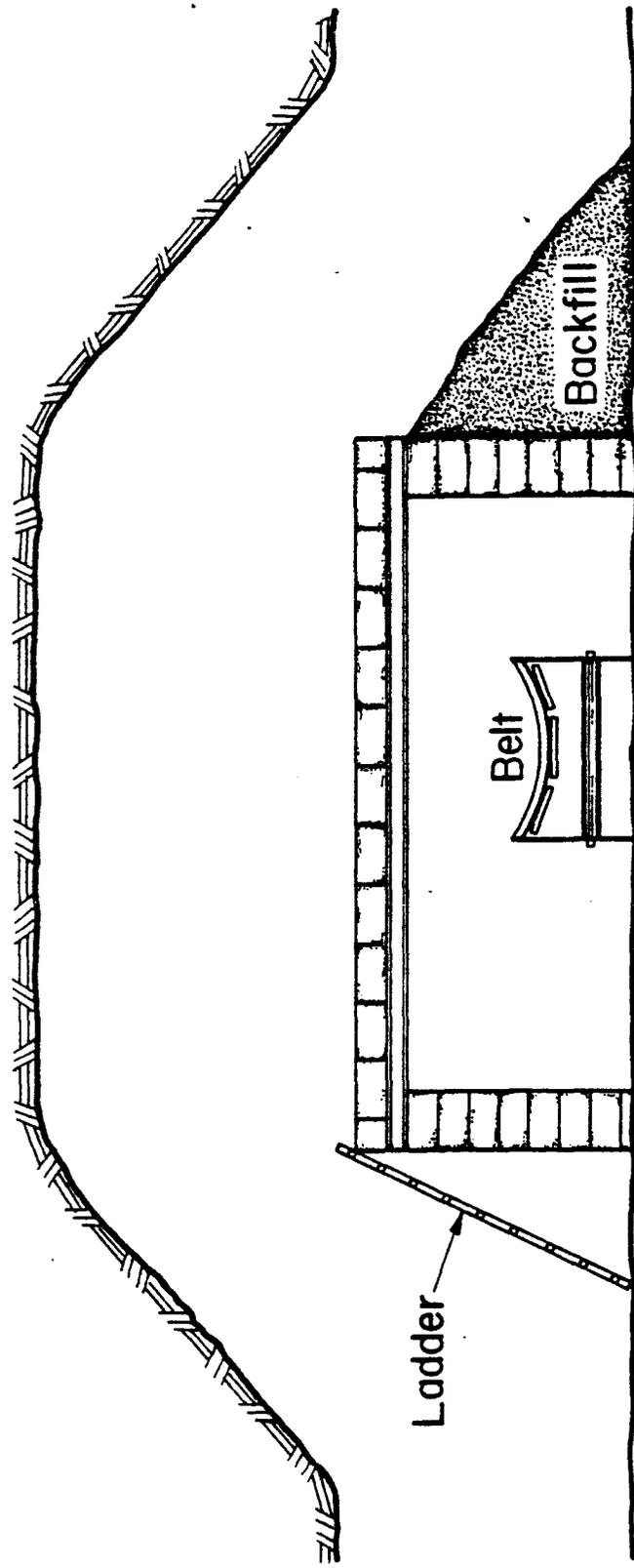


FIGURE 8. - Typical overcast

Undercasts are mainly just floors the full width of the entry with short walls as needed to keep the air currents separated. Here again advance planning when excavating the overcast can save the construction of walls. The typical undercast has the roof (or floor) supports setting on natural bottom and filled in with the same materials as the floors of overcasts. It should be cautioned that in most mines the bottom of the excavation has to be pumped at least occasionally.

Doors are another source of air leakage. In trackless mines double doors are hung on substantial wooden forms to allow passage of rubber tired haulage equipment. Since most bottom tends to get wet and muddy during the summer months, extra caution should be used during winter months in selecting a location for the doors. In track entries single doors are the rule since there is usually sufficient height to allow adequate cross bracing.

Plywood doors are the easiest and least expensive to build. This door can be strengthened by adding a 2 in. x 8 in. stiffener horizontally along the door where the bumpers of vehicles hit it when pushing the door open. Two of these plywood sheets will give a clearance of up to 15 ft wide in low coal applications. (About 1 ft is lost due to overlapping, hinges, etc.) The doors should be hung so that they open against the air and will thus be held closed by the air, and should be made self closing, which can be done by hanging a weight on a rope or wire so that the door will be pulled closed unless held open. A skirt of used belting will reduce air leakage around the bottom and a piece of brattice cloth on the edge of the overlapping door will reduce leakage between the doors. The walls on either or both sides should be of concrete blocks. If the pressure is too great a small door should be made to relieve the pressure; the overlapping door can be made to hinge in the middle so that the air seal is "broken" before the whole door has to be opened. (Even a 2 in. water gauge can exert a force of over 300 pounds against a 4 ft x 8 ft door.) If the airflow is still too great an "air lock" will have to be built, which is a second door. This second door should be far enough away so that a trip of coal (or supply cars) will fit between the doors. Hinges can be ordinary gate type or, if a heavier door is built, strap hinges should be made. Strap hinges should extend approximately 18 in. in from the end of the door.

Where there is sufficient height as in a track entry, a single door sturdy enough can usually be built. These doors are built of two layers of tongue and groove lumber. The layers are built at an angle to each other so that they make a strong door. In addition, cross bracing can be used to further strengthen the door. The trolley wire should be recessed into the top of the door groove on the hinge side and properly guarded. Doors of this construction should be limited in width to twice their height. When the air pressure is too great against the door, a small man door should be made to allow passage of men and to "break" the pressure when the big door must be opened. In this case, a 1 in. water gauge against a 6 ft x 12 ft door results in a force of over 350 pounds holding the door closed. The same skirting used on the double doors should be attached to this type door. The hinges should be adjustable so that any sag can be taken out as required. These hinges should be the strap type and come in up to 6 ft from the edge of the door. A bumper block of 2 in. x 12 in. x the door

length offers good protection against the door being opened by motors. The doors should open against the air and be self closing using a weight on a rope or wire.

Another type of door consists of pieces of heavy belting installed so they overlap and hang across the track entry. Vehicles merely push their way through while a person only has to lift one piece to travel through. This is a very simple and effective air door.

Regulators are of two types -- travel through and permanent. The travel through regulators are simply wood doors which are opened to a fixed position. The doors can be hinged or sliding; the important thing to remember is to mark the position of the door before opening it. The permanent regulator is often simply a stopping with a hole knocked in it. As more or less air is required the hole is enlarged or filled up with blocks.

Seals referred to here are not for pollution control such as are found when sealing a mine but rather for ventilation control. These seals are for control of air only and should not be counted on to retain a significant head of water. In fact, it is recommended that the seals have U-tubes built in to drain any water build up that may occur. Usually a 2 in. pipe should be placed in the seal near the top to facilitate gas checks and pressure build ups. The blocks should be 6 in. x 8 in. x 16 in. or larger. Normally it is not necessary to hitch the seal into the ribs 2 ft. A solid footing at least 6 in. thick hitched at least 6 in. into the bottom is recommended.

Where and when to install an air control device are important considerations. There are the legal requirements, both Federal and state laws, and functional requirements, namely keeping the mine well ventilated. There usually are many ways to accomplish these goals but with the ground rules constantly changing it is often confusing to discern the best of all possibilities. On top of this, many of the state and Federal laws are subject to different interpretations. Table 3 is a list of some of the pertinent laws concerning main ventilation. One of the purposes of this table is to show the differences between state and Federal law. In any disagreement or conflict between state and Federal laws, the strictest of the two applies. The second purpose is to show that all is not in the written law, but that there is an unwritten law or "interpretation" which is at least as important as the written law. The third purpose was to try to check out specific recommendations so that those exceptions due to certain state laws could be cited.

The table is composed of all those states which produce coal (and some which do not) from underground mines. Some of the items were listed because specific numbers can be compared. The first item, for example, states the requirement for the fan offset in the Federal law is 15 ft while the states vary from 0 to 30 ft. Some states with no requirement probably enforce an unwritten law requiring an offset. Another part of the same law requires new fan installations to be on the surface. While many states do require this location, those which do not probably would not allow a fan to be installed underground either. Because the 1969 law is in effect and the table is self explanatory, only current problems will be discussed here.

TABLE 3. - List of laws referring to main ventilation

Section	Topic	Requirement	Effect	AL	IL	IN	KY	MD	NY	OH	PA	TN	VA	WV	IA	KS
75.300	Main fans	They must be installed on the surface and offset 15 ft.	Booster fans installed underground are not permitted.	ES		ES		NR	ES-Booster fans allowed	ES	ES	ES	ES	ES	NR	NR
75.309	CH ₄ in returns	Maximum allowable is 1%	The quantity of air must be increased to dilute the methane below 1%.	ES		ES		NR	ES	ES	ES	ES	ES	ES	NR	NR
73.312	Air route	Air that has passed through abandoned areas cannot be used to ventilate a working place.	May require additional entries or rerouting of air.	NR		ES		NR	ES	ES	ES	ES	ES	ES	NR	NR
75.316-1 75.316-2e 73.329 & 75.329-1	Bleeders	Must provide ventilation of gob areas, be travelable (if possible), be evaluated weekly, contain less than 2% CH ₄ .	The requirements are constantly changing. Eventual goal will be to surround the entire area being pillared with travelable entries. New interpretations are the major factor. Will almost certainly require additional air.	NR		ES		NR	ES	ES except the evaluation points can be at entrances of the gob.	See PA	NR	See PA	Air from seals must to re-turns.	NR	NR
75.316-2	Stoppings	Shall be of substantial and incombustible materials within 2 cross-cuts of the face.		ES		ES		NR	NR	ES	ES	ES	ES	ES	NR	NR
75.326	Belt entries	Requires that these entries be isolated from the intake and that turn entries and that the velocity be minimized and that the air be directed into the returns.	The belt entry is lost as far as being used for an intake entry.			NR		NR	NR	NR	ES	ES	NR	NR	NR	NR
75.327 & 75.327-1	Track entries	Requires that the velocity be less than 250 fpm.	To limit the velocity required an extra line of stoppings and air doors with the resulting loss of quantity especially in low coal mines.			NR		NR	NR	NR	NR	ES	NR	NR	NR	NR
75.1105 & 75.1106	Special areas	Requires that certain areas such as shops, charging stations, compressor stations, etc be on separate splits that are ventilated directly to the returns.	This also uses some air that would otherwise go to the faces.			ES		NR	NR	NR	NR	ES	ES	ES	NR	NR
75.1704 75.1704-1 75.1704-2 75.1707	Escapeways	That 2 separate passageways (entries) at least one of which is an intake be provided from the face to the surface. These entries must be separated from the belt and track entries.	This often requires isolating another entry, with a line of stoppings and with a resulting loss of an intake entry.			See PA		NR	See PA	ES except trolley wire is acceptable in the intake.	ES	ES	ES	NR	NR	NR

NR = No requirement; ES = Essentially the same

TABLE 3. - List of laws referring to main ventilation (continued)

Section	Topic	Requirement	Effect	MO	OK	TX	AK	AZ	CO	MT	NM	ND	SD	UT	WY	
75.300	Main fans	They must be installed on the surface and offset 15 ft.	Booster fans installed underground are not permitted.	NR	NR	NR	NR	NR	ES	ES				ES	ES exhaust only	
75.309	CH ₄ in returns	Maximum allowable is 1%	The quantity of air must be increased to dilute the methane below 1%.	ES	NR	NR	NR	NR	ES	ES				ES	ES	
73.312	Air route	Air that has passed through abandoned areas cannot be used to ventilate a working place.	May require additional entries or rerouting of air.	NR	NR	NR	NR	NR	ES	ES				ES	ES	
75.316-1 75.316-2e 73.329 & 75.329-1	Bleeders	Must provide ventilation of gob areas, be travelable (if possible), be evaluated weekly, contain less than 2% CH ₄ .	The requirements are constantly changing. Eventual goal will be to surround the entire area being pillared with travelable entries. New interpretations are the major factor. Will almost certainly require additional air.	NR	NR	NR	NR	NR	ES	ES				ES	ES	See PA
75.316-2	Stoppings	Shall be of substantial and incombustible materials within 2 crosscuts of the face.		NR	NR	NR	NR	NR	ES	ES				ES	ES	
75.326	Belt entries	Requires that these entries be isolated from the intake and return entries and that the velocity be minimized and that the air be directed into the returns.	The belt entry is lost as far as being used for an intake entry	NR	NR	NR	NR	NR	ES	ES				ES	ES	
75.327 & 75.327-1	Track entries	Requires that the velocity be less than 250 ppm	To limit the velocity required an extra line of stoppings and air doors with the resulting loss of quantity especially in low coal mines.	NR	NR	NR	NR	NR	ES	ES				NR	ES no limit on velocity	
75.1105 & 75.1106	Special areas	Requires that certain areas such as shops, charging stations, compressor stations, etc be on separate splits that are ventilated directly to the returns.	This also uses some air that would otherwise go to the faces.	NR	NR	NR	NR	NR	ES	ES				ES	ES	
75.1704 75.1704-1 75.1704-2 75.1707	Escapeways	That 2 separate passageways (entries) at least one of which is an intake be provided from the face to the surface. These entries must be separated from the belt and track entries.	This often requires isolating another entry with a line of stoppings and with a resulting loss of an intake entry.	NR	NR	NR	NR	NR	ES	ES				ES	ES	See PA.

NR = No requirement; ES = Essentially the same

Isolation of belt entries can still be a problem. This requirement prohibits air in this entry from being used to ventilate the section. To prevent this air from going beyond the tailpiece it is normal for the air to be bled directly into the returns by leaving a few blocks out of the last stopping. This of course requires "dumping" of some air that would ordinarily be used at the faces. If the belt entry has intake entries on both sides then the air from this entry must be carried across the intake entry into the returns. Normally this would have been done with overcasts, but to construct overcast(s) at each belt move is prohibitively expensive so pipes are commonly used to transport the air across the intake entries (Figure 9). Bricks, concrete blocks, or even rocks placed in the end of the pipe(s) can be used to regulate air. Another problem has been the incorporation of escapeways and miscellaneous requirements in the overall ventilation scheme. These conflicts and problems are so numerous and yet can have such an impact on a mine's ventilation capabilities that the importance of communication with local MSHA and state officials cannot be overemphasized. One example of this problem is a three entry panel which could be used for typical room and pillar mining or for longwall development. There are different approaches to the problem of escapeways, such as using tractor trailer haulage instead of belt haulage or placing the track in the belt entry, or using battery powered rail or adding a fourth entry to the panel, etc. The main problem is that the intake escapeway cannot have live exposed power lines, such as trolley wire, installed in this air course. The problem and the remedy is best illustrated in Figure 10 which shows the original (pre-law) method and the remedy, which adds a fourth entry to the panel.

The increased emphasis on bleeders shows up in requiring a more positive evaluation of airflow through the gob or pillared area. Essentially this means that a "block of coal" will have to be surrounded with main and panel entries before or at least as it is being mined. Obviously one can expect an increased water gauge at the fan when these evaluation points are moved in. The economics of incorporating such a system may change contemporary thinking on the length of panels, etc. Another factor which is related to this is the maximum air velocity which can be used without re-entraining previously allayed respirable dust in the air stream. This velocity probably varies from one seam to the next but it has been reported as low as 440 fpm. Nevertheless, it appears reasonable that the reentrainment of dust would not be a continuing source of dust since once the respirable dust on the surface is carried away, there would be further supply until the surface was disturbed again, e.g., by a man walking. Another example would be a belt traveling at 500 fpm which stirs up little or no dust until it passes through a check where it runs against an air velocity of 600 fpm or more. The relative velocity then becomes 1100 fpm and even larger particles of coal will often become airborne, and while the larger particles will settle out the respirable dust will not.

