9. Flammable Gas

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9.1 Purpose

This chapter deals with hand-held and portable battery-powered flammable gas measuring instruments (FGMIs) and flammable gas warning devices (FGWDs) for the routine detection and measurement of the concentration of flammable gases in air by electronic means.

FGMIs and FGWDs discussed in this chapter may be suitable for the detection of a wide range of combustible gases, but are primarily designed for the detection of methane or hydrogen or a mixture of both. Caution should be exercised when FGMIs or FGWDs are used in environments where other combustible gases (e.g. fuel vapours and other organic vapours) may be present in the atmosphere or when gases from sealed off areas, i.e. during a fire, are sampled.

Although FGMI and FGWD are designed and tested to accurately detect Methane and/ or Hydrogen, variations in sensor cross sensitivity as well as variations in the lower explosive limits for other combustible gases, means that one can not blindly use these instruments in such environments. If combustible gases other that Methane or Hydrogen are to be detected, the equipment manufacturer should be consulted to determine the suitability of the particular FGMI or FGWD. It is also known that the sensitivity of the sensors used in most FGMI and FGWD can be impaired by the presence of various poisoning agents including silicone vapours. As such it is imperative that these poisoning agents be eliminated from the working environment and charge-rooms and to ensure that daily pre-shift calibration checks are conducted as required by law.

Gas detection is conducted to test for the presence of flammable gases and to determine whether the concentration in the atmosphere complies with the legal requirements.

9.2 Flammable Gas Occurrences

Flammable gas may be present in strata of all mines and can be very inconsistent and often of short duration. As there are no defined patterns, it is essential that a high level of training, awareness and caution be maintained by all employees, at all times.

It is therefore extremely important that employees are aware of how and where flammable gas can enter or accumulate in the workings, as summarised below:

- At faults, fissures and dykes.
- From worked out and or abandoned workings through seals.
- At diamond drilling cover holes.
- With high pressure pockets for which existing ventilation is inadequate.
- During pilot hole and normal shot hole drilling.
- At fractures in strata caused by blasting and seismic events.
- With water intersections.
- With changes in barometric pressure and changes in season.
- With absence of ventilation - “dead ends” and poor ventilation flows.

- With negligence on the part of employees (responsible persons) to test for flammable gas and examining the condition and operation of the ventilation appliances / systems that can effect the airflow through their workings.
- Any workings underground where it is least expected.
- Badly ventilated flammable gas storage areas on surface.
- Naturally occurring in coal seams.

The main flammable gases found underground and at surface works are listed in Table 9.1.

9.3 Methodology

9.3.1 Apparatus and Facilities

A FGMI and a FGWD are used for the routine measurements and detection of flammable gases in underground mines. FGMIs are usually allocated to supervisory staff that are required to test for the presence of flammable gas in the general atmosphere at predetermined places and times and record the concentrations present.

FGWDs are usually allocated to frontline staff, i.e. rock drill operators, as an additional measure to warn them if conditions suddenly change during their working shift, i.e. when flammable gas is intersected during drilling operations.

Although the FGWD can be used as an additional safety measure, it can not be considered as a replacement for the FGMI, as it is not designed to take readings at elevated positions or to give readings of the actual gas concentration, as mandated.

9.3.2 Description of Apparatus

9.3.2.1 Flammable gas measuring instrument (FGMI) (see also Glossary)

A Flammable gas measuring instrument (FGMI) is a portable hand-held spot or continuous-duty instrument which allows the user to measure the presence and concentration of flammable gas in the range of 0 % to 5 % v/v as Methane (CH_4).

The actual flammable gas concentrations will be indicated for concentrations up to 5% v/v Methane. For concentrations exceeding 5% a full scale meter - or an over-range indication will be indicated. A clearly audible and visible alarm will also be generated should these instruments be placed in an atmosphere containing a concentration of flammable gas which equals or exceeds the alarm set point.

The FGMI also has a facility, or is able to be lifted above the head of the user to enable the testing for gas at elevated positions such as under the hanging wall.

Table 9.1 Characteristics of Flammable Gases

GAS	FORMULA	CHARACTERISTICS	SG	SOURCES AND OCCURRENCE	OEL	METHODS OF DETECTION
Carbon Monoxide	CO	Poisonous. Explosive 12.5% to 74.2%	0.97	Fires, explosions, blasting operations, exhaust gases from diesel locomotives.	30 ppm TWA 100 ppm C	NMAM 6604 Portable Direct Reading CO Monitor, Detector tubes
Hydrogen	H_2	Non-toxic. Explosive 4% to 75%. High concentrations can be associated with an oxygen deficiency.	0.07	Battery charging stations. Can also occur in conjunction with methane.	1.4 % C	Flammable Gas Measuring Instrument, Laboratory analysis, Detector tubes
Hydrogen Sulphide	H_2S	Poisonous. Explosive 4.0% to 44.0%.	1.2	Stagnant water, water fissures, faults and dykes. (Often associated with methane)	10 ppm 15 ppm STEL	Direct reading H2S Monitor, NMAM 6013 Filter plus solid sorbent tube, Detector tubes
Methane	CH_4	Non-toxic. Explosive 5% to 15%. High concentrations can be associated with an oxygen deficiency	0.55	Water fissures, dykes and faults, "blowers" and coal strata.	1.4 % C	Flammable Gas Measuring Instrument
Butane	C_4H_{10}	Burns < 1.5% Explosive 1.5-8.8% Oxygen deficiency > 8.8%.	2.05	Can occur in conjunction with Methane.	Note 1	Flammable gas measuring instrument calibrated for Butane. See note 2.
Ethane	C_2H_8	Burns <2.7% Explosive 2.7-14% Oxygen deficiency > 14.0%	1.04	Can occurs in conjunction with Methane.	Note 1	Flammable gas measuring instrument calibrated for Ethane. See note 2.
Propane	C_3H_8	Bums<2,1% Explosive 2,1-9.5% Oxygen deficiency > 9.5%	1.56	Can occurs in conjunction with Methane.	Note 1	Flammable gas measuring instrument calibrated for Propane. See note 2.

Note 1: Alarm levels should be set to allow an appropriate safety margin. In general alarm levels should be set at a level that is at least 2 to 3 times lower than the lower explosive limit of the target gas.

Note 2: Many instruments are not designed to detect explosive gases other than Methane and Hydrogen (even if recalibrated). Instruments designed for detecting such other explosive gases may also not be appropriate for detecting Methane and Hydrogen. In general, instruments designed for detecting explosive gases other than Methane and Hydrogen are more sensitive to sensor poisoning. It is essential that the instrument manufacturer be consulted before using an instrument to for detecting flammable gases other than Methane and Hydrogen.

Figure 9.1 Flammable Gas Measuring Instruments

9.1.1.1 Flammable gas warning device (FGWD) (see also Glossary)

The flammable gas warning device (FGWD) is a continuous-duty device that will issue a clearly audible and visible alarm, if placed in an atmosphere containing a concentration of flammable gas (Methane and/or Hydrogen), which equals or exceeds the alarm set point. The FGWD has no display and will not indicate the actual gas concentrations present. It is usually incorporated into the caplamp or caplamp battery of the user.

Figure 9.2 Flammable Gas Warning Device

9.3.3 Principle of Operation

9.3.3.1 Types of flammable gas measuring instruments

(a) Catalytic combustion

The air being sampled passes through two chambers, each containing a heated platinum filament that is covered with a porous alumina or ceramic bead. The bead of one filament is coated with a catalyst which causes any flammable gas present to be oxidised on the bead (i.e. the gas burns on the surface of the bead). The other bead is coated with a poisoning agent that prevents the oxidisation of flammable gas on its surface. The two filaments are

connected in an electronic “bridge” configuration. If the two filaments are at the same temperature the "bridge" is said to be in balance and the meter reading is zero.

Oxidation (or burning) of the flammable gas on the catalytic bead causes its temperature to rise. This increase in temperature results in an increase in the resistance of the platinum filament inside the bead. The "bridge" becomes unbalanced, resulting in an output signal that is proportionate to the concentration of the flammable gas being detected. The use of two filaments in a bridge configuration results in a sensor that has very good compensation against changes in temperature, humidity and pressure, as these effects affect both filaments equally and do therefore not unbalance the bridge. As the porous bead greatly increases the catalytic area exposed to the flammable gas, the filaments can be operated at a lower temperature than in bare platinum filament type sensors.

