22. Ergonomics

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22.1 Purpose

To provide the reader with basic tools in the form of checklists to identify ergonomics related risk factors in a workplace. These will allow the user to do elementary hazard identification and risk assessment, and also to identify areas where specialist ergonomics advice is required. In the present context an ergonomics programme is regarded as a systematic approach for anticipating, identifying, analysing and controlling ergonomics related hazards. The hazard identification process provides the data needed to identify, control, and prevent work-related injuries and illnesses.

22.2 General Background

Ergonomics is the science and practice of designing systems to fit people so that the tasks required of the human user are within their limitations, but also to ensure that best use is made of their functional capabilities. Unhealthy, unsafe or inefficient situations at work could be avoided by taking into account the physiological and psychological capabilities and limitations of humans.

Ergonomics is a multidisciplinary science as specialists from various areas contribute to the body of knowledge of ergonomics for example engineers, physiologists, medical practitioners, psychologists, industrial designers and occupational hygienists. Ergonomics should therefore not be viewed in isolation when applied in the work environment and it is essential to draw on all available skills and experience from the above mentioned disciplines in a multidisciplinary team.

Ergonomics differs from other fields by its interdisciplinary approach and applied nature. As a consequence the ergonomics approach results in the adaptation of the work environment or workplace to fit people, rather than the other way round.

A large number of factors play a role in ergonomics such as working postures (sitting, standing, stooping), body movements (pushing and pulling, lifting), physical nature of the task (energy expenditure), environmental factors (thermal stress, noise, vibration, illumination, air, information gained through displays (visually or through other senses), the relation between displays and controls, as well as general work organisation. These factors largely determine the health, safety, comfort and efficiency of task performance in the workplace.

The ultimate goal of ergonomics is to improve and maintain the well-being of the individual worker. At the same time the well-being of the organisation, reflected by increased productivity, will also be improved and maintained. The application of sound ergonomics principles in the workplace will minimise design-induced human error, and also eliminate significant occupational health and safety risks (especially those related to the musculoskeletal system).

The identification of ergonomics-related hazards in the workplace should ideally be part of a mine’s ergonomics programme, which in turn should form an integral part of the occupational

health and safety programme at the mine. Most mines have as a result of the requirements of Section 11, of the MHSA established risk management systems which include elements such as hazard identification, risk quantification, training, audit, feedback and a management system. A formal ergonomics programme should ideally be attached to and integrated into existing risk management systems.

22.3 Legislation

"Ergonomics" is not a new concept in the South African mining industry. The MHSA makes specific reference to ergonomics. Section 21(1)(c) of the Act states that: any person who designs, manufactures, erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during design, manufacture, erection or installation.

22.4 Methodology

22.4.1 Principles

In practice it is essential that the design of workstations and optimal working conditions take the following into consideration:

- The physical size of people and its implications for the fit of the person at the workplace and within the facility
- The cardiovascular system and its limitations on physically demanding work, as measured by work physiology
- The major musculoskeletal system and its limitations on manual materials handling
- The minor musculoskeletal systems and their limitations on fine work, manipulation and dexterity
- Environmental factors such as lighting, noise and thermal comfort, and their impact on worker performance
- Cognitive capabilities of people and their impact on the processing of information and "human error"

22.4.2 Identification of Ergonomics Related Hazards

Ergonomics surveys should ideally be conducted on a regular basis to identify any significant changes in the workplace. Effective and regular analysis of the potential hazards on the mine will allow for a greater degree of control of the risks identified. The selection of a particular task or workplace for further or more detailed investigation should always be done by considering the priority areas of the mine and also in consultation with the relevant personnel in a given work area. Some factors which may indicate the need for ergonomics intervention include: an increase in incidence of musculoskeletal injury, greater prevalence of absenteeism and significant reductions in worker productivity.

22.4.3 Factors Influencing Data Acquisition

One of the major challenges facing the occupational hygienist or ergonomist is the complexity of human responses. No two workers will respond to a given situation in the same way. Various data acquisition techniques are available to assist the occupational hygienist or ergonomics practitioner. The ergonomics experience of the assessor will have an effect on the level of sophistication of the data acquisition techniques used. The type of work being done will guide the practitioner in data collection, with ergonomics data acquisition being useful for health surveillance, assessment of workstation design and selection of tools or equipment, product design, quality aspects, participative aspects and education, training and information. Due to the complexities associated with the field of ergonomics, it is recommended that simple methods be used to identify potential hazards. It is strongly recommended that basic checklists be used whenever a work process is changed or when new tasks are introduced, and periodically (especially after new cases of musculoskeletal disorders are reported) to detect whether trends exist across jobs that use similar equipment, tools or processes.

22.4.4 Limitations

An effective ergonomics hazard identification and risk assessment should allow for the classification of possible high risk jobs in the mining environment. However, the data acquisition process will be influenced by the level of ergonomics knowledge of the person administering the checklist. In instances when the risks or hazards associated with the job are considered to be extreme when compared with recognised standards it is strongly recommended that a trained ergonomist be consulted. Certain jobs may require extensive re-design and this should be done in consultation with input from the interdisciplinary team members.

22.4.5 Procedures

When conducting an ergonomics risk assessment the following general steps listed below should be followed[1].

- Identify potential hazards in the workplace
- Estimate the risk for each hazard
- Evaluate the risk
- Prepare risk control action plans

The control of workplace hazards requires regular assessment of working conditions on the mine. Occupational surveillance systems include the following components: data collection relating to the specific or general working area, analysis of the data, and some action or response to ensure that surveillance activities are translated into preventive action.

Once areas of priority have been identified it is possible to follow a BASIC ERGONOMICS SURVEY along the lines suggested by the USAF School of Aerospace Medicine Ergonomics Programme, 2004 as given below[2].

Step 1: Prepare for the workplace ergonomics risk assessment

At the outset it is usually helpful to review the data used to identify a shop or work area as a potential ergonomics problem area. It is also useful to familiarize yourself with the processes and job activities that are performed in each work area.

Step 2: Conduct a workplace/work area visit

The workplace evaluation needs to be arranged with relevant personnel working in that area of the mine. Various checklists may be used to evaluate the current work demands and should be used cautiously when making generalisations about the working environment. Examples of checklists are given in Appendix 1.

Step 3: Complete the ergonomics assessment checklist

In conducting an assessment of the workplace it is important to ensure that task or job requirements are clearly detailed. The information needed to complete most work related checklists can usually be collected by observation and also through talking to the workers or the supervisor. Employee involvement is critical in the problem identification and problem solving processes. Most checklists enable the recording of any comments or suggestions that the employee may have on how to improve the job/ process. Employee suggestions can be helpful later when controls for identified hazards are being evaluated and selected.

Step 4: Assess hazards

Potential workplace hazards will become apparent during the completion of the risk assessment. There are very few workplaces where there are no hazards, so quantification of exposure is important. A useful general guideline is to assess the frequency of exposure and to make general notes relating to the type of work done for the majority of the working shift.

Step 5: Hazard control selection (corrective actions)

Once workplace hazards are identified and evaluated using the checklist, the next logical step is to identify appropriate corrective actions (controls) for the hazards that pose the greatest risk of work-related musculoskeletal disorders (WMSDs). Generally, the corrective actions should be identified for any hazard presented in a task that receives a task rating of "medium" or "high." The goal is to eliminate or reduce the magnitude of the hazard to the point where the task would be rated as "low" priority on follow-up evaluation.

Step 6: Summarise recommendations

Once a list of potential corrective actions has been developed, you will need to prepare a final report for the organisation that summarises the recommendations and justifications for implementing them. The intent of this recommendation report is for your supervisor to use the report for planning and implementing Corrective Actions. Since this report is a summary, only provide the most critical information from the Checklist Scoring Summary and the Corrective Actions List.

22.4.6 Evaluation and Interpretation of Results

A key purpose of ergonomics is to enable a work system to function better by improving the interactions between workers and machines[3]. Following the basic ergonomics survey it is essential to evaluate the results collected in the workplace. The risk assessment should have assisted in the identification of any current or potential hazards to the workers. In evaluating the results it is important to consider the following aspects of any manual task[3] as given below.

- Force
- Posture
- Repetition
- Duration

Selected jobs may well require a high level of specialisation and risks may require further investigation by an occupational hygienist, medical practitioner or ergonomist. It is strongly recommend that a trained professional be consulted for complex work related problems that are not simple to interpret or where corrective steps may require significant workplace changes.

22.4.7 Summary of procedures

Ideally, actions to prevent ergonomics related hazards should proceed before injuries and/or symptoms develop. Sound ergonomics principles should therefore be applied proactively rather than reactively in the workplace.

The first step in a hazard survey is to establish whether functional job descriptions are available. A functional job description typically identifies essential functions, or fundamental job duties, and the physical and mental abilities needed to perform these functions. If functional job descriptions are available, they may provide useful information for identifying potentially stressful jobs or jobs requiring unique skills or special endurance.

The next step in the identification of ergonomic risk factors in the workplace is a walk-through survey. Investigators observe job activities to detect obvious risk factors, interview workers and supervisors to obtain job information not apparent from observation, and use checklists to score job features against a listing of risk factors.

Examples of checklists that might be used for ergonomic hazard identification are given at the end of this chapter (Appendix 1). Hazard surveys should be administered whenever a job, task or process is changed substantially, when new jobs are introduced, and periodically (especially after new cases of musculoskeletal disorders are reported) to detect whether trends

exist across jobs that use similar equipment, tools or processes. The following checklists have been included: a general ergonomics checklist for use in cases when there are instances of heavy manual materials handling, high physical job demands, poor environmental conditions and lack of general workplace organisation, a checklist for evaluating vehicle cab design and a computer/office ergonomics checklist.

22.5 Reports

The final report on any ergonomics survey should include relevant information from the workplace that identifies priority areas and makes available relevant recommendations that may be applied in the workplace.

22.5.1 Ergonomics Report Guidelines

The report should include, where relevant, a selection of the sub-sections listed below.

- Checklist findings and selection of priority / action areas. These findings should be based on the general ergonomics checklist in the following format:
    - Manual materials handling – list of the major risks associated with manual work
    - Physical energy demands – list of the major risks associated with energy outputs required by the worker
    - Other musculoskeletal demands – list of major risks associated with working procedures (e.g. repetitive motions or poor working posture)
    - Environmental conditions- list of the major risks associated with environmental conditions (e.g. heat, cold, lighting or noise)
    - General workplace – list of major risks associated with the workplace including obstructions and working heights
- Short description of the current "worst case" or priority sites
- Practical Recommendations

22.5.2 Guideline for an Ergonomics Action Plan

The ergonomics report should also include an "action plan" that will allow progress to be monitored in priority areas. The plan provides a simple summary of the control options to ensure that progress is monitored.

When completing the action plan following an ergonomics survey (following HSE Guidelines[4]), the guideline given below provides a useful framework.

- Summarise and prioritise the control options;
    - Examine the completed general ergonomics checklist and the comments to prioritise action. Identify the categories with the highest number of 'Yes' ticks and then set up a priority listing. For example, manual materials handling may have 5 out of 5 'Yes' ticks and therefore require immediate action in that area.

  - In areas where injury reporting is high or recent cases of injury have been recorded as well as risk factors established in your survey, view this combination as a HIGH PRIORITY for implementing control measures.

- Develop a short, medium and long term strategy to implement controls, and place dates against these;

- Propose a date for re-evaluation in the action plan table to ensure that implementation dates are monitored in a particular work area.

22.6 References

1. Van Tonder, J.A. and Schutte, P.C. Ergonomics. Chapter 11 in SIMRAC Handbook of Occupational Health Practice in the South African Mining Industry. SIMRAC, Johannesburg, South Africa 2001.

2. USAF Ergonomics Course Modules. USAF School of Aerospace Medicine, 2001. Web: http://www.brooks.af.mil/afioh/Files/ergocbt/

3. Bridger, R.S. Introduction to Ergonomics. Taylor and Francis, London, UK 2003.

4. Upper limb disorders in the workplace. HSE, UK 2002.

22.7 Bibliography

1. NIOSH Computer and Office Evaluation Checklist. NIOSH, USA. Web: http://www.cdc.gov/od/ohs/PDFFILES/evalcheck.pdf

Chapter 22 Appendix: Checklists

1. General

When completing any checklist the procedures outlined below should be observed (HSE Guidelines, 2002: 68).

- Place a tick in the 'Yes' box where you observe examples of risk factors and a tick in the 'No' box when you do not;
- Write down a short note (in the comments column) of what the worker is doing in relation to that risk factor, including:
    - Body part(s) affected
    - How long the task is being done (times per minute, hour or day)
    - What aspects of the task are presenting the risk
    - Type of work equipment being used
- Write down any possible control measures that can be taken to minimise the risk of injury.

2. Practical example of an action plan

Summary of findings: A worker is required to lift heavy objects from floor level and place them overhead for the entire working shift. The load exceeds 25kg and the task is repetitive in nature. During the task the worker bends to lift the load and there is also excessive twisting of the spine. The working environment is hot and noisy with only basic PPE provided. Housekeeping is acceptable, the floor is even and clear. Date of survey: 31 March

Action Plan: Workstation 1, Area X

Checklist Reference	Controls to be implemented	Priority	Who is responsible for implementing controls	Target implementation date	Date of re-evaluation
1 Manual Materials Handling	• Minimise repetitive manual handling • Investigate a hoist	High	Person A	31 May	31 July
2 Physical Energy Demands	• Investigate reduced load • Job rotation to reduce operator loading	High (load exceeds 25kg)	Person A	31 May	31 July
3 Other Musculo-skeletal Demands	• Minimise repetitive motions	High (posture is poor)	Person B	31 May	31 July
4 Environment	• Evaluate noise PPE • Ensure that fresh water is available	Moderate	Person B	30 June	31 July
5 General Workplace	Housekeeping and work area are acceptable.	No.	N/A	N/A	31 July

GENERAL ERGONOMICS CHECKLIST

AREA:	
Number of Workers:	

(Tick the block if answer is "Yes" to the Question. A "yes" answer response indicates that an ergonomic risk factor may be present which requires further investigation).

1. Manual Material Handling	**Yes**	**No**	**Comments**
• Is there lifting of loads, tools, equipment?			
• Is there lowering of loads, tools, equipment?			
• Is there overhead reaching for loads, tools, equipment?			
• Is there bending at waist to handle loads, tools, equipment?			
• Is there twisting at the waist to handle loads, tools,			

2. Physical Energy Demands	**Yes**	**No**	**Comments**
• Do tools and equipment used weigh more than 25 kg?			
• Is reaching more than 55 cm?			
• Is bending, stooping, or squatting a primary task activity?			
• Is lifting or lowering loads a primary task activity?			
• Is walking or carrying loads a primary task activity?			
• Is stair or ladder climbing with loads a primary task activity?			
• Is pushing or pulling of loads a primary task activity?			
• Is reaching overhead a primary task activity?			
• Is operating equipment or tools above shoulder height a primary task activity?			

3. Other Musculoskeletal Demands	**Yes**	**No**	**Comments**
• Do manual tasks require frequent, repetitive motions?			
• Does work posture require frequent bending of neck, shoulder, elbow, wrist or finger joints?			
• Does worker kneel (one or both knees)?			
• Is the worker unable to change body position often?			
• Does the work involve forceful, quick, or sudden motions?			
• Does the work involve whole hand grasping with straight elbows?			
• Does job posture involve sustained muscle contraction of any limb for periods of more than 30 min?			
• Does worker stand continuously for periods of more than 30 min?			

GENERAL ERGONOMICS CHECKLIST
(Continued)

4. Environment	Yes	No	Comments
• Is the temperature too hot or too cold?			
• Is there dust. Is the workplace poorly lit?			
• Is it a noisy environment?			
• Is the worker working with vibrating hand tools or equipment?			
• Is the worker working with hazardous chemicals?			
• Is the worker subjected to whole body vibration?			

5. General Workplace	Yes	No	Comments
• Are the walkways uneven?			
• Is the floor surface free of obstacles and flat?			
• Is the workplace at a gradient?			
• Is the ceiling height less than 2.5 m?			
• Is there inadequate clearance to or accessibility for performing the task?			
• Is housekeeping poor?			

