# Preventive facilities and emergency operations in case of fires in CdF coal mines

Jean-Pierre Amartin, Jean-Pierre Josien

# PREVENTIVE FACILITIES AND EMERGENCY OPERATIONS IN CASE OF FIRES IN CdF COAL MINES

**J.P. AMARTIN**

*H.B.L. General Safety Section, Houilleres Du Bassin De Lorraine, France*

**J.P. JOSIEN**

*INERIS Industrial Safety Department INERIS,. France*

**ABSTRACT:** Charbonnages de France are presently winning in Lorraine coalfield seams presenting a high level of spontaneous combustion risk associated with high methane emissions. The operators have had to establish a strategy for spontaneous combustion prevention and fight based on several parameters

- limitation of parasitic air leaks,
- rapid isolation of districts,
- inerting with nitrogen.

Several combustions have turned into gas ignition in the goaf, hopefully limited to the upper intersection of the longwall face with the air return. As in such cases, after evacuation of personnel, rescue teams were used to rapidly isolate the affected districts by closing doors previously erected for this purpose, on the intake and return roadways.

After isolation and in order to suppress the fire, the districts have been kept under an inert atmosphere for a period of almost two months. They have then been reopened in accordance with a strict methodology. It has been possible then to resume coal winning, which has continued until the normal termination of the panel.

## 1. INTRODUCTION

The coalfield worked by Houilleres du Bassin de Lorraine (HBL), Charbonnages de France Group,. is situated in north-eastern France. This is a dense deposit made up of two groups of over ten seams of coal, separated by a conglomerate bed nearly 200 metres thick (figure 1).

The upper group consists of a bituminous soft coal, the lower coke coal.

The field is sharply folded along two parallel axes resulting in varied types of workings within the following two ranges of dip :

- flat seams from 8 to 30$^{o}$ or even more locally;
- steep seams from 60 to 80$^{o}$

This configuration, together with the great depth (over 1,000 metres) leads locally to substantial stresses causing fairly considerable initial fissuring or even fracturing of the rock mass.

The coalfield is also fairly gassy, with specific emissions of 50 to 60 $m^3$ of $CH_4$ released per tonne of coal extracted being not uncommon, necessitating very high airflows in the workings (commonly > 40 $m^3/s$ per face in operation) for adequate dilution of the gas.

Finally some seams have a high concentration of pyrite which facilitates oxidation and accelerates the process of spontaneous heating.

The principal mining method is the retreat longwall technique with caving in the flat seam which account for more than 80% of the output (figure 2).

On the whole therefore, HBL coalfield has the following characteristics:

- fissuring related to depth;
- easy oxidation related to the presence of pyrite;
- high methane content of coal.
- Working the field requires so the use of large quantities of air.

27th International Conference of Safety in Mines Research Institutes,
New Delhi, 20-22 février 1997, p. 443-456