Instruments based on this principle have a long life, fast response times, and linear outputs and are not affected by environmental parameters such as temperature, humidity and pressure.

The sensitivity of catalytic combustion sensors can be inhibited by poisoning agents such as silicone vapours given off by silicone sealants, lubricants, grease and oils, as well as H_2S, chlorine and chlorinated hydrocarbon compounds. Great care should be taken to eliminate these from the working place and charge rooms and to ensure that daily pre-shift calibration checks are performed as required by law.

Catalytic combustion FGMIs do not give correct readings if the oxygen content is too low to support effective combustion i.e. below 16 per cent. Where this condition is suspected the methanometer must be used in conjunction with an oxygen deficiency detector.

(b) Thermal conductivity

The thermal conductivity of many gases differs from that of air. See table below:

Table 9.2 Thermal Conductivity of Gases

Gas	Thermal Conductivity (at 100^{o}C)
Air	1.00
Nitrogen	0.99
Oxygen	1.01
Carbon Monoxide	0.97
Methane	1.45
Butane	0.66
Ethane	0.9
Hydrogen	6.8
Water Vapour	0.74

Some instruments make use of this principle to measure the concentration of these gases. One such instrument is a high range (0 - 100 %) FGMI used for measuring concentrations of Methane in drainage systems.

As with catalytic sensors, thermal conductivity sensors use two heated platinum filaments coated with porous beads and connected in an electronic bridge configuration. In this case however the beads are not coated with a catalyst. One of the beads is also enclosed, or sealed, in an air pocket and is thus not exposed to the atmosphere. The other bead is exposed to the atmosphere and the gas to be measured. A high concentration of the target gas, such as Methane or Hydrogen, results in a differential cooling of the filaments, resulting in the sensors output.

As the one filament is enclosed and thus not exposed to the atmosphere this type of sensor does not have the high level of compensation against changes in temperature, pressure and especially humidity inherent in catalytic combustion sensors.

Note that thermal conductivity sensors have a very high sensitivity to Hydrogen and that these sensors can be affected by cross sensitivity to other gases.

Thermal conductivity sensors are generally not accurate enough to be used for measuring Methane in the 0 to 5% v/v range.

(c) Semiconductor sensor

Semiconductor sensors make use of a sintered metallic oxide semiconductor pellet (mainly SnO_2 tin dioxide) "doped" with impurities. A coil is embedded at each end of the pellet. An electric current is passed through one coil to heat the pellet and control its temperature while the other coil serves as an electrical contact for measuring the conductance of the pellet from one coil to the other. When the sensor is exposed to air containing certain gases including methane, propane, carbon monoxide, organic solvent vapours, etc., oxygen absorbed onto the surface of the pellet reacts with the gas. The reaction products are desorbed reducing the amount of absorbed oxygen, thus increasing the electrical conductance between the two coils. This change in conductance can be measured and converted to an output signal related to the concentration of gas present, provided the pellet temperature is kept constant.

Although these sensors have a higher sensitivity, long life and lower cost, compared to catalytic combustion sensors they generally suffer from higher power consumption, higher cross sensitivity (to non targeted gases), higher drift over time as well as reduced linearity and are not inherently compensated against variations in humidity.

These sensors are not suitable for use in either FGMI or FGWD.

9.3.4 Preparation of Apparatus

It is essential that FGMIs and FGWDs be calibrated and maintained, in accordance with the instructions of the Original Equipment Manufacturer (OEM). This is generally done by the lampsman who is to be trained and certified by the OEM. Calibration and response checks are performed by applying a standard methane-air mixture of known concentration to the instrument.

9.3.5 Checks performed by the end user

*9.3.5.1 On receiving of the instrumen*t

The checks and procedure, to be conducted by the end user, on receiving a FGMI or FGWD from the lamp or charge room, must be complied with. In general the end user will be required to:

- Acknowledge receipt by signing the record book, if so required.
- Check that the instrument number corresponds to the instrument number allocated to him.
- Check that the battery is charged.
- Visually check that the casing and display window and indicators are not cracked or damaged, and that the instrument is sealed.
- Check that the instrument's gas intake port is not damaged or blocked.
- Check that the carrying case and lifting rod attachment is in good condition.

Before proceeding underground, the following pre-use or pre-shift checks must be performed on the instrument:

- Check that the zero indication of the instrument is within the range allowed. This check is to be performed in fresh air or with zero air applied to the instrument.
- Check the span calibration of the instrument by applying a known and certified methane-air mixture at the lamp-room test station. During this test the operation of the alarms, the alarm set points and time to reach the alarm points should also be verified.
- Check that the instrument returns to "zero" again, when exposed to fresh air.
- If the end-user is not satisfied that the instrument is fully operational he should return it to the lampsman, indicating the reason, and request a replacement instrument.

9.3.6 Measurement Procedure

Underground working places may contain dangerous accumulations of toxic or explosive gases. The testing for these gases can be done accurately and safely provided the observer is fully aware of the dangers involved and conversant with the characteristics and limitations of the instruments at his disposal.

The safety slogan "knowing is not enough - do it the safe way", should be kept well in mind when testing for gas.

9.3.6.1 Operating instructions

The operating instructions will vary in detail from one type (e.g. spot or continuous, etc.) or make of instrument to another.

The operating instructions and procedures provided by the OEM must be complied with.

Effective and efficient tests for flammable gas must be conducted as follow:

Complete Examination / Test

- At the commencement of each shift in all workings or headings even if shifts are changed on the face.
- After a partial or total power failure.
- After a ventilation failure, noticeable deterioration in ventilation condition or when a reversal in the ventilation occur.
- With all routine environmental surveys.
- At designated intervals during the shift in Colliery production sections.
- Mechanical Miners in Collieries are equipped and operate continuously with on board monitors.

Additional test must be done:

- After pilot holes have been drilled
- After shot holes have been drilled
- Before charging up and before connecting up.
- Immediately before blasting at the blasting point (if hand blasting)
- Before starting any electrical or diesel equipment.
- When water, a dyke, a fissure or fault has been intersected.
- Whenever the presence of flammable gases is suspected
- Before lighting any cutting torch or blow-lamp.
- Before using any electrical welding apparatus or camera flash.
- Before commencing work in any established underground workshop, sub station, battery charging bay, hoist room, pump chamber or truck / hopper repair bay, etc.
- At diamond drilling and cementation sites as follow:
    - At commencement of shift.
    - Every hour on the hour.
    - As soon as water or a dry fissure is intersected.
    - If the presence of flammable gases are suspected.

Below, are recommended guidelines where to test for flammable gas in Development ends and Stopes.

9.3.6.1 Flammable Gas Testing In Development Ends - Forcing System

To test for flammable gas in a development end, ventilated with a force fan, the following guidelines can be used.

Refer to the Figure 9.3:

1. In through ventilation, upstream from fan switch

2. At the fan switch
3. Around the fan.
4. Five meters downstream from the development end break-away in through ventilation, where the return air from the development end mixes with the through ventilation.

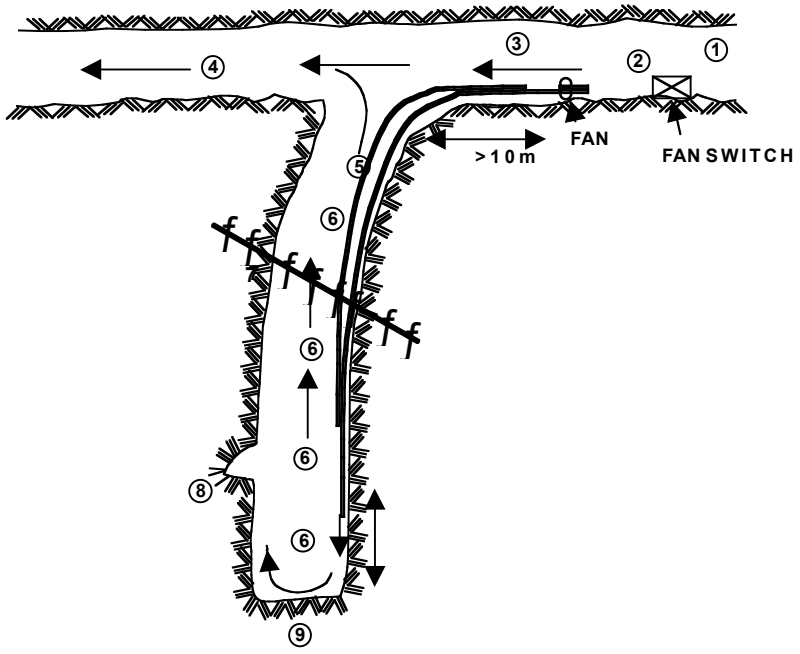

Figure 9.3 Development End – Force system

5. Five meters into the development end in the general air and against the hanging.
6. Depending on the length of the development end, test at regular intervals against the hanging wall in all cavities, domes and high places.
7. Test at the fault, doing a complete traverse (i.e. start on the foot-wall and all along the fault from one side-wall up, against the hanging, and down the opposite side-wall).
8. Test at the diamond drill cubby:
    - At the collar of the diamond drill hole.
    - 0,5m away and above the hole.
    - At the highest points in the cubby.
9. When reaching the face, continue with flammable gas testing on the face as follow (See Figure 9.4):
10. Test at the bottom pilot hole and continue with a horizontal traverse, testing at all drill hole sockets or at 0.5m intervals along the face until the top pilot hole is reached as shown on the above sketch.