CHECKLIST FOR EVALUATING THE CAB DESIGN OF A CONSTRUCTION OR MINING VEHICLE:

	Area for Consideration:	Yes	No	N/A
1	Is the seat height adjustable?			
2	Can the seat be adjusted horizontally?			
3	Is the seat set at the proper height?			
4	Does the seat have a back support?			
5	Does the seat have a lumbar support?			
6	Are there armrests available?			
7	Are the armrests adjustable?			
8	Are the armrests set at the proper height?			
9	Do you feel any vibration from the equipment through the seat?			
10	Do you feel any vibration from the equipment through the floor?			
11	Do you feel any vibration from the equipment through the controls?			
12	Is the seat firmly mounted to the floor of the cab?			
13	Can the seat be tilted backward?			
14	Can the seat swivel?			
15	Is the location of the controls or levers adjustable?			
16	Can you easily reach the levers or controls?			
17	Can you easily operate the levers or controls?			
18	Can you easily reach the pedals?			
19	Can you easily operate the pedals?			
20	Is the cab area large enough (e.g., uncramped area) for you?			
21	Do you have sufficient upward visibility?			
22	Is your view of the operation obstructed (e.g., cab guards, pipes/hoses, etc.)?			
23	Do you feel the cab is noisy?			
24	Can you control the temperature of the cab?			
25	Does the equipment have steps?			
26	Does the equipment have handrails?			
27	Can you easily open/close the cab doors?			
28	Does the equipment have proper means for entering the cab?			
29	Does the equipment have proper means for exiting the cab?			
30	Do you have a good general view of the ground?			
31	Are the cab windows free from distracting reflections?			

NIOSH Computer and Office Evaluation Checklist

(http://www.cdc.gov/od/ohs/PDFFILES/evalcheck.pdf**)**

(Shade the block if answer is "Yes" to the Question. A "yes" answer response indicates that an ergonomic risk factor may be present which requires further investigation).

Desk/Workstation	**Yes**	**No**
1. Do you have enough room on your work surface for all your computer accessories?		
2. Is your desk surface deep enough to provide at least 45cm between your eyes and the computer screen?		
3. Are your most frequently accessed items (e.g., phone, manuals, etc.) easy to reach?		
4. If your desk has a fixed height, is the keyboard tray adjustable?		
5. Have you removed all under-desk obstructions?		
6. Do you have a document holder to hold paper for prolonged computer inputting?		
7. Do your arms rest on, or contact any sharp or square edges on your work surfaces?		
8. If a large percentage of your time involves using a phone do you use a phone headset?		
9. Is your source light out of your line of sight?		

Chair	**Yes**	**No**
1. Is your chair height adjustable?		
2. Is your chair back adjustable up and down?		
3. Is your chair back contoured to support the lower back?		
4. Is your backrest large enough to support your entire back, but not interfere with the use of your arms?		
5. Is your lumbar support a minimum of 30 cm wide?		
6. Is there room (2-4") between the front edge of the seat pan and the back of your knees?		
7. If your feet do not rest flat on the floor when your chair is properly adjusted, do you use a footrest?		
8. Is the top of your footrest covered with a non-skid material to reduce slippage?		
9. Do your chair arms interfere with you getting close to your work?		
10. Do your chair arms allow you to sit with your shoulders relaxed and not elevated?		
11. Does your chair have removable armrests?		
12. Is the distance between your armrests adjustable?		
13. Are your knees bent forming approximately a 90 degree or greater angle?		
14. Does the chair have a stable base supported by five legs with casters?		

Monitor	Yes	No
1. Is the viewing distance to your computer monitor somewhere between 45 - 75 cm?		
2. Is the top of your computer screen at or just below eye level?		
3. If you wear bifocals or trifocals, can you see the computer monitor without having to tilt your head back to read the screen or other items in your work area?		
4. Is your computer monitor free of glare or reflections?		
5. Is the monitor screen clean?		
6. Is character size easy to read?		
7. Do you have blinds on the windows near your computer?		
8. Do you use a glare screen to reduce glare on your monitor?		

Keyboard	Yes	No
1. With your chair adjusted properly is your work surface at approximately elbow level?		
2. Are your shoulders relaxed and not elevated when you work at your work surface?		
3. Is the height of your keyboard low enough so your arms are relaxed at your side?		
4. When you address your work surface to type or write is there approximately a 90 degree angle between your forearms and upper arms and are your elbows close to your body?		
5. When you address your work surface to type are your wrist in line with your forearms and not bent upwards, downwards, or side-to-side?		
6. Do you have a wrist rest to support your wrists in a straight and neutral position?		

Mouse, Trackball, or Other Input Device	Yes	No
1. Is your mouse, trackball, or other input device (i.e., touchpad, etc.) located directly in our immediate reach zone?		
2. Is your mouse or trackball positioned next to your keyboard?		
3. Is your mouse or trackball placed together with our keyboard on an adjustable work surface or tray?		
4. Is our mouse work surface stable?		
5. Is the mouse or trackball at the same level as your keyboard?		

Work Habits	Yes	No
1. Do you take short and frequent breaks every 20-30 minutes?		
2. Do you frequently change body positions while working?		
3. Do you provide your eyes with vision breaks every half hour?		
4. Are you free from experiencing any pain or discomfort while working?		

23. Air Flow Measurement

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23.1 Nature of the hazard and its consequences

There are numerous hazards associated with poor ventilation. These hazards primarily include the presence of flammable gas and various airborne pollutants, heat build-up and an oxygen deficient atmosphere. It is important to understand that the hazard of flammable gas build-up, for example, will lead to the risk of explosion. The function of ventilation is to remove heat, dust and gases from the workplace and to provide sufficient oxygen for breathing to the work place.

Airflow measurements are conducted to determine compliance with ventilation control measures and standards. Control measures are implemented and used to mitigate risks associated with poorly ventilated working areas.

23.2 Legislation

It is a legal requirement that a Code of Practice be prepared and implemented to address any matter that may impact on the health and safety of people affected by the activities of a mine or operation. These Codes of Practice contain risk control measure requirements for an operation and are based on risk assessments and / or guidelines issued by the Legislating Authorities. The requirements are the legal rules against which compliance is measured, e.g. minimum air velocities through workplaces, maximum air velocities in airways and shafts, airway sizes and air quantities at specified positions.

23.3 Methodology

23.3.1 Delta Pressure Measurement

Air will only flow when a difference in pressure exists in an airway, duct, workplace or ventilation district. The apparatus used for measuring the pressure difference will be discussed since the movement and/or displacement of air is directly related to the pressure difference between two points. This is referred to as the “delta pressure”.

The most common means of delta pressure measurement are:

(a) Vertical manometer: Measure the pressure differential between two points

(b) Inclined manometer: Measure the pressure differential between two points, but more accurate than with the vertical manometer

(c) Digital manometer: A device that measures the pressure differential between two points electronically and is accurate to a few decimal parts of the measuring units selected

(d) Pitot tube: Measure the velocity and total pressures inside ventilation ducts and fans and is used with a vertical or inclined manometer

(e) Barometer: A Barometer is an instrument used for measuring the absolute pressure of the air, i.e. the pressure due to the total mass of the atmosphere, above the measuring point. (Section by James van Rensburg)

23.3.2 Airflow Quantity Measurement

The basic methods of airflow quantity measurement applied in the working environment are performed through the application of the following techniques:

(a) "Smoke" or "dust" method: applied to measure airflow where the velocity is less than 1m/s

(b) Wet Kata thermometer: used to determine the cooling power of the air and low air velocities

(c) Vane anemometer: used to measure airflow where the velocity is more than 1m/s

(d) Hot wire anemometer: electronic device for airflow measurement

These chapters are aimed at providing a holistic view of the factors that need to be considered during the process of airflow measurement. One must realise that the activity of measurement is an integral part of the risk assessment because it quantifies the effectiveness of control measures intended for a particular risk. The values obtained through measurement are used in the process of risk management and are compared against the stipulations in the Codes of Practice and must be accurate.

23.3.3 Measuring Equipment and Methods
23.3.3.1 Delta Pressure Measurements

The Vertical Manometer

Purpose

The vertical manometer is used to determine the pressure difference between two points.

Principle of Operation

The two ends of a transparent U-tube half-filled with water are connected by means of tubing to the points between which the pressure difference is to be measured. The difference in height of the water levels in the two legs, as measured on a suitable scale, is a measure of the pressure difference.

Description of Apparatus

The U-tube is made either of glass or of transparent plastic tubing with a minimum inside diameter of 5 mm.

A scale, clearly-marked at fixed intervals is mounted behind the U-tube. Zero should be either at the bottom or the top of the scale.

It is an advantage to have the scale mounted so that it can be adjusted vertically.

The framework to which the U-tube and the scale are attached is made of wood, steel or aluminium, depending purely on the use for which the manometer is intended. A manometer for a permanent installation at a main fan is often mounted in a strong box with a hinged door and sometimes with a built-in spirit level, while a portable instrument intended for routine observations is made as small and as light as possible (Fig.1).

The manometer is usually fitted with a short length of plastic or rubber tubing for connecting it to the measuring point. The connecting tubing and its joints must all be airtight.

Figure 23.1 Vertical Manometer

Preparation Before Use

Before a manometer is used:

(a) Ensure that the tubes are not damaged or perished, and that the free end of the connecting tube has been cut smooth and square.

(b) See that the U-tube is clean and is approximately half-full of clean water.

(c) Remove any air bubbles from the water by blowing into one of the tubes so as to rock the water to and fro.

(d) Remove any water present in the connecting tube.

(e) Check that the water moves freely in the U-tube.

(f) Check for leaks by withdrawing air from the connecting tube to produce a difference of at least 200 Pa between the water levels in the two columns. Close the end of the connecting tube. Stretch the tube slightly and watch for any change of the water levels that would indicate the presence of a leak.

Selection of Observation Positions

Where possible, all observations should be made at a distance of at least ten duct diameters away from bends and obstructions.

Taking Readings:

(a) Hold the instrument vertically and check that the water levels in both columns are the same as in Fig 23.2 (a).

(b) Fit the connecting tube to the test point.

(c) Read each column separately, taking care to keep the eye at the same height as the meniscus to avoid errors of parallax. Read at the bottom of the meniscus. If the level fluctuates, a mean should be estimated.

(d) Check whether the pressure is positive or negative as in Fig 23.2 (b) and 23.2 (c).

(e) Remove the connecting tube from the measuring point and check that the two water columns return to the same level and that the instrument is still vertical.

(f) Replace the tube and take a check reading. Continue doing this until consistent results are obtained.

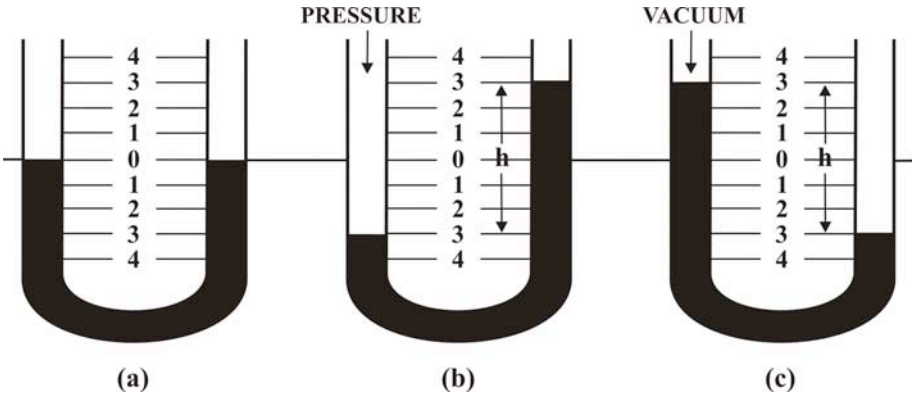


Figure 23.2

Calculation of Results

With higher pressure p1 being applied to column A and lower pressure p2 to B, the liquid in column A is forced down until the pressure p1 is equalised by the pressure in column B.

The difference in pressures is determined by the height of the liquid h. The scale has been calibrated as a result of the selection of the fluid used, as different fluids at different densities will give a different change in height for the same pressure applied.

$$That\ is \quad \frac{p^1 - p^2}{rg} = h(Pa)$$

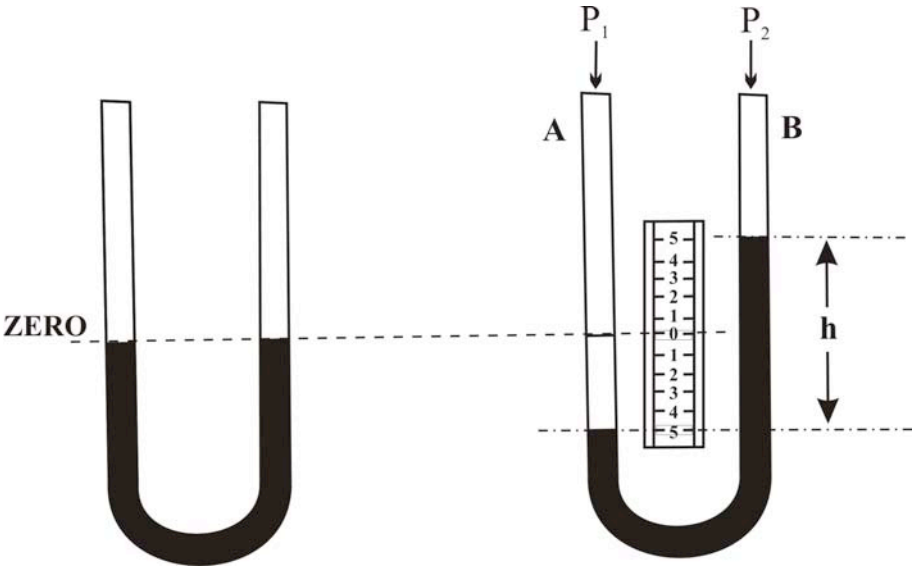


Figure 23.3 Reading a Pressure Difference

Application of the Manometer

Pressure across doors and stoppings

Pass the end of the connecting tube through a hole in the door or stopping so that it reaches a point where the air velocity is negligible.

The pressure difference across an airlock is measured across each door separately with the other door open. The higher reading is recorded.

Static pressure in ventilation pipes

Hold the open end of the connecting tube over a smaller hole drilled in the pipe, making sure that no air leaks between the end of the tube and the pipe.

Pressure across fans

The pressure difference across a fan can be measured directly by connecting the limbs of the manometer to the selected points in the intake and discharge of the fan and observing the difference in levels on the manometer. It is more common to measure the differences in

pressure between the air inside and outside the pipe at each selected point (i.e., at the intake and discharge of the fan) and then to obtain the fan pressure by the algebraic difference of these readings. The measurement of fan pressures when the fan is installed in different positions is complex and has been explained in detail in reference 1.

Limitations and Precautions

The Capillary Effect

When a small tube is used, it should be noted that the level of the fluid is read at the center of the tube.

The Inclined Manometer

Purpose

The inclined manometer is used to accurately measure the pressure difference between two points.

Principle of Operation

One or both limbs of the inclined manometer are connected by means of flexible tubing to a reservoir containing measuring fluid. These limbs may be adjusted to alternative inclined positions usually 1:5, 1:10 and 1:20, or to a vertical position depending on the differential pressure to be measured. The pressure may be read directly off a suitably calibrated scale or the reading may be multiplied by the relevant factor for conversion to Pascal's. To obtain a pressure differential the reservoir or top end of the measuring limb (in the case of a negative pressure) is connected by means of tubing to the point being measured. In the case of use with the pitot tube both the reservoir and the measuring limb may be connected simultaneously to measure the velocity pressure directly.

Description of Apparatus

The measuring limb usually consists of a glass tube with a minimum inside diameter of 5 mm, connected to a flexible tube that in turn is coupled to a reservoir containing the measuring fluid.

A mirrored surface is provided behind the measuring limb to avoid errors of parallax, whilst a suitable scale is attached to the limb in such a way that readings may be obtained.

The top end of the adjustable tube usually slots into a suitable notch on a holding plate on which the incline is indicated, e.g. 1:10. The reservoir is fitted with an adjustment device that allows the user to adjust the meniscus to a preselected position, usually at the zero mark on the scale.