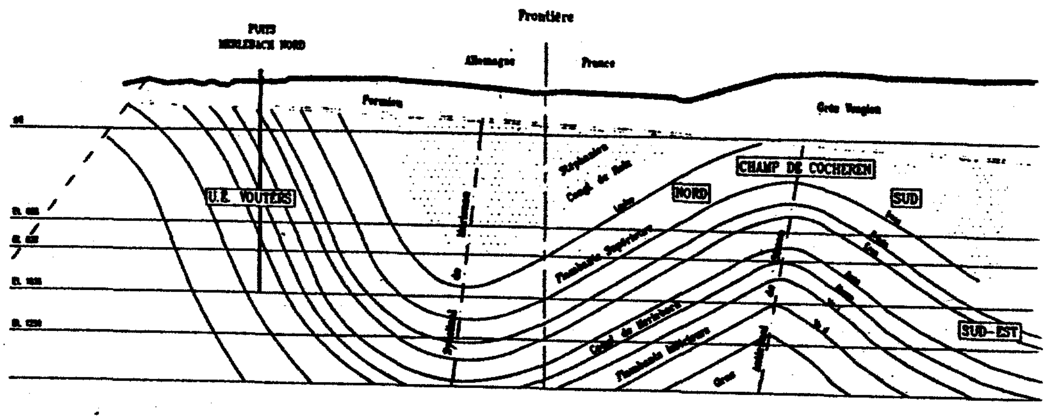



Figure 1 : · Section of the Houillères du Bassin de Lorraine coalfield

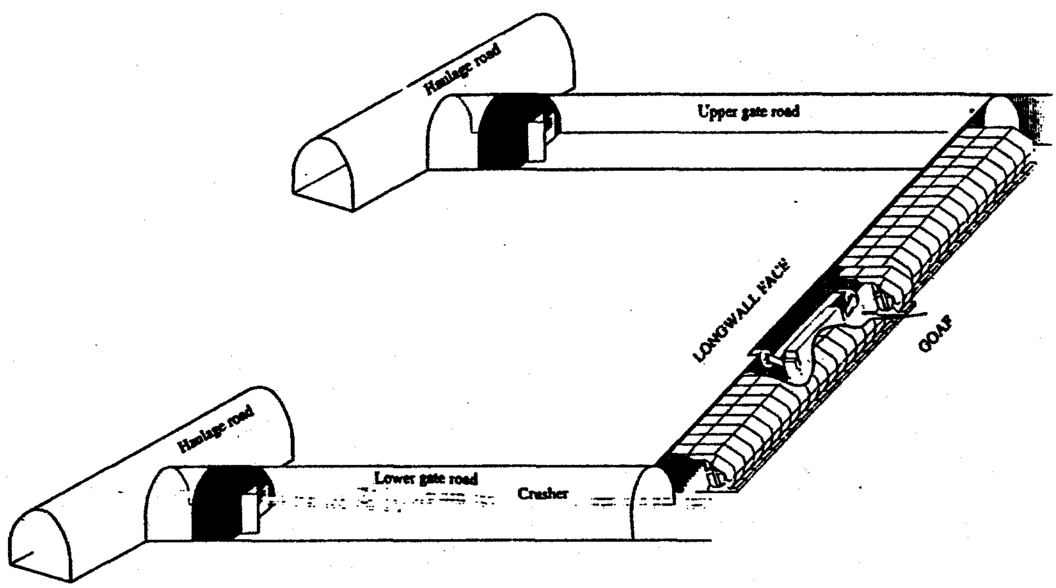



Figure 2: Diagram of a mechanised retreating longwall face

Hence all the factors that can lead to spontaneous heating and methane ignition are present.

In fact in the past HBL have had to deal with many spontaneous combustion turning into fires, often leading to the definitive closure of a district and the abandonment of its equipment.

Over the last seven years, besides the preventive measures taken continuously during mining, HBL have defined a prevention strategy whereby, in the most recent incidents, the district involved has been rapidly closed off, and then inerted. It was possible subsequently to reopen the district without difficulty, and to resume operations which then continued to the end of the original schedule.

For this strategy to be effective it must be possible for the district to be isolated very quickly; this technique is based on two main requirements:

- closure systems that are easy to operate;
- rapid inerting by injecting nitrogen into the old workings.

## 2. FAST-ACTING DISTRICT CLOSURE SYSTEMS

Various arrangements for rapidly closing off districts have been tested, but here are described only the two methods that have been adopted for HBL strategy.

### 2.1 Water stopping (figure 3)

To implement a strategy based upon the rapid closure of a district by creating a water stopping, a particular configuration is required :

* There must be low points in the district access roadways with a high enough change in level. In fact this drop (d) must exceed the height of the gallery (h) if the water stopping is to be able to cope with the pressure surge resulting either from any explosion that occurs or simply from the additional gas introduced by nitrogen inerting;

* Large quantities of water must be rapidly available, because the volume of the water stoppings may reach a few thousand cubic metres and must be established as quickly as possible.

For this method of closure to be used, arrangements must be made when the district workings are still at the design stage. In fact the choice is either :

- To make use of a natural change in level in the seam itself;
- Or to create a low point, not strictly necessary for normal working of the panel, in both bottom and tail gates.

Also, the water supplies to the district must be sufficient to provide the necessary flow, with the control valves positioned so that they remain accessible from safe areas where the atmosphere is clean.

### 2.2 Stoppings with fast-closing doors

Erection of these stoppings must be completed before work begins in the district.

They do not in fact represent additional expenditure because they are erected outside the panel to be worked and will serve as definitive closure dams when work on the panel is complete and equipment has been removed.

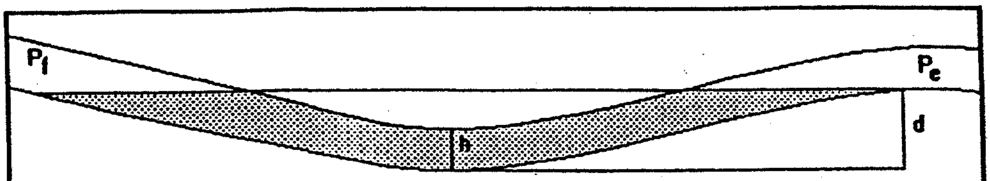
The stoppings should be erected on both access roadways and be identical in principle but with specific arrangements to :

* make allowance for the different equipment used in these roadways;
* facilitate any subsequent reopening of the district.

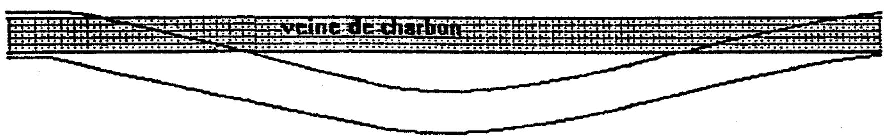
a) Stopping in the return gate (figure 4)

This is a solid stopping, built with good quality anchoring, made of concrete or anhydrite about 3 metres thick.