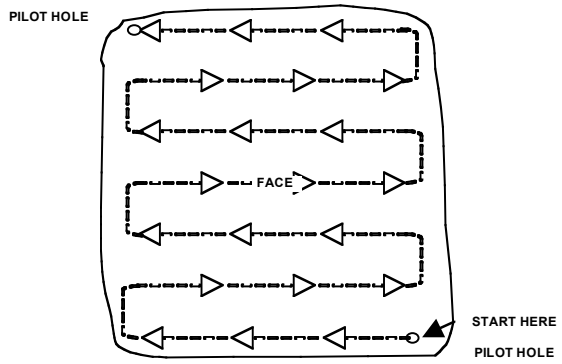

Figure 9.4 Development End – Face Test

9.3.6.3 Flammable Gas Testing In Development Ends - Exhaust Overlap System

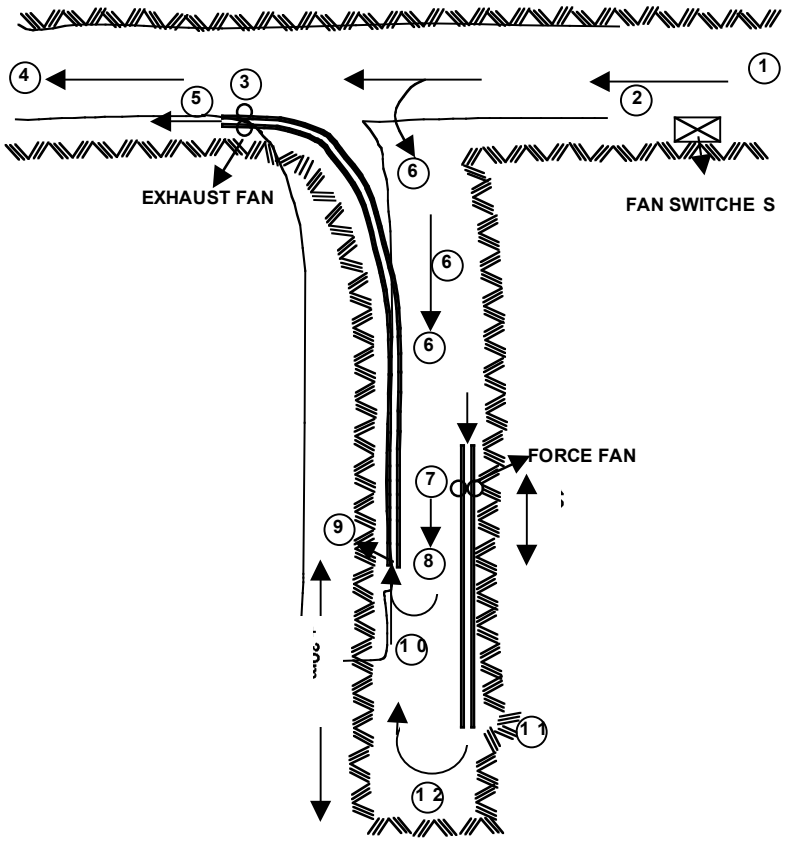

Figure 9.5 Development End – Exhaust Overlap system

To test for flammable gas in a development end ventilated with an exhaust overlap system, the following guidelines can be applied:

Refer to the Figure 9.5:

1. In through ventilation upstream from fan switches.
2. At the fan switches.
3. Around the exhaust fan.
4. In through ventilation 5 m downstream from the exhaust fan discharge.
5. In the exhaust fan column discharge.
6. Depending on the length of the development end, at regular intervals against the hanging in all high places, cavities and domes.
7. At the force fan intake and around the fan.
8. In the total distance of the overlap (10m) against the hanging in all high places, cavities and domes. (Measure the air velocity in the overlap).
9. In the exhaust column intake.
10. In the general return air from the face and against the hanging in all high places and cavities.
11. At the diamond drill cubby:
    - At the collar of the diamond drill hole.
    - 0.5 m away and above the hole.
    - At the highest points in the cubby.
12. On the face - the same as for the forcing system.

    It is important that the force fan is electrically interconnected with the exhaust fan, so, that should the exhaust fan fails the force fan will also stop automatically, in order to prevent re-circulation of the air from the force fan.

    Any other electrical appliances (for example a winch), installed in any mechanically ventilated workings, must be electrically interconnected with the fan(s) ventilating such workings.

9.3.6.4 Flammable Gas Testing In Stopes

Testing for flammable gas in stopes is of utmost importance at the beginning of the shift and during the shift. It is also important to maintain effective “in stope” ventilation controls (brattices, curtains etc.) to ensure high air velocities on the working faces, should flammable gas be intersected. A guideline for flammable gas testing is as follow:

Refer to the Figure 9.6:

In fresh air at waiting place - check the instrument and test for flammable gas.

1. In return air from workings below (where applicable).
2. At winches and electrical switch gears (also before starting).
3. Along strike gully and “east” or “south” sidings at regular intervals for heavy flammable gas (e.g. butane, ethane etc.).
4. In the advance strike gully at all sockets and high place.
5. Along the face at all drill hole sockets, high places, cavities and foot-wall.
6. In the top limit of the face (”west” or “north” siding) - “potential trap”.
7. In the “up-dip end” in drill hole sockets, high places and cavities.

8. In the return air from S1 face.
9. Repeat steps 5-9 above in S2 face.
10. All along the fault (west or north siding).
11. In the return air from the stope.
12. In the dip gully ("centre gully") at regular intervals in high places, cavities and domes.
13. At least every second day in the return air of the ledging faces not working, at high places, cavities etc. to prevent possible flammable gas accumulations.

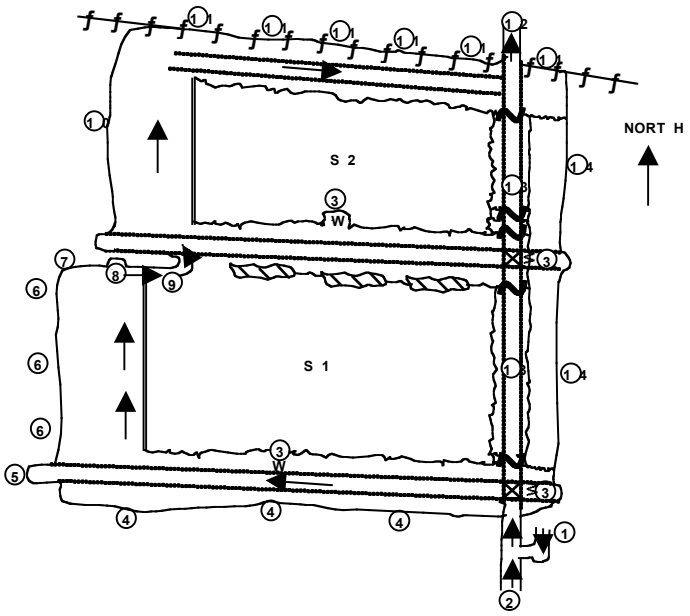

Figure 9.6 Stope Face

9.3.6.5 Testing for Flammable Gas Roof Layers

Flammable gas roof layering is when such a gas, emanating from the rock strata into the workings, tends to form a layer against the hanging which is not dispersed by the ventilating air. These layers may persist for a distance of a hundred metres or even more. Commonly, the layer will move in the same direction as the ventilating air, but under certain conditions it may flow against the direction of air flow, called "counter-flow".