The most important consideration is where to install the stoppings. Before the 1969 act the only requirement in most states was functional, that is the intakes had to be kept separate from the returns. Now, however, in addition to the escapeway requirement the belt entry must be isolated and velocity on the track entry must be limited. Isolation of the belt entry requires a second row of stoppings. To reduce the velocity in the track

LEGEND

- | | | | |
|-----------------------------------------------------------------------------------|------------------|------------------------------------------------------------------------------------|-----------|
|  | Line brattice |  | Stopping |
|  | Intake air |  | Regulator |
|  | Return air |  | Track |
|  | Curtain stopping | | |

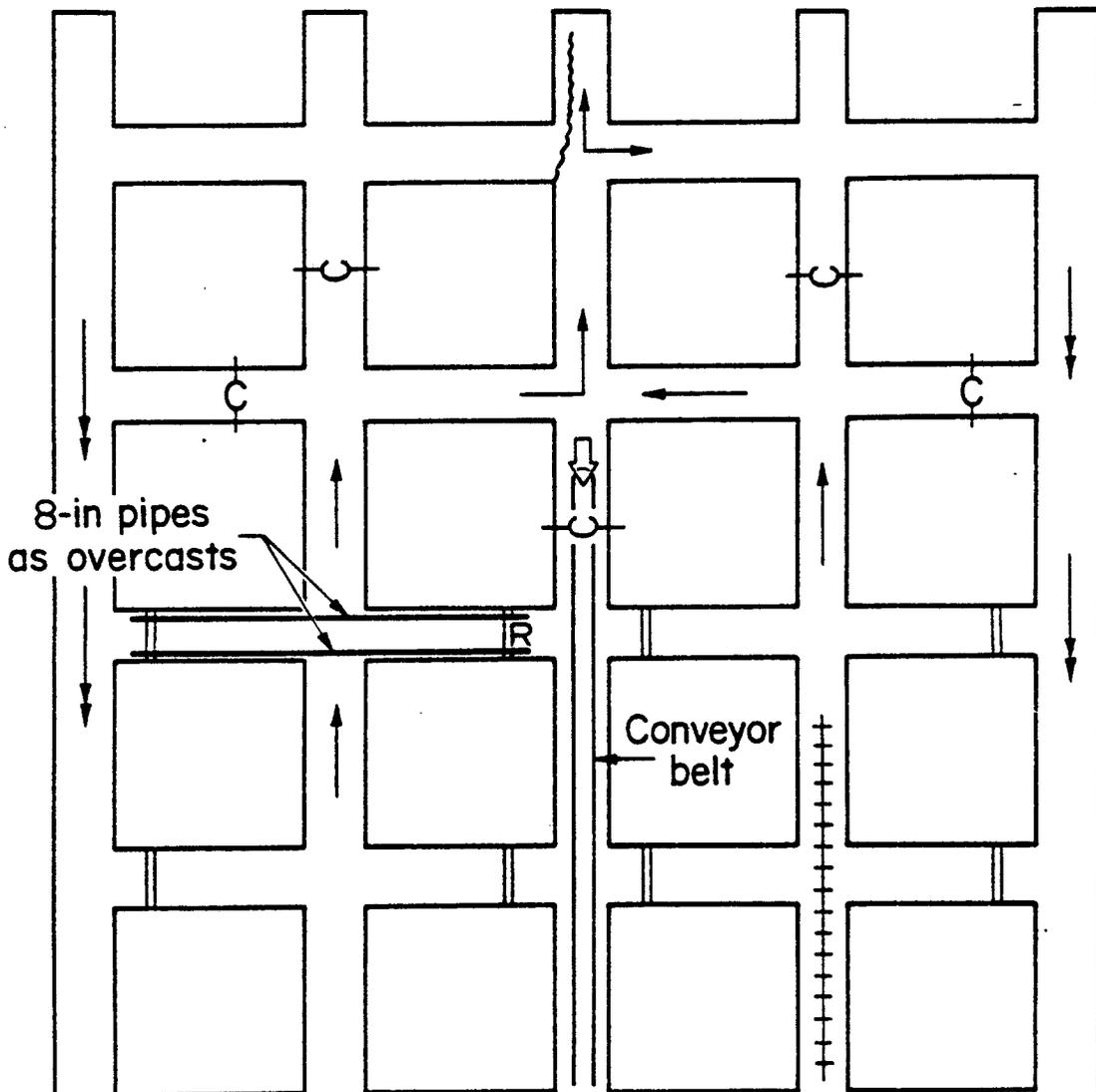


FIGURE 9. - Use of pipes to direct belt air directly to return airway

LEGEND

- | | | | |
|-----------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------|--------------------|
|  | Intake air |  | Stopping |
|  | Return air |  | Stopping with door |
|  | Curtain stopping |  | Track |
|  | Regulator |  | Conveyor belt |

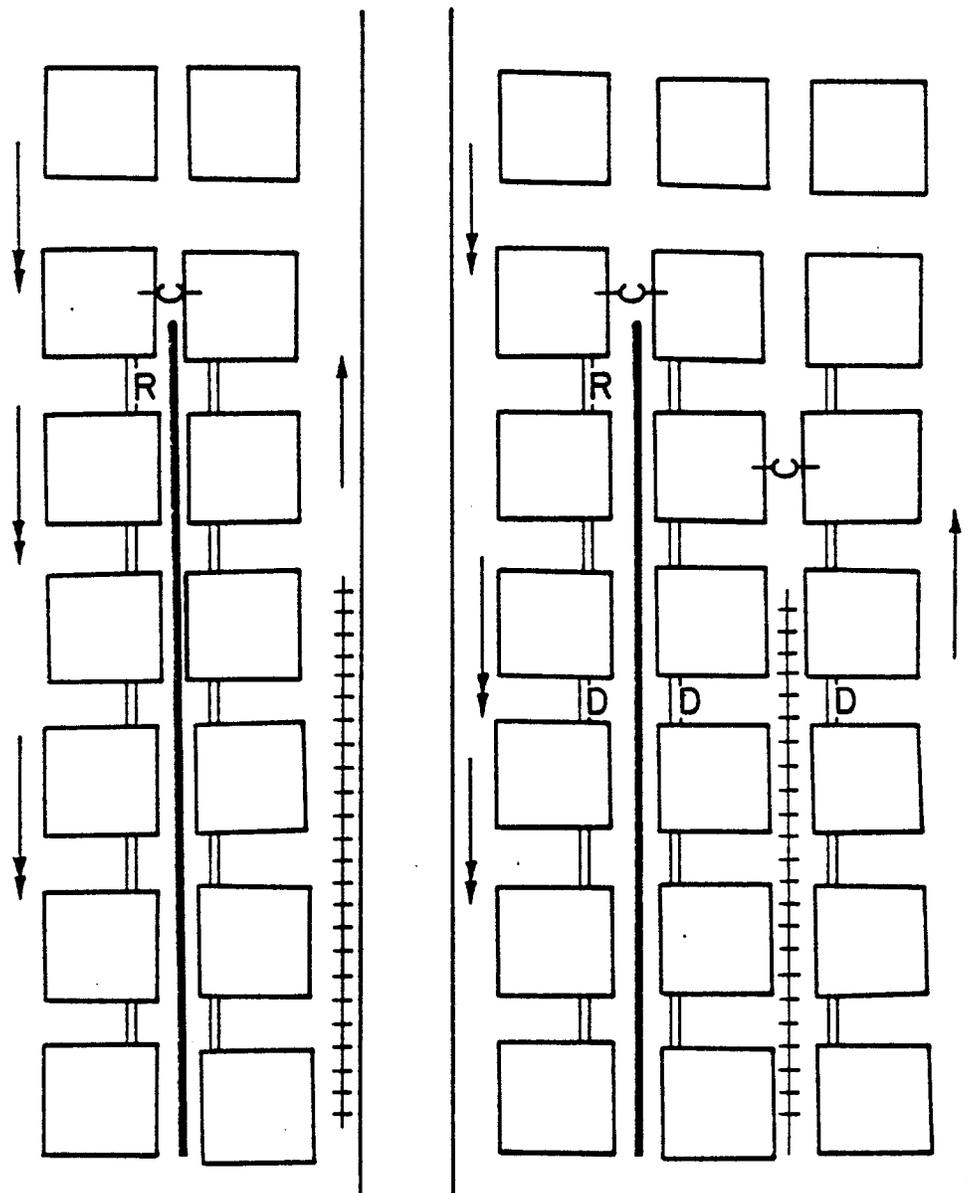


FIGURE 10. - Addition of a fourth entry as an escapeway

entry usually requires a third row of stoppings and if the air is "fishtailed" (split at the face) a fourth row of stoppings is required. To illustrate the above situations, Figure 11 shows an acceptable pre-1969 law method of panel ventilation. Figure 12 shows the same panel with the belt entry isolated and the air velocity in the track entry reduced to less than 250 fpm. Figure 13 again shows the same panel with the air fishtailed at the face. It is obvious that in almost every situation a minimum of three entries is required and if track is installed four entries are probably required.

The primary purpose of these modifications is to reduce the amount of respirable dust in the air. Isolating the belt entry and dumping this air into the returns facilitates this purpose. Double split ventilation is especially helpful in conventional mining where there are many sources of dust generation in the face area.

Other areas such as shops, compressor stations or battery charging stations should be built adjacent to returns when possible. When it is not possible to locate these facilities next to a return they should be located so that pipes can be installed to vent the air directly to the returns. The size of the tubing or pipes will be determined by the air pressure at the location and the distance to the returns.

Timing in main ventilation planning is not done on a day-to-day basis but by planning weeks and months in advance. Overcasts or undercasts have to be built before a section starts mining. Air doors have to be built before the velocity in track entries exceeds 250 fpm. Isolation stoppings along belts have to be built as soon as practical. Planning and construction of shafts must be done years in advance of need.

3.3 Section Ventilation

This area of the mine is inby the dump point and to the last open crosscut. The dump point is the location where the face haulage unit discharges its coal. The usual face haulage units are shuttle cars, bridge conveyors (continuous haulage), or scoops all of which usually discharge within four or five crosscuts of the face. Tractor trailer units must also be included and these units can haul 10 or more crosscuts to the dump point. The dump point itself is usually a belt-tailpiece (or a feeder at a belt tailpiece) or a boom hole (where coal is loaded directly into mine cars).

The devices used to direct the air to the last open crosscut between each entry are checks or check curtains and flys which are run through checks and stoppings. The checks can be brattice cloth (jute) which resembles burlap, plastic mylar, reinforced plastic, plastic impregnated burlap, rigid plastic sheets and, of course, concrete blocks. All of these materials are available in various sizes, strengths and weights and except for the concrete blocks all are commonly called brattice cloth.

Checks are used to keep the air routed to the last open crosscut and resemble a temporary stopping in appearance and construction. These devices block off an opening, thereby preventing a flow of air through that opening. Checks can usually pass a man and occasionally they pass equipment

LEGEND

- | | | | |
|-----------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------|------------|
|  | Line brattice |  | Stopping |
|  | Fly stopping |  | Intake air |
|  | Curtain stopping |  | Return air |
|  | Track | | |

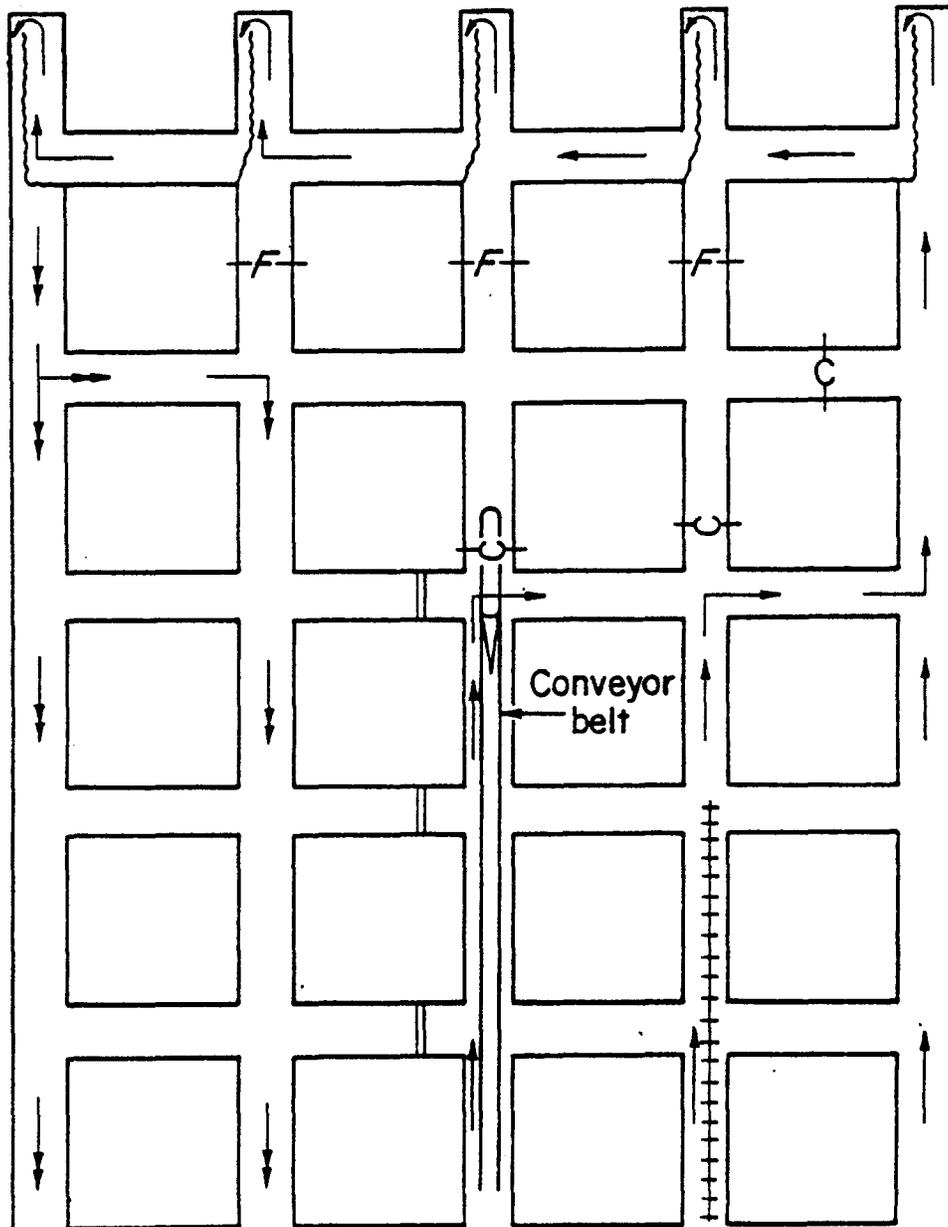


FIGURE 11. - Pre-1969 ventilation pattern.