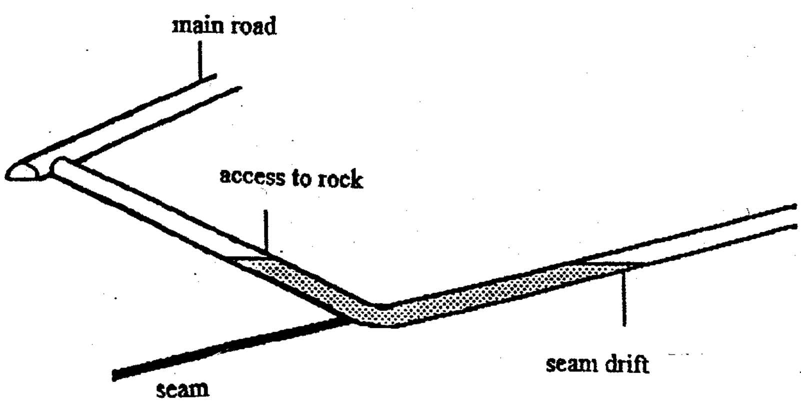
It is provided with apertures whose total area is related to the ventilation flow rate (of the order of 35 to 45 $m^3/s$) necessary in the district in order to dilute the methane and to maintain a breathable atmosphere for the workers.