The factors affecting the formation of a layer and its stability are:

- The rate of emission of the gas.
- The density of the gas.
- The dip of the airway.
- The air velocity.
- The degree of turbulence of the ventilating air.

Flammable gas roof layering generally occurs at such a source of issuing, when the ventilating air velocities are low and may also occur when underground fires are sealed off

and in old worked out areas which are not ventilated. Whenever a flammable gas source is detected, tests for the presence of a roof layer must always be carried out.

When testing for flammable gas layering, the normal procedure to test for flammable gas must be applied:

- Perform all the pre-use checks on the FGMI.
- Test for flammable gas in the normal way by raising the instrument to the hanging wall (never use a probe). In measuring at elevated positions enough time should be allowed before moving on to take a next measurement. Refer to the OEMs training manual to obtain the minimum measurement period.
- If a flammable gas source is detected, continue with testing upstream and downstream from the source of issue against the hanging wall, in order to detect and determine whether any roof layering has occurred.
- If any roof layering has occurred, take further tests / readings to explore the extent, thickness and concentration of the flammable gas roof layer.
- Determine the velocity of the ventilating air flowing over the source.
- Never attempt to disperse the roof layer during the shift, but make arrangements to do it during the off-shift period or under controlled conditions by competent people.
- Action the withdrawal procedure.

9.3.7 Limitations and Precautions

FGMIs and FGWDs are only able to measure and detect a flammable gas concentration in the range of 0 – 5 % v/v methane. Therefore when a FGMI is exposed to flammable gas concentration of > 5% the meter will indicate a full scale, or a clear indication that the upper limit of the measuring range has been exceeded and has latched. A FGWD will indicate the condition with an over-range indication and alarm.

FGMIs should not be used in atmospheres containing < 13% oxygen, as oxygen forms an integral part of the operation of the instrument. FGMIs must not be used to determine the flammable gas content inside a diamond drill hole.

FGMIs and FGWDs should be stored in accordance with OEM recommendations and the area should be clean, oil free, free of silicone-based cleaners and sealants, well ventilated and well illuminated to prevent it from being poisoned. Also note that high temperatures in charge rooms may lead to a reduction in the life of rechargeable batteries.

9.4 Bibliography

1. Flammable gas training material, AngloGold Ashanti Training and Development Services

2. South African National Standard SANS 1515-1:2006 Gas measuring equipment primarily for use in mines Part1: Battery-operated portable, flammable gas measuring instruments and warning devices

9.5 Acknowledgements

Pictures of FGMIs and FGWDs are published courtesy of Logica Technologies, Schauenburg and GfG and are used for illustration purposes only.

10. Stonedust Sampling and Analysis

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10.1 Purpose

Stone dust is applied in collieries in order to limit the propagation of a coal dust explosion. A high ratio of incombustible dust particles to coal dust particles has been proven to limit explosions. Stone dust sampling is, for this reason, conducted in order to determine effectiveness of stone dust application within the workings of a colliery.

10.2 Methodology

Various methods for taking stone dust samples exist throughout the world. What follows is common practice within the South African Coal Mining industry.

10.2.1 Apparatus and Facilities

The main apparatus used in taking stone dust samples are sampling brushes used in conjunction with collection devices. In high places where samples are required (e.g. high seam roofs) use is made of a sampling brushe attached to long wooden pole which is surrounded by a collection device. Samples are taken at predetermined positions which are located and measured off by means of a long measuring tape. Samples taken are collected into plastic containers or bags and labelled by means of adhesive or attachable tags.

10.2.1.1 Description of Apparatus

- 100m Tape Measure (non metal)
- Adhesive or attachable tags.
- A 2mm aperture sieve.

Sampling Brush

- Sampling brushes are normal stiff-bristled paint brushes 100mm in width.
- Stiffer bristled brushes enable easier collection of samples.

Floor Samples

- A sampling brush 100mm used in conjunction with a plastic dust collection pan.

Roof Samples

- A long wooden pole is used onto which is attached a collection device (normally a plastic funnel) which in turn surrounds a sampling brush. Not that the plastic funnel would normally have a quarter of its circumference shaved off in order to facilitate brush the sides. This is discussed later on.

It should be noted various alternatives to the above are used in practice and this in turn makes little difference provided the materials used are;

- Not constructed of aluminium.
- Able to sample adequately in terms of the requirements.
- Designed in such a manner that the material sampled is adequately retrieved.

10.2.1.2 Preparation of Apparatus

Prior to use all equipment should be adequately cleaned and in good working order. Particular attention should be paid to the condition of the sampling brush. Worn and damaged brushes must be replaced.

10.2.2 Care and Maintenance

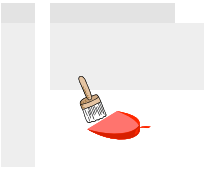
Tape measures may, after prolonged use and exposure to the elements, stretch. For this reason regular checks should be conducted to check for accuracy. A simple test to check a tapes accuracy is to extend the tape to it's fullest length, fold it in half and ensure that the halfway mark reads correctly on the tape. Inaccurate tapes should be discarded and replaced.

10.2.3 Measurement Procedure

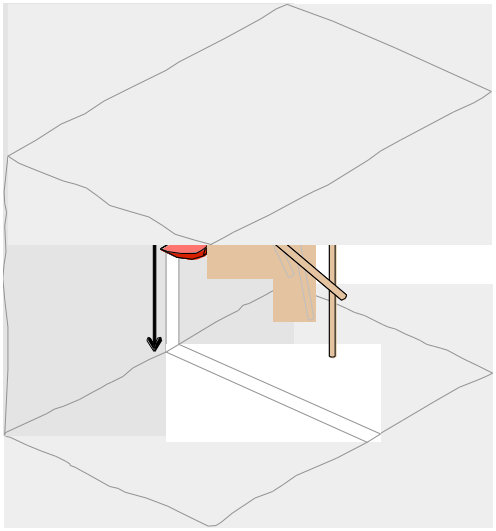
Compliance Sampling

Stone Dust Samples are systematically collected from the roads in all the accessible workings of a colliery. The workings of a colliery are divided into the face areas (Inbye) and zoned back areas (Outbye). For each of these separate sampling methods are used, however, the following principles are common:

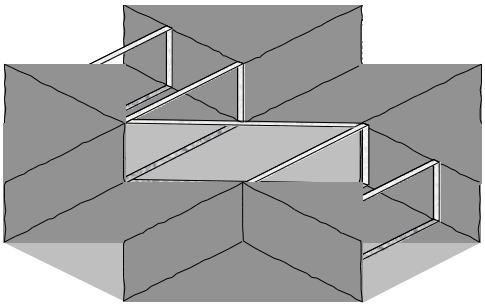
- The sample of dust taken on the roof and sides must be taken separately from the sample of dust on the floor.
- Each sample must be collected by a method of strip sampling by which the dust is collected from a succession of transverse strips, 100mm wide and equally spaced not more than 5.0m apart.
- In the case of dust on the floor the sample must be taken to a depth not exceeding 25mm.
- Every floor sample taken must be representative of the length of road.
- Every roof sample taken must be representative of the whole surface of the roof and sides.



- In the case of dust on the roof and sides the sample must be taken to a depth not exceeding 6mm.
- When taking the roof and side samples (and depending on the height of the roof), it is normally advisable to make use of the long wooden pole used in conjunction with the funnel and sampling brush. This arrangement should, however, change when the brush reaches approximately chest height to avoid spillage from the funnel. At this stage it is more advisable to make use of a sampling brush used in conjunction with the dust collection pan. Both the sample funnel and pan should then be mixed together and is considered representative of the roof and sides.



- Intersections must be sampled diagonally across to include a sample from at least two pillar corners.
- Where it appears that the roof and sides or the floor, as the case may be, is wet, the sample must nevertheless be collected. Excess water must be drained off by placing the sample on a 2mm aperture sieve, for at least one minute.
- Areas where water has collected in pools on the floor need not be sampled but must be recorded as such.