LEGEND

- | | | | |
|-----------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------|--------------------|
|  | Line brattice |  | Stopping |
|  | Fly stopping |  | Regulator |
|  | Intake air |  | Stopping with door |
|  | Return air |  | Track |
|  | Curtain stopping | | |

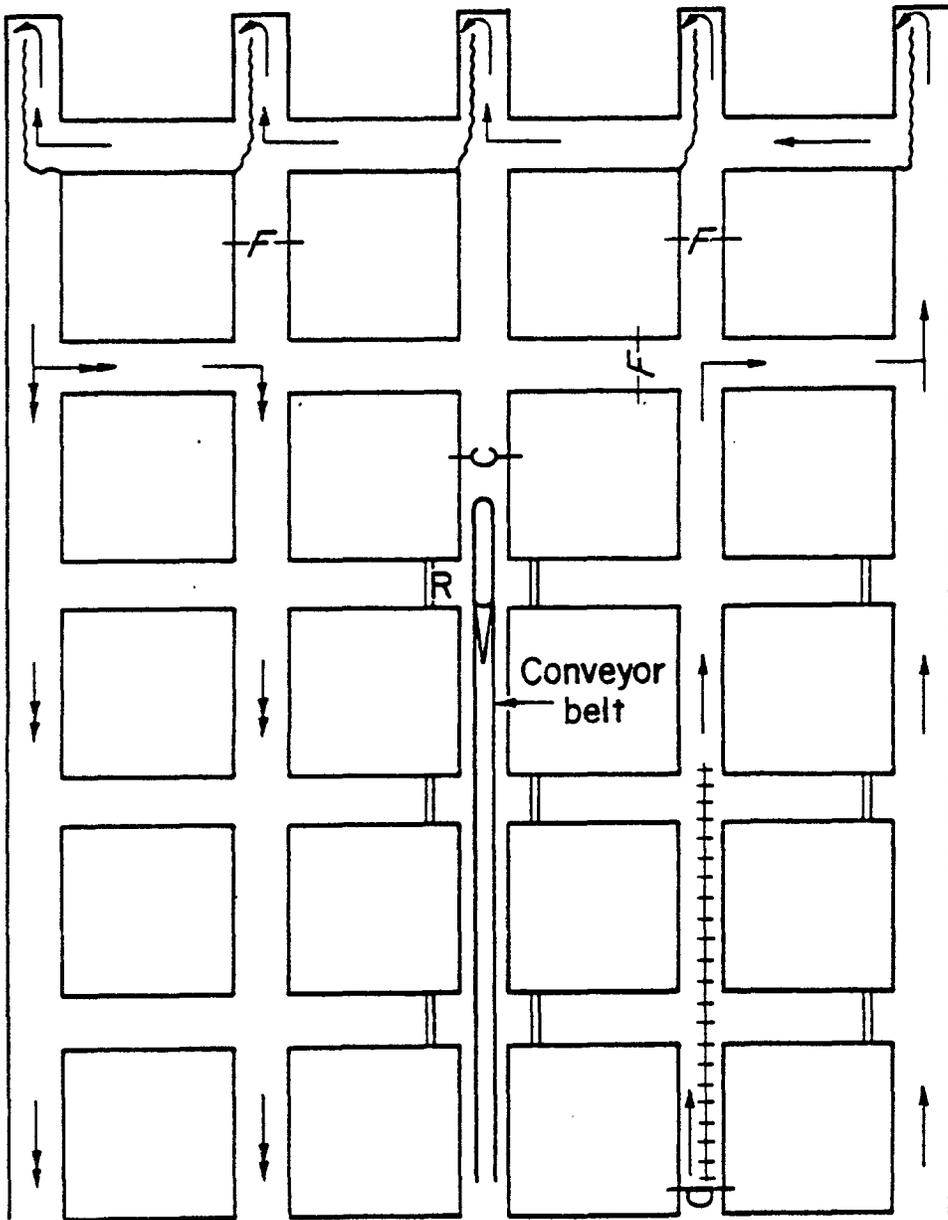
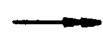


FIGURE 12. - Post-1969 ventilation pattern

LEGEND

- | | | | |
|-----------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------|--------------------|
|  | Line brattice |  | Stopping |
|  | Fly stopping |  | Regulator |
|  | Intake air |  | Stopping with door |
|  | Return air |  | Track |
|  | Curtain stopping | | |

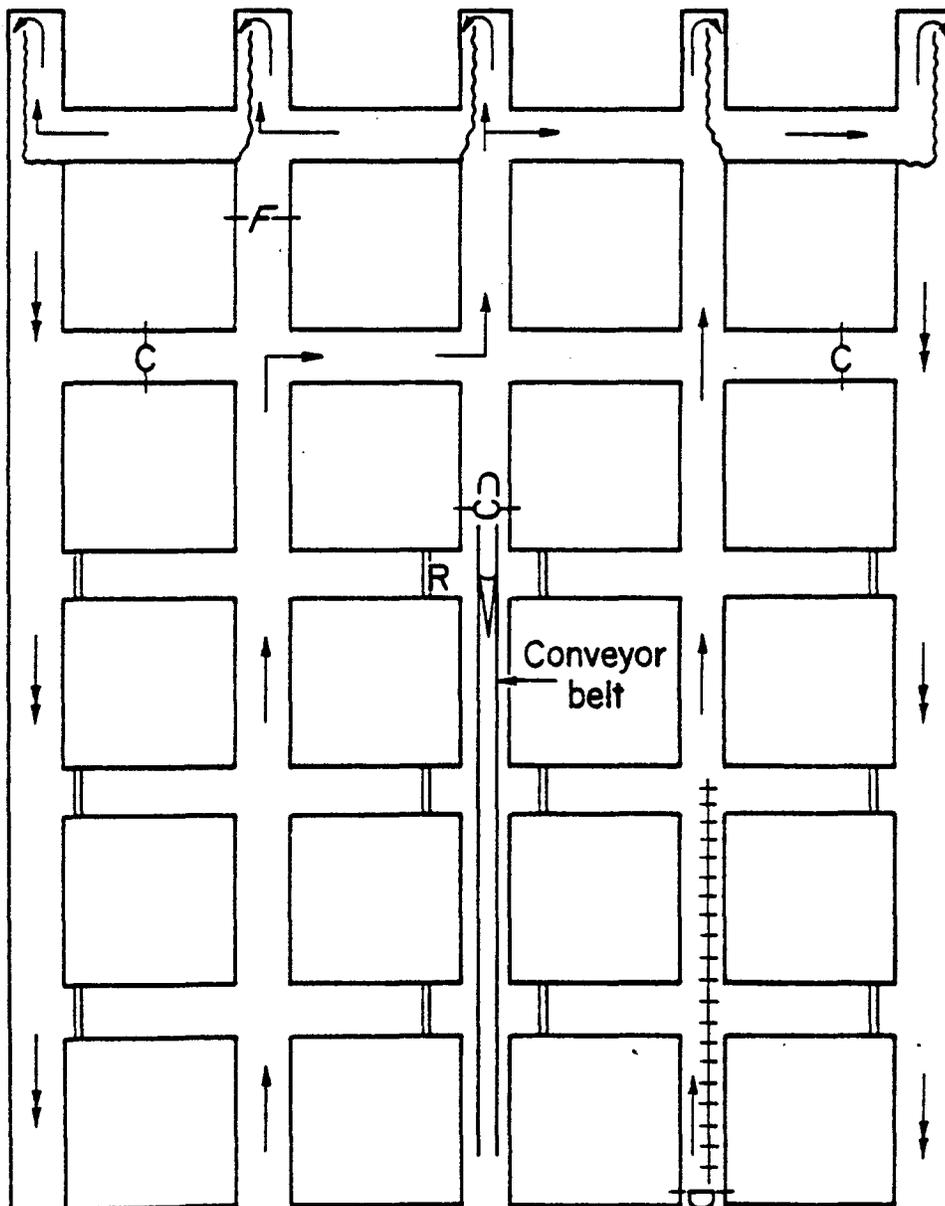


FIGURE 13. - Split return, fishtail ventilation

through them, but basically they are not meant to travel through. A check is used as a temporary stopping and as such should not be installed where equipment is going to be traveling through.

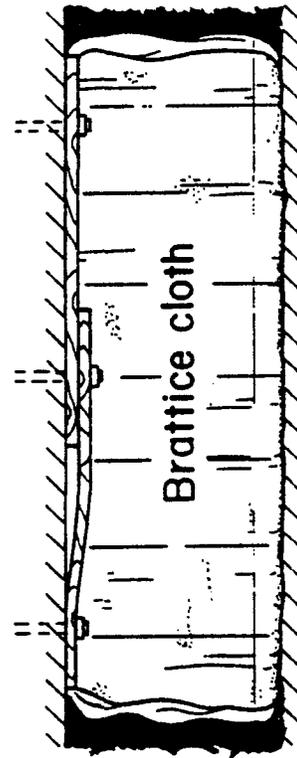
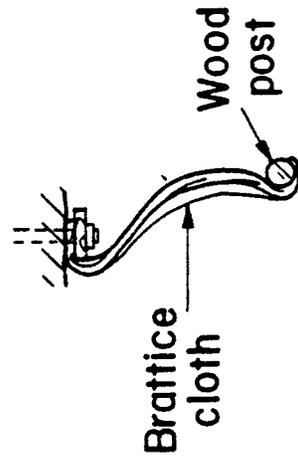
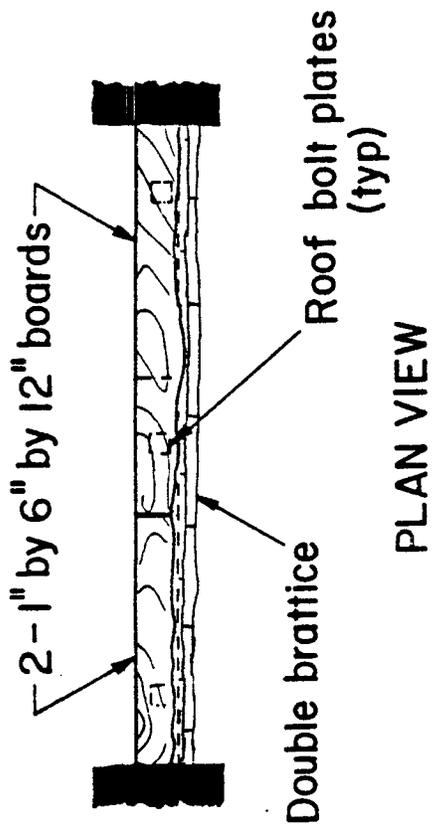
Flys are used for the same purpose as checks but are used where equipment will be passing through. They can be used if needed and where needed any place on a section, the only problem being that leakage might be excessive.

The installation of check curtains often begins with the roof support cycle when 1 in. x 6 in. x 14 ft boards are roof bolted to the top at predetermined locations. These boards are later used to hand the brattice cloth on when the faces have advanced sufficiently. Depending on the actual shape of the roof the brattice cloth should be supported every 2 ft or so. These planks will usually bend and follow the contour of the roof within reasonable limits. The boards are overlapped so that they reach from rib to rib. The brattice cloth is attached to the board with nails (16d) which are driven through the brattice about 2 in. or more from the top of the brattice cloth. The idea here is to allow sufficient overlap so that the cloth will contact the roof improving the seal. When there is sufficient air pressure against the cloth to raise it off the floor it should be weighted down with blocks, rocks or posts. Nailing the bottom of the brattice to posts is most effective but this is also troublesome when the check curtain must be traveled through. In fact if an unsuspecting equipment operator attempts to run through a check nailed to posts he will usually tear it down with a resulting immediate interruption in ventilation, requiring reinstallation of the brattice. The brattice cloth can be held against the ribs with posts or with spads driven into the coal.

A variation of the 1 in. boards bolted to the roof uses 2 in. x 6 in. (or 8 in.) x 16 in. to 24 in. drilled half headers to attach the curtain to. The half headers are often used to provide additional bearing surface against the roof so all that has to be done is to position them correctly for hanging the brattice cloth to. The brattice cloth can then be attached to the coal near the roof in the corners with spads or posts. The bottom and sides can be held down as when boards are used since the brattice cloth is attached to a good support, which can take considerable weight. Figure 14 shows how brattice can be hung from boards or half headers.

Brattice can also be hung from roof bolts similar to the methods used for boards or half headers. In this case nails are usually driven through the brattice cloth and between the roof bolt plates and the roof. This method is not nearly as secure an arrangement as the previous two but does work where there is little pressure against the brattice cloth and height is at a premium.

When posts are available and the air pressure is high they make excellent attachment points for the brattice cloth. The posts should be set on no more than 5 ft centers and as close to the rib as possible. The cloth should be nailed on the pressure side as near to the top of the posts as possible leaving 4 in. or more to fit against the roof. Unless the air pressure is too great one side should be left unattached so men can travel



FRONT ELEVATION

SIDE ELEVATION

FIGURE 14. - Typical brattice installation

through the brattice. If a passageway cannot be left open on the side the bottom can often be left unattached so men can crawl under the brattice. By placing the passageway at the same place, men become familiar with the brattice and will not tear it down trying to get through.

By installing brattice cloth on a wood frame a quite substantial and airtight temporary stopping (or temporary brattice) can be built. If the entry is over 16 ft wide, at least 3 posts should be set and boards nailed to the posts on the pressure side at the top and bottom. If a door is needed a simple wood frame attached to the posts with pieces of belt can be very effective. This door should be above 2 ft wide and about a foot less than the height of the entry so that it rests against the wood frame when closed. At least one post must be set in the high part of the entry when there is a vertical offset as when there is a tree stump (kettlebottom) in the roof. The major disadvantage of this type brattice is that equipment cannot travel through without tearing out the brattice.

Flys are brattices that equipment, generally shuttle cars, run through on a regular basis, but flys must be designed for other face equipment as well. The installation of flys should be as rugged as possible but it must be recognized that no matter how well the fly is installed, any of the self-propelled mobile equipment on a section is capable of tearing down any fly. The best flys are installed on boards at least 2 in. thick by 6 in. or more in width and usually 12 ft or more long. If boards are not pinned to the top they should be set on posts or jacks and securely anchored to the top. As with brattices it is possible to position these boards and pin them to the top as part of the face cycle. The brattice cloth should be nailed every 6 to 12 in. along the board with 16d nails or by using a piece of scabbing, with the cloth nailed between the scabbing and the board. Wedges are often split and used in this manner. The brattice cloth should be long enough to reach the floor plus 2 in. While clear plastic does allow some visibility, the plastic soon becomes dirty and scratched so that about all that can be seen are lights.

There are three types of flys. The first and simplest is just a piece of brattice cloth suspended the full width of the entry. This is the easiest to install but also the easiest to tear out. If the brattice cloth is longer than the board and this excess length is used to close off the rest of the opening, the cloth should be cut at the end of the board so that the remaining brattice will not hold down the fly and cause it to catch on the equipment and tear. A smooth plastic cloth is the best for this purpose with the old burlap type the most prone to catch on the equipment. When there is high pressure, 2 or 3 layers are often needed to hold the fly down. The major disadvantage to this type of fly is that if just one corner tears out the fly can no longer be traveled and worse yet the ventilation is interrupted.

The second type of fly is one which uses several strips of heavy plastic hung from a board. These strips are about 3 ft wide and overlap a few inches on each side so that a reasonably tight air seal is effected. The strips are nailed individually to the board so that if one is torn out the rest provide at least some restriction to the air flow. For this type

fly a heavy plastic or reinforced plastic material appears to be best. Here again two, three or more layers can be suspended to hold the fly down in the case of high air pressure.

The third type of fly uses sheets of heavy semi-rigid plastic. These are relatively narrow and hung as in the previous type. It is important that they are not too long as they will catch on the floor and be torn off. This type does not work as well in low coal since the sheets are rigid and should be pushed up from the bottom to minimize the leverage against the hinges. Figure 15 shows a typical fly installation.

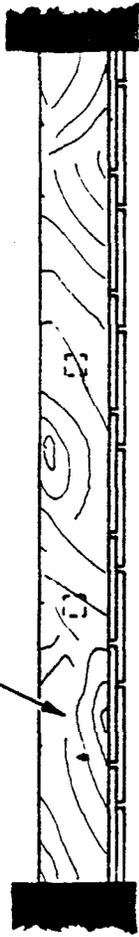
Where and when to install air control devices are influenced by the mining cycle and state and Federal regulations. The legal requirements have not and do not have the impact in this area that they have had in the other areas. The major laws as they are enforced are 1) 9000 cfm is required in the last open crosscut, 2) only two open crosscuts are allowed and 3) the belt must be isolated. The 9000 cfm requirement was an increase from 6000 or so cfm in some states but really has not been and is not too difficult to comply with. The two open crosscuts requirement is actually not a new law but the vigorous enforcement is new. Isolation of the belt entry has had very little effect on mining. Table 4 is a list of these laws and the variation of these laws in different states.

The greatest impact on production has been the requirement for keeping the line of brattices within two crosscuts of the face. In mines with belt haulage, which is almost always in the center entry, the routes (crosscuts and entries available for shuttle cars to travel) have been greatly reduced (at least on one side of the section). This is best shown on Figure 16 where the left side shows the routes under the present law and the right side under the former law.

The major goal in this area of the mine ventilation plan is to get as much of the air as possible that reaches the last stopping to the last open crosscut. Not only does the quality of the temporary checks and flies influence this goal but also the location of the checks and flies. For example, if a fly is positioned so that every shuttle car that approaches the dump has to run through this fly then not only will the fly soon be damaged but the air reaching the last open crosscut will often be short circuited. This situation can exist for example when the mining operation moves back to the entries after completing the room or rooms off to the right.