(a) Water trap in a roadway



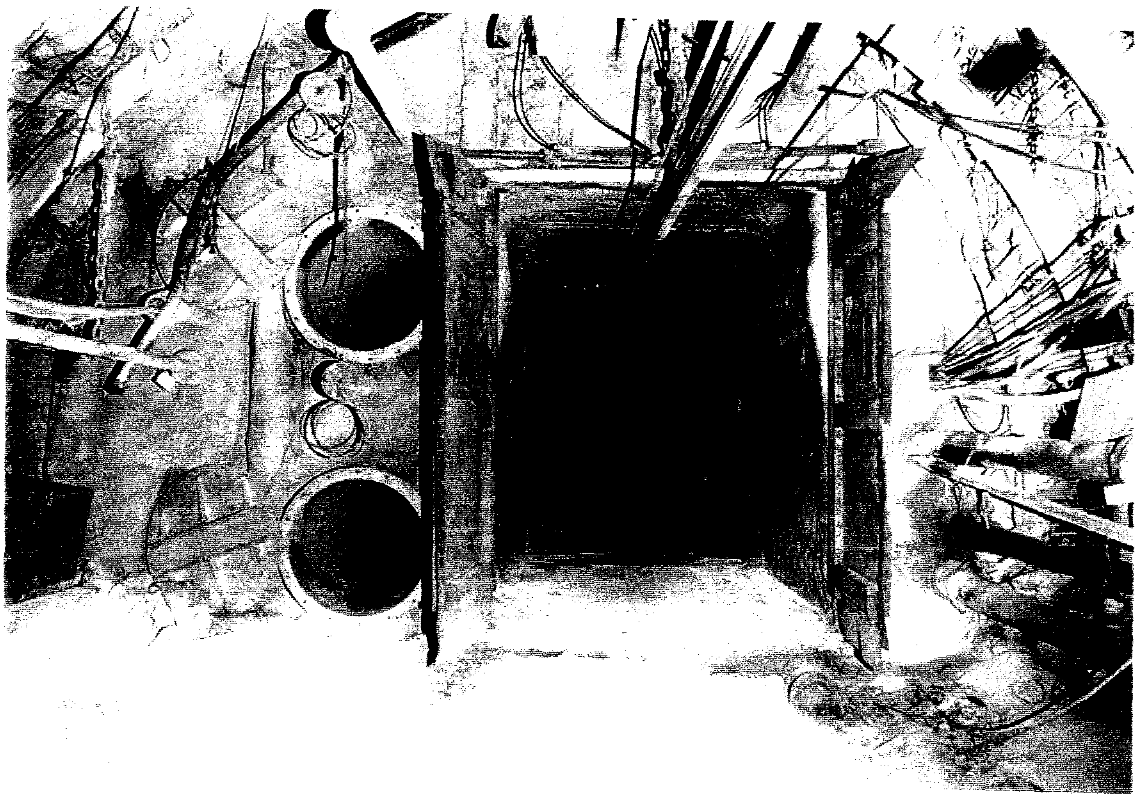

(b) Water trap made in a seam drift




**(c) Water trap made usihg access roads**

Figure 3: Rapid closure of a district by water trap

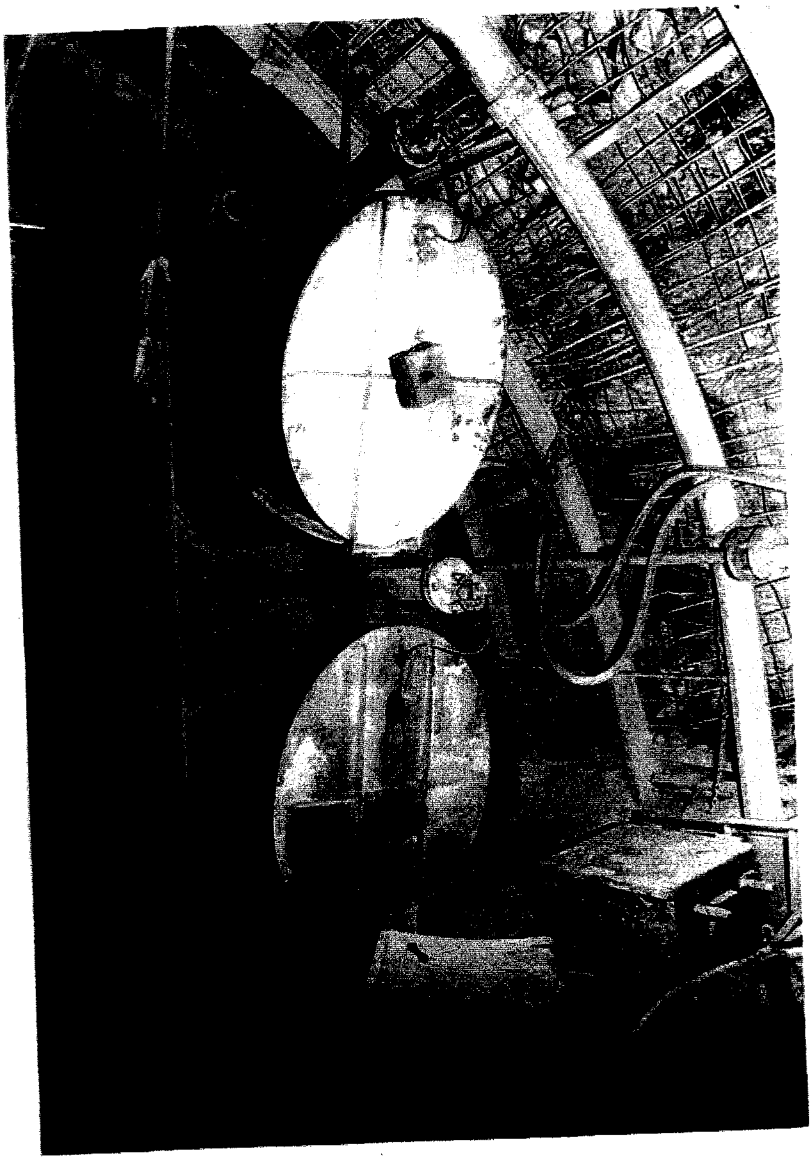
Figure 4.      Rapid closure dam in outlet airway



a)      Outside surface

b)      Inside surface (coalface side)

Figure 4 bis: Rapid closure dam in outlet airway



Detail of explosion panels

Hence there is :

* 1 door (1.9 x 2.6 m) capable of withstanding a pressure surge of at least 2 atmospheres operated remotely by compressed air, on each face of the stopping. The door dimensions must be compatible with the space taken up by a monorail that is easily removable or against which the doors close.
* 2 explosion panels, 800 mm or even 1 metre in diameter, together with their flaps and a mechanical system for remote opening and closing (to facilitate reopening of the district). The electric cables passing through the stopping are bundled inside pipes which are carefully sealed with a resin material.
* 2 or 3 short pipes let open on the side facing the coalface for subsequent operations of :

- checking the atmosphere behind the stopping;
- inerting;
- injecting sealing materials.

In certain circumstances it is worth providing a water drain. This must then terminate in a gooseneck on the accessible side of the dam.

b) Stopping in the intake gate (figure 5)

This has the same geometry as the dam in the return gate, although since there is usually a conveyor belt in this roadway the stopping has to be provided with a special system for sealing off the conveyor compartment.

This system may be :

* a pneumatically operated shutter that grips the conveyor belt in such a way as to limit ventilation leakages. When this shutter has been closed it is then necessary to finish its sealing off using expanded foam;
* a shutter fitted by hand after partially dismantling the conveyor. The other systems on this stopping will be the same as those on the stopping in the return gate, i.e.:

- door with space for the monorail;
- explosion panel (a single panel is sufficient);
- pipes for instruments, water removal, injection or inerting.

As regards the stopping in the air intake roadway, the closure systems can either be operated remotely (compressed air) or manually.

The pneumatic controls are grouped on control units which can be installed a few tens of metres from the doors in an area where there is no risk of bad air.

## 3. EMERGENCY INTERVENTIONS

Despite the precautions taken during mining operations such as:

* strict control of ventilation;
* continuous monitoring of $CH_4$, CO and $O_2$ concentrations in the goaf and return roadway;
* limiting or eliminating air leaks;
* pressure balancing;
* preventive inerting.

HBL during the last six years have had to deal with a number of critical situations (self-heating in old workings ($^{o}x$)), two of which resulted in the ignition of gas in the goaf of active faces. This led us to carry out six emergency district closures : these were subsequently reopened in accordance with a carefully planned procedure.