The entire instrument is mounted on an adjustable base with one or more spirit levels so that the instrument may be set up in a horizontal position. See Figure 1 for an picture of the inclined manometer.

Figure 23.4 Inclined Manometer

Preparation Before Use

Before use the inclined manometer is used:

(a) Ensure that the measuring limb (or limbs) is not damaged or cracked.

(b) Check that there are no bubbles present in the visible part of the fluid (it is not possible to determine whether there are bubbles present in the reservoir, but if the instrument is handled with care the reservoir is usually free of bubbles).

(c) Ensure that the end of the flexible tubing is securely connected to the measuring limb.

Note:
It sometimes happens that the flexible tubing loses its suppleness with age, and if the measuring limb is unduly forced into another position this might lead to the glass tube being cracked or broken. Should this be the case the flexible tubing has to be replaced with new tubing.

(d) Ensure that the meniscus is clearly visible and, if necessary, adjust the measuring scale so that this is the case.

(e) See that the instrument is set up in a level position on a stable surface, so that the bubble is centred within the small ring in the case of a circular water/spirit level. In the case where two water/spirit levels are provided, both bubbles should be centred between the demarcation lines on the levels.

(f) Check that the measuring fluid moves freely in the measuring limb.

(g) Checking for leaks:

(i) Where a negative pressure is to be measured, adjust the measuring limb to the vertical position, connect a flexible piece of tubing to the connector at the top end of the limb and by applying negative pressure draw the measuring fluid about three-quarters of the way up the limb. Seal the end of the tube, stretch it slightly, release the tension and see whether the level of the measuring fluid has changed which would indicate the presence of a leak.

(ii) Where a positive pressure is to be measured, connect the end of the flexible tubing to the connector provided at the reservoir end, apply positive pressure and repeat the procedure described in (i) above.

(iii) Where both connectors are to be used simultaneously, as in the case of the pitot tube, steps (i) and (ii) must both be followed.

Taking Readings

(a) Once a measuring station has been selected, determine whether the pressure to be measured is positive or negative.\

(b) Measure the approximate pressure difference using a manometer, as this would give an indication of which incline (i.e. 1:5, 1:10, 1:20 or vertical) should be used, to prevent the measuring fluid from being sucked or blown out of the instrument.

(c) Place the instrument on a reasonably level, stable base and adjust the feet so that the instrument is level.

(d) Carry out the checks described in the preceding section.

(e) Adjust the measuring limb to the required incline, and by turning the adjusting knob set the meniscus of the measuring fluid to the zero mark. See Figure 2(a) that shows the position of the meniscus relative to the zero mark.

(f) Place the measuring end of the flexible tubing over the pre-drilled hole at the measuring site, making sure that it seals properly.

(g) Wait for the fluid level to stabilize and read off this value. See Figure 2(b) that shows the position of the meniscus relative to the reading.

Note: Where the pressure continually fluctuates, it is good practice to take several spot readings (approximately 10) at short, regular intervals of about 15 seconds and then average the resulting readings.

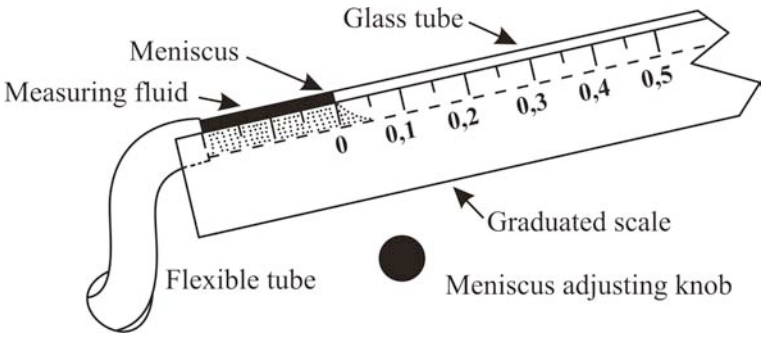


Figure 23.5 (a): Zeroing Meniscus

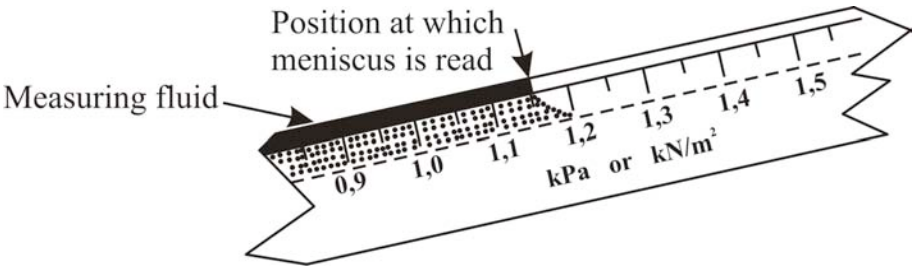


Figure 23.5 (b) Reading Meniscus

(h) When using the pitot tube to measure the velocity pressure in a duct, the total pressure tube should be connected to the "reservoir" side of the inclined manometer, while the static pressure connection should be connected to the top end of the inclined measuring limb. Where a large total or static pressure difference is encountered that would blow or suck the fluid from the inclined manometer if connected separately to any one of the two connectors, it is advisable to pinch both the flexible tubes closed and then insert the pitot tube into the duct to be measured. Once the pitot tube is in position, the tubes are gradually and simultaneously released so that both sides of the connecting limb react to the pressure applied at the same time.

(i) Where it is necessary to determine differential pressure across an orifice plate, venturi meter or fan the "high pressure" side should be connected to the reservoir tapping and the low pressure side to the measuring limb. Once again care should be taken in controlling the pressure released to the inclined manometer to prevent the measuring fluid from being blown or sucked out of the manometer, especially where high pressure differentials exist.

(j) Once a reading has been obtained, disconnect the flexible tubing from the measuring points and check to see that the meniscus returns to the original setting.

Calculations of Results

To calculate the actual pressure measured when the instrument is set to a vertical or to an inclined position, the following corrections apply:

(i) With the measuring limb adjusted to the vertical position:
Actual reading = reading x fluid correction factor*
(ii) At the 1:5 inclination; reading x fluid correction factor x 0,2
(iii) At the 1:10 inclination; reading x fluid correction factor x 0,1
(iv) At the 1:20 inclination; reading x fluid correction factor x 0,05

*The fluid correction factor applies to situations where the density of the measuring fluid differs from that of the fluid for which the scale graduations have been calibrated.

The Digital Manometer

Purpose

The digital manometer is used to determine the pressure difference between two points.

Principle of Operation

The one end the digital manometer is connected by means of tubing to the points between which the pressure difference is to be measured. The difference in pressure measured on a suitable scale is displayed on the digital manometer.

Description of Apparatus

The digital manometer is an electronic pressure measuring device with either a digital or analogue display. A scale, clearly-marked at fixed intervals can be selected on the front panel. The zeroing of the instrument should be user defined. The manometer is usually fitted with a short length of plastic tubing for connecting to the measuring point. The connecting tubing and its joints must all be airtight. A typical digital Manometer is shown in Figure 1.

Figure 23.6 Digital Manometer and Accessories

Preparation Before Use

Before a manometer is used:

(a) Ensure that the tubes are not damaged or perished, and that the free end of the connecting tube has been cut smooth and square.

(b) See that the battery life is ok.

(c) Check the zero setting.

Selection of Observation Positions

Where possible, all observations should be made at a distance of at least ten duct diameters away from bends and obstructions.

Taking Readings

(a) Hold the instrument up right in one hand.

(b) Select the correct pressure scale to be measured.

(c) Fit the connecting tube to the test point.

(d) Record the pressure reading displayed on the screen. If the reading fluctuates, a mean should be estimated.

(e) Check whether the pressure is positive or negative.

(f) Remove the connecting tube from the measuring point and check that the display on the screen of the instrument return to zero.

(g) Replace the tube and take a check reading. Continue doing this until consistent results are obtained.

Application of the Digital Manometer

Pressure across doors and stoppings

Pass the end of the connecting tube through a hole in the door or stopping so that it reaches a point where the air velocity is negligible.

The pressure difference across an airlock is measured across each door separately with the other door open. The higher reading is recorded.

Static pressure in ventilation pipes

Hold the open end of the connecting tube over a smaller hole drilled in the pipe, making sure that no air leaks between the end of the tube and the pipe.

Pressure across fans

The pressure difference across a fan can be measured directly by connecting the limbs of the manometer to the selected points in the intake and discharge of the fan and observe the reading on the display. It is more common to measure the differences in pressure between the air inside and outside the pipe at each selected point (i.e., at the intake and discharge of the fan) and then to obtain the fan pressure by the algebraic difference of these readings. The measurement of fan pressure when the fan is installed in different positions is complex and has been explained in detail in reference 1.

The Pitot Tube

Purpose

The Pitot tube is used for measuring static, velocity or total pressure within a duct. After obtaining the velocity pressure and the density of the air inside the duct, the air velocity can be calculated. It is especially useful for taking measurements in small and inaccessible places such as inside ventilation ducting and fan casings.

Principle of Operation

When a tube connected to one limb of a manometer containing fluid is held in such a position that the movement of the air has no effect on the meniscus position, only the static pressure of the air is then acting on it. However, when the air inside the duct is at a higher pressure than the atmospheric air and it is held to face directly into the airstream, both the static pressure and the velocity pressure of the air act on it and thus the total pressure is measured. The velocity pressure is determined by subtracting the static pressure from the total pressure, or by measuring it directly with the Pitot tube.

A Pitot tube consists of two concentric tubes of which the inner has an open end (see Figure 1) which is held so as to face directly into the air stream, while the outer tube is sealed at the end and rounded so as not to cause turbulence and has several small holes drilled into its side static pressure ports. Because the air flows smoothly past these holes, the velocity pressure has no effect on them and only the static pressure is measured. If the two tubes are connected to the two limbs of a manometer, the pressure indicated by the difference in water levels, is equivalent to the velocity pressure.

The velocity pressure measured in this way is dependent on only two parameters, the air velocity and the density of the air. If the air density is determined and if the instrument is properly constructed according to standard specifications and correctly used in straight flowing air, the air velocity can be measured to within one per cent if the velocity is more than about 10 m/s. No calibration is required and for this reason the Pitot tube is considered as the basic instrument for determining velocities, against which other instruments such as the anemometer can be calibrated.

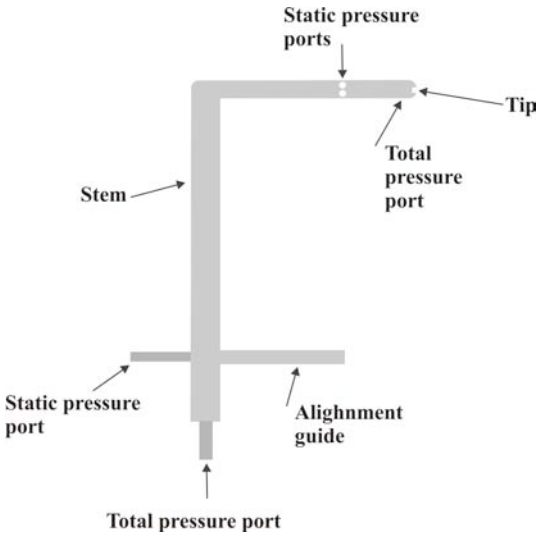


Figure 23.7 A Diagram of the Pitot Tube

Apparatus Required for Measurement

(a) A standard Pitot tube of suitable length.

(b) A sensitive manometer such as the inclined manometer or digital manometer.

(c) Two lengths of transparent plastic tubing.

(d) An accurate rule or measuring tape.

(e) A whirling hygrometer or loose thermometers.

(f) An aneroid barometer.

(g) A handdrill for drilling holes in ducts.

(h) A length of string.

(i) A clinometer rule.

(j) A vertical manometer.

Description of Apparatus

(a) ***The Pitot Tube***

The National Physical Laboratories (NPL) of Great Britain and other similar institutions has approved various standard tubes. Figure 23.8 shows the standard hemispherical head which is more robust and which is also less sensitive to yaw (angular deviation from the true direction) than the sharp-ended head or the ellipsoidal head.

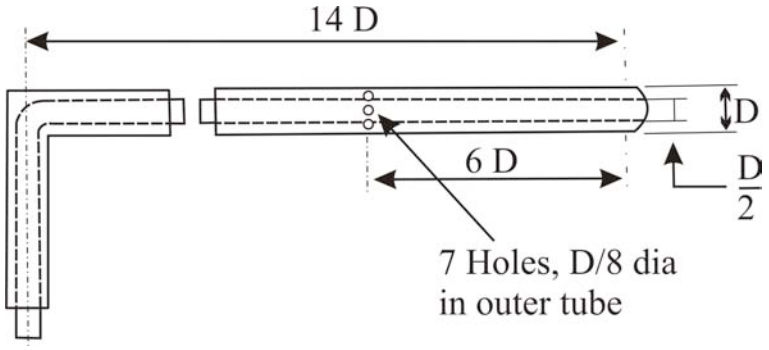


Figure 23.8 Standard Hemispherical Pitot Head

The tubes are made of stainless steel, copper or bronze to limit rusting, especially of the static holes and the inside of the tubes.

The outer tube normally has an outside diameter of 6 to 8 mm and the inner tube about two-thirds as much. The length of the tube is optional, depending only on the application for which it is required.

The ends of the tubes to which the plastic tubes are connected are thickened to facilitate leakless joints and these two ends are aligned with the Pitot head to assist in the alignment when the head cannot be seen because it is inside a duct.

(b) ***The Manometer***

To avoid errors of more than 1 per cent in the velocity measurements, the velocity pressure reading must be correct to within 20 Pa if the velocity is 40 m/s, within 1 Pa if the velocity is 10 m/s and within 0,3 Pa if the velocity is 5 m/s. Thus a vertical manometer, who's smallest convenient reading is about 5 Pa, is unsuitable unless the air velocities are extremely high or unless great accuracy is not required.

For routine work inclined manometers or digital manometers are used for greater accuracy. When using the inclined manometer the true pressure is obtained by multiplying the difference in height between the water in the two legs by the sine of the angle of inclination of the manometer. By this means, and by furthermore using a coloured liquid of low density that also gives a more definite meniscus than water, the accuracy of pressure measurements can be improved to 1 Pa.

For even greater accuracy micromanometers or hook gauges can be used, but this is not necessary for routine underground work.

(c) ***Plastic Tubing***

Any tubing of a suitable diameter to ensure tight leakless connections with the Pitot tube and the manometer is acceptable. However, it is preferable to use a type of tubing that does not kink easily and it is easier to detect water blockages in the tube if it is transparent.

(d) ***Rule or Measuring tape***

The rule or measuring tape must be graduated in millimetres to facilitate the accurate marking of the stem of the Pitot tube before insertion into a duct.

(e) ***Whirling Hygrometer or Thermometers***

The temperature of the air inside the duct must be known for the calculation of the air density. If it is not possible to reach inside the duct with a whirling hygrometer, a loose thermometer must be inserted through the hole in the duct, first dry and then covered by a damp cloth in order to observe the dry and wet bulb temperatures.

(f) Aneroid Barometer

The barometric pressure at the point of measurement is required for the calculation of the air density. A relatively coarse instrument accurate to say 100 Pa would suffice.

(g) ***Handdrill***

If the Pitot tube has a rectangular bend between the head and the stem, the drill bit must be about 50 % larger than the Pitot tube.

Selection of Measuring Sites

The object is to determine the average air velocity in a duct, which may then be multiplied by the cross-sectional area of the duct in order to obtain the air volume flowing. Each

measurement with the Pitot tube yields only the velocity pressure, from which the air velocity can be calculated, at one particular spot in the duct. It is therefore necessary to take sufficient readings to yield a reliable average velocity in the duct.

It is most essential that a measuring site be selected where the air flow is as even and regular as possible and where the air has no pulsations and no swirl or eddies. In a large duct that the operator can enter, this is ascertained by tying a piece of cloth to a rod and observing its reactions in various positions in the duct. In a small duct a rapid preliminary traverse with the Pitot tube will indicate whether it is suitable. In essence, a position is selected as far as possible downstream from any fans, bends or obstructions.