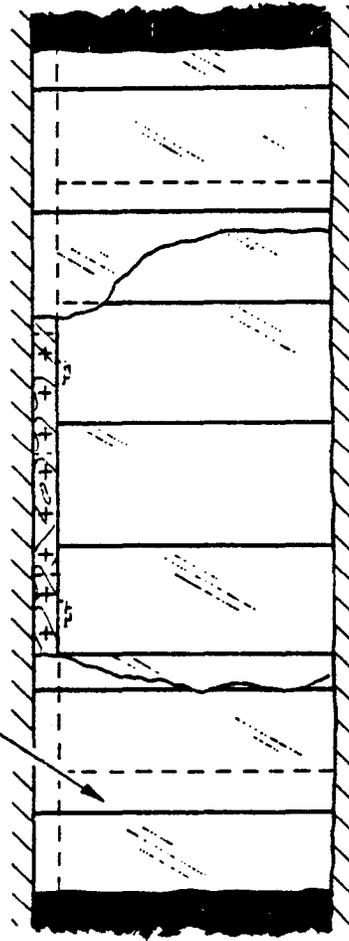
The preferred system for installing check curtains is in such a way that the shuttle cars will run through a minimal number of flies when traveling between the miner and the dump location. One such system is called the box check system and is shown in Figure 17. This is really a system of installing double checks so that the check (or fly) outby the last open crosscut in the entry being mined can be removed or rolled up during this time. The backup or box checks outby the last stopping prevent air from short circuiting and bypassing the last open crosscut. The position of the miner, the checks left in place and one of the shuttle car routes for mining each entry is shown in Figure 18. A simpler system uses only one

Board 2" by 8" by
(as required)



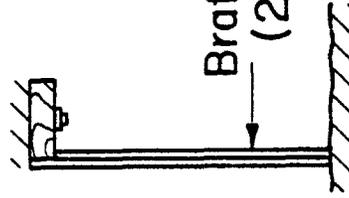
PLAN VIEW

Brattice cloth



FRONT ELEVATION

Brattice cloth
(2 layers)



SIDE ELEVATION

FIGURE 15. - Typical fly installation

TABLE 4. - List of laws referring to section ventilation

<u>Section of the Law</u>	<u>Topic</u>	<u>Requirement</u>	<u>Effect</u>	<u>AL</u>	<u>IL</u>	<u>IN</u>	<u>KY</u>	<u>MD</u>	<u>PA</u>	<u>IN</u>	<u>VA</u>	<u>WV</u>	<u>IA</u>	<u>KS</u>	<u>MO</u>
75.301 & 75.301-3	Quantity and where measured	A minimum of 9000 cfm of air is required in the last open cross-cut between each entry or room.	Very positive control of the air is required on a section to keep this amount of air up to the last open cross-cut.	NR	6000 cfm	6000 cfm	NR	NR	6000 cfm	6000 cfm	6000 cfm	ES	NR	NR	NR
75.316-2	Permanent Stoppings	Permanent stoppings should be erected between the intake and return air courses to and including the third outby connecting crosscut from the face of the entries.	This reduced the number of haul roads available for hauling coal on at least one side of a typical section.	NR	ES	ES	NR	NR	ES	ES	ES	ES	NR	NR	NR
75.301 & 75.301-3	Quantity and where measured	A minimum of 9000 cfm of air is required in the last open cross-cut between each entry or room.	Very positive control of the air is required on a section to keep this amount of air up to the last open cross-cut.	NR	NR	NR	NR	NR	ES	NR	NR	NR	12,000 cfm	6000 cfm	NR
75.316-2	Permanent Stoppings	Permanent stoppings should be erected between the intake and return air courses to and including the third outby connecting crosscut from the face of the entries.	This reduced the number of haul roads available for hauling coal on at least one side of a typical section.	NR	NR	NR	NR	NR	ES	NR	NR	NR	ES	ES	ES

NR = No requirement; ES = Essentially the same

LEGEND

- | | | | |
|-----------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------|---------------------|
|  | Line brattice |  | Stopping |
|  | Fly stopping |  | Present regulations |
|  | Intake air |  | Former regulations |
|  | Curtain stopping | | |

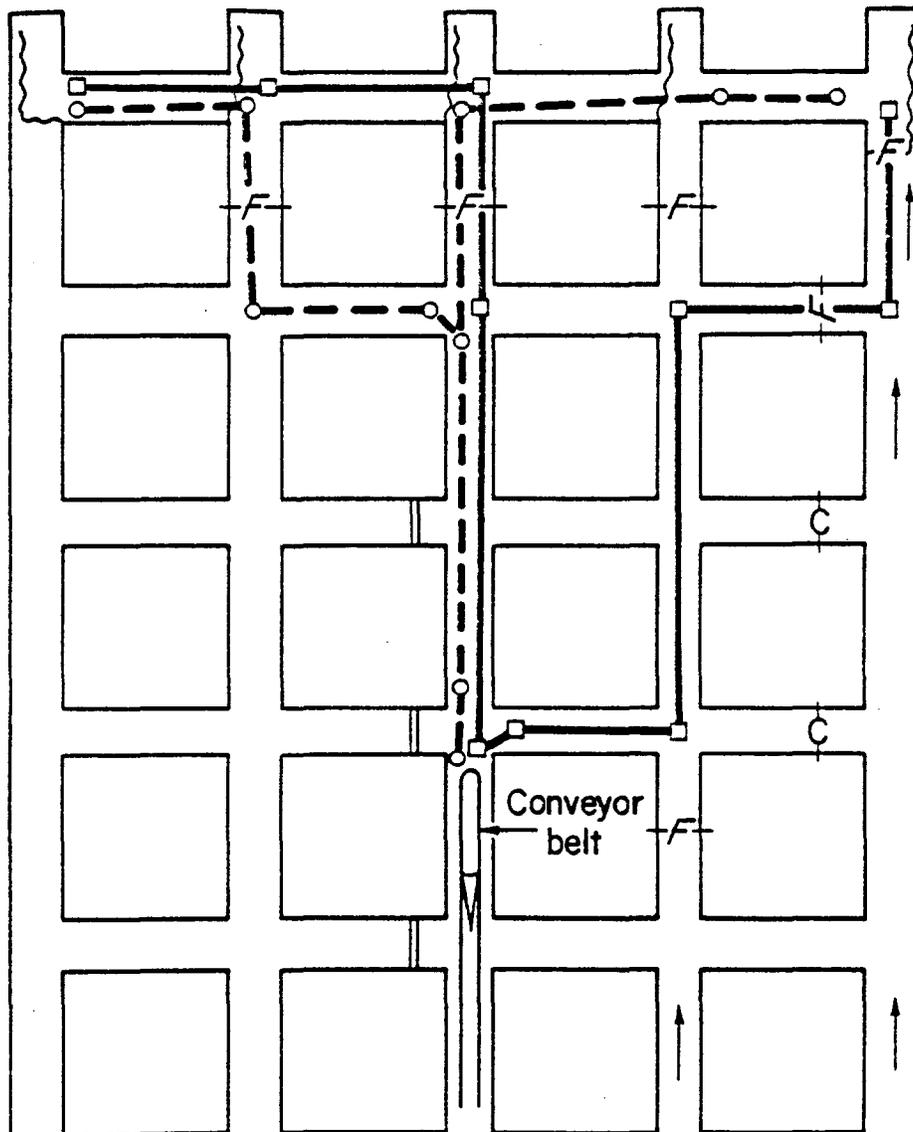


FIGURE 16. - Haulage routes

LEGEND

- | | | | |
|-----------------------------------------------------------------------------------|---------------|-----------------------------------------------------------------------------------|--------------------|
|  | Line brattice |  | Stopping |
|  | Fly stopping |  | Regulator |
|  | Intake air |  | Stopping with door |
|  | Return air |  | Curtain stopping |

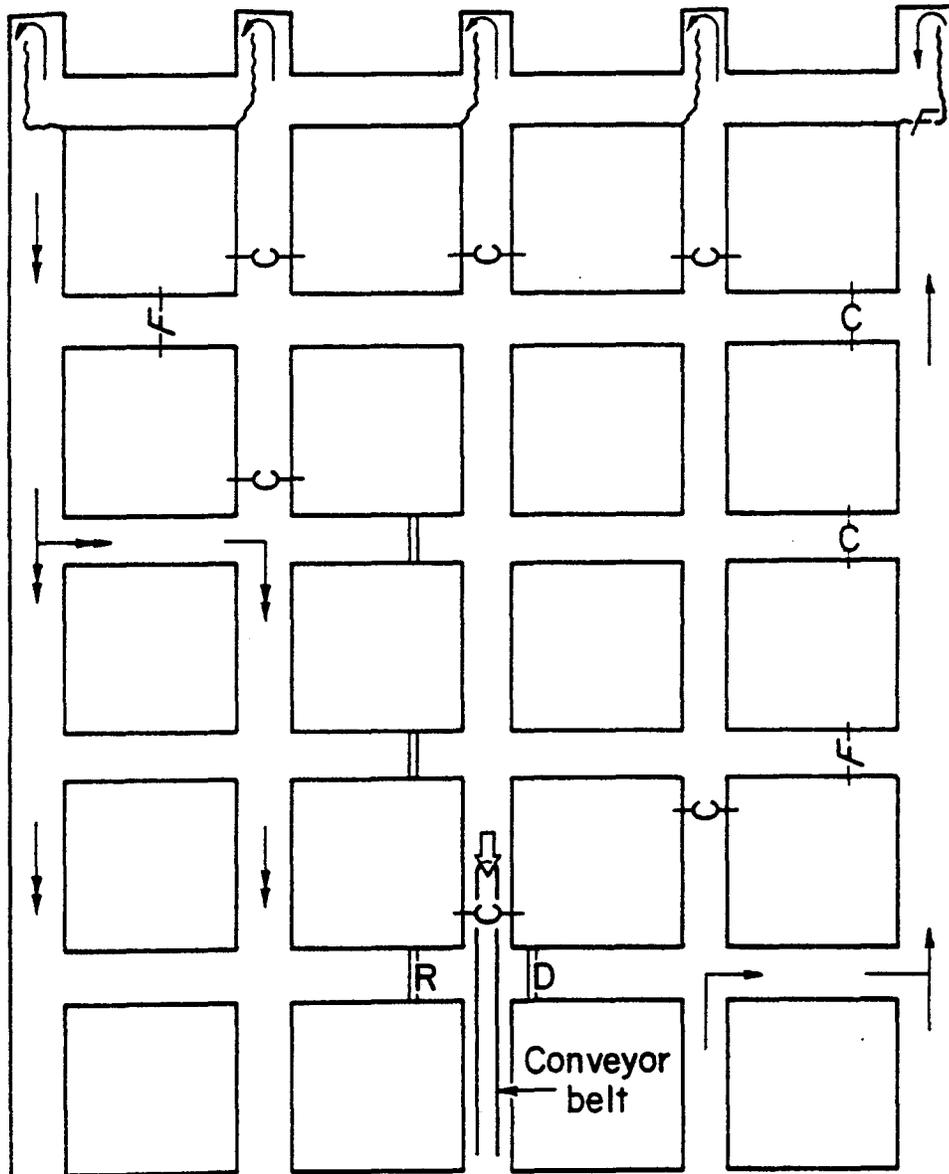


FIGURE 17. - Box check system

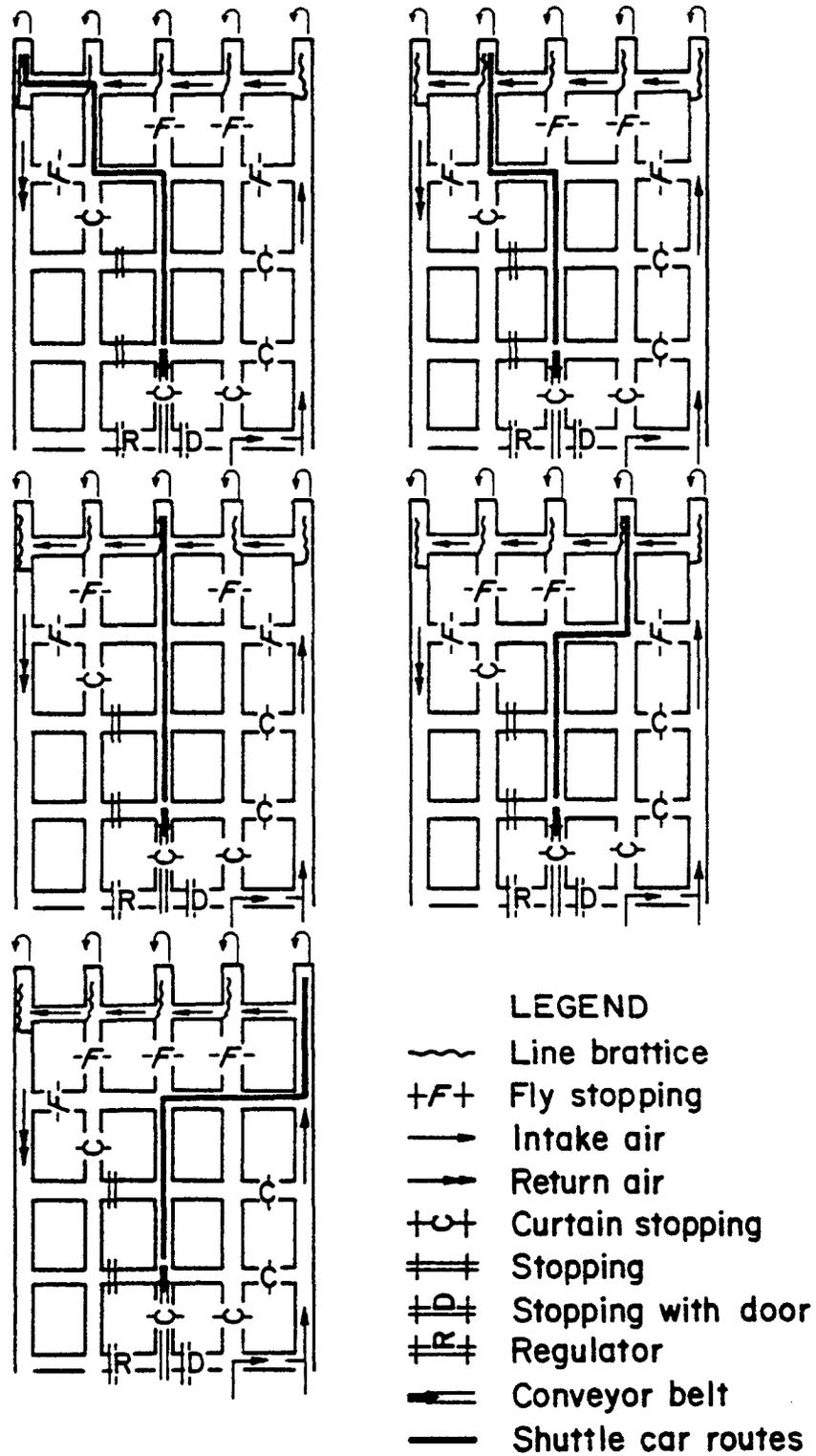


FIGURE 18. - Shuttle car routes, box system

line of checks or flys up one side of the section and a line of flys in the middle entries across the middle entries outby the last open crosscut. This method allows the air to short circuit the faces albeit momentarily every time a shuttle car travels to or from the face to or from the dump point.

There is no doubt that compliance with the law has resulted in increased haul times for the shuttle cars. For example, when there are three or more open crosscuts, the change out points for shuttle cars are almost always moved inby at least one crosscut. Similarly, at the face, it is not uncommon for the change out points to be moved outby one crosscut from the last open crosscut.

When locating flys it is important to try to locate them so that equipment, especially shuttle cars, will not be turning as it travels through the fly. In other words any equipment should not start the turn at least until the operator is through the brattice cloth or preferably after the equipment is through the brattice cloth. Similarly, coming back it should have completed the turn and be heading straight before the operator goes through the brattice cloth. When equipment is turning as it is going through the fly it is much more likely to catch on the brattice cloth than when it is going straight through the fly.

Generally, the major changes in location of flys and checks are made when a new crosscut holes through. A part of the line curtain can be used to make a quick check curtain or fly if immediate corrective action is required. Often, however, no change is needed until after the place is roof bolted and mining starts again. Most of a shift only minor changes are needed, such as rolling up or temporarily removing flys. Stoppings must be built immediately after the crosscut is "holed through" between the intake and returns.

The major advantage to fishtailing the air in a nongassy mine is that more of the men more of the time are working in fresh air and not downwind of the miner. This is particularly beneficial to the roof bolting operation on a continuous miner section. On a conventional section all face people benefit equally since they all spend about the same amount of time working downwind of each other. Their exposure is one-half when compared with single split ventilation.

3.4 Face Ventilation

This area of the mine extends from the last open crosscut to the working face, or as defined in CFR Title 30, the working place. The face is the smallest of the three areas but it is by far the largest dust producing area. The face distance rarely exceeds 200 ft and is limited by both state law(s) and practical realities. The maximum distance is normally reached when driving the crosscut from one entry to another entry. Some exceptions occur when driving entries in from the drift mouth and around shaft and slope bottoms. This latter drivage is justified because it is always desirable to maximize the shaft (or slope) pillars.