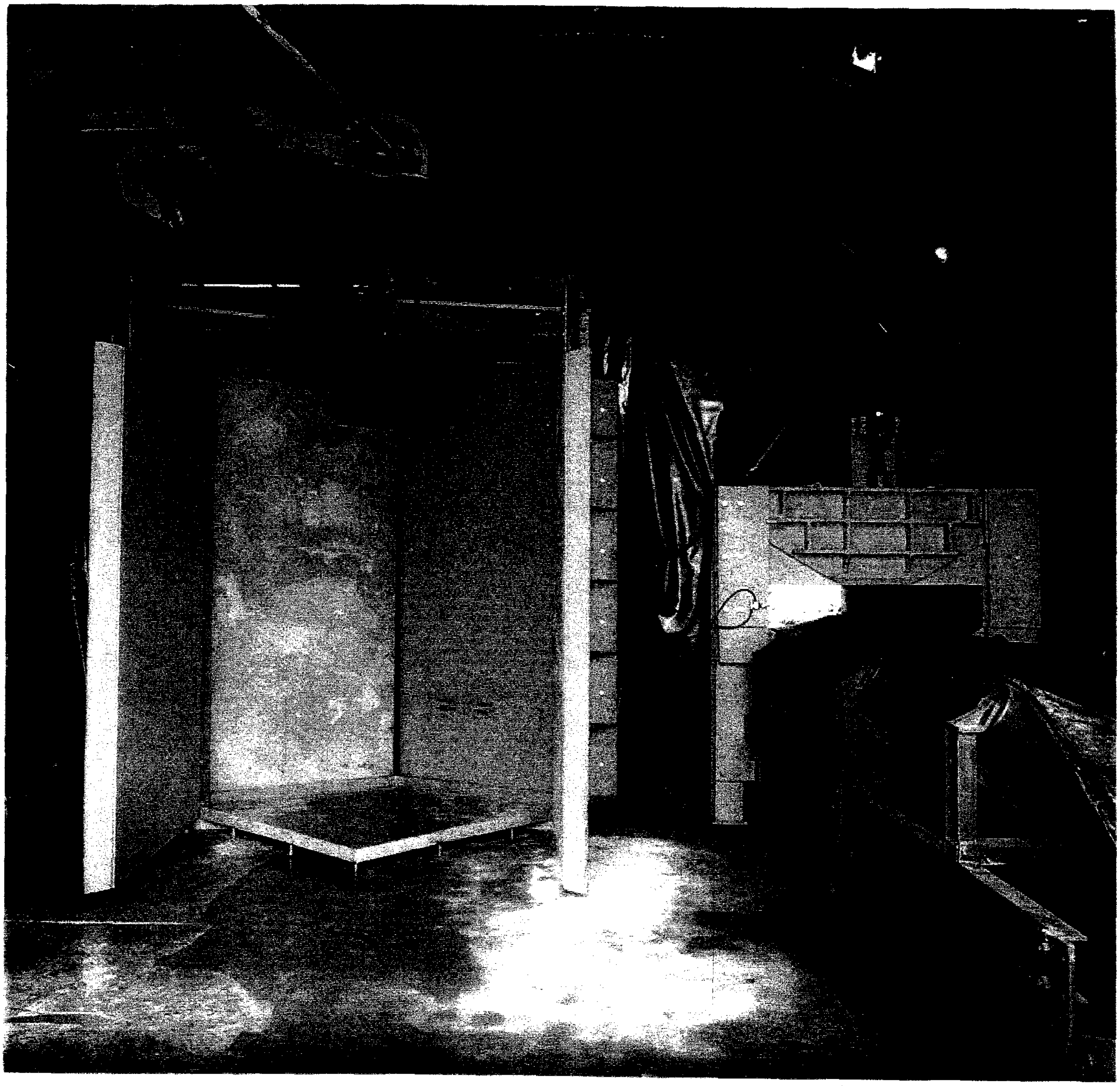
### 3.1 Evacuation of workers

In the event of a rapidly developing incident, for example a localised gas fire with the release of large amounts of toxic gases or even smoke, it is essential to be able to contact all workers as quickly as possible and give them precise evacuation instructions.

This is greatly facilitated by three factors :

a) The installation of a large number of sensors in the galleries providing regular data, at very short time intervals, of changes in the concentrations of gases ($CH_4$, CO, $O_2$ ) as well as any changes in ventilation flow, all of

Figure 5: Rapid closure dam in inlet airway
Penetration for conveyor and monorail



which are essential for the extent of the incident to be evaluated from the control and monitoring station at the surface. These instruments also make it possible to select the best route for withdrawing workers to a safe area. Thus in each HBL mine, it is possible to obtain information from about 150 sensors in less than four minutes; these data are processed by computer and easily retrieved in the form of trend curves.

b) The use of a dedicated telephone network capable of continuously broadcasting pre-recorded warning messages or instructions appropriate to the circumstances, via a simple selection procedure on a microcomputer in the control room. Each HBL mine is fitted with such a network (which is in fact a public address system) which carries out a daily self-test.

c) Workers are provided with individual self rescuers (closed circuit oxygen production) with a sufficient reserve for them to reach the fresh air muster points or slightly pressurized shelters.

Thus every Charbonnages de France miner always carries his self rescuer (Mini-Apeva) capable of supplying him with 30 minutes of oxygen, sufficient for him to reach the pressurised shelters arranged along the roads giving access to the workings (figure 6). The locations of these shelters are determined on the basis of a prior study of evacuation pathways using simulations of the ventilation system, under normal working conditions and in the event of fire.

**3.2 Intervention by rescue teams**

In order to isolate the district in the safest possible conditions, it is necessary first :

* to expose the smallest possible number of workers;
* to take action quickly.

For these two reasons it is important to recruit well-trained rescue teams and to equip them with flameproof suits, high-capacity breathing apparatus and even refrigerated suits if the air is hot and, naturally, portable monitoring equipment.