When the best cross-sectional area is selected, the positions of the measuring points can be determined as shown in Table 23.1 and Figure 23.9.

Table 23.1

Number of points or traverse lines	Proportional distance of measuring positions from inside wall of airway*	Minimum ratio of short side to pitot tube diameter
5	0,074; 0,288; 0,500; 0,712; 0,926	25
6	0,061; 0,235; 0,437; 0,563; 0,765; 0,939	25
7	0,053; 0,203; 0,366; 0,500; 0,634; 0,797; 0,947	25

*

$(\frac{X}{b} \ or \ \frac{Y}{h})$

Measuring Procedure

In the case of the more common circular duct, the procedure is as follows:

(a) Hang a string with two weights attached over the pipe as in Figure 23.10. Mark one point at the side of the pipe where the string just touches it and another at the bottom (or top) midway between the two strings.

(b) Drill holes at these two points just large enough for the tube to be inserted with ease.

(c) Set up the inclined manometer, making sure that it is level in both directions. If an inclined U-tube type manometer is used the liquid must be level in the two limbs, while if a single limb type is used the liquid must be set at the zero mark.

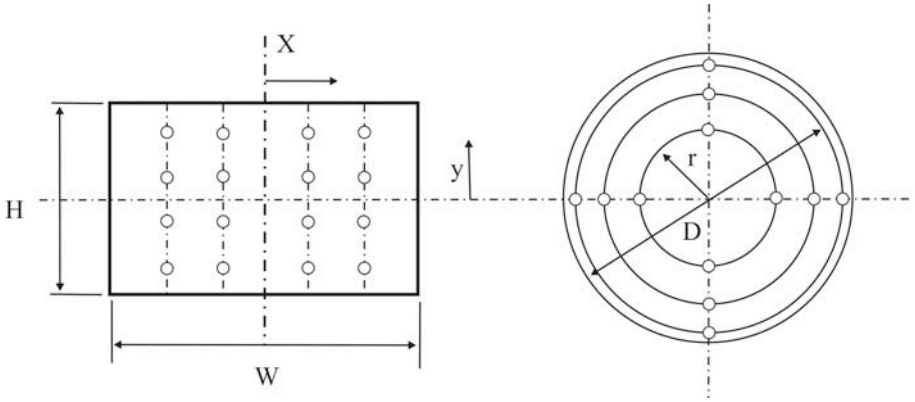
(d) Clean the Pitot tube and ensure that the small static holes are not blocked or burred on the outside.

(e) Mark the 10 points required for the particular size of duct clearly on the stem of the Pitot tube, and an eleventh point corresponding to the full diameter of the duct (see Figure 23.9 and Table 23.1).

(f) Blow through the two plastic tubes and ensure that they are neither choked nor kinked.

(g) Attach the tubes to the manometer and to the Pitot tube.

(h) Blow gently into the impact hole of the tube until there is a large difference between the liquid levels in the two legs of the manometer, then stop the hole with a finger and watch the manometer for about a minute. If the levels stay constant there is no leakage. Repeat the same process but this time close the static holes.



Rectangular ducts - Centroids of Equal Areas

Rows or Points/Row	Distance from Center-line, x/W or y/H			
4	±0.125	±0.375		
5	0	±0.2	±0.4	
6	±0.083	±0.25	±0.417	
7	0	±0.143	±0.286	±0.429

Circular ducts - Centroids of Equal Areas

Points/radius	Distance from Center, r/D					
4	0.204	0.353	0.457			
5	0.177	0.306	0.395	0.468		
6	0.158	0.274	0.354	0.418	0.474	
7	0.144	0.25	0.323	0.382	0.433	0.479

Figure 23.9 Measuring Grid

(i) Pinch both plastic tubes simultaneously to prevent loss of manometer fluid due to high pressure differentials as the Pitot tube enters the duct.

(j) Insert the Pitot into the duct. Release the pinched plastic tubes and make quite sure that the head points upstream.

(k) Insert the tube until it encounters the far side of the duct and check that this agrees with the 11th mark on the stem. Then withdraw it to the 10th mark.

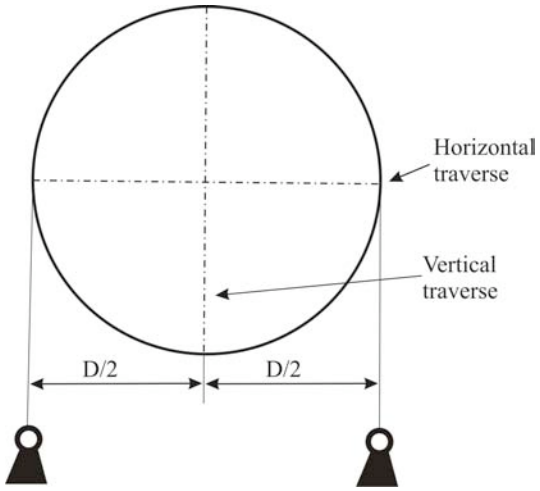


Figure 23.10 Positions for Holes to be Drilled

(l) Use a clinometers rule to check that the tube is held at right angles to the side of the pipe and perfectly horizontally (or vertically as the case may be) and also check that the two outside ends of the Pitot tube are aligned with the longitudinal direction of the pipe, which means that the head is pointing in the same direction.

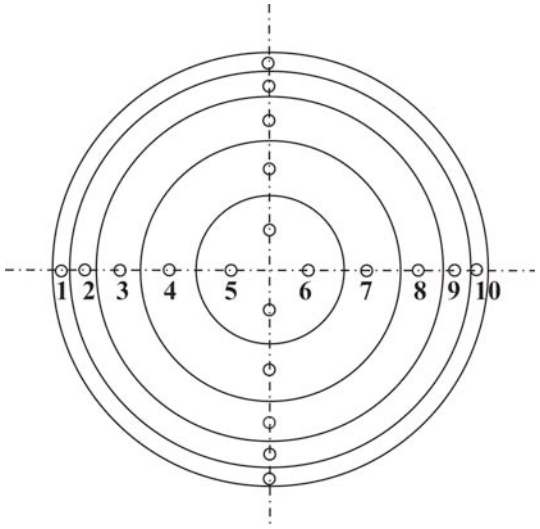


Figure 23.11 10-Point Measuring Grid

Table 23.2 Distances from duct side for a 10-point survey

Point Number	General Case	562 mm duct	762 mm duct
1	0,026 d	15 mm	20 mm
2	0,082 d	47 mm	62 mm
3	0,146 d	84 mm	112 mm
4	0,226 d	129 mm	172 mm
5	0,342 d	196 mm	261 mm
6	0,658 d	376 mm	501 mm
7	0,774 d	443 mm	590 mm
8	0,854 d	488 mm	651 mm
9	0,918 d	525 mm	700 mm
10	0,974 d	557 mm	742 mm

(m) A second person now observes and records the reading on the manometer. As a final check the tube is rotated slightly in each direction to ensure that the head is pointing directly into the airstream. The highest reading obtained is the correct reading.

(n) Repeat the measuring process at the other nine points and also along the other diameter.

(o) Again pinch the two plastic tubes just before removing the Pitot tube from the duct.

(p) When the Pitot tube is removed from the duct, hold it in a place where there is negligible air movement and check that the manometer reads zero. If it does not, the measurements have to be repeated after correcting the alignment of the manometer.

(q) Measure the dry and wet bulb temperatures inside the duct.

(r) Measure the barometric pressure.

(s) Measure the static pressure in the duct with a vertical manometer.

(t) Record the inclination of the manometer and the specific gravity of the liquid used.

Precautions

If there is considerable oscillation of the liquid in the tube, this can be dampened by inserting a short length of capillary tubing into one of the plastic tubes. Alternatively, 10 (say) spot measurements can be taken at regular 5 second (say) intervals, and these averaged. However, excessive oscillation should rather be taken to indicate that the measuring point is unsuitable for obtaining accurate results.

Calculation of Results

(a) Calculate the actual velocity pressures by multiplying the manometer readings by the sine of the angle of inclination and by the specific gravity of the liquid, unless these factors have already been corrected for in the scale of the instrument.

(b) Calculate the barometric pressure inside the duct by adding the static pressure in the duct to the barometer reading if it is positive and by subtracting the static pressure if it is negative.

(c) Use the barometric pressure and the temperatures inside the duct to obtain the air density from a psychrometric chart or a density chart.

(d) The air velocity at any point can now be calculated by using the formula

$$V = \sqrt{\frac{2VP}{\omega}}$$

$$Where\ V = airvelocity\ (m/s)$$

$$VP = velocity\ pressure\ (Pa)$$

$$\omega = air\ density\ (kg/m^3)$$

If the mean air velocity is required, as is generally the case, the velocity at each of the 20 points can be calculated and the 20 answers averaged without any weighting because each represents the mean velocity in an equal area. However, it saves time to calculate only the square roots of the 20 velocity pressures and to take the average of the answers, and then

To multiply this figure by $\sqrt{\frac{2}{\omega}}$

Under no circumstances must the average of the velocity pressures themselves be taken because this would be meaningless.

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The Barometer

Author: James van Rensburg, Impala Platinum Ltd.

Purpose

A Barometer is an instrument used for measuring the absolute pressure of the air, i.e. the pressure due to the total mass of the atmosphere, above the measuring point. As the density and therefore the mass of the air in the earth's atmosphere reduces with increasing height, it follows that as we ascend from sea level and low-lying parts of the earth's surface, the mass of air will decrease.

Principle of Operation

Principle of Operation

There are several types of barometers viz mercury barometer, aneroid barometer and electronic barometers. The most commonly used Barometer used in the mining industry today is the electronic barometer. These units feature pressure transducers, appropriate circuitry and a digital readout. They use detection cells with sufficiently sensitive resistance or capacitance levels to measure small changes in atmospheric pressure. The pressure sensor in the unit provides an accurate linear voltage output that is directly proportional to the atmospheric pressure. The barometric pressure is then indicated by means of a digital display.

Figure 23.12 Digital Barometer

Calibration

Calibration of the electronic Barometer is necessary to receive reliable readings. Digital Barometers must be calibrated annually or before a major survey and these calibrations must

be conducted by the Original Equipment Manufacturer (OEM) or a recognised calibration facility.

Operating instructions

The operating instructions vary in detail from one type of instrument to another but will generally be based on the principles outlined below.

There are three main controls, a button to switch the instrument on or off, the “mode” button to switch between hi and low values and the “zero” button which sets the display to zero.

A typical operating sequence will be:

1. Switch on the instrument by pressing the “on/off” button.

2. Check the battery level and ensure that it displays

3. Check that the correct unit is displayed. (typically mbar = hPa)

The unit is now ready to take measurements.

Measurements

The following measurement procedure should be followed:

a) Select a measurement site that is representative of the area to be surveyed.
b) Hold the instrument at arms length or place on a flat surface and allow it to stabilise for one minute.
c) Take a reading and proceed to the next measurement point.
d) The unit commonly used for measuring barometric pressure is Newton per square metre or Pascal. The barometer will display the measurement in millibars. (1millibar = 100 Pascal.)

Application of Barometric Pressure

Barometric pressure readings are usually taken for one or more of the following reasons:

a) For measuring variations in the natural atmospheric pressure.
b) To determine the barometric pressure at a point for use in conjunction with temperature readings to calculate the psychrometric value of air at that point.
c) To measure precisely the barometric pressures at a number of related points in a ventilation circuit.
d) Barometers are also used to determine the air pressure losses in airways and shafts.

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23.3.3 Measuring Equipment and Methods
23.3.3.2 Airflow Quantity Measurements

Measurement of low air velocities by the "smoke" or "dust" method

Purpose

To measure air velocities that are less than one metre per second.

Principle

The measurement of the time that a visible cloud of smoke or dust travels over a known distance.

Apparatus

(a) Smoke, powder or dust disperser.

(b) Measuring tape.

(c) Stop-watch.

(d) Cap lamp.

Method

(a) A portion of an airway of regular cross-section and remote from bends and obstructions is selected, and two points, at least three metres apart, are marked on the sidewall.

(b) An assistant provided with a dust disperser aligns the beam of his lamp at right angles to the direction of airflow at the upstream mark and then releases a cloud of dust in the centre of the airway at arm's length upstream of this mark.

(c) The observer stationed opposite the downstream mark starts his stop-watch as the dust cloud enters the beam of his assistant's lamp and stops the watch as the dust cloud enters the beam of his own lamp which is aligned at right angles to the downstream mark.

(d) This procedure is repeated at least three times.

Calculation

The mean air velocity is calculated from the formula:

$$v = \frac{fd}{t}$$

Where v = *mean velocity in meters per second*

f = *velocity distribution factor*[1], *normally* 0,8

d = *distance in metres*

t = *time in seconds*

Velocities should be reported to 2 significant figures.

Limitations and Precautions

(a) Dust samples can be contaminated when aluminium dust is used to measure air velocities.

(b) Aluminium dust is not permitted in coal or any fiery mine.

(c) Aluminium dust is not suitable for measuring air velocities below 0,3 m/s, while smoke is not suitable for measuring air velocities above 0,5 m/s.

(d) If the mean of the observed velocities is more than 1 m/s an anemometer should be used.

The Vane Anemometer

Purpose

The vane anemometer is the instrument commonly used for the routine measurement of air velocities greater than 0,5 m/s.

Principle of Operation

The moving air rotates a spindle to which vanes are attached. Gearing converts the spindle revolutions into readings that are indicated on a dial or dials that represent the length in metres of the air column that has passed through the instrument. The air speed is then calculated by taking an observation over a measured period of time.

Apparatus Required

(a) Anemometer with carrying-case
(b) Anemometer extension rod
(c) Stop-watch
(d) Measuring tape
(e) Crayon or paint

Description of Apparatus

Anemometer

Multi-purpose anemometers that measure air velocities in the range 0,5 to 30 m/s and high speed anemometers that measure in the range 5 to 50 m/s are required. A multi-purpose type anemometer is shown in Figure 1.

Figure 23.13 The Vane Anemometer

Anemometers are fitted with a clutch mechanism for disconnecting the dials from the spindle. Multi-purpose anemometers are normally provided with a zero setting device in addition to the clutch. It is recommended that the clamp and ring swivel, usually found on anemometers, be replaced by a fitting for attaching an extension rod when used for mining work.

Anemometer extension rods

Tests have shown that hand-held instruments give inaccurate and inconsistent readings and it is recommended that the operator holds the anemometer a distance of at least one metre from his/her body by means of an anemometer rod. A typical extension rod is shown in Figure 2.

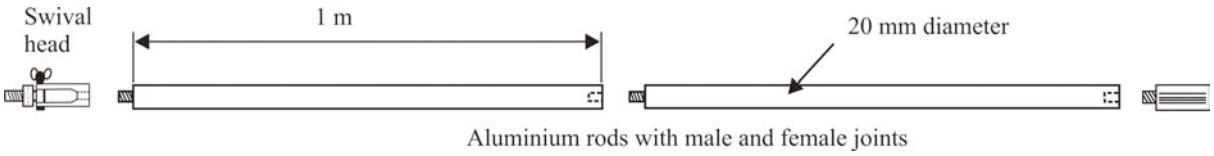

Figure 23.14 A Typical Extension Rod

Stop-watch

Mechanical or digital stop-watches may be used but in fiery atmospheres they will require to be intrinsically safe.

Measuring tape

A metallic tape, approximately 15 m long, graduated in centimetres, is suitable. A brass ring at the end of the tape serves as the zero mark and is used to attach the tape to a rod when measurements are required from points beyond normal reach.

Crayon or paint

An indelible crayon or paint is required for marking off places where the air quantities have to be measured and for recording the cross-sectional area on the side wall. If paint is used, it should be of a colour different from that used by the surveyors.

Care and Maintenance of Apparatus

All anemometers should be sent for calibration to a recognised authority such as the South African Bureau of Standards, or the National Mechanical Engineering Research Institute of the Council for Scientific and Industrial Research (CSIR). In addition, some of the companies that supply anemometers have facilities for calibration and repair. Anemometers in regular use should be calibrated at least once a year and, in addition, checked monthly against a special instrument kept in the office for that purpose.