Line curtains and/or auxiliary fans are used to direct air to the face. The line curtains and fans are classified as either exhausting or blowing. The classification of the line brattice depends on the direction of the air flow over the miner operator, while the classification of the fan depends on the direction of the air flow in the air dust between the fan and the face. It is coincidental, but the classification of the fan results in the same flow of air over the miner operator. Line checks are made from brattice cloth (jute), plastic mylar, reinforced plastic or plastic impregnated burlap. Auxiliary fans are available in several sizes and horsepower and must be permissible.

The installation of line curtains should start with the roof support cycle. If roof bolts are used, the plates can be used to hang the brattice cloth. In mines where half headers are used, the half headers should be turned in such a direction that they can be used to support the cloth. For example, if the roof bolts are in the proper location, the half headers should be turned parallel with the line brattice. If the roof bolts are too close to or too far from the rib, the half headers should be turned perpendicular to the line brattice and the brattice cloth nailed to the appropriate end of the half header. The line brattice should be fastened as close to the roof as possible and at least 4 in. down from the edge of the cloth. If the top is soft, spads or nails can be used to attach the cloth to the roof between bolts. If a blowing brattice is used, the cloth will be blown away from the rib and the bottom will only have to be held down if the pressure is so great that the brattice cloth is pushed out into the shuttle car runway. The cloth can be held down with rocks, posts, lumps of coal, bundles of roof bolts, etc. If an exhausting brattice is used, the bottom will almost always have to be held away from the rib unless the entries are high and wide. In severe cases, the bottom can be held down and out away from the rib by fastening one end to a crib block and positioning the other end against the rib. Care must be used here because the brattice cloth will often be blown against the rib so that the proper flow of air is prevented.

When posts are used, the brattice cloth should be placed so the air pressure pushes the brattice cloth against the posts. The cloth should be attached to the top of the posts or even on the wedges if practical and down about 4 in. from the edge of the cloth. When the air pressure is very high the cloth may even have to be attached to the bottom of the posts. If the top is soft, spads or nails can be used to attach the cloth to the roof. Figure 19 shows how to install a line brattice.

The above methods are used to install the line brattice up to the end of the permanent supports. From this point on, the line brattice must be installed on temporary supports to within 10 ft of the face. In a conventional mining situation it is possible that the brattice will be within 10 ft of the face if the place was roof bolted up to the face before this cut was taken. Legally and operationally it is seldom required to have the brattice closer than 7 or 8 ft of the face, therefore three temporary supports set on 5 ft centers are all that is required to extend the line brattice the required distance. Supports as used here are primarily for roof support although they serve the dual purpose of supporting the brattice cloth.

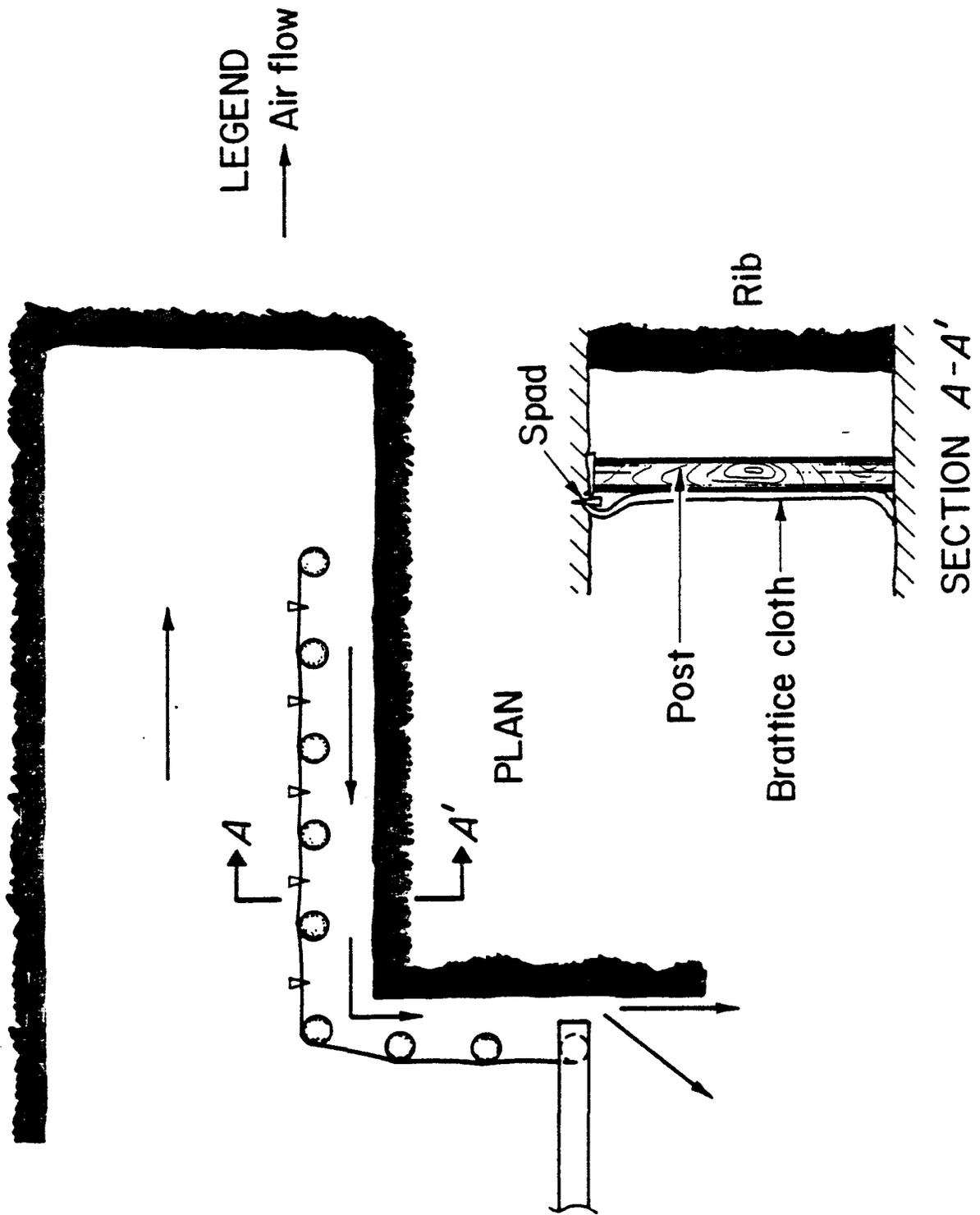


FIGURE 19. - Typical line brattice installation

Additional supports may also be required to provide protection for men when cleaning up and rock dusting. While posts work well for mines on a conventional (timbering) or combination (timbering and roof bolting) method of roof supporting, it is usually advantageous to use timber jacks (screw type or ratchet type) or hydraulic props when using all roof bolts for roof support. These latter supports have the advantages of being installed more quickly and easily which reduce the amount of time workers are exposed under unsupported roof, and since they are more quickly installed less time is lost mining coal. Before a support is set, the floor should be cleaned of any spillage to provide a solid foundation. By using a half header or cap pieces, a place is provided for attaching the brattice cloth.

The quickest and easiest way to install line brattice is by hanging it from spads. Triangular shaped spads which can be installed with spad guns or hammers are available and will penetrate moderately hard coal or even soft top. These spads can be driven through the brattice cloth into the coal on 2 ft centers, or closer if necessary, virtually insuring a well installed brattice cloth. When removing the brattice cloth, two taps with a hammer knocking the spad back and forth will loosen it so it can be easily pulled out with the brattice cloth.

Tubing which can be rigid, flexible, or wire wound flexible is best suspended from the top or sides by means of wires. The wires can be attached to roof bolts, spads or posts. Hanging the tubing has the advantage of keeping the tube out of the way of coal if it is dumped on the floor behind the miner and then picked up with a loading machine. Suspending the tubing also keeps it out of the way for clean up activities. Many states have laws which prohibit anything except exhaust fans. While these laws refer to main fans, the laws are often being enforced in the use of auxiliary fans. This has resulted in most of the present auxiliary fans being used in the exhaust mode, which in turn requires the tubing be noncollapsible. There are two types of noncollapsible tubing, rigid and wire wound. The wire wound tubing is flexible, easier to store, and easier to carry. The flexibility allows the tubing to go around corners and in general follow the wall of the entry. A major disadvantage is that it is somewhat more difficult to install. The rigid tubing does not go around corners or follow the rib as closely as the flexible, but does have the advantage of being able to telescope one tube inside the other, eliminating the need for men to install ventilation under unsupported roof. There are at least three different shapes of tubing available: circular, oval and a modified oval shape designed specifically for a twin borer entry. Legally, tubing must be kept within 10 ft of the face, and often closer to clear the face of methane.

After the cutter or loader leaves a place, line brattice must be installed for face ventilation if the fans are to be removed or stopped. If an exhausting fan will not keep the face clear of gas it is possible to install a (blowing) line brattice up one side of the entry in conjunction with an exhausting fan (and tubing) down the other side of the entry. Such a scheme is shown in Figure 20. To keep the dust out of the next place (which is usually where the roof is being bolted), a tube can be attached to the exhaust side of the fan (if an exhaust fan is being used) and extended past the next downwind entry. This arrangement is shown in Figure 21.

LEGEND

- ⇨ Intake air
- ⇩ Return air

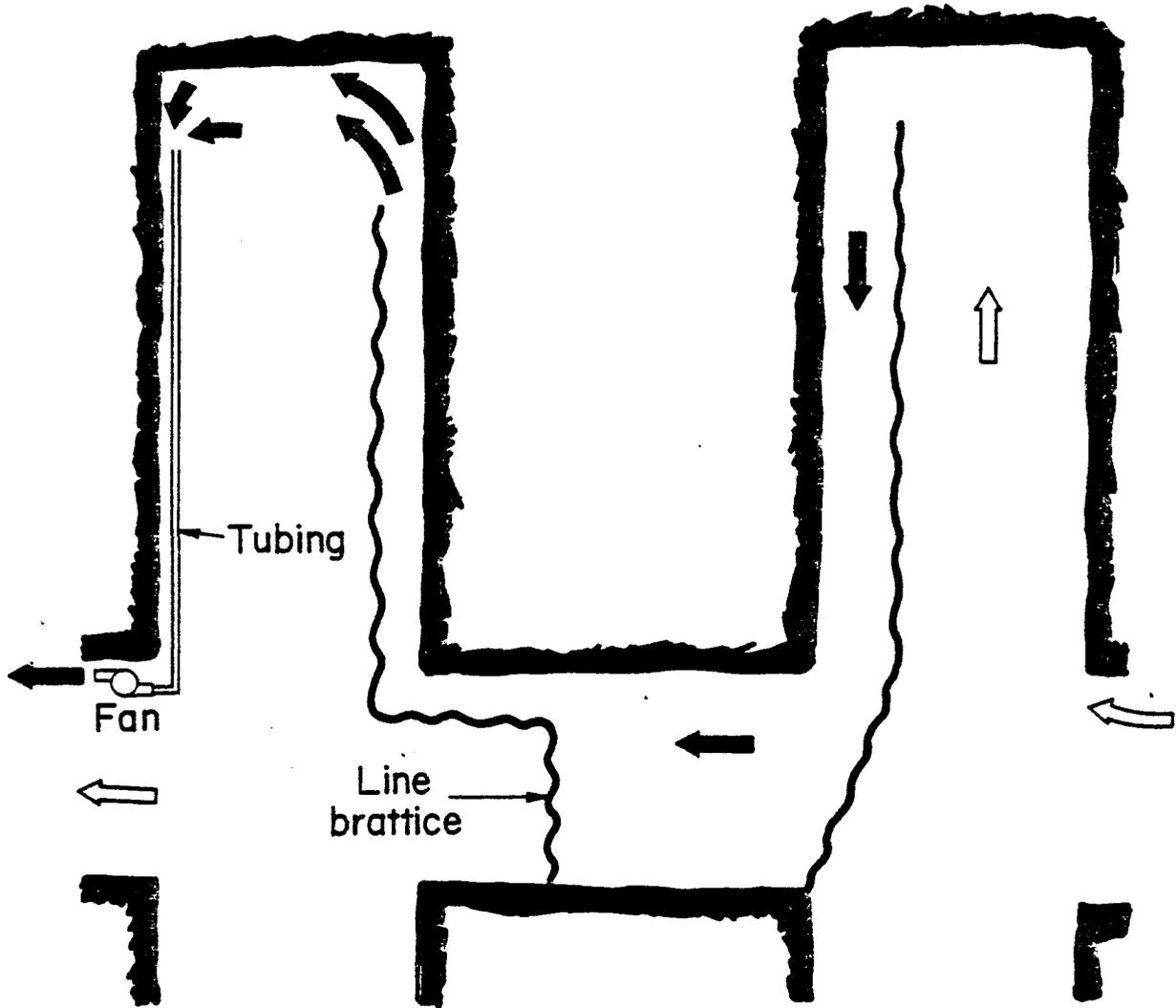


FIGURE 20. - Combination line brattice and tubing

LEGEND

- Intake air
- Return air

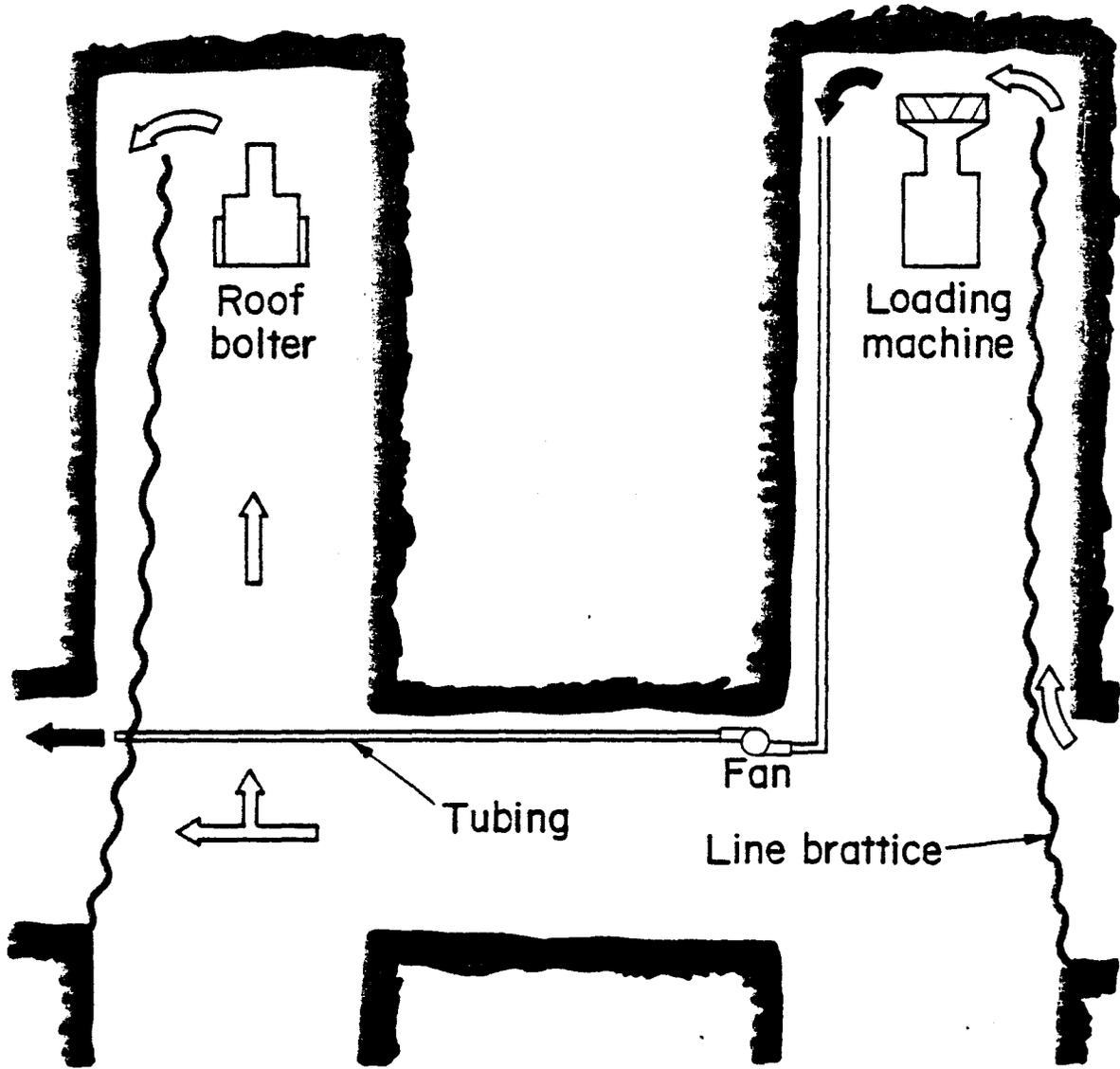


FIGURE 21. - Discharge from fan exhausting to return

Where to install line brattice or auxiliary fans is determined by whether an exhausting or blowing device is required. Two major legal requirements are that there must be at least 3000 cfm (6000 in Utah) reaching the face and that the mean velocity must be at least 60 fpm. A third major legal requirement established by many states is the maximum distance allowed between crosscuts. This distance is not limited by Federal law. This distance is really an effort to limit the maximum allowable drivage in the solid (any combination of crosscut and entry) and is usually about 200 ft. A summation of these three laws is shown in Table 5.