Sampling of the Working Face Area (Inbye)

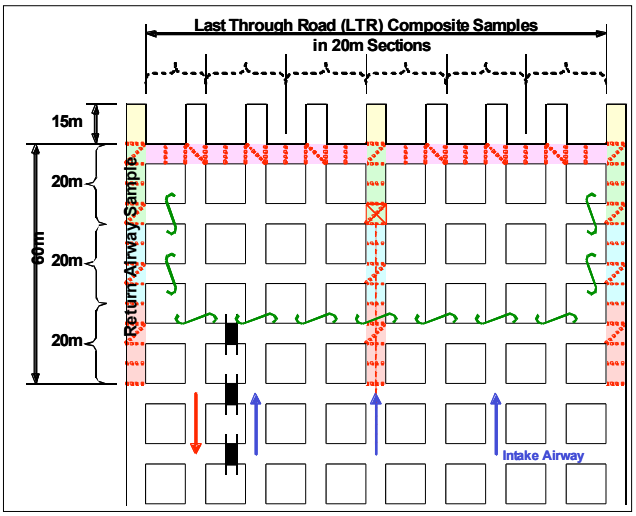


Figure 10.1 Sampling of the Working Face Area

- Samples from face areas must be taken at intervals not exceeding 14 working days, or at lesser intervals, if so determined by the specific colliery's risk assessment.

- In the face area, a composite sample must consist of the combined material, collected from 5 equally spaced transverse strips (except where measurements are affected by diagonal sampling at intersections), over a measured distance of 20m. The dust on the roof and sides must be taken separately from the samples of dust on the floor and the two sets of results reported separately.
- A series of 3 composite samples must be collected from all return airways, the belt road, and at least one intake airway, over a distance not less than 60m length of roadway, commencing at a location approximately 15m from the face. Similarly, a series of composite samples must be collected over the full length of the last through road.
- In the case of either long wall or short wall mining, a series of 5 composite samples must be collected from all gate roads over a distance of not less than 100m length of roadway, commencing at the face.

Sampling of the Back Area (Outbye)

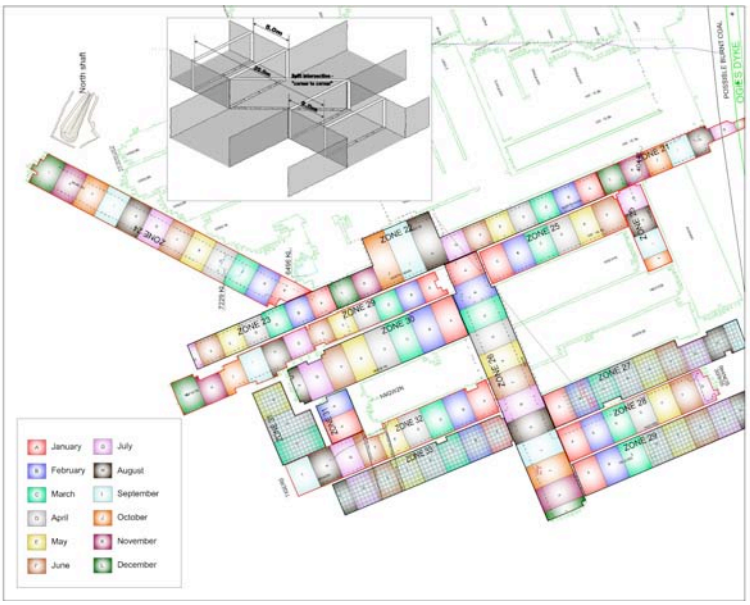


Figure 10.2 An Example Sampling in the Back Area

- The workings of a colliery out bye of the face area must be divided into zones not exceeding 1200m in length. These zones must further be divided into sub-zones, not exceeding 100m in length, from which representative samples must be taken at intervals not exceeding 30 days. Such zones must be clearly demarcated on plan demarcated for the purpose.
- In the back area a composite sample must consist of the combined material collected from 11 equally spaced transverse strips (except where measurements are affected by diagonal sampling at intersections) over a measured distance of 100m. Samples from the roof and sides should be treated separately from those obtained from the floor.
- Samples from sub-zones must comprise of composite samples taken from at least one return airway, the belt road and one other intake airway.

- Sampling of zones must be scheduled so that each sub zone is sampled at least once per year.

10. 2.4 Limitations and Precautions

- Prior to taking any measurements ensure that the roof and sides are safe.
- Avoid contamination of the sample. The primary sources of contamination are:
    - Taking the sample to deeply.
    - Collecting hydrocarbons that spilt onto the floor from machinery. They boost the calorific value of the sample significantly.
    - Confusing roof and floor samples.
- Always ensure that once a sample has been taken it is immediately placed into a sampling bag and container and clearly demarcated.

10.3 Stone Dust Sample Preparation and Colourimetric Analysis

This is done in order to prepare stone dust samples for colourimetric and laboratory analysis.

10.3.1 Methodology

Colourimetric analysis evaluates the degree of inertisation in the shortest possible time. For more accurate results the more time consuming laboratory analysis method is used.

Colourimetric analysis of samples can be done on surface or underground. In both cases the method described remains the same. For the underground option drying facilities and adequate lighting must be provided.

The colour of a sample of dust is compared with that of a scientifically prepared standard colour sample, known to contain 80% (for inbye samples), or 65% (for outbye samples) as the case may be, of incombustible matter content.

When on doing such a comparison, the colour of the sample is found to be the same colour or lighter than that of the standard sample, the incombustible matter content in the dust is taken to comply with the prescribed percentage of the total incombustible matter content.

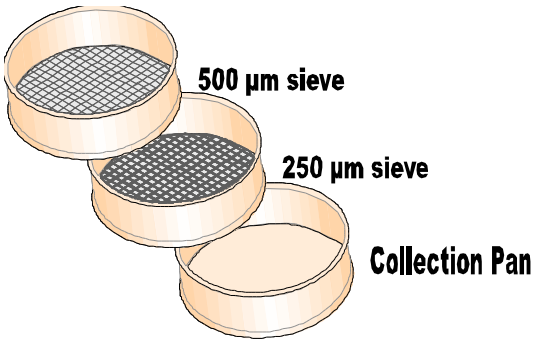
The person performing this duty must be trained to prepare the samples and to conduct the colourimetric test. Furthermore, that person’s ability to distinguish between the colour ranges, must have been determined.

10.3.1.1 Apparatus and Facilities

An adequate work surface with sufficient lighting is used. Underground samples are dried then passed through a series of sieves (which are preferable able to fit into one another) to remove larger particles and collected in a collection pan. The sample is then placed into a test tube and compared to a standard sample or alternatively sent to a laboratory for analysis.

Description of Apparatus

- A 500 µm sieve
- A 250 µm sieve
- A collection pan
- Test tubes
- Colourimetric Standard Samples



Preparation of Apparatus

Colourimetric Standard Sample

A separate standard colour sample is prepared for each geographical/working area of a mine in the following manner:

- Grind some dry coal dust from the coal seam in each area for which the standard colour sample is being prepared so that it passes through a 250 µm sieve.
- Determine the ash content of the sieved coal dust. The ash content must not exceed 20% by mass on a dry basis.
- Pass through a 250 µm sieve some dry stone dust of the type used in the mine.
- Weigh quantities of the sieved coal dust and sieved stone dust in proportions that will give the desired incombustible matter content i.e. 65% and 80%.
- Mix the dust thoroughly by stirring, shaking or rolling. Do not grind the mixture.
- Using the approved laboratory method, determine the incombustible matter content of the mixture and verify that it is not less than the required.
- Place the prepared sample into a test tube, which is then sealed by means of a stopper and demarcated accordingly with the geographical/working area, seam, incombustible matter content and date of preparation.

Care and Maintenance

Colourimetric Standard Sample

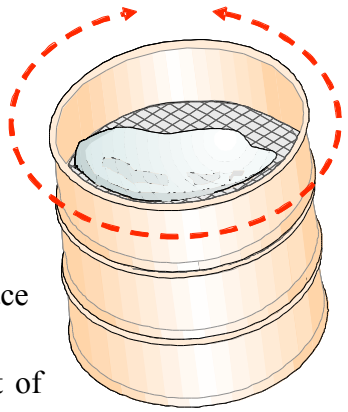
- Whenever there is change in the colour or reflectivity of the stone dust supplied to the mine, and whenever the reflectivity of the coal seam changes distinctly, new standard samples must be prepared.
- Such samples will be prepared in any event at intervals of not more than 3 months. The sample should then be retested and records of those results must be kept.

Measurement Procedure

The procedure for the preparation and evaluation of a collected stone dust sample is as follows:

- Split the sample and retain one half of the sample, if required, for laboratory analysis.