These rescue teams will go into action simultaneously, being co-ordinated by the unit manager in the surveillance and control room on the surface.

The rescue teams working in the intake airway can usually work in a breathable atmosphere with no need to wear breathing apparatus; however the team in the return airway will face a polluted atmosphere and sometimes have to work in reduced visibility. In these circumstances the rate of progress will be dictated by whoever is working in the more difficult conditions.

**3.3 Closure of doors and isolation of the district**

Once the decision has been taken to intake the district, the task given to the rescue teams is therefore simultaneously to close the doors in the previously erected stoppings.

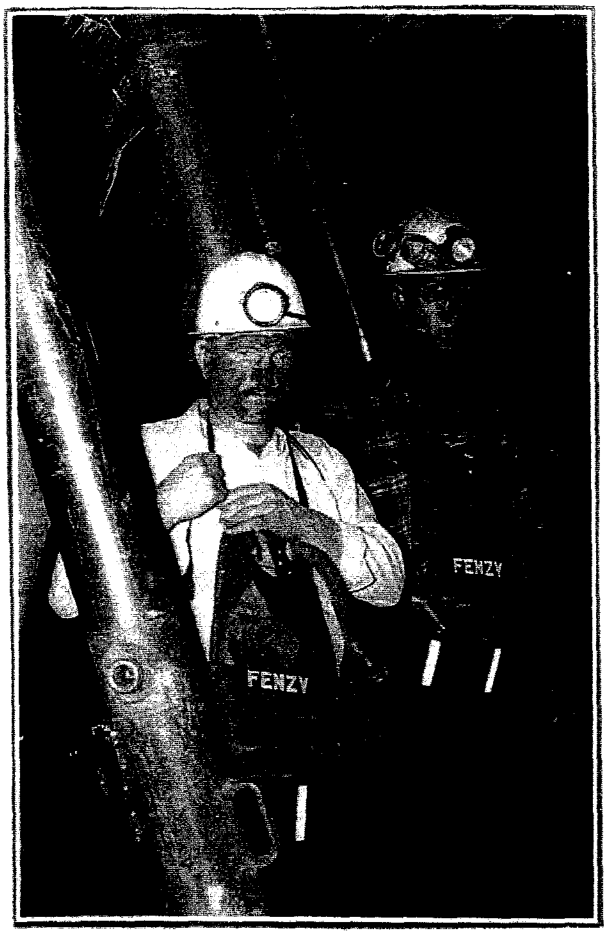
The job of the team in the intake airway will therefore be to clear away the monorail installation (dismantle a rail and cutting the cable), to close the shutter on the service conveyor or dismantle it and seal the compartment using expanded foam, to clean up the door surroundings to ensure that it will close easily, and to check the functioning of the explosion panel.

Besides dealing with the service conveyor, the team in the return gate will have the same preparatory work to do, occasionally in conditions of reduced visibility, wearing breathing apparatus and continuously monitoring the atmosphere, the results being immediately transmitted to the control room.

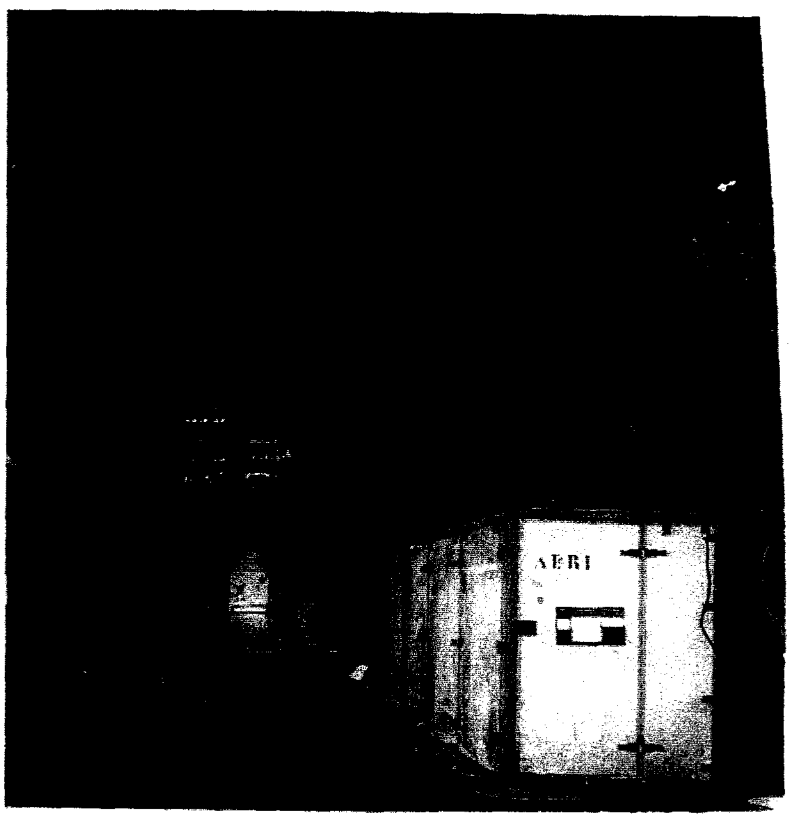
To facilitate the task of these teams, the equipment necessary for this preparatory work is placed in containers which are installed near the stoppings together with pumps and stocks of sealing resin.