Most of the air brought into a mine for use at the face is lost in this last 100 or so feet. In low coal mines the cross sectional area is such that relatively high velocities and pressure drops are required to keep a sufficient volume delivered to the face. In high coal mines the cross sectional area is so great that the velocity is very low even with relatively good quantities of air being delivered to the face.

There is no doubt that an exhausting system is a better system for maintaining a lower respirable dust concentration in the air than a blowing system. Perhaps an acceptable solution is to install both blowing and exhausting devices in the same working place when gas liberation becomes an impediment to production. Possible solutions are shown in Figure 22. Of course blowing fans can only be installed where they are legal. In these combination systems it is recommended that the air being exhausted from the face exceed the air blowing to the face by at least 25%, which should be sufficient to keep clean fresh air blowing over the machine operator and other workers.

The quantity of air is measured at the inby end of the brattice cloth on either side of the brattice cloth. The velocity of the air is calculated by determining the cross sectional area of the entry on the working side of the line brattice at the end of the brattice cloth. This area is then divided into the volume of air previously determined; the resulting velocity is the mean velocity.

The line brattice is often installed across a shuttle car runway so that the shuttle car must go through the line brattice on the way to or from the face. When this is done, part of the line brattice becomes a fly. One method to facilitate shuttle cars turning into the working place is to install the fly down the crosscut about half the length of the shuttle car from the edge of the rib. The line brattice is then extended around the corner to the fly. This prevents turning while going through the fly and is shown in Figure 23.

Fans must be located so that recirculation of air is not possible. For example, an exhaust fan must be located on the downwind side or the entry. The fan capacity should not exceed one-third of the flow of air in the crosscut or the air carried to the face will be part of the exhausted air from the fan. Not only will this air contain methane, if originally present, but it will also contain respirable dust. Unless the coal is very high the tubing should not cross over a shuttle car route since it is likely

TABLE 5. - List of laws referring to face ventilation

<u>Topic</u>	<u>Requirement</u>	<u>Effect on Mining</u>	<u>AL</u>	<u>IL</u>	<u>IN</u>	<u>KY</u>	<u>MD</u>	<u>NY</u>	<u>OH</u>	<u>TN</u>	<u>VA</u>	<u>WV</u>	<u>IA</u>	<u>KS</u>
Air reaching the face	Minimum quantity of 3000 cfm of air required within 10 ft of each face where coal is being prepared or loaded.	While this is approximately the same as previous laws the more stringent enforcement of this law has had a serious constraint on production.	NR	ES	NR	NR								
Velocity of air at the face	The minimum mean entry air velocity required is 60 fpm.	Very little effect except in very high coal.	NR											
Solid drivage is limited to 200 ft	Working places shall not be driven more than 200 ft without providing a connection that will allow the free flow of air currents.	No effect since most states have always had this law and still do.	ES	ES	ES	NR	NR	ES	ES	NR	ES	ES	NR	NR
<u>Topic</u>	<u>Requirement</u>	<u>Effect on Mining</u>	<u>MO</u>	<u>OK</u>	<u>TX</u>	<u>AK</u>	<u>AZ</u>	<u>CO</u>	<u>MT</u>	<u>NM</u>	<u>ND</u>	<u>SD</u>	<u>UT</u>	<u>WY</u>
Air reaching the face	Minimum quantity of 3000 cfm of air required within 10 ft of each face where coal is being prepared or loaded.	While this is approximately the same as previous laws the more stringent enforcement of this law has had a serious constraint on production.	NR	NR	NR	NR	NR	NR	ES	NR	NR	NR	6000 cfm	NR
Velocity of air at the face	The minimum mean entry air velocity required is 60 fpm.	Very little effect except in very high coal.	NR	NR	NR	NR	NR	NR	ES	NR	NR	NR	NR	NR
Solid drivage is limited to 200 ft	Working places shall not be driven more than 200 ft without providing a connection that will allow the free flow of air currents.	No effect since most states have always had this law and still do.	NR	NR	NR	NR	NR	300 ft	NR	NR	NR	NR	NR	300 ft

NR = No requirement; ES = Essentially the same

LEGEND

→ Direction of air flow

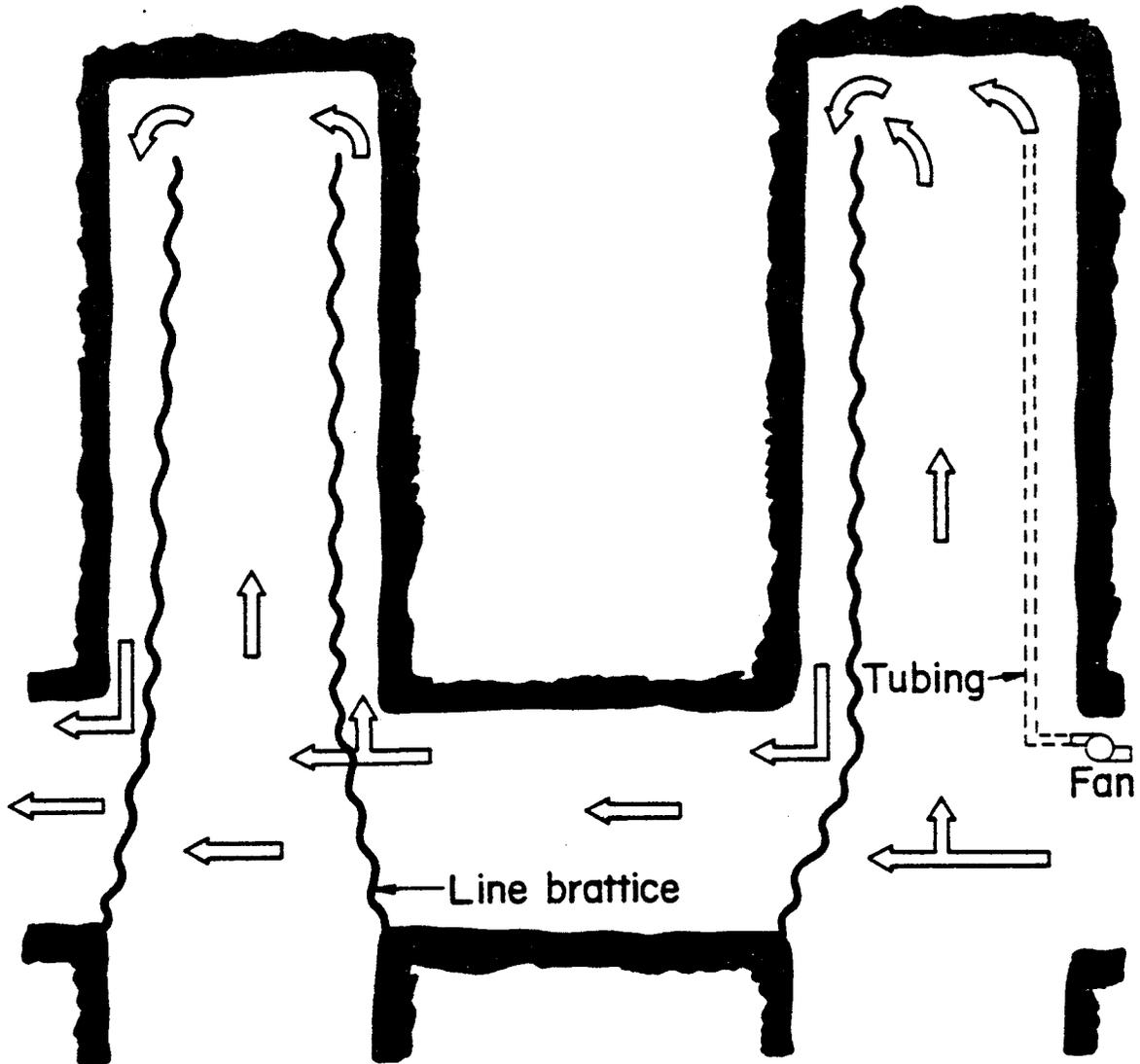


FIGURE 22. - Combination exhausting/blowing face ventilation

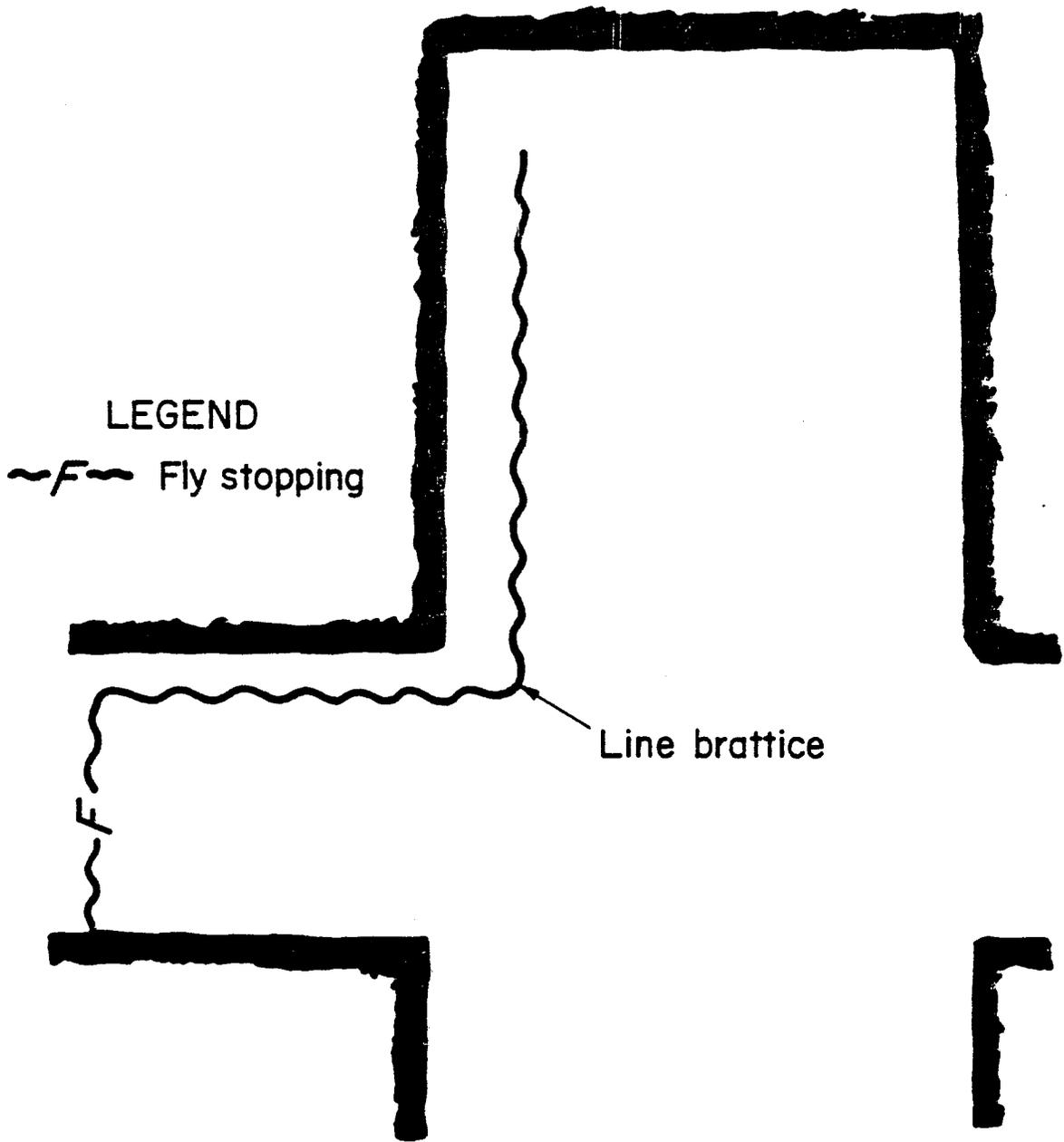


FIGURE 23. - Line brattice/fly combination

that the tubing will be disconnected if it is bumped by coal piled up on the shuttle car.

Good face ventilation can be attained through constant maintenance of line brattice or tubing during the mining cycle. Mining equipment is always brushing against and tearing out the line curtain. When a loading machine is used, the digging arms will often catch the brattice cloth and tear it loose from the roof. The hazardous part is not when the brattice cloth falls on the ground because this is obvious, but when the cloth is just loosened and falls away from the roof a foot or so. This gap in low coal is often sufficient to short circuit sufficient air and to allow a buildup of methane at the face. A partial interruption in the flow of air is often not noticed when mining activities have ceased as, for example, between shuttle cars. The only remedy is constant vigilance by all concerned.

There is no doubt that keeping the line curtain within 10 feet of the face requires great care in those mines which produce only a moderate amount of gas. This is because 1) visibility in the face area is reduced, 2) much more maneuvering of the miner is required when mining on the curtain side, 3) mining is often delayed when installing the line brattice, and 4) the maintenance and presence of the line brattice slows up other activities such as shuttle car haulage, clean up, etc. Delays to production can be minimized by proper placement of line brattice and installing the brattice at the correct time. Generally speaking, the major changes in a line brattice are made when 1) a place "holes through", 2) a place is started off and 3) a fan is to be replaced with a line brattice. By proper planning it often will not be necessary for the brattice to be rehung from the roof during subsequent operations.

Conventional mining requires all equipment and the blasting cycle to be ventilated. A typical cycle consists of cutting, drilling, shooting, loading and roof bolting. There are many variations of the typical mining cycle, even though all of these elements must be done to mine coal. The biggest variations concern drilling and roof support. Drilling, when done with a handheld drill, can be combined with the cutting machine or with the roof bolting machine. Roof support is usually done with roof bolts although it is possible to use timber without using roof bolts.

The important fact to remember is that 3000 cfm of air must be supplied to within 10 ft of the face when any of the above operations are taking place. Timbering is a possible exception to this rule, although there is a move afoot to require 3000 cfm wherever men are required to work. Timbering as described herein would replace roof bolting as part of the roof support cycle. This type of roof support is not frequently used as a sole means of roof support. Essentially, five activities must be ventilated with 3000 cfm of air. For all practical purposes, at least four working places are required to maintain production. When haulage is considered, an odd number of places is suggested to optimize production. Since four is the minimum number of operations, five is then suggested as the minimum number of places required from a production standpoint. Indeed, as many as

21 places have been observed on one operating section. The more the places, the greater the flexibility in operation, of course. The more tradeoffs there are, the more places to ventilate and a larger area to manage.

The preferred way of ventilating the faces is to ventilate all of the faces continuously by keeping the line brattice installed in each entry or crosscut as it is being mined. Usually this means that the brattice cloth is within 10 ft of the face since the last operation performed in the working place required this to be so. There are exceptions of course such as when blasting the coal tears out part of the line curtain, or when the brattice cloth is removed for temporary use someplace else. In this situation, it is the responsibility of the person making the face check to re-install the line curtain to within 10 ft of the face. Needless to say, all of these line curtains installed present quite a resistance to the flow of air across the section. In addition, there is always the danger that the line curtain will choke off the air on the section reducing or stopping the flow of air to all of the faces. This situation is more likely to occur with an exhausting system than a blowing system of face ventilation, since the line brattice is always being blown to the near rib. The only remedy to this possibility is for all people on the section to use constant vigilance and correct any restriction to ventilation as soon as it is seen. The most immediate concern is a build up of methane, of course. With all of the dust suppression devices and methods available today, it is not as easy to determine when the flow of air has been interrupted as it once was, since the build up of dust takes a much longer time than formerly.

The two most complicating factors to ventilation on a conventional section are 1) the constantly changing shuttle car routes and 2) the rapid and continuous movement of equipment. The changing of shuttle car routes will result in either the change out points being located farther from the load and dump points or necessitate the shuttle cars running through check curtains or flies. The constantly changing routes require a high degree of planning, training and monitoring during mining. There are always deviations to a standard plan occurring such as when a crosscut holes through ahead of the other entries, or an unexpected belt move during a breakdown, etc. The best approach in these situations is to keep the ventilation controls as near the face as possible.