- Air-dry the sample portion to be compared if necessary.
- Place on top of the collection pan the 250 µm sieve and above that the 500 µm sieve.
- Sieve the sample through the sieves and mix the sample thoroughly but do not grind it. For this purpose rotating the collection of sieves and pan in a circular motion will be sufficient.



- Collect the prepared sample from the collection pan and place it into a clean dry test tube.
- Compare the colour of the mixed sieved sample with that of the standard colour sample.
- The comparison must be made under good and even illumination.
- When conditions permit, and if by choice, this comparison is done underground, it must take place at a designated site. The comparison must be done in a suitably designed light box.

Limitations and Precautions

Any sample that appears to be below the prescribed percentage of incombustible matter content as well as at least 10% of the remaining samples are to be analyzed using the laboratory method. Note that all samples sent for analysis must first be sieved and placed in an appropriately demarcated container.

Laboratory Analysis

Analysis of stone dust samples in a laboratory must be carried out by the following method or by other methods approved by the laboratory concerned:

- The residue of a weighed quantity of dust, after that quantity has been dried at a temperature not exceeding 140°C, and the loss of mass attributable to moisture ascertained, must be heated in an open vessel to a temperature not less than 480°C, and not more than 520°C, until the coal is completely burnt away. The incinerated residue must be weighed.
- The sum of the masses of moisture and incinerated residue must be recorded as incombustible matter and be expressed as a percentage of the total mass of the dust.
- Where samples were air dried before analysis by the laboratory method, a correction may be made to the incombustible matter content of the dust sample analyzed by laboratory method. The corrected total incombustible content is equal to M+I (100-M/100) where M is the percentage loss of mass during air-drying and I is the percentage of total incombustible matter in the dust as determined by the method described in the preceding paragraph.

Record Keeping

- The certificates showing the quality of stone dust supplied to the mine must be retained for **2 years**.
- In addition, a record must be kept of the date, places sampled and results of the analysis of the mine dust sampling program.

- Failure of more than **20%** of the number of samples of a given area is unacceptable and requires immediate remedial action, which must be reflected in the record above.

10. 4 Bibliography

1. DME Guideline (DME 16/3/2/1 - A1) for a Mandatory Code of Practice: The Prevention of Flammable Gas and Coal Dust Explosions.

11. Biohazards

Author: Dawie vd Heever, VDH Industrial Hygiene.

11.1 Purpose

11.1.1 Significance of occupational biohazards

Occupational biohazards occur in the work environment and are derived by micro- and macro-organisms and structures and/or substances from these organisms that show deleterious effects on workers that normally leads to occupational disease.

Hazardous agents of biological origin (infectious micro-organisms, biological allergens, and toxins) in the workplace are not very well known and defined when compared with chemical and physical agents. One possible reason for this is that biological agents usually appear in working environments as unwanted contaminants of processed materials whose isolation, identification, and scientific recognition of action usually require many years of research. Another reason is related to the broad range of the biohazards and the variety and complexity of their effects on humans.

Occupational biohazards were previously identified only as infectious micro-organisms presenting a risk for medical care and laboratory workers or as agents of zoonotic diseases. Due to significant progress in immunological and microbiological methods since the early 1960's, the number of newly discovered and characterised biological agents causing occupational disorders (mainly of allergic character) has increased rapidly. The following examples were documented:

- Establishing the causative role of thermophilic actinomycetes and of Aspergillus umbrosus in the aetiology of hypersensitivity pneumonitis;
- Providing the evidence for the etiologic role of endotoxin produced by Gram-negative bacteria in byssinosis;
- Identification of sea-squirts (Ascidiacea) as a cause of "Hoya asthma" among oyster breeders; and
- Recognition of the carcinogenic action of wood dust.

Occupations that are mostly endangered by the occupational biohazards are agricultural, medical, and laboratory workers, and it appears that the number of occupations at risk is increasing.

11.1.2 Diseases caused by occupational biohazards

By applying the knowledge gained from toxicology and the mechanisms of inflammation, it has become possible to systematise the diseases caused by bio-aerosols based on their pathogenesis. Bio-aerosol exposure can cause infectious diseases and also diseases related to an inflammation or cell sensitisation, but without invasive growth of micro-organisms.

11.1.3 Infectious diseases

Human pathogenic bacteria present in bio-aerosols such as Mycobacterium tuberculosis, Legionella pneumophila or opportunistic organisms such as Aspergillus fumigatus, Candida albicans, Histoplasma capsulatum and Cryptococcus neoformans cause infection.

Tuberculosis can be transferred from one infected person to another, especially in indoor environments. Pneumonia caused by Legionella is also commonly found across the world. Furthermore, infections from fungi have been documented as a result of pigeon manure in buildings although the prevalence appears to be low. Common viruses and bacteria such as those responsible for colds, flue, measles, etc are widely spread in work environments but almost never studied by environmental monitoring. The transmission of zoonotic diseases such as anthrax, psittacosis and Q-fever is of great concern where workers handle animals.

11.1.4 Inflammatory diseases

Toxic pneumonitis, airways inflammation, chronic bronchitis, hypersensitivity pneumonitis, asthma, rhinitis and conjunctivitis are some of the inflammatory diseases that can be caused by bio-aerosols.

Toxic pneumonitis can result after an acute exposure to bio-aerosols and is characterised by fever, chill, muscle ache and joint pain. Symptoms normally appear 4-6 hours after exposure but disappear by the following day. Several agents can cause toxic pneumonitis although the data on endotoxin are the most abundant.

Airways inflammation develops slowly over a period of time and is characterised by irritation in the airways and/or stuffy nose with an increased airway responsiveness and cough. The inflammation is often experienced by systemic symptoms such as headache, fatigue and joint pains. Endotoxin is regarded as the causative agent and animal experiments suggest that (13)--D-glucan exposure may enhance the response.

Chronic bronchitis is characterised by an increased number of goblet cells in epithelium, enlarged sub-epithelial glands and increased production of mucous in the airways. Increased amounts of mucous render the affected person more susceptible to microbial infections in the airways. Smokers commonly show the symptoms although non-smokers may also show the symptoms when exposed to high levels of air pollution.

Hypersensitivity pneumonitis, also known as farmer's lung, is initially characterised by a lymphocyte infiltration in the interstitium and airways. If the exposure continues, granulomas may become detectable and eventually fibrosis may develop. The disease normally shows a modest increase in body temperature, breathing difficulties and excessive fatigue. The most widely recognised causative agent is moulds that are abundant in many aerosols of biogenic origin.

Asthma, rhinitis and conjunctivitis are classical reactions after exposure to specific allergens such as animal protein, fungal allergens or pollen. The subjective symptoms are shortness of breath and wheezing. Substances such as tobacco smoke, ozone and sulphur dioxide may act as triggers for sensitive persons.

It is documented that bio-aerosols can cause systemic effects such as headache, fatigue, joint pain and neurological symptoms. Several of these effects are regarded as caused by inflammatory mediators produced in the lung after inhalation of bio-aerosols and distributed to different parts of the body via blood. Several case studies have reported mycotoxins as suppressors of the immune system and decreasing the normal defence mechanisms.

Airborne aflatoxin is known to increase the risk of liver cancer after occupational exposure. Studies showing the effects of Stachybotris chartarum in agriculture workers working with contaminated hay and fatalities among children that developed pulmonary heamosiderosis are examples of systemic effects caused by bio-aerosols.

Several etiologic agents other than bio-aerosols may produce symptoms that look alike**.** These agents might cause the same inflammatory reactions as bio-aerosols and additive effects have been reported. It is further complicated by the simultaneous occurrence of various agents in the environment.