Stop-watches must be checked monthly against a reliable watch over periods of at least five minutes and should not have an error greater than 3 seconds. Stop-watches should also be checked against each other for short periods to detect starting and zeroing errors. Measuring tapes should be checked monthly either against a standard tape or by doubling it up at say the 3m mark and checking that the zero just reaches the 6m mark, because the first few metres are liable to stretch after some use.

Selection of Measuring Points

Measurements should be made at points where the airway is of regular cross-section, reasonably straight and unobstructed. When bends or obstructions are present, measurements must be made upstream of them.

Measurement of Air Velocities in Airways

(a) Mark off the chosen position at right angles to the general air direction. Obviously, in an inclined airway this mark will not be vertical but will be at right angles to the dip of the airway.

(b) Estimate whether the air velocity is in the range of the anemometer, i.e. 0,5 to 30 m/s. If the velocity is less than 0,5 m/s then the method described for low air velocities by the "smoke" or "dust" method should be used.

(c) Attach the rod to the anemometer while the instrument is still in the carrying-case to minimize the possibility of damage.

(d) Blow onto the vanes to see that they turn freely.

(e) Check the clutch and zeroing devices.

(f) De-clutch and set the pointers to zero.

(g) Stand facing a side-wall, slightly downstream of the marked position. With the "upstream" hand grip the rod at the anemometer controls and position the anemometer in the lower corner of the measuring station with the vanes facing the airstream.

(h) Hold the stop-watch in the other hand.

(i) Clutch the anemometer in and start the stop-watch simultaneously, immediately releasing the watch and allowing it to hang by the string.

(j) Grasp the rod with the "downstream" hand, moving the other hand immediately to the bottom of the rod. Then remove the "downstream" hand from the rod.

(k) Start traversing the anemometer across the airway, taking particular care that it is always held normal to the direction of airflow, at least one metre away from the body and in line with the marked position. At about mid-way across the airway step under the anemometer and turn the body to face the opposite side-wall, switching hands on the rod during this change so as to remain downstream of the anemometer. Make sure that the anemometer vanes continue to face the airstream. Complete the traverse, terminating in the bottom corner. Stop the anemometer and the stop-watch simultaneously. The speed of traversing should be less than 0,2 m/s. It is not necessary to traverse for a fixed time period but the minimum acceptable period of traversing is 50 seconds.

(l) Record the readings of the anemometer and stop-watch.

(m) Repeat all the steps from (f), starting from the point at which the first traverse was completed.

(n) Calculate the uncorrected velocities by dividing the anemometer readings (metres) by the traverse times (seconds). A difference of more than five per cent between the two readings indicates either an error in the observations or unsteady flow conditions. When this occurs, further measurements should be taken.

(o) Apply the calibration correction to the average of the results.

(p) Velocities should be reported to 3 significant figures e.g., 1,72 m/s or 17,2 m/s when they are greater than 1 m/s, but to 2 significant figures when they are less.

Measurement of Air Velocities in Pipes or Ducting

Either the traversing method or the centre-spot method may be used for measuring air velocities in pipes or ducting. Neither method provides accurate readings under operational conditions underground but both are acceptable for most routine measurements. For accurate measurements the Pitot tube should be used.

Traversing method

(a) Traverse the anemometer slowly and evenly along a horizontal diameter for 50 seconds and record the anemometer reading. Take a second reading.

(b) Make two similar traverses along the vertical diameter, again recording the anemometer readings.

(c) Calculate the air velocities by dividing each reading by 50.

(d) If the velocities obtained by the two horizontal traverses or the two vertical traverses differ by more than five per cent, further readings should be taken.

(e) Apply the calibration correction to the mean of the velocities obtained under (c) above.

(f) Calculate the velocity by multiplying the mean corrected velocities by 0,82 and 0,92 for measurements made at the inlet and outlet respectively.

Centre-spot method

(a) Take two readings, each over a period of 50 seconds, with the anemometer in the centre of the pipe inlet or outlet.

(b) Calculate the air velocities by dividing each reading by 50.

(c) If the velocities differ by more than five per cent, further readings should be taken.

(d) Apply the calibration correction to the mean of the readings obtained under (b) above.

(e) Calculate the velocity by multiplying the mean corrected velocities by 0,87 for both inlet and outlet.

Limitations and precautions

(a) The anemometer should not be inserted directly into the pipe as sudden entry into a high velocity airstream might damage the instrument. It should be introduced into the airstream at a distance of approximately one metre from the end of the pipe and then slowly moved nearer the pipe.

(b) The axial position of the anemometer, relative to the end of the pipe, has a large effect on the accuracy of the readings, particularly at the inlet. The instrument should be held at right angles to the axis of the pipe, with the rod touching the end of the pipe. It is important that the rod be 20 mm in diameter as the correction factors are based on this size.

(c) When a screen is fitted to the pipe, the traversing method will give more reliable results.

(d) Velocities should be reported by 3 significant figures e.g. 8,68 m/s or 25,2 m/s when they are greater than 1 m/s but to 2 significant figures when they are less.

(e) If the end of the pipe is damaged then the centre-spot method cannot be used and a traverse should be made.

Measurement of Cross Sectional Areas

When cross-sectional areas are measured, the areas of fixed obstructions, such as of large pipes, must be deducted. Special care must be taken in inclined airways to ensure that the measurements are made at right-angles to the dip of the airway.

The areas of airways with fairly regular cross-sections can be calculated from the average of three measurements each of width and height. For airways of irregular cross-section, a greater number of measurements of width and height should be taken.

The widths and heights of the airways should be measured to the nearest centimetre and the area recorded to 3 significant figures.

At places where important measurements are made periodically, the cross-sectional area is required with greater accuracy. The survey department may be requested to off-set and planimeter these areas.

Calculating Air Volumes

The volume of air flowing through any airway or duct at any particular point is the product of the corrected air velocity and the cross-sectional area at that point and should be recorded to 3 significant figures if more than 1 m^3/s or to 2 significant figures if less.

The Hot-wire Anemometer

Purpose

The hot-wire anemometer is used for measurement of fluid velocities between 0 to 5 m/s at -20 to 0 °C and 0 to 10 m/s at 0 to +50 °C.

Principle of Operation

The hot-wire probe generate an electrical resistance that will be proportional to the temperature of the hot wire. The probe contains a bridge circuit that is set up by adjusting the resistor to the resistance required from the probe and it's leads during operation. An electric current through the probe heats it to the temperature that gives the selected resistance. When the probe is exposed to the flow of air (or water), it will try to cool it. In order to maintain the temperature (resistance) constant, the bridges voltage will increase and this value is displayed as velocity. Thus the faster the flow, the higher the voltage and the velocity.

Various shapes and manufacturing material of hot-wire probes are available. An example of probe construction is illustrated in Figure 1.

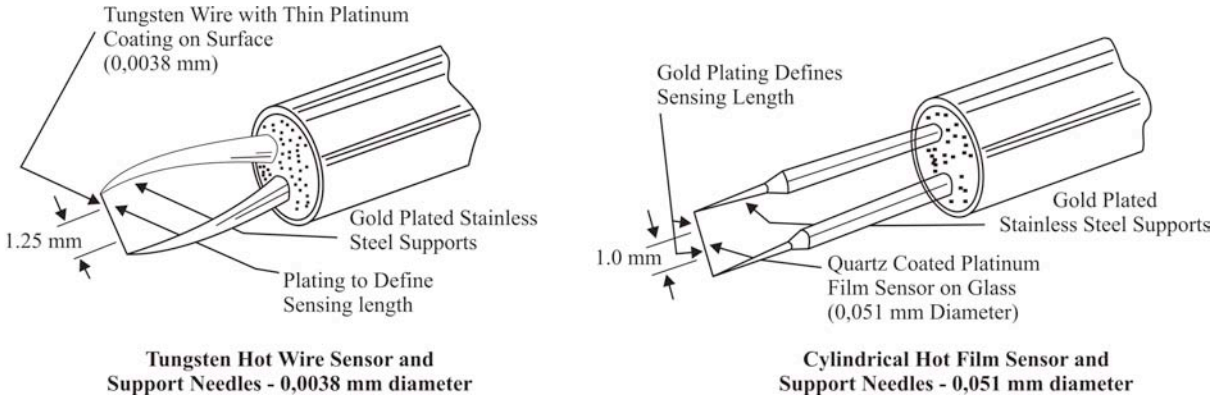

Figure 23.15 Illustration of Probes

Description of Apparatus

Hot-wire anemometers are manufactured to be used for static location monitoring or roving measurements depending on the requirements of the workplace application. Various designs of measuring apparatus with hot-wire technology exist. Some examples of these instruments are shown in Figure 23.16.

Figure 23.16: Handheld Instrument and Fixed Point Sensor

Apparatus Required for Handheld Measurements

(a) Hot-wire anemometer with carrying-case

(b) Probe and connector

(c) Stop-watch

(d) Measuring tape

(e) Crayon or paint

Measurement of Air Velocities in Airways and Ducting

The principle of measurement of air with a hot-wire anemometer is the same as in the case where a vane anemometer is used. Refer to the section for measurement of air with a vane anemometer to view the principles of measurement and calculation of results. The primary difference between the use of the two instruments however is the calculation of the resultant velocity when the vane anemometer is used. The electronic display on the hot-wire anemometer indicates the velocity.

Volume flow calculation

The volume flow is calculated as the product of the size of the airway or duct and the velocity measured as displayed at the touch of the measurement value button. The swivel head (if fitted) can be turned at an angle of 180° making the display easy to read.

The Wet Kata Thermometer

Purpose

The wet kata thermometer is used in South African mines to determine:

(a) the cooling power of the air, and

(b) low air velocities.

Principle

The kata thermometer is heated in water and then allowed to cool in the atmosphere being measured. The time taken for it to cool over a specified range of temperature, divided into a given factor, given factor, gives the "wet kata reading". This combines various properties of the air, principally the wet bulb temperature and the air velocity, into a single index.

Apparatus Required

(a) Kata thermometer.

(b) A strong clean carrying container.

(c) Stop-watch (graduated in fifths of a second).

(d) A suitable vacuum flask.

Description

The instrument is shown in Figure 23.17. The glass thermometer contains coloured alcohol and has a bulb 40 mm long and 18 mm in diameter which is covered by a sleeve of fine net. The stem is about 190 mm long and incorporates three small reservoirs, one above the bulb and the other two near the top of the stem. A ring is provided to which a loop of string is attached.

Marks corresponding to 36 °C, 37 °C and 40 °C are engraved on the stem. The standard sleeve is made of thin cotton thread woven into a honeycomb net. The sleeve must fit closely and be long enough to cover the whole bulb; it is tightened around the stem above the bulb by means of a draw-thread. The sleeve must be renewed if it becomes damaged or soiled, and at least every six months when in regular use. Sleeves are obtainable from the Research Laboratories.

Kata thermometers for use on the South African mines are calibrated by the Research Laboratories and the factor is taped onto the instrument.

Figure 23.17 The Wet Kata Thermometer

The factor should also be recorded against the number of the instrument. The factor should also be recorded against the number of the instrument.

A small vacuum flask filled with clean hot water is taken underground and used to wet and heat the kata thermometer.

Preparation Before Use

(a) Select a kata thermometer that has been calibrated.

(b) Check that the sleeve is in good condition; replace it if necessary.

(c) Check that the string for suspending the instrument is in good condition.

(d) Fill the flask with clean hot water (50 °C).

(e) Heat the bulb in the hot water until all the bubbles are driven out of the alcohol and a continuous column to the top reservoir is produced. Allow the instrument to cool without timing. No separation of the column should occur and no alcohol should remain in the top reservoir. If either of these occur the instrument should not be used.

Positions at which Readings Should be Taken in Routine Work

Sufficient kata readings should be obtained to provide an overall picture of the environmental conditions affecting the workers.

Readings should be taken at positions within two metres of the workers in a gang, and the position of the measuring point relative to the gang should be such that the readings represent the conditions to which the gang is exposed. Exact positions can be determined only according to the circumstances of each place. Readings should be taken near workers in the vicinity of the working face. In addition, measurements should be taken near gangs working in situations where conditions are likely to be unfavourable, for example in scraper gulleys in stopes, haulages used for hand-tramming, reclamation areas, and so on.

When readings are taken, the kara thermometer is held stationary at arm's length at the level of the worker's chests, in such a way that the observer does not obstruct the flow of air past the instrument. The kata must not be exposed to any air current, for example compressed air, that does not reach the workers.

Since a kata reading reflects the conditions only at the point at which the thermometer is held, and since conditions vary from one point to another, more information will generally be obtained by taking successive readings at different points than by taking repeated observations at the same point.

When a series of wet kata readings is being taken in one working area, for example along a stope face, the readings will provide a rough check among themselves; there will usually be no need to make check readings at each measuring position. However, if the working place is being tested at only one point, then a second observation should be made as a check.

Measuring Procedure

Immerse the bulb completely in the hot water and heat until the reading is 40°C.

Remove the kata from the hot water and allow excess water to run off; if a drop of water remains at the bottom of the bulb it should be removed by touching the bulb against a clean surface. The sleeve must not be squeezed or wiped.

Hold the instrument stationary at the selected point at arm's length and chest height.

Time the fall of the alcohol from the 37 °C mark to the 36 °C mark, to the nearest fifth of a second.

Calculation of Results

(a) Wet kata cooling power

$$K = \frac{F}{T} \text{ where } K \text{ is the kata reading, } F \text{ is the factor and}$$
$$T \text{ is the measured time in seconds}$$

In practice, the value of K is given as a dimensionless number, but the units implied are millicalories per square centimetre per second.

Table 23.3 The Wet Kata Reading and its Approximate Relationship to the Unventilated Wet Bulb Temperature and Velocity of the Air

	Air velocity (metres per second)													
	0,1	0,2	0,3	0,4	0,5	0,6	0,8	1,0	1,5	2,0	2,5	3,0	4,0	5,0
34	2,5	2,9	3,1	3,3	3,5	3,7	4,0	4,3	4,8	5,3	5,7	6,1	6,8	7,3
33	3,6	4,0	4,4	4,7	4,9	5,2	5,6	6,0	6,7	7,4	8,0	8,5	9,5	10,3
32	4,6	5,2	5,6	6,0	6,3	6,6	7,2	7,7	8,7	9,5	10,3	10,9	12,2	13,2
31	5,6	6,3	6,9	7,3	7,7	8,1	8,8	9,4	10,6	11,6	12,6	13,4	14,9	16,2
30	6,6	7,5	8,1	8,7	9,2	9,6	10,4	11,1	12,5	13,7	14,8	15,8	17,6	19,1
29	7,6	8,6	9,4	10,0	10,6	11,1	12,0	12,8	14,4	15,9	17,1	18,2	20,3	22,0
28	8,6	9,8	10,6	11,3	12,0	12,5	13,6	14,5	16,4	18,0	19,4	20,7	23,0	25,0
27	9,7	10,9	11,9	12,7	13,4	14,0	15,2	16,2	18,3	20,1	21,7	23,1	25,7	27,9
26	10,7	12,1	13,1	14,0	14,8	15,5	16,7	17,9	20,2	22,2	24,0	25,5	28,4	30,8
25	11,7	13,2	14,4	15,3	16,2	17,0	18,3	19,6	22,1	24,3	26,2	28,0	31,1	33,8
24	12,7	14,3	15,6	16,7	17,6	18,4	19,9	21,3	24,1	26,4	28,5	30,4	33,8	36,7
23	13,7	15,5	16,8	18,0	19,0	19,9	21,5	23,0	26,0	28,5	30,8	32,8	36,5	39,6
22	14,7	16,6	18,1	19,3	20,4	21,4	23,1	24,7	27,9	30,7	33,1	35,3	39,2	42,6
21	15,8	17,8	19,3	20,7	21,8	22,9	24,7	26,4	29,8	32,8	35,4	37,7	41,9	45,5

Unventilated wet bulb temperature °C.