The rapid movement of equipment means that cable handling must be done in a manner that does not allow the cable to twist up or interfere with other cables on the section or interfere with the check curtains or flies. This usually means cables must be hung through flies and check curtains in such a manner that the curtains or flies do not have to be removed, even temporarily, for hanging or removing the equipment cables. The movement of this equipment usually requires that flies and checks must be much better installed than on a continuous miner section since the frequent passage of equipment increases the likelihood of equipment tearing out a device. This equipment is often moved by one man and is also shaped with sharp edges, in such a way as to catch on the brattice cloth.

One of the better methods of ventilating the faces is the box-check method of face ventilation (Figure 17). The principle of this method

is that the section area is boxed in with check curtains in such a manner that there is actually a double row of check curtains and flies used to keep air to the face. There are four advantages to this method: 1) the flow of air to any number of faces can be interrupted without interrupting the flow of air to the remainder of the faces, 2) except when a specific line brattice is raised the flow of air to the face does not have to be interrupted, 3) there are two brattices directing the air to the last open crosscut, which reduces leakage considerably and 4) shuttle cars do not have to run through flies. The major disadvantage to the box check method is the extra brattice cloth required to implement this method of section ventilation.

During roof bolting at least 3000 cfm (6000 cfm in Utah) of air must be delivered to the face (more air may be required if methane dilution necessitates it). The main problem arises when roof bolters must work downwind from the mining operation. This, of course, is not a problem if the dust from mining can be suppressed but with most miners this is not possible or feasible. There are two ways to minimize the dust. The first method can only be put in practice when auxiliary exhaust fans are used during the mining cycle. Simply extend the exhaust end of the tubing from the fan past the entry the pinner is in. The second method is to fishtail or split the air at the face and operate the pinner on the split which is not being mined (Figure 24). These two ways of handling ventilation usually do not adversely affect production since they work around or cater to the mining operation. They do have the distinct disadvantage of sometimes causing a delay to pinning after the mining cycle is completed. Other methods, such as not mining or roof bolting when dust from operation blows over another operation, have a very deleterious effect on production.

When installing brattice it usually makes little difference whether it is a blowing or exhausting brattice since the roof bolting operation itself does not normally make much methane. However, it is important to keep the line brattice as close to the face as possible and never over 10 ft from the face. Many roof support plans require that the working place be supported on 5 ft centers, therefore after the miner has left, these temporary supports can be used to install the line brattice on. When tubing is used, it must not be left where it could be blocked off with water, loose coal or slabs of roof. A further word of caution is due here and that is, when tubing is extended past one operation, sufficient air must be made available to ventilate the bypassed operation.

LEGEND

- | | | | |
|-----------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------|--------------------|
|  | Line brattice |  | Stopping |
|  | Fly stopping |  | Regulator stopping |
|  | Intake air |  | Roof bolter |
|  | Return air |  | Loading machine |
|  | Curtain stopping |  | Track |

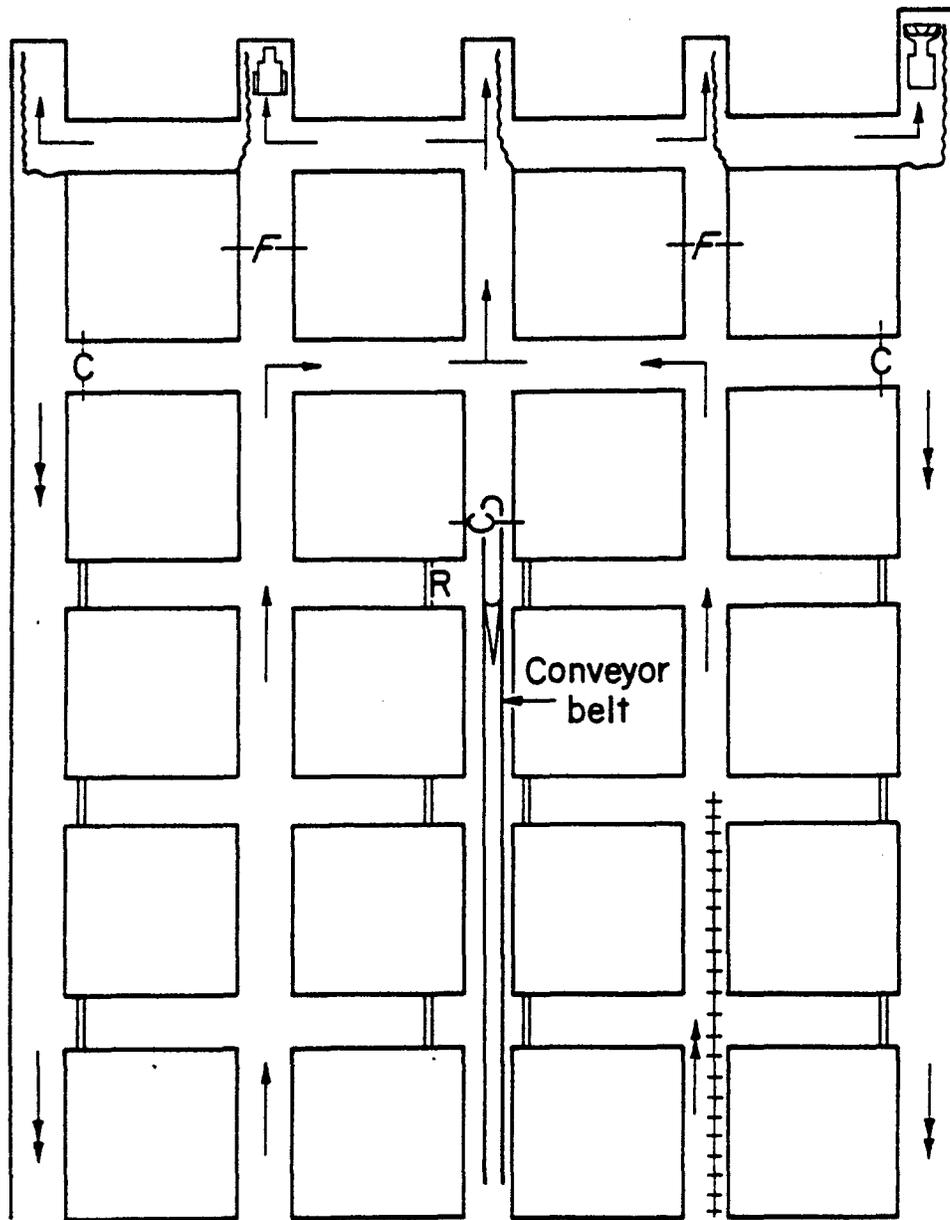


FIGURE 24. - Split ventilation

4.0 WATER AND WATER SPRAYS

4.1 Introduction

Water sprays and ventilation are the two primary methods of controlling dust in underground mining operations. The primary effect of water sprays is to prevent the formation of dust during cutting, drilling, loading and transferring operations; secondary benefits of water sprays include immobilization and capture of dust particles which have been generated.

A large number of studies have been conducted to determine the effects and the effectiveness of water sprays. These studies have revealed that the type and number of sprays are important factors in the overall effectiveness of water spray systems. Other factors include location, direction, distance from the dust generation activity and water pressure and volume. A nonclogging water supply system will assure continuous, maintenance-free operation of the water spray systems.

Documentation of the effectiveness of water spray systems determined during past studies is not incorporated in these guidelines. Since the effectiveness of dust control systems is influenced by the seam being mined, natural moisture content of the seam, specific mining operations and so on, effectiveness of water spray systems as determined under other conditions can only serve as relative information. However, the mine operator can review the information made available in these guidelines and determine the most practical approach to the solution of the problems in his mine.

4.2 Water System

Water Supply - The main water supply on the surface is retained in reservoirs or storage tanks. Water is supplied to the working level through large diameter pipes, e.g., 6 in. diameter. Smaller diameter pipes, e.g., 4 in. are used to distribute water to the working sections. At the face, 1 in. to 2 in. diameter pipes are used. Quick disconnects at the last open crosscut provides a water supply to equipment from entry to entry.

Water Pressure - Water pressure is developed by the water head from the surface supply. Pressures of 80-100 psi at the face are typical of most operations. Pressures can be reduced with a pressure reducing valve or increased with a booster pump.

Water Volume - Spray nozzles operate at various consumption rates, but 0.5 gpm is normally used. A conventional section may require the following:

1. Cutting Machine - 3 nozzles @ 0.5 gpm = 1.5 gpm
2. Loading Machine - 12 nozzles @ 0.5 gpm = 6.0 gpm
3. Drilling Machine (hollow steel drill) = 5 gpm

This amounts to approximately 12-13 gpm per section at the faces. Additional water may be required on section to set down the coal pile after shot firing and during loading, and at the section dump.

Spray Nozzles - A variety of nozzles are available:

1. Full cone (Figure 25a)
2. Hollow cone (Figure 25b)
3. Flat spray (Figure 25c)

These can be purchased in a number of different sizes from the following manufacturers:

1. Bete Fog Nozzle, Inc.
2. Delvan Corporation
3. Senior Conaflo
4. Spraying Systems Co.

The full cone nozzle is the most widely used in the mining industry.

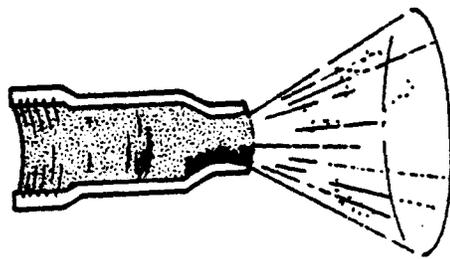
Nonclogging Water System - Clogging of water spray nozzles results in insufficient use of water and/or excessive maintenance and replacement requirements. Solids present in the mine water supply or rust and scale from the pipes cause clogging. A simple, nonclogging water supply system was developed under Bureau of Mines funding. The system consists of an in-line Y-strainer, a hydrocyclone, a backup filter and two quick opening valves for flushing particulates from the strainer and hydrocyclone (Figure 26). The total estimated cost is \$1000 to \$1200.

The system is flushed by opening the valves on the Y-strainer and the hydrocyclone for a few seconds. The system should be flushed at least once per week; more frequent flushing may be required if the water is exceptionally dirty or if large volumes of water are treated.

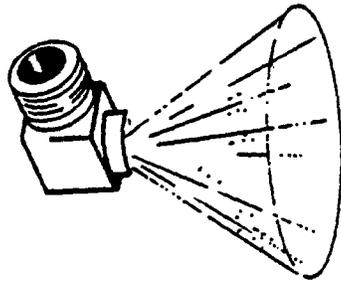
Cutting Machine - Water can be supplied to a cutter bar through the cutter bar (wet bar system) or by spraying directly onto the cutting bits. Figure 27 shows a combination of a wet bar and spray system.

Loading Machine - Dust during loading results from the gathering arms and the conveyor. Water sprays will reduce the amount of dust made during loading operations. Figure 28 is a typical water spray arrangement for a loading machine. Wetting the coal pile following shot firing and during loading will minimize the amount of dust generated, also.

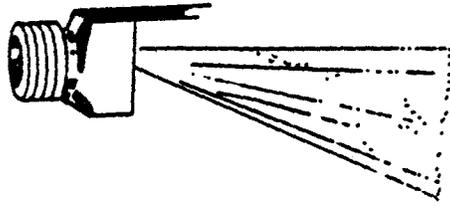
Drilling Machine - Most drilling is currently done with hollow steel drills. Water flowing through the drill bit effectively controls dust during this operation.



Full cone
(a)



Hollow cone
(b)



Flat spray
(c)