The teams make regular progress reports to the control room so that the manager in charge of the operations can take whatever

Figure 6. Facilities for worker evacuation




a) Miners equipped with the Mini Apeva




b) Pressurised shelter

measures are appropriate (adjusting the ventilation system, modifying the flow of inerting nitrogen, and so on) in conjunction with the engineers in the ventilation computer centre who carry out the necessary simulations in real time.

When the teams have completed their preparatory work, they retreat to points designated by the operations manager, report in and await the closure order.

This instruction is given by the manager in charge of the operations in such a way that the district is closed off simultaneously at the two stoppings, following an increase in the amount of nitrogen injected into the district if necessary.

The district is isolated by closing the large doors (pneumatic remote operation), and then finally by closing the explosion panels.

During actual events at HBL, the preparatory work for the closures carried out by the rescue teams required between one hour and five hours (when there was smoke in the return airway); simultaneous closure of the doors took five to ten minutes.

Thus it is possible in less than eight hours to isolate a district in which there has been severe self heating and burning gases, with minimum exposure to workers and with maximum precautions.

### 3.4 Inerting

Once the district has been isolated by closing the doors and panels in the stoppings, the inerting procedure should be carried out as quickly as possible by :

* Continuing to seal off the stoppings (at the anchoring points, door frames, pipe penetrations, etc.) by spraying sealant;
* Adjusting the nitrogen flow to maintain an overpressure at the stoppings on both roadways;
* Assisting the removal of heat by establishing an extraction flow, if possible, compensating for the excess nitrogen injected;
* Improving the sealing of the district by additional injection sealing, etc.

## 4. REOPENING AN ISOLATED DISTRICT

### 4.1 Monitoring the district

When a district has been isolated for the reasons given above, changes in its atmosphere should be monitored frequently from samples taken from the pipes penetrating the stopping in the return gate.

Depending on the changes occurring in the different parameters monitored, a number of other jobs, of varying extent, will have to be carried out while a reopening strategy is prepared.

### 4.2 The reopening strategy

The reopening strategy should be based upon two factors :

#### a) Ventilation calculations

These calculations should be carried out beforehand to give guidance during the reopening operation. They should also indicate the methodology to be adopted for closing the district again without risk if a further uncontrolled incident should occur during the reopening operation.

They are based upon the need to avoid the effects, first, of any sudden impact by too great a natural pressure surge on the stopping in the return gate and, secondly, too high an air flow during the reopening process.

The calculations determine in advance :

* the extent to which work in the mine should be halted even before operations commence;
* the possible flow rate through the district, together with the pressure distribution after every change made at the stoppings (door, panels, etc.);
* the size of the optimal open section to achieve the selected flow rate on completion of the operation.