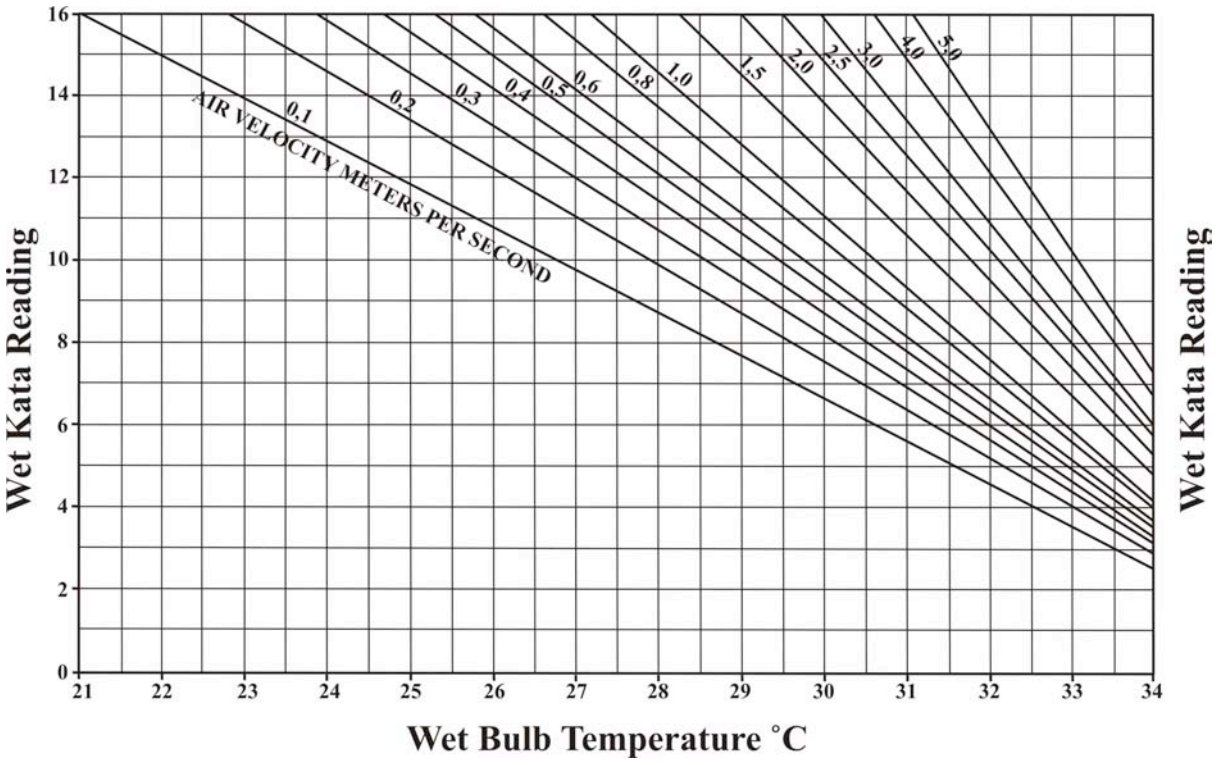

Figure 23.18 The Wet Kata Reading and its Approximate Relationship to the Unventilated Wet Bulb Temperature and the Velocity of the Air

(b) Air velocity

Air velocity is calculated from the following formula:

$$V = \frac{(K - 0{,}7\theta)^2}{\theta} \quad where$$

$V = air\ velocity\ in\ metres\ per\ \sec ond,$

$K = wet\ kata\ cooling\ power,$

$\theta = 36{,}5 - t_{wb}$

$twb = unventilated\ wet\ bulb\ temperature\ in\ °C$

The formula is approximately correct for all barometric pressures and for air velocities normally found in working places.

Ideally, t_{wh} should be the reading of an unventilated wet bulb thermometer, but in most underground situations no significant error is introduced when the normal wet bulb temperature is used. In places where there is al large gap between the wet bulb and dry bulb temperatures the unventilated wet bulb temperature will differ appreciably from the normal wet bulb temperature here.

The wet kata thermometer will not give reliable readings for air velocities below about 0,1 metres per second as convection currents caused by the heated bulb have a velocity of this order.

Table 23.3 and Figure 23.18 show the relationship between air velocity, wet kata reading and wet bulb temperature.

While the table and the figure contain air velocity values up to 5 m/s this does not imply that it is good practice to use the kata thermometer to measure air velocities as high as this. Air velocities higher than say 0,5 to 1m/s should normally be measured with an anemometer.

When the wet bulb temperature and the air velocity are known, the wet kata cooling power can also be calculated by means of the same formula rewritten in the form $K = \theta(\sqrt{V} + 0{,}7)$.

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24. Sampling and Analysis of Mine Water

Author: Casper J. Badenhorst, Anglo Platinum.

24.1 Purpose

Samples of mine water are required for:

a) the determination, by the deep-cell method or nephelometer, of the amount of rock dust in the water;
b) the determination of the acidity or alkalinity (pH);
c) chemical analysis;
d) bacteriological examination;
e) the determination of free chlorine content; and
f) the determination of the quality of water for human consumption.

24.2 Apparatus required

Dust estimation and pH determination
Clearly numbered 200 ml bottles with wide mouths and fitted with screw tops.

Chemical analysis
Clearly numbered bottles of at least one litre capacity, provided with well-fitting stoppers.

Bacteriological analysis
Clearly numbered sterile bottles of 50 - 60 ml capacity fitted with ground glass stoppers and housed in an ice-box. Samples must be transported between 6oC and 18oC and protected against heat and sunlight.

Chlorine content
A comparator, relevant diethyl-p-phenylene diamine (DPD) tablets and comparator chart.

Legionella analysis
Clearly numbered sterile 1 litre plastic/nalgene/glass containers. Cooler/ice box filled with ice blocks. Paper towel, waterproof marker, labels, 70% alcohol solution and thermometer.

24.3 Sampling points

Dust estimation
Samples should be taken where water is likely to be atomised or sprayed, e.g. at rockdrills. If such samples reveal unacceptable high dust concentrations, further samples should be taken along the route of the supply to determine the cause of the high concentrations.

Chemical analysis or pH determination
Samples may be taken at any point in the distribution system or at any source of water about which information is required.

Bacteriological examination
Samples are collected at representative points in the machine and drinking water systems.

Legionella examination

Samples are collected from sludge, slimes or sediments particularly where accumulation occurs. Dip samples are collected from storage tanks below the surface of the water.

- Sampling points of Cooling Towers
  - − Collect sample from incoming supply to the tower.
  - − Take samples from any storage tanks or reservoirs in the system (e.g. chilled water return tanks or header tanks).
  - − Collect bulk water samples from cooling water basins as far away from any make-up supplies as possible to prevent incorporating make-up water into the sample.
  - − If tower basin is inaccessible, collect re-circulating water from a valve in the pipe after sterilising and flushing the valve.
  - − Collect water returning from the circulation system at the point of entry to the tower.
  - − Collect bulk water samples from heaters from the bottom drain valve after sterilising the valve with 70% alcohol.
  - − Take a sample from any standing water in the condensate trays or from the coils.

- Sampling Points of Faucets and Showers
  - − Collect samples of showers and distribution points of potable hot and cold water systems after sterilising the outlet with 70% alcohol.
  - − Collect a “before flush” or initial flow sample.
  - − Collect an “after flush” (flush for 2 minutes) sample when the maximum temperature has been reached.
  - − Swabs can be taken from showerheads, pipes and faucets and re-hydrated in water taken from sampling site.
  - − Swab samples of scale build up are taken by removing showerheads, faucet screens and aerators to reach inside of systems.

- Sampling Points of Domestic Water Heaters
  - − Take sample from bottom drain.
  - − Collect sample from outlet pipe if plumbing provides access.

- Sampling Points of Humidifiers, Swamp Coolers and Spas
  - − Sample from the water reservoirs and from the incoming water supply if accessible.

Chlorine content
Sampling is done at representative points, such as the clear water sump outlet and places where water is normally used, e.g. rockdrills.

25.4 Sampling procedure

Dust estimation, pH determination and chemical analysis
Samples should be collected at taps or other outlets and only when this is not possible should be taken by immersing the sample bottle in the water.

Before samples are taken at taps, hose outlets, pipes, etc., the water should be allowed to run for a short while to clear away any rust or sludge. After the rust and sludge have cleared, the bottle is rinsed, then three-quarters filled.

"Grab" samples are usually adequate, but average concentrations can be determined from "drip" samples taken over a period of time.

Bacteriological analysis
These samples must be collected aseptically in sterilised bottles. Before samples are taken at taps, hose outlets, or pipes, the water must be allowed to run freely for a short period. The cloth cover and glass stopper are removed, the bottle three-quarters filled and the stopper and cloth replaced immediately, care being taken not to touch the inside of the stopper.

Bottles containing samples for bacteriological analysis are placed in an ice-box and sent to surface without delay. On reaching the surface, the box is refilled with ice and sends as soon as possible to an accredited laboratory to be analysed. The chilling of the samples and their prompt despatch are necessary in order to prevent the multiplication of bacteria.

Chlorine content
Rinse comparator thoroughly with water from the point to be sampled. Submerge the vessel underneath the surface and fill, or fill with water direct from machine. Place DPD tablet in the applicable vessel, seal with finger (hands should be washed and as clean as possible0 and shake thoroughly. Compare the colour with the colour chart provided and read of the chlorine content. The colour should be read immediately for a true free chlorine reading.

Note: Besides the method described here, two other methods for testing the free chlorine content of water may also be used, namely amperometric titration and the syringgaldazine method, either which should be used in the case where chromate treated water is used as the comparator test overestimates the free chlorine content in this case. More details on these tests which are more complicated than the comparator test are obtainable from manufacturers of water treatment chemicals.

Legionella analysis
Remove cap of the sterile sampling bottle. Take care not to touch the inside of the neck of the bottle or the inside of the cap. Take a sample by filling the container but ensure a headspace of approximately 20mm. Screw lid on well and ensure that the container does not leak. Label the sample with the waterproof market. Data that needs to be given on the data label are: i) sample name/sample number/sample description, ii) date and time; and iii) Name of sampler. A typical data sheet for sampling is shown in Appendix A. Place the sample in a cooler box with ice blocks. Ensure samples must be kept and transported between 6oC and 18oC and protected against heat and sunlight.

25.5 Sample analysis

24.5.1 Laboratory analysis
The chosen laboratory used for water sample analysis must have skilled technologists to perform the analysis and to handle the expensive laboratory equipment required for accurate analysis. The laboratory should be part of a reputable organisation. It is preferable that the laboratory be accredited by a trustworthy organisation e.g. South African National Accreditation System (SANAS) or at least participate in a proficiency test scheme.

24.5.2 Particulates in mine water

24.5.2.1 A deep-cell method of counting particulates in mine water

a) Purpose

The deep-cell method is used for estimating the concentration of dust particulates in suspension in mine water as a check on the quality of the water supplied underground for dust suppression.

b) Principle

The particles in a known volume of water, from which acid soluble salts have been removed, are counted under a microscope.

c) Apparatus required

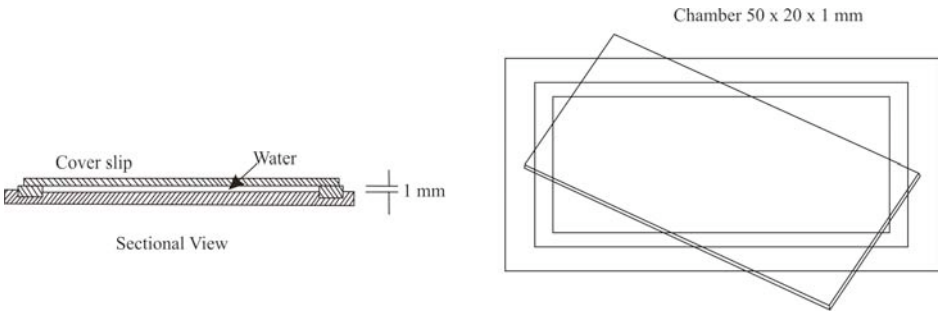
- Deep-cell.
- Konimeter microscope fitted with a special stage.
- Water cooling trough if a microscope with a sub-stage lamp is used.
- Sampling bottles of 200 ml capacity.
- Two measuring cylinders; one of 100 ml capacity with a plastic or ground-in stopper for the water sample, and one of 25 ml capacity for adding acid.
- Concentrated hydrochloric acid (chemically pure).
- Distilled water.
- An anti-static cloth.

d) Description of apparatus

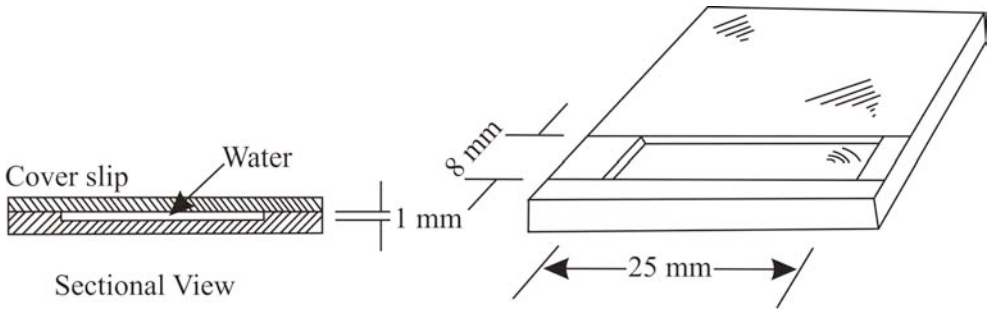
Deep-cell
The construction and dimensions of commonly used cells are shown in Figure 5.1. Any type of counting cell may be used. The depth of water in the cell must be known and the thickness of the floor of the cell must not exceed 2 mm, so that the condenser of the microscope can be racked-up to the correct position for dark-field counting.

Microscope
The microscope employed is the same as that described in the chapter on konimeter work, with the addition of a suitable stage for supporting the deep-cell. The squares ruled on the eyepiece graticule are used in deep-cell counting. The apparent size of the squares on the graticule and the depth of the cells must be measured. These measurements are usually done by the Air Pollution Division of the Research Laboratories.

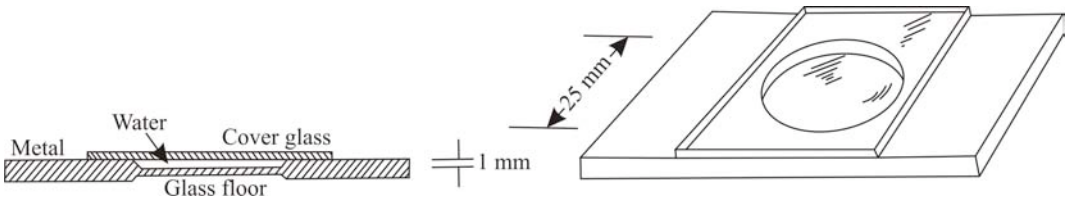
Sampling bottles
These are the same as those described in the chapter on the sampling of mine water.



Sedgewick-Rafter Type Cell



All Glass Square Type Cell



Metal-Glass Circular Type Cell

Figure 24.1. Types of deep cell

e) Dilution and treatment of samples

Samples must be treated before assessment and this treatment varies according to the appearance of the water. Chemically pure hydrochloric acid is added to dissolve non-siliceous matter. (On coal mines no acid is added). In addition water samples which contain high concentrations of dust particles must be diluted with distilled water before the particles are counted, otherwise the deposit on the floor of the cell will be too dense to allow accurate counting.

A suitable dilution is that which will give a count of 10 to 20 particles per counting section, as explained below. A guide to the dilution required is as follows:

Water Appearance	Volume (ml)			Dilution Factor
	Sample	Hydrochloric acid	Distilled water	
Clear	95	5	Nil	1.05
Slightly cloudy	50	5	45	2.00
Cloudy	20	5	75	5.00
Opaque	10	5	85	10.00

f) Procedure

Preparation of sample

(i) Clean the cell and cover-glass by rinsing them in distilled water and drying with a clean anti-static cloth or by moderate heating.

(ii) Examine under the microscope to see that there is no contamination on any of the four surfaces concerned, especially the floor of the cell.

(iii) Shake the bottle containing the sample and pour the appropriate amount into a measuring cylinder.

(iv) Add the required amount of distilled water.

(v) Add 5 ml of concentrated hydrochloric acid and shake well. (No acid added on coal mines.)