FIGURE 25. - Spray nozzles

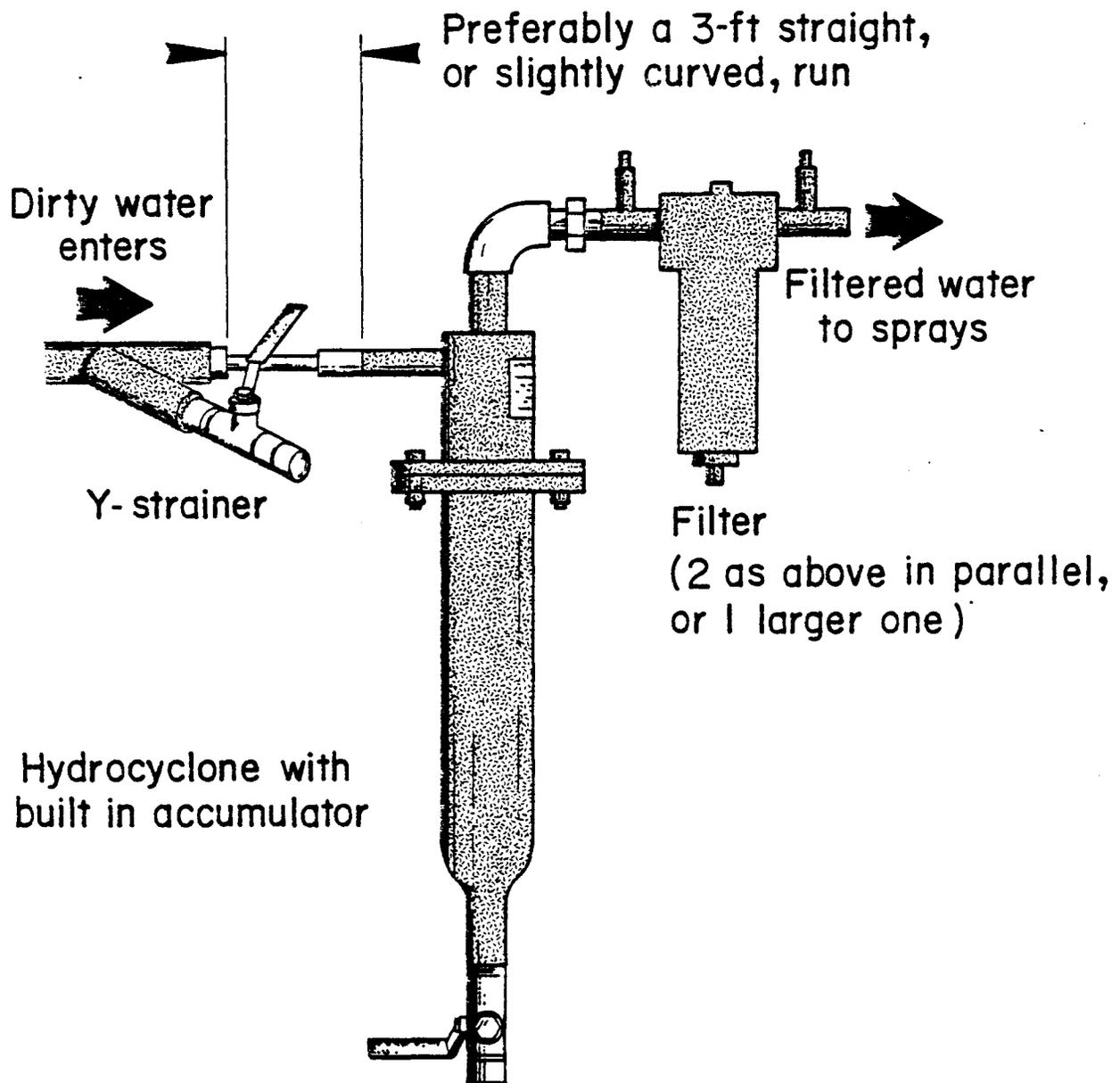


FIGURE 26. - System components

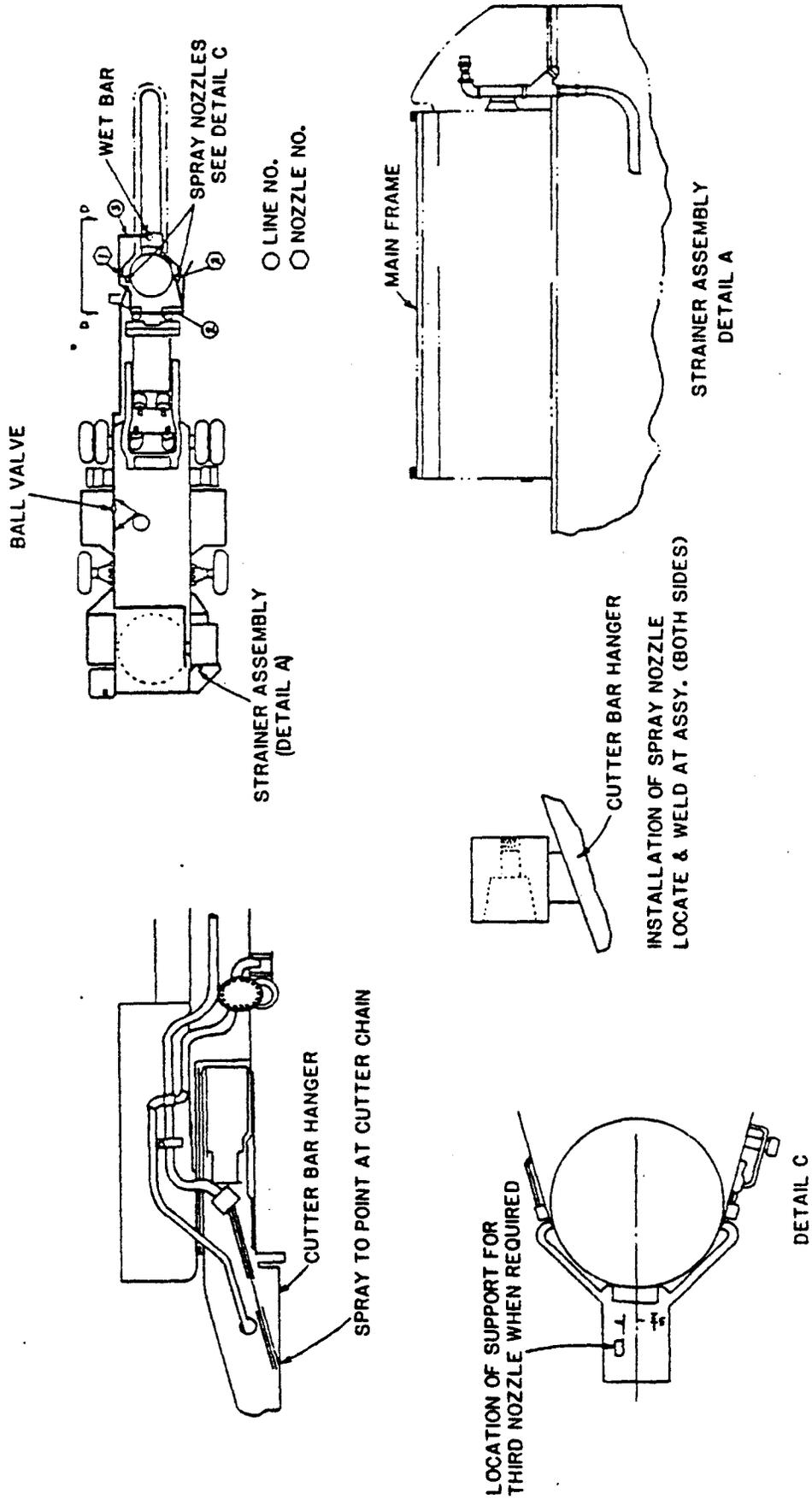
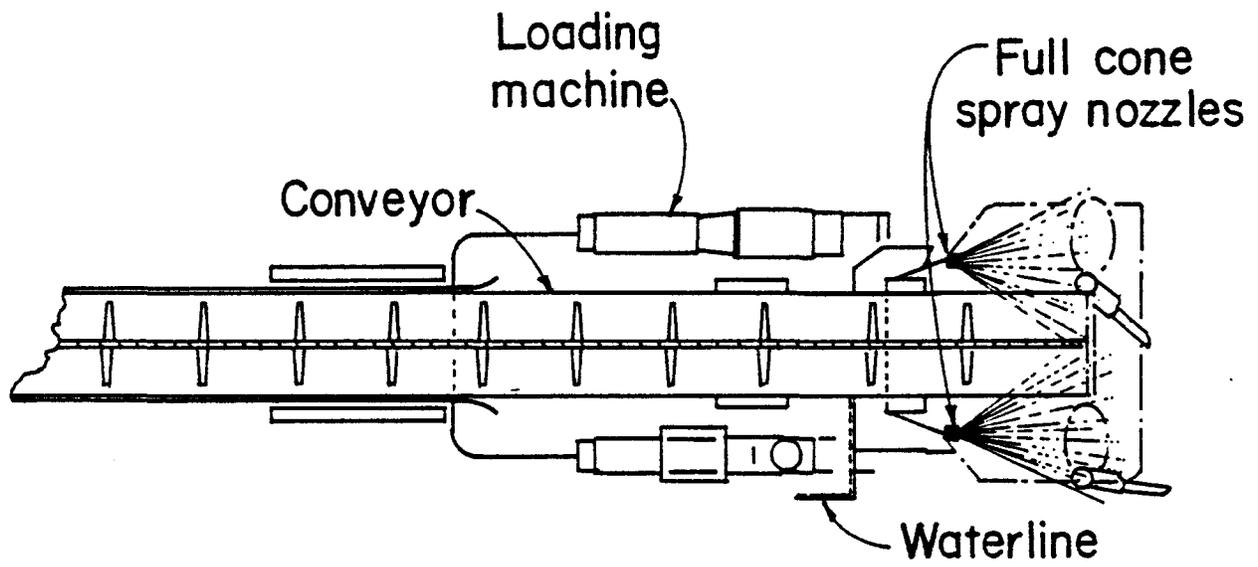
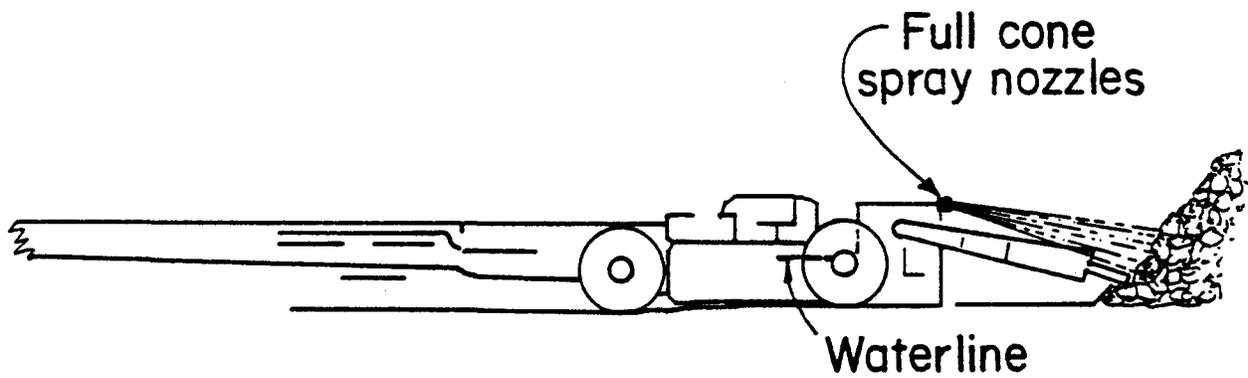


FIGURE 27. - The wet bar system in conjunction with two sprays (Courtesy of Joy Manufacturing Co.)



PLAN VIEW



SIDE VIEW

FIGURE 28. - Water spray arrangement on gathering arm loaders
(Courtesy of Spraying Systems Co.)

5.0 ADDITIONAL METHODS OF DUST CONTROL

Ventilation air and water sprays are, by far, the most effective means of dust control in conventional mining operations. However, there are other methods and procedures which can reduce the total on-section dust inventory and/or miner exposure to dust. Alternate methods to shot firing are available which will reduce the amount of dust make, and administrative controls can be used to minimize miner exposure.

5.1 Alternate Methods to Shot Firing

The use of explosives and blasting agents is the most commonly used method for breaking coal in conventional mining operations. These methods do have the advantage of producing larger product size, less respirable dust and no toxic or noxious fumes:

1. Cardox
2. Airdox
3. Hydrox
4. Chemical
5. Hydraulic and bursters

The Cardox system uses liquefied carbon dioxide which is vaporized to fracture the coal. It is charged at 2000 psi to a steel tube; the CO₂ liquid is then vaporized at 88°F (31°C). The rapid pressure rise fractures the coal and actuates two retaining pawls to hold the tube in the hole (Figure 29).

Airdox uses compressed air (11,000-12,000 psi) to fracture the coal (Figure 30). The shell is charged only after it has been placed in the hole, and since there are no chemical reactions or sparks, these devices are extremely safe. Some state laws dictate that this is the only type of "shot" firing which can be used.

Hydrox works on the same principle as the Cardox system, except that high pressures are generated by the reaction of sodium nitrate and ammonium chloride to form steam and nitrogen.

Chemical is similar to the Hydrox system. The chemical reaction is initiated electrically, and pressures of 18,000-22,000 psi are generated. Because of the electrical ignition system, it is not always permitted to be used in gassy mines.

Hydraulic coal bursters use water pressure to break the coal. Pressures of the order of 1500 psi are generated. This type of mechanical breaking is relatively slow, but it does produce significantly less dust than explosive blasting.

KEY

- 1. Ignition head
- 2. Connection from firing cable
- 3. CO₂ filling duct
- 4. Initiator
- 5. Gas charge
- 6. CO₂ filling
- 7. Bursting disk
- 8. Gas escape openings
- 9. Expanding jaws
- 10. Discharge head
- 11. Shell body

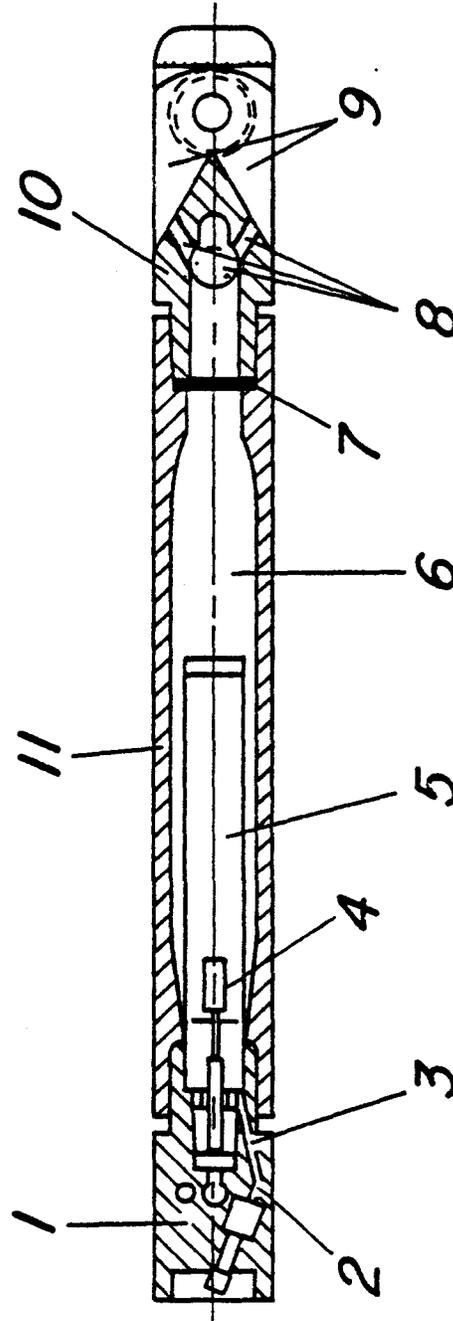
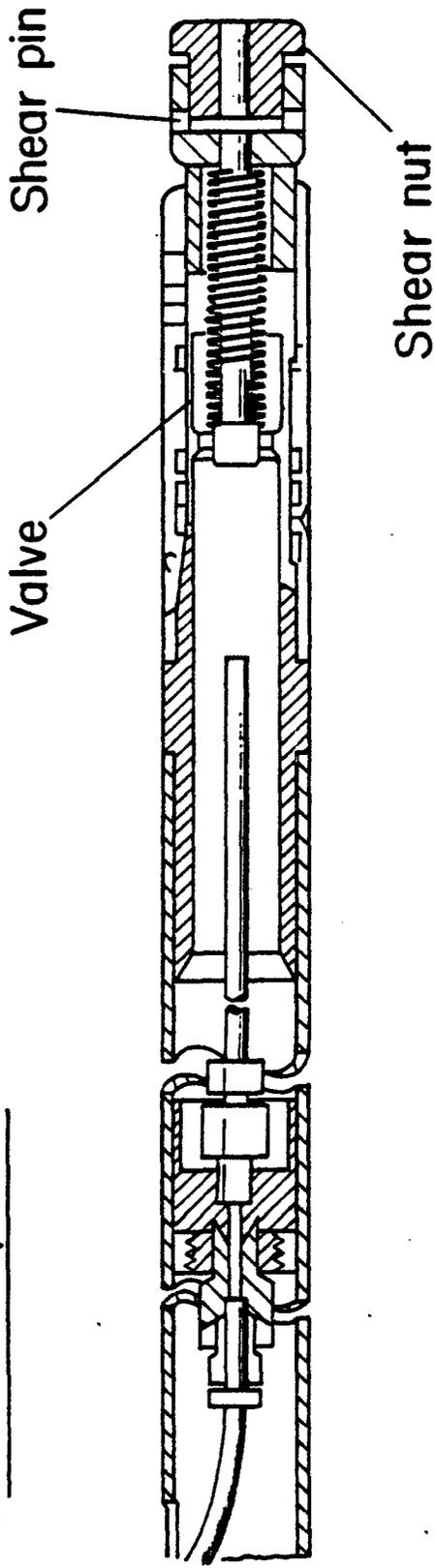


FIGURE 29. - Cardox shell

A. Shell with piston



B. Shell with rupture disk

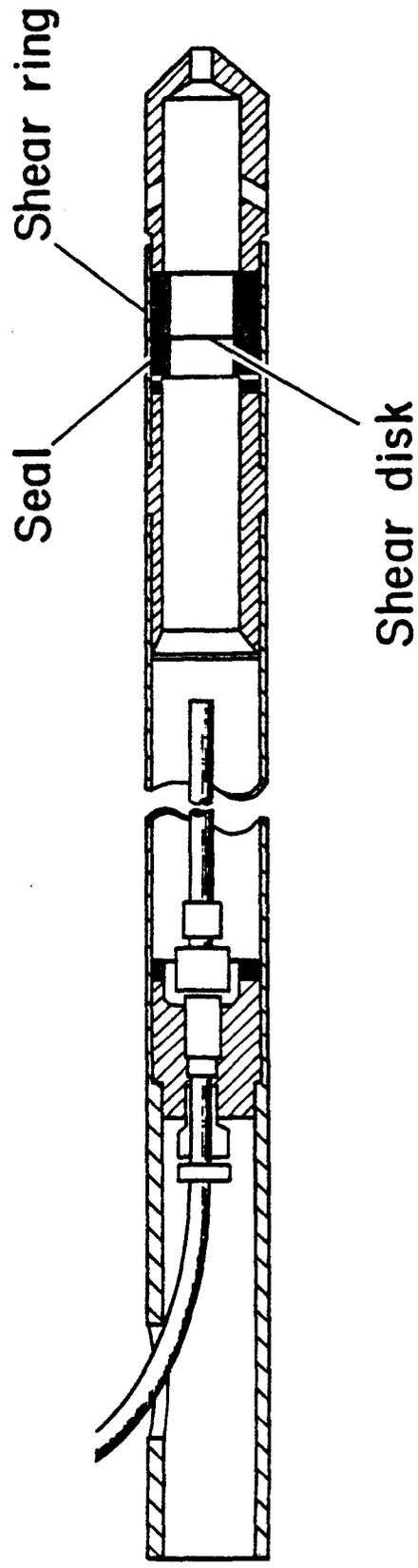


FIGURE 30. - Airdox shells

5.2 Administrative Controls

The use of administrative controls, i.e., rotating workers from one set of entries or one type of operation to another set of entries or operations, can expose the mine personnel to lower average daily dust concentrations. When series ventilation is used across a number of entries, personnel working nearest the intake entry are subjected to less dust during the shift, while those working nearest the return entry are exposed to dust created by all of the upwind mining activities. Rotating personnel from high dust make operations (cutting, loading) to low dust make operations (drilling, roof bolting) during the shift will result in lower full shift dust exposure.

5.3 Personal Protection Equipment

Personal protective equipment has been discussed extensively in the open literature. Respirators capable of removing respirable size particulates are commercially available from a number of suppliers. However, the technology of controlling dust in conventional mining operations is available and engineering controls can be implemented to maintain low dust concentrations.