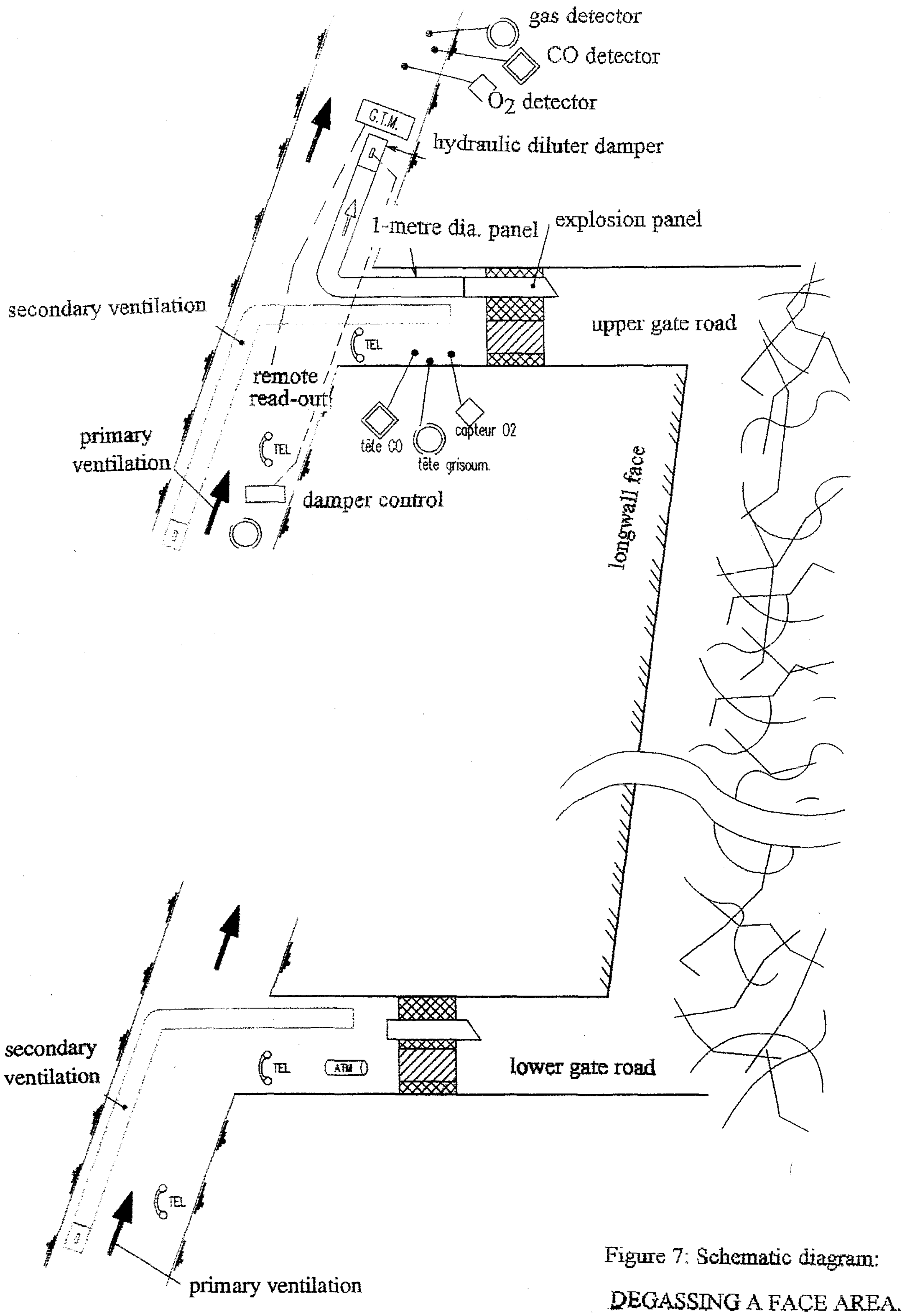



Figure 7: Schematic diagram: degassing a face area.

b) **Preparatory work**

This will involve :

* installing an adequate number of well-placed sensors to monitor changes in the atmosphere, within the confined zone and in the primary ventilation system during purging of the district;

* installing a system to facilitate decompression of the stopping in the return gate, and the purging of the confined zone. This system may consist of a linc of rigid ducts connected to one of the explosion panels, terminating at its other end in a diluting duct operated remotely (figure 9).

c) **Reopening the district**

District reopening is supervised from the control room at the surface having access in real time to all the information provided by the sensors installed for monitoring the operation. Two teams are needed, both fully briefed on the procedure to be followed: one at the stopping in the intake, the other at the stopping in the return end. Both teams are in telephone communication with the control centre and act only on its instructions.

**The reopening procedure is in five stages :**

1. **Passing on the overpressure at the stopping to a purge system exposed to primary ventilation**

This is done by opening the flap in the explosion panel to which the previously installed purging line is connected. In this way the high pressure is fed directly to the diluting duct exposed to substantial primary ventilation.

2. **Decompressing the confined zone**

This involves simply opening the diluting duct at the end of the line. By this stage the overpressure (500 Pa WG) has disappeared, a small amount of gas has been driven out, but as yet no air is circulating in the district.

3 **Controlled purge of the district**

The order is then given to the team located at the stopping in the intake airway to open the flap on the explosion panel. Once this is done, air begins to circulate naturally in the district and will drive the gases to the outlet system. The team at the return side will then adjust the position of the diluting duct so as to limit the flow in the district and observe the rules governing the concentrations limits in the primary ventilation downstream of the stopping. When the diluting duct is fully open this indicates that preliminary degassing of the district is complete.

4. **Increasing the flow**

The degassing process must then be continued by gradually increasing the flow of air into the district; the rate of increase in flow is continuously monitored by a series of sensors located in the ventilation system in the air return.

**The following operations are carried out in the order shown:**

* the large door in the stopping in the intake airway is opened;

* the second explosion panel at the air return side is opened;

* finally the door at the air return is opened and the flow adjusted to the desired value by installing an air door having the aperture section previously calculated.

Throughout this operation, nitrogen injection and methane drainage must be constantly adjusted. It is also important to check regularly that the flow entering the district for a given configuration agrees with the prior calculations for the same configuration.

**Inspection of the district**

This can be done once a flow of fresh air is established and the atmosphere in the return roadway is breathable. This inspection should follow the direction of normal airflow.

## 5. CONCLUSIONS

The strategy developed at HBL, based upon the construction of stoppings fitted with fast-closing, remotely-controlled doors at the ends of the roadways serving areas of longwall faces with sublevel recovery has proved its worth.

In the last six years, these arrangements have been used on six occasions, for closing off districts in which serious incidents had occurred, including two gas fires with considerable release of toxic gases and smoke. In every case, these arrangements have allowed the workings to be reopened easily and operations to restart.

This strategy is supplemented by :

- a reliable and effective warning system;
- a proven self rescuer in which the workers have confidence;
- a network of pressurised shelters;
- a nitrogen distribution system linked directly to a high capacity production unit (12,000 $m^3/h$);
- a workforce training programme.
- To be successful, this strategy also necessitates
- highly motivated and properly trained rescue teams;
- a rigorous maintenance procedure for the closure systems (equipment stowed, regular cleaning of door frames, and so on);
- regular monitoring of the strategic equipment (injection pumps, stocks of resin, equipment containers, etc.);
- an advanced ventilation computer centre with complete understanding of the mine's ventilation system, and provided with the most up-to-date and comprehensive software for ventilation simulation.