(vi) Allow to stand for at least half an hour, and after further shaking immediately fill the cell.

Filling the cell

(i) Pour enough of the sample into the cell, so that the cell overflows. Place the cover-glass over it and press down carefully to expel excess liquid. The cover-glass should adhere to the top of the cell. If an air bubble is formed, refill the cell.

(ii) Wipe the outside surfaces of the cell with absorbent material to remove excess liquid.

(iii) Place the cell on the leveled microscope stage.

(iv) Allow the coarse particles to settle for five minutes before starting to count.

Counting

(i) Focus the microscope on the floor of the cell which is the third field to come into view when the barrel is racked down, the other two fields being the upper and lower sides of the cover-glass.

(ii) Move the condenser up until it almost touches the bottom surface of the cell to provide maximum illumination.

(iii) Count all the particles present on the floor of the cell within one square of the graticule. Rack up the barrel slowly to the underside of the cover-glass, counting all the particles in suspension in the same square as they come into view. Care should be taken to avoid including in the count imperfections on the floor of the cell and the underside of the cover-glass. The sum of the floor count and of the particles in suspension is the total count for one section.

(iv) Repeat this procedure in nine other sections of the cell.

g) Calculation of the results

The concentration in millions of particles per millilitre is given by

$$\frac{\text{N x DF}}{\text{CF}}$$

where N = total number of particles counted in 10 sections;
DF = dilution factor, and,
CF = cell factor.

The cell factor depends on the depth of the cell and the size of the graticule squares. It is calculated as follows:

Assume that a counting section is a square with sides L micrometres and that the depth of the cell is x micrometres; the volume of water examined per single counting section

$$= xL^2\,\mu m^3 = \frac{xL^2}{(10000)^3}\,ml\ (as\ 1\,ml = 10000^3\,\mu m^3) = \frac{xL^2}{10^{12}}\,ml$$

Therefore, volume of water examined per ten counting sections

$$= \frac{\text{xL}^2}{10^{11}}\,ml$$

$$1\,ml\ of\ water\ will\ then\ contain \frac{\text{N x } 10^{11}}{\text{xL}^2}\ particles, or$$

$$\frac{\text{N x } 10^5}{\text{xL}^2}\,million\ particles$$

$$Cell\ factor = \frac{\text{xL}^2}{10^5}$$

The dilution factor depends on the quality of the distilled water and acid used. If these both have counts of zero, the dilution factor is given by

$$\text{DF} = \frac{100}{\text{sample volume}}$$

if a 100ml measuring flask is used.

Accuracy of results
Although the count will include carbon and other non-siliceous matter insoluble in acid, the results obtained provide a practical guide to the purity of the water. Because the accuracy of the method is limited, the count is usually reported to the first decimal place.

Standard of mine water
A count of 10 million particles per millilitre obtained by method is the maximum satisfactory concentration.

24.5.2.2 The nephelometer

a) Purpose

A nephelometer may be used as an alternative to the deep-cell to measure the amount of dust in mine water.

b) Principle of operation

A parallel beam of light is projected upwards through the sample which is contained in a special test-tube. Dust particles in the water scatter some of the light onto photoelectric cells located around the test-tube. The electric current so produced is related to the concentration of dust in the water.

c) Description

Two types of nephelometer are available, namely. Type A and Type B.

Type A (Fig. 25.2)
Current is supplied to the lamp A from a constant-voltage transformer B, which is connected to the main power supply through a switch C. Light from the lamp passes through an iris diaphragm D, controlled by the "sensitivity" level E. The curved bottom of the special test-tube F acts as a lens which produces a parallel beam of light. Six photoelectric cells G, located around the test-tube, are connected to the micro-ammeter J, which has a scale marked from 0 to 120. Extraneous light is excluded by a cover H.

Type B (Figs. 25.3 and 25.4)
Type B differs from Type A in that

(i) a reflector M surrounding the test-tube F and a single annular photoelectric cell N are used in place of the six ph<?toelectriccells;
(ii) a unigalvo is used in place of a micro-ammeter, and
(iii) a four-aperture wheel 0 is incorporated in the nephelometer head. This contains three colour filters and a blank aperture. The blank aperture is used in assessing mine water samples.

A standard glass rod in the shape of a test-tube is supplied with both types of nephelometer. This is used to set the instrument to a standard value before use.

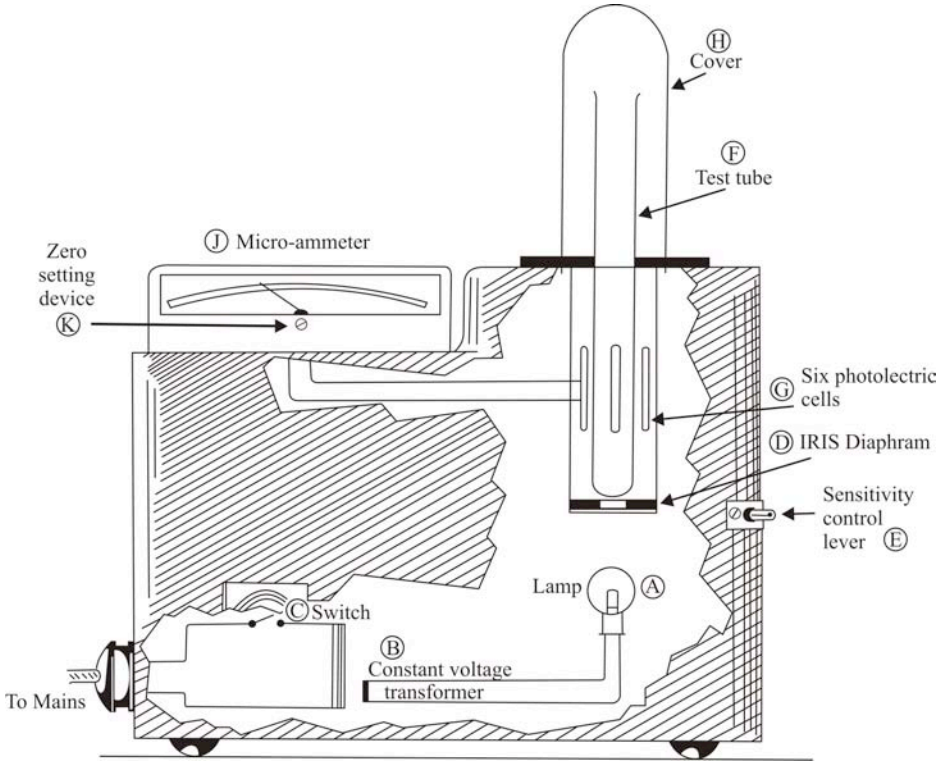


Figure 24.2 Diagrammatic sketch of the constituent parts and layout of a nephelometer (Type A)

d) Apparatus requires

- Nephelometer.
- Glass standard rod.
- Special nephelometer test-tubes and rack.
- Chemically pure hydrochloric acid.
- 10 ml pipette; 25 ml and 100 ml measuring cylinders.

e) Collection and treatment of samples

As described in Sections 25.3 and 25.4 of this Chapter.

f) Operation

Type A unit

(i) Close the iris diaphragm D.
(ii) Zero the ammeter with setting screw K.
(iii) Switch on the nephelometer and wait five minutes.
(iv) Insert the standard rod in the nephelometer and replace the cover H. The rod should always be placed in the same position in the socket in the nephelometer head. This is achieved by aligning the marks provided for this purpose on the rod and the socket.
(v) Adjust the iris diaphragm D to give a reading of 100 on the microammeter J.

(vi) Shake the prepared water sample and pour into the clean nephelometer test-tube F until the tube is approximately three-quarters full.

(vii) Dry and clean the outside of the test-tube thoroughly.

(viii) Place the test-tube in the nephelometer and replace the cover.

(ix) Wait for the micro-ammeter needle to reach a steady reading and record this reading to the nearest whole number.

(x) Remove the test-tube and insert the standard rod. If the reading is not 100 :t 2, repeat steps (v), (viii), (ix) and (x).

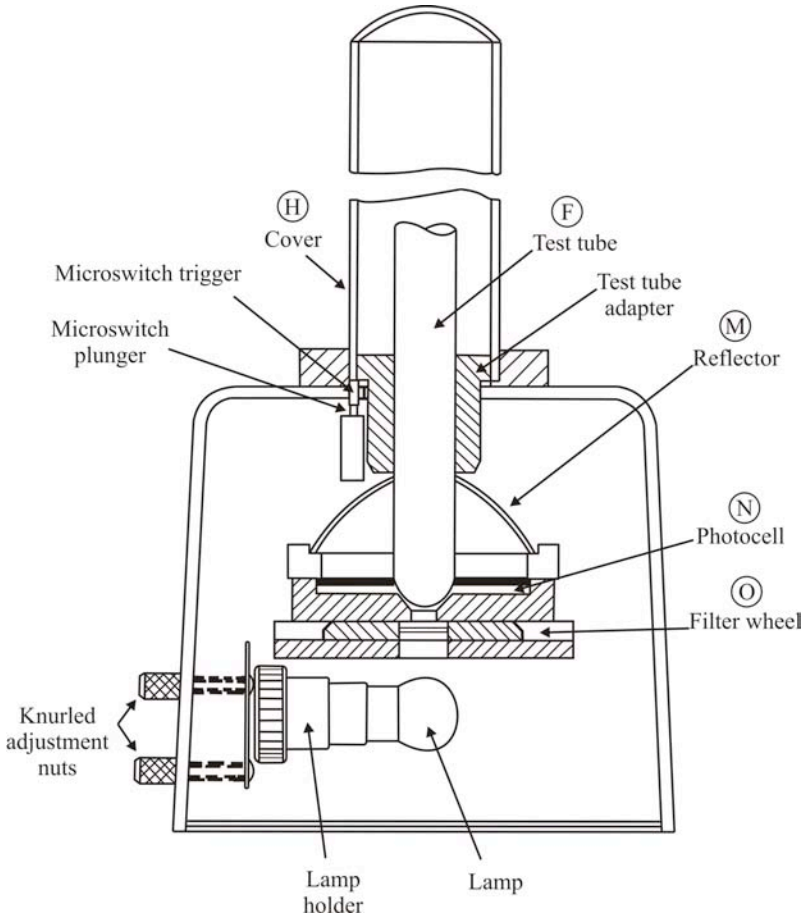


Figure 24.3 Diagrammatic sketch of the constituent parts and layout of the nephelometer head (Type B)

Type B unit

(i) Turn the unigalvo sensitivity control P to "OFF" to reduce the possibility of overloading.

(ii) Turn knob Q to free the unigalvo movement.

(iii) Switch on the unigalvo and wait five minutes.

(iv) Zero the unigalvo by means of the zero control T.

(v) Insert the standard rod in the nephelometer and replace the cover H. The rod should always be placed in the same position in the socket in the nephelometer head. This is achieved by aligning the marks provided for this purpose on the rod and the socket.

(vi) Connect the nephelometer head to the unigalvo input socket R.

(vii) Adjust the unigalvo sensitivity control to give a reading of 100 on the linear (black) scale U.

(viii) Shake the prepared water sample well. Pour into the clean nephelometer test-tube F until the tube is approximately three-quarters full.

(ix) Dry and clean the outside of the test-tube. thoroughly.

(x) Place the test-tube in the nephelometer and replace the cover.

(xi) Wait for the unigalvo spot to reach a steady reading and record this reading to the nearest whole number.

(xii) Remove the test-tube and insert the standard rod. If the reading is not 100 :t 2, repeat steps (xii), (x), (xi) and (xii).

Off-scale readings

For both types of units, if the reading is off the scale,

(i) transfer 10 ml of the water sample from the nephelometer test-tube to a clean 100 ml measuring cylinder;

(ii) add 90 ml of distilled water;

(iii) shake well and three-quarter fill a clean nephelometer test-tube;

(iv) assess this diluted sample in the normal way;

(v) take the nephelometer reading for the distilled water used in diluting the sample;

(vi) calculate the true nephelometer reading (X) of the original water sample by means of the formula:

where Y = the value for the diluted water, and Z = the value for the distilled water.

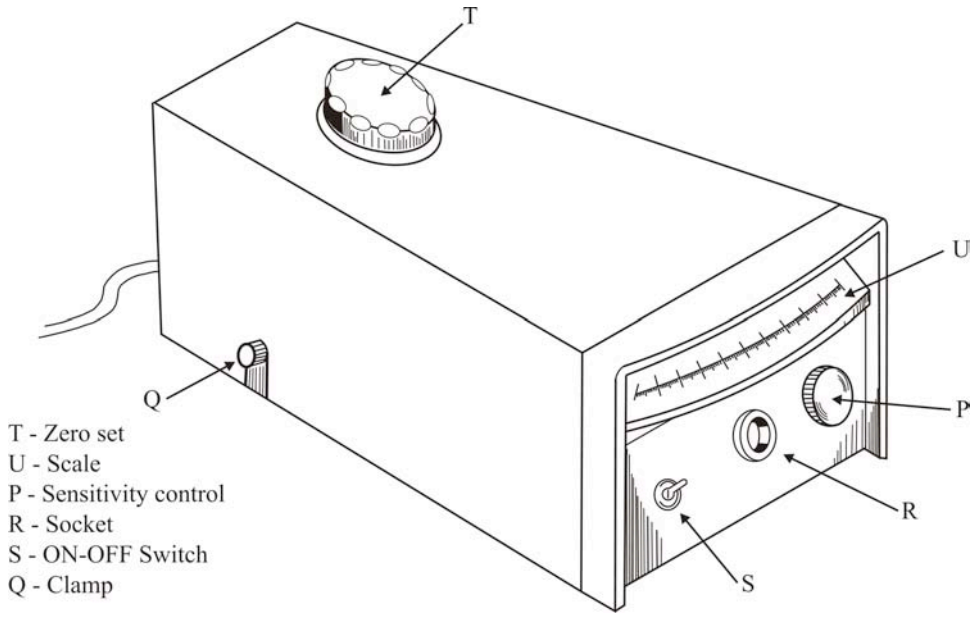


Figure 25.4. Unigalvo

g) Care and maintenance

(i) Do not handle the nephelometer roughly.

(ii) Do not allow the nephelometer to be exposed to any chemical fumes, especially those of hydrochloric acid, as these fumes will damage the photoelectric cells. It is particularly important that drops of water containing hydrochloric acid should not be allowed to fall into the instrument.

(iii) Keep the nephelometer covered when not in use.

(iv) If the lamp burns out, replace it in accordance with the manufacturer's instructions. Re-centre the lamp and re-calibrate the instrument.

(v) Apart from the adjustments mentioned in (d) above, do not attempt any maintenance or repair work on the nephelometer. If any other fault develops, or if a reading of 100 cannot be obtained with the standard rod, return the instrument to the agents for repair.

(vi) The special test-tubes must not be used for any other purpose. Scratches on these tubes may affect the instrument 'reading. The presence of scratches can be detected by testing each tube in turn, using the same sample of distilled water. If any reading is significantly greater than the average reading, the test-tube concerned should be rejected.

h) Calibration

The dust content of mine water is expressed in millions of particles per millilitre. It is, therefore, desirable to calibrate the nephelometer so that its readings can be expressed in these units. The relationship is not an exact one since the performance of the nephelometer is sensitive to the particle size. It has, however, been found in practice that there is normally a satisfactory correlation between the deep-cell counts and nephelometer readings. To obtain this relationship, which varies from one nephelometer to another and which depends also on the particular standard rod in use, proceeds follows:

(i) Take nephelometer readings and deep-cell counts for at least 20 water samples obtained from different parts of the mine and covering the widest possible range of dust concentrations.

(ii) Plot the nephelometer readings against the deep-cell counts. Draw the best-fitting straight line through the points. This line will not necessarily pass through the origin. Insert the date opposite each plotted point.

(iii) Use this calibration chart to convert all subsequent nephelometer readings to the equivalent deep-cell count. Report all results as the equivalent number of millions of particles per millilitre, ego 3,5 million particles per millilitre.

(iv) Each month, plot at least two further points on the graph by comparing nephelometer readings with deep-cell readings for further mine water samples. Insert the date of assessment against each point. This procedure will indicate any change in calibration.