Table 1I.1: Various forms of hypersensitivity pneumonitis caused by micro-organisms

Disease	***Antigen***
Bagassosis	*Thermoactinomyces sacchari*
Humidifier lung*	*Aureobasidium pullulans, Paecilomyceslilacinus, Aspergillus fumigatus, Acremonium ssp., Penicillium spp.*
Malt worker's lung	*Aspergillus fumigatus, Aspergillus. clavatus*
Cheese worker's lung	*Penicillium spp.*
Sequoiosis	*Aureobasidium, Graphium*
Maple bark disease	*Cryptostroma corticale*
Woodworker's lung	*Alternaria spp.*
Cheese washer's lung	*Penicillium "casei"*
Sauna taker's lung	*Aureobasidium*
Lycoperdonosis	*Lycoperdon (puffball) spores*
Compost lung	*Aspergillus fumigatus*
Paprika splitter's lung	*Rhizopus stolonifer*
Wood trimmer's disease	*Rhizopus rhizopodiformis, Aspergillus fumigatus, Penicillium spp.*
Japanese summer house hypersensitivity (pneumonitis)	*Trichosporon beigelii, Trichosporon cutaneum*
Paprika worker's lung	*Mucor stollinifer*

Disease	***Antigen***
Hot-tub lung	*Cladosporium*
Winegrower's lung	*Botrytis cinerea*
Woodman's disease	*Penicillium spp.*
Straw hypersensitivity	*Aspergillus versicolor*
Citric acid fermentation hypersensitivity	*Penicillium spp., Aspergillus fumigatus, Aspergillus niger*
Shower curtain hypersensitivity	*Phoma violacea*
Maize grain hypersensitivity	*Aspergillus flavus*
Suberosis (cork lung)	*Penicillium glabrum*
Mushroom culture hypersensitivity	*Pleurotus ostreatus, Pholiota nameko*
Out grain hypersensitivity	*Aspergillus fumigatus*
Farmer's lung	*Aspergillus umbrosus, Aspergillus fumigatus, Thermomonospora viridis, Thermoactinomyces vulgaris*
Mouldy wall hypersensitivity	*Penicillium spp., Cladosporium spp., Aureobasidium pullulans*
Household timber hypersensitivity	*Serpula pinastri*
Sausage worker's lung	*Penicillium jensenii*
Rabbit farm hypersensitivity	*Aspergillus clavatus*
Ventilation pneumonitis	*Micropolyspora faeni, Thermoactinomycetes vulgaris, T. candidus, T. sacharii, T. viridis*
Micropolyspora faeni, Thermoactinomycetes vulgaris, T. candidus, T. sacharii, T. viridis	*Penicillium spp., Alternaria alternata*
Bird breeder's lung	*Avian (proteins)*
Snuff lung	*Bovine, porcine (proteins)*
Laboratory technician's lung	*Rat urine proteins*
Oyster shell pneumonitis	*Oyster shell proteins*
* fungal agents of diseases also caused by other organisms	

11.1.5 Reason for measurement

Typical reasons for the measurement of bioaerosols are:

- Identification of the agents, gathering of information and evaluation of existing data (exposure history, infectious dose, severity of the disease and availability of treatment).
- Evaluation of the effluent streams through which biohazards can escape containment. Biological egress includes infected humans, animals, insect vectors, waste disposal (water, solid and hazardous waste) as well as exhaust air.
- Determination of the level of personnel proficiency and adequacy of laboratory practices.
- Determination of the availability of PPE and equipment designed to minimise or mitigate operation biohazards.
- Assessment of the capability of each facility or room to contain the material during normal and emergency situations (fire, power failure, malfunctioning equipment).
- Determine whether potential exposure is permissible (ethics, policy, legislation). Notifying local officials about the planned use of biohazardous agents, risk assessments, mitigation practices and laboratory procedures.
- To determine whether the acceptance of risk is voluntary or imposed.
- To recognise the factors that give the illusion of the lack of risk (unknown history of the agent, long latency period, lack of models to test the organism).

11.2 Legislation

Statutory requirements for sampling of biological agents are required in terms of the Regulations for Hazardous Biological Agents, 2001. Regulation 7 of Hazardous Biological Agents Regulations, 2001, states that:

(1) An employer shall ensure that the exposure of employees to a HBA is monitored in accordance with a suitable procedure that is standardised, sufficiently sensitive and of proven effectiveness in any case which it is -

(a) requisite for ensuring the maintenance of adequate control of the exposure of employees to HBA; or

(b) otherwise requisite for protecting the health of employees.

11.3 Methodology

11.3.1 Principle of operation

For the Surface Air System (SAS), air is aspirated at a fixed speed for variable time through a cover, which has been machined with a series of small holes of a special design. The resulting laminar flow is directed onto the agar surface of a "contact plate" containing medium consistent with the microbiological examination to be performed. When the preset sampling cycle is completed, the plate is removed and incubated. The colonies of organisms are then visible to the naked eye and can be counted for an assessment of the level of contamination.

11.3.2 Outline of procedure

11.3.2.1 Summary

In summary:

- Ensure that the head has no obstructed holes such as foreign matter, agar, etc. Hold it up to the light for visual inspection.
- Disinfect the cover or the air sampler at the beginning of each sampling programme by treating the inside and the outside part with a disinfecting alcohol or an alcohol swab.
- The cover with its protective plastic lid can be autoclaved at 121°C for 15 minutes. If this procedure is repeated regularly, a stainless steel head is recommended. It is therefore useful to have spare heads available. Alternatively, the unit can be sanitised using a disinfecting aerosol at about 30 cm from the head when the fan is running. Thirty seconds contact time is sufficient to disinfect the air path.
- Remove the cover of the air sampler by unscrewing it, holding onto the edge of the cover. Avoid touching the inside and outside of the drilled area.
- Insert a closed filled "contact plate" into the retaining slots and then remove the lid. Avoid contamination from droplets and aerosol infection.
- Replace the sampling head and start the aspiration cycle. At the end of the cycle, unscrew the sampling head, replace the "contact plate" lid and remove the "contact plate".
- Make sure that the "contact plate" is identified with the appropriate sample data.
- Incubate the "contact plate" for the specified time at the appropriate temperature.
- At the end of the incubation time, count the number of visible colony forming units/ organisms (CFU) and relate this number to the volume of air sampled.

11.3.2.2 Selection of measuring position/site

The use of a SAS sampler is appropriate in clean rooms as well as other applications demanding fast sampling times. In clean rooms for example, it is important to test larger volumes of air because the level of microbial air contamination is very low. In other

applications such as piggeries, the sampling volumes should be low since the air contains large numbers of micro-organisms.

Sampling for bioaerosols in rooms is normally performed on a tripod with a height of 1.5 - 1.6m above the floor to approximate the breathing zone of a worker or other person exposed to the dusts. However, sampling can be performed wherever the technician wants to determine the contamination levels such as inside ventilation ducting or at ventilation outlet openings. Locate the sampler where it will not disturb the air flow patterns around the sampling inlet(s).

Inside the facility, collect not less than 5 replicate samples at each sampling site.

Outside the facility, collect not less than 3 replicate samples at the upwind site(s) and not less than 5 replicate samples at the downwind site(s).

Wide variations in reported microbiological aerosol levels within facilities make it unlikely that the collection of 5 samples will yield a tight distribution of results; therefore, where economically feasible, it is recommended that the sample size be increased to more than 5.

11.3.2.3 Factors influencing measurements

The following factors may influence the measurement results:

- If an agar “contact plate” is contaminated during the sampling or throughout the whole process, the results will be influenced drastically.
- The aspirated volume of air at high altitude could be different from the declared instrument reading due to the different barometric pressure and temperature. It is therefore necessary to re-validate the instrument at this specific altitude to know the true value of aspirated air.
- The level of contamination cannot be determined with the naked eye and it is recommended that sampling in workrooms with unknown bioaerosol counts be performed at low, medium and high aspirated air volumes. If sampling at high aspirated air volumes is done, the “contact plates” may show overgrowth of organisms and the quantification cannot be done accurately.

11.3.2.4 Limitations

The following limitations need to be taken into account:

- At temperatures below 5°C, the sampling medium may crystallise, thus affecting recovery of micro-organisms.
- The length of time needed to collect each sample is dependent upon the type of sampler used and the concentration of microbiological aerosols present in the air. Trial sampling runs may be necessary to determine if a satisfactory plate loading can be obtained within the limitations of the equipment used.

11.3.1.5 Health and Safety precautions

Due to the nature of each sampling assignment, common sense dictates that some precautions should be observed. Depending on the site where sampling is done, recommended safety practices should be followed such as wearing hard hats, safety shoes, safety glasses, gloves and respirators as well as washing hands before eating and smoking.

11.3.3 Apparatus and facilities required

A Surface Air Sampler (SAS) and a microbiological test laboratory are required for bioaerosol sampling. Airborne micro-organisms are collected on microbiological agar by impaction produced by aspiration. Different samplers are available such as the SAS Super 100 that samples air at a rate of 100 litres per minute or a SAS Super 180 that has a rate of 180 litres of air per minute.

11.3.4 Description of apparatus

The sampler consists of a polyurethane resin casing and an aluminium or stainless steel aspirating head. The aspirating head of the instrument is used for positioning of the "contact plate" during sampling. The turbine of the instrument is made of antistatic plastic resin and the instrument weighs 1750g. It is fitted with a rechargeable Nickel Metal Hydride battery that allows aspiration of approximately 40 000 litres of air. The sampler has air volume ranges of 10, 20, 30, 50, 100, 200, 500 and 1000 litres that are permanently memorised for the standard mode. Up to eight other volumes can be selected and memorised by the operator in the user mode. The maximum volume of air per cycle is 1800 litres.

Figure 11.1 Surface Air Sampler

11.3.5 Care and maintenance

Collect, pack, transport, and manipulate air samples prior to analysis in a manner that safeguards against any change in the microbial activity in the sample, such as, extreme heat and cold and radiation, including sunlight. Use the proper media to ensure preservation of a sample until its identification. If samples must be shipped prior to analysis, positive controls should be included with each shipment.

A SAS sampler does not require special care and maintenance procedures. Clean the outside surface with a mild non-corrosive detergent.

11.3.6 Calibration

It is important to verify that the volume of air you are sampling with your air sampler is correct to avoid errors in monitoring the contamination of the environment. The motor speed and consequently the air flow are related to the electrical power supply, motor bearing conditions, etc. It is therefore suggested that the unit should be validated at least every six or twelve months. The validation of the air flow rate should be done by using a certified Politecnic SAS validation system. Air sampler validation is also recommended each time the air flow rate could be changed due to extended use of the instrument or after other events that could compromise the flow rate.

The flow meter of "Politecnic" should be calibrated by an official agency at regular intervals (usually every year). The following procedure should be used for validation or calibration:

Position the instrument on a flat clean bench with the command panel in front of the operator. Connect the compressed air tubing to the air flow meter inlet on the left side of the instrument. The compressed air source should be provided from a tap. Remove the small cap on the left part of "V" indicator tubing and insert the indicator fluid by a syringe up to reach the line number 2 on the graduated scale.

Figure 11.2 Politecnic calibration/validation system

Ensure that the compressed air outlet is closed and the air flow meter knob is in closed position (clockwise turned). The tunnel pressure tap/valve of the indicator must be in the closed position (horizontal).

Insert the "SAS" air sampler (complete with aspirating head and contact plate) in its housing from top to bottom on the right side of the "Politecnic" instrument. Fasten the four fixing knobs with diagonal operation to be sure about the sealing of the aspirating head.

The rear part of "SAS Super" air sampler should be open in case it is necessary to modify the volume of aspirated air for a new calibration (this operation should be performed only by authorised personnel, on the regulation trimmer on the electronic card).

Open the compressed air outlet tap slowly. Open the air flow meter knob slowly upwards to read the requested value on the graduated scale of the air flow meter by looking at the

indicating ball. Use the conversion table below to get the flow rate in litre/min. Convert the SCFH readings of the air flow meter to litres per minute (Table 11.2).

Table 11.2 Conversion table for air flow rates of the SAS sampler

SCFH	Litre/min	SCFH	Litre/min	SCFH	Litre/min
180	84.96	255	123.42	330	163.68
185	87.47	260	126.05	335	166.43
190	89.98	265	128.68	340	169.18
195	92.51	270	131.33	345	171.95
200	95.04	275	133.98	350	174.72
205	97.58	280	136.64	355	177.50
210	100.13	285	139.31	360	180.29
215	102.68	290	141.98	365	183.08
220	105.25	295	144.67	370	185.89
225	107.82	300	147.36	375	188.70
230	110.40	305	150.06	380	191.52
235	112.99	310	152.77	385	194.35
240	115.58	315	155.48	390	197.18
245	118.19	320	158.21	395	200.03
250	120.80	325	158.21	400	202.88

Switch the “SAS Super” air sampler on and program it for at least a sampling volume of 500 litres. Press the START button.

Slowly open the tunnel pressure tap/valve of the indicator. Adjust the knob of the air flow meter to obtain equilibrium of the colour fluid in the pressure indicator. The fluid should be positioned on the same level of the two arms of the transparent “V” device. This rest position identifies an equivalent pressure between the outside atmospheric pressure and the inside tunnel pressure. In this condition, the air sampler is aspirating the volume of air indicated on the scale of the air flow meter (same volume inlet and outlet air).

If the coloured fluid of the tunnel pressure indicator is going upwards at the left tube, it means that the air sampler is aspirating a volume of air lower than the value indicated by the air flow meter.

If the value is in the range of tolerance of the sampler, report the figure on the certificate and you do not need to act on the electronics of the air sampler.

If the obtained value is outside the range of tolerance of the sampler, the calibration technician should act on the trimmer of the air sampler up to obtain the correct value.

If the coloured fluid of the tunnel pressure indicator is moving upwards in the right tube, it means that the air sampler is aspirating a volume of air higher of the value indicated by the air flow meter.

Close the taps of the compressed air feed, air flow meter, tunnel pressure tap valve indicator and disconnect the air sampler from the "Politecnic" by unscrewing the four fixing knobs at the end of the test.

11.3.7 Measurement procedure

The measuring procedure is as follws:

- Collect samples when the air temperature at the sampling site is above 5oC
- Record air temperature and relative humidity for each location sampled.
- Switch the sampler on by pressing the On/OFF switch.
- Remove the stainless steel head of the air sampler by unscrewing it, holding onto the edge of the head. Avoid touching the inside and outside of the drilled area.
- Insert a closed filled "contact plate" into the retaining slots and then remove the lid. Avoid contamination from droplets and aerosol infection.
- Replace the sampling head and start the aspiration cycle by pressing the START button in order to sample the same air volume as the last sampling cycle.
- To change the volume of air, use the arrows to select "Standard Mode" from the menu. Press ENTER to confirm the selection.
- Press CLEAR each time you need to end an action. The unit will revert to the initial configuration.
- Press ON/OFF switch at the end of the sampling operations.
- Label all petri dishes (contact plates) to denote sampling run, location, and stage impactor.

11.3.8 Calculations

The number of colonies counted on the surface of the "contact plate" must first be corrected for the statistical possibility of multiple passing through the same hole. The statistical formula is taken from work by American researchers. Correction tables are given below. The probable count (Pr) is used to calculate the Colony Forming Units (CFU) per cubic metre of sampled air.

Example of calculation of results:

x = (Pr x 1000) / V

Where:

V = Volume of sampled air = 200 litres of air

r = Colony forming units (CFU) counted on 55mm "contact plates" = 67

Pr = Probable count obtained by positive hole correction = 80

x = Colony forming units per 1000 litres (1 cubic metre) of air

x = (80 x 1000) / 200 = 400 CFU per 1000 litres of air (1000 litres = 1m3)

11.4 Reporting and recording

11.4.1 Acquisition

A report describing the results of air sampling for bioaerosols should include:

Numerical data

Total CFU/m3 should be provided for each sample. The percentage of CFU/m3 values that pertain to each type of organism should be specified.

Taxonomic data

Information on the genus can be used during the interpretation of data and for comparing indoor to outdoor biodiversity.

Other data

The results of bulk and surface sampling performed in the same study should always be included in the report to support and augment the interpretation of air sampling. The environmental conditions of sampling, especially temperature and relative humidity and any ventilation measurements that were made should also be reported.

11.4.2 Analysis & evaluation of results

The information that should be included in a laboratory report of the analysis of air sample collection media for organisms and the interpretation of results depend largely on the purpose of the investigation. Information on the ecology, toxigenic potential and/or pathogenicity of the organisms should briefly be noted.

Occupational hygienists should work with microbiological laboratories of their choice to select a suitable medium for collection and isolation of bacteria important in their projects. A number of culture media have been used to collect airborne micro-organisms in impactor samples and the media used during the project, should be specified in the report. The specific methodology or documented method used during the project must be stated in the report.

Air sampling for viable organisms is a useful tool to detect indoor contamination; however, it should be used in conjunction with appropriately collected bulk sample data and careful visual inspection. There is a consensus that a comparison of biodiversity between indoor and outdoor samples (taken at the air intake) is a reliable determinant of the existence of growth of micro-organisms in a building or growth near the HVAC intake.

11.4.3 Preparation of reports

Reports should be prepared according to protocol as described in Chapter 2.

11.5 Bibliography

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