(v) After any overhaul of the nephelometer, or introduction of a newstandard rod, re-calibrate the instrument.

i) Value and accuracy of the method

The nephelometric method is more rapid than the deep-cell method. A trained operator can deal with more than one sample per minute. If the same sample is measured repeatedly in a nephelometer results will agree more closely with each other than will repeated counts in a deep-cell. Also, if readings for the same sample are taken by a number of operators, the nephelometer results will agree more closely than deep-cell counts. A far larger volume of

water sample is examined by means of the nephelometer than by the deep-cell. The nephelometer, therefore, gives a more representative value.

24.6 Standards

24.6.1 Mine Health and Safety Act and Regulations

Potable mine water should comply with the following limits prescribed in Chapter 22.9(2)(c) of the Regulations of the Mine Health and Safety Act (29/1996).

a) Quality

Potable Water Quality	Physical Requirements	Chemical Requirements	Conductivity Requirements
Allowable Limit	Odour and Taste: Not to be objectionable	pH 5.5 min 9.5 max	
Recommended Limit	Turbidity 1 (NTU) Colour 20 mg/l of Platinum	pH 6.0 min 9.0 max	70 ms/m
Maximum Allowable Limit	Turbidity 5 (NTU) Colour not specified		
Maximum Limit			300 ms/m

(NTU) = Expressed in Nephelometric turbidity units

b) Macro, Micro Determinants and Bacteriological Limits

Determinants	Formula	Maximum Allowable Limit
Macro Determinants		
Total hardness	$CaCO_3$	650
Magneium	Mg	100
Sodium	Na	400
Chloride	Cl	600
Sulphate	SO4	600
Nitrate + nitrite	N	10
Fluoride	F	1.5
Zinc	Zn	5.0
Micro Determinants		**ug/l**
Arsenic	As	300
Cadmium	Cd	20
Copper	Cu	1000
Cyanide	CN	300
Iron	Fe	1000
Lead	Pb	100
Manganese	Mn	1000
Mercury	Hg	10
Phenolic Compounds	Phenol	10
Selenium	Se	50

Determinants	Formula	Maximum Allowable Limit
Bacteriological Limits Total coliform bacteria count Faecal coliform bacteria count Standard plate count		 5 oer 100 ml NIL per 100 ml Not specified

b) Other constituents

The water shall not contain any other constituents in concentrations, which may render it unsuitable for use as drinking water.

24.6.2 SANS 241:2005

Limits specified for drinking water suitability and acceptability in SANS 241:2005 should be considered in addition to those limits specified in Chapter 22.9(2)(c) of the Regulations of the Mine Health and Safety Act (29/1996).

24.6.3 Particulate content

A count of 10 million particles per millilitre obtained by the deep cell method is the maximum satisfactory concentration for mine water.

24.6.4 Chlorine content

Due to the short residual time of free chlorine in water, free chlorine should be detectable at the outlet of the clear water sump, or where dosing takes place in a storage dam at the outlet of such a dam. At some mines a detectable level of free chlorine is required at machinery and appliances where water is used.

24.6.5 Legionella analysis

Only guideline values for water treatment when action is required for Legionella levels are available. The levels for action vary from the source on the assumption that some routes of human exposure result in a greater dose to the human lung. Humidifiers, misters and evaporative condensers produce an aerosol mist that can directly be inhaled and need to be controlled at lower levels. The guideline values are intended to apply to water systems only.

Water System	Legionella Count/L
Cooling Tower	100 000
Domestic water	10 000
Humidifier	1 000

24.7 Reports

Appropriate systems should be put in place to ensure that the results and findings of water monitoring programmes are reported to management and the Occupational Medical Practitioner. Adequate information should be kept to enable reporting on the management of

water quality and the reporting on water quality must enable management to take appropriate and preventive action. SANS 241:2005 recommends that water quality performance against the Standard be reported or published at least annually in a suitable media accessible to relevant stakeholders.

24.8 References

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2. Beadle, D. G. The determination of the dust content of water. Bull. Mine Vent. Soc. S. Afr., Vol. 8, 1955, p. 59-69.

3. Rabson, S. R. Notes on the estimation of dust in mine water. Bull. Mine Vent. Soc. S. Afr., Vol. 8, 1955, p. 252-257.

4. Vannierop, J. A. Note on deep-cell counting. J. Mine Vent. Soc. S. Afr., Vol. 25,1972, p.203.

5. 8.5 SANS 241:2005. Drinking water.

6. South Africa Mine Health and Safety Act and Regulations (29/1006)

7. Coubrough, P. and Genthe, B. Guidelines for Legionella levels in water – a Code of Practice.

APPENDIX A

DATA SHEET FOR SAMPLING (LEGIONELLA LEVELS IN WATER)

Name of Company: …….....

Date of sampling: …….....

Time of sampling: …….....

Contact person: …….....

Telephone number: ……

Purpose of sampling : …….....

…….....

Cooling tower:

- Incoming supply
- Storage tanks
- Point of entry to tower
- Standing water
- Chillers
- Coolers
- Open system
- Closed system
- AHU
- Condenser

Raw water / Bulk water

Humidifier

Domestic water

- Showers: Before flush After flush
- Faucets: Before flush After flush
- Bottom drain
- Outlet pipe

General Notes …….....

…….....

Signature ……

25. Checking of Rock Drills

Author: Mike de Koker, Gold Fields Ltd.

25.1 Purpose

To ensure that the rockdrill complies with the requirements of the MHSA.

25.2 Methodology

Water tube gap rod:

This rod is used to measure the gap between the end of the water tube and the end of the jumper when in the operating position. There are many types of gap measuring rods. The simplest consists of a wooden or metal rod approximately 300mm long and 20mm in diameter marked at 5mm intervals. (Fig. 25.1)

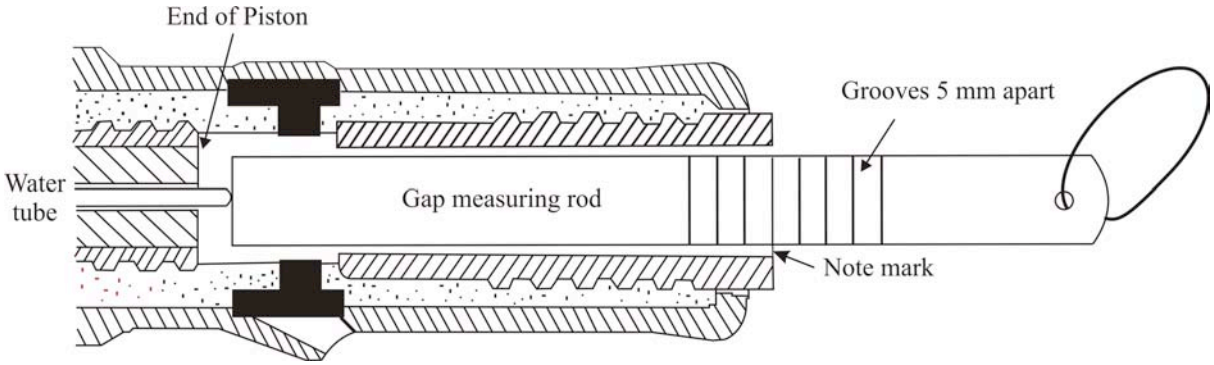

Figure 25.1 Gap measuring rod (not to scale)

Pressure Gauge:

The gauge should read from 0 to 1000kPa with 20kPa graduations. A convenient size is 50mm in diameter. The gauge should be checked against a standard gauge when first acquired and at monthly intervals thereafter. The readings should not differ by more than 20kPa. A typical gauge is shown in Fig. 25.2

Hypodermic needles:

The hypodermic needles must have thick walls and be approximately 13mm long. Recommended type is an 18G vetinary hypodermic needle.

The needle should be such that it can be fitted to the gauge easily and rapidly. A suitable form of connection is shown in Fig. 2. The gauge and three or four needles and a short length of thin strong wire for clearing blocked needles are carried in a small case

Water sampling bottles:

Clearly numbered 200 ml bottles with wide mouths and fitted with screw tops can be used.

Sound level measuring instrument:

Instruments for noise measurements are described in Chapter 15.

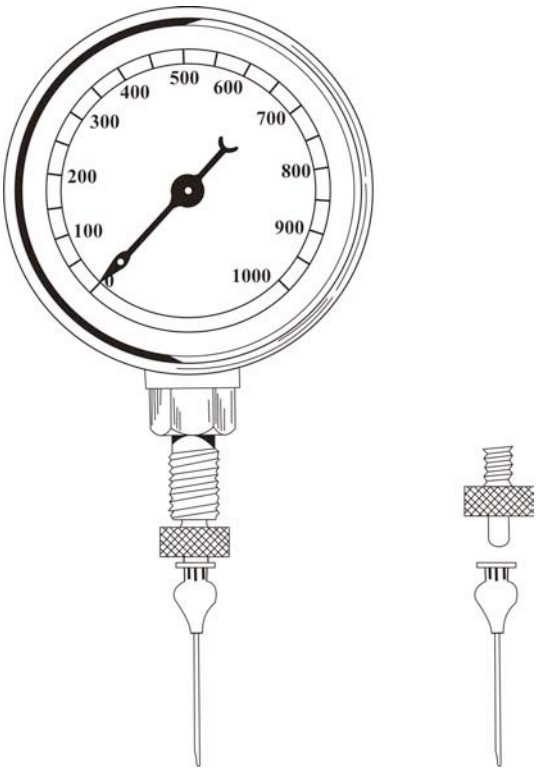

Figure 25.2 Pressure Gauge with hyperdermic needle

25.2.1 Checking the Rockdrill

a. ***Hose length:*** For standard pneumatic rockdrills, supply hoses should not exceed 50m in length. In the case of a hydropower rockdrill, the length of hose between distribution manifold and the machine must not exceed 20m. This should be checked by inspection.

b. ***Absence of branch hoses:*** No branch hoses should be fitted to the hose supplying water to the rockdrill. This must be checked by inspection.

c. ***Water hose connection:*** Check that the water hose is properly connected to the water bend at the handle end of the rockdrill and that the water bend is tightened securely. Also check that there is no axial play between the water swivel and the rockdrill. The existence of any such play will result in a variable gap.

d. ***Flow of water through the jumper:*** With the jumper inserted into the chuck of the machine, check visually that a steady flow of water emerges from the bit of the drill.

e. ***Condition of the water tube:*** Remove the jumper and check whether the water flows out of the chuck in a centrally located circular stream (with hydropower and electro-pneumatic machines, the drive mechanism of the rockdrill must be activated). If the water does not exit the chuck uniformly, there is most likely damage to the water tube / outlet port. Disconnect the water supply, and shine a light into the chuck of the machine, if necessary push the piston back so that the water tube becomes visible. Examine te end of the water tube for damage, burring or bends. The water tube should have a smooth circular end aligned to the centre of the chuck of the rockdrill.

f. ***Water tube gap:*** The gap between the end of the water tube and the end of the drill steel must not be less than 6mm or more than 25mm, or the water tube shall project not less than 25mm into the drill steel.

For this type of rockdrill, using the simple type of gap rod described above, proceed as follows:

i. Make sure that the piston is pushed back beyond the end of the water tube.
ii. Insert the gap measuring rod until the end rests against the water tube.
iii. Note the point on the rod which falls opposite the outside edge of the chuck (Fig. 25.1). Remove the measuring rod and compare the distance between this point and the end of the measuring rod, with the length of the drill shank. The difference is the water tube gap.

g. ***Water pressure and temperature:*** This must be measured while water is flowing through the machine. Clean the water hose at a point approximately one meter from the rockdrill and insert the needle of the gauge (Fig. 2) through the wall of the hose at an angle of about 45O until it enters the water stream. Read the pressure indicated on the gauge. The working pressure at the rockdrill must not be less than 150kPa. This method of measurement is also suitable where water cooled electro pneumatic rockdrills are used. However, in the case of the hydropower rockdrill, this method of water pressure measurement obviously does not apply. See Fig. 4 and Fig. 5, illustrating electro-pneumatic and hydropower rockdrills.

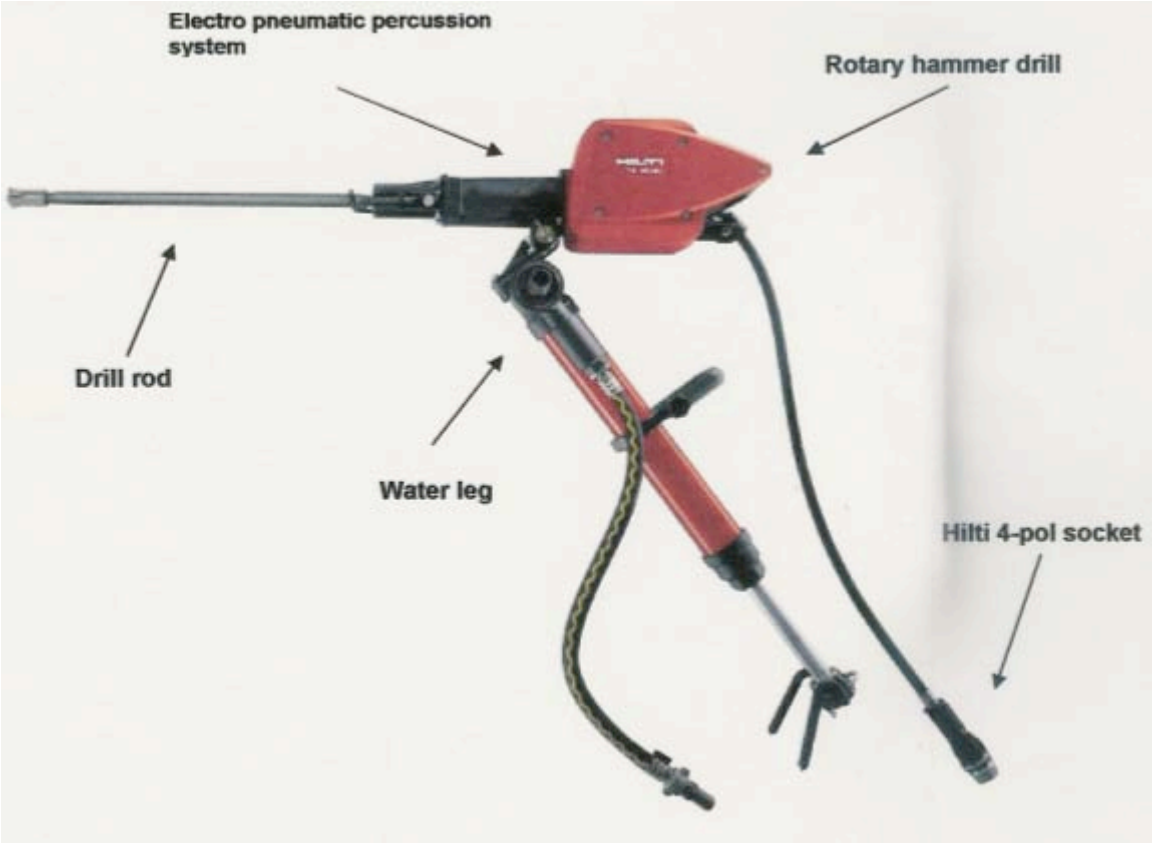

Figure 25.4 Electro pneumatic rockdrill

On many mines, it is often required that the temperature of the drilling water is measured, particularly on mines where chilled service water is used. To measure water temperature, it is first necessary to collect the water in a receptacle (such as a hard hat) a thermometer is then inserted into this water and the temperature is measured

Figure 25.5 Hydropower rockdrill with thrust leg

h. ***Front head release ports:*** These are situated near the front end of the machine and are provided to allow any compressed air which has leaked into the front head of the machine to escape. The front head release ports must be inspected regularly to ensure that they are not blocked or obstructed. Obstructions will cause air bubbles to pass through the drill steel and liberate entrapped dust into the atmosphere

i. ***Water quality:*** Water used for drilling should be sampled regularly. The methods of taking and assessing these samples are described in Chapter 24.

j. ***Fogging:*** This is observed while the rockdrill is operating. Distinction must be made between fogging produced at the front head release ports, which is a sign of excessive leakage of compressed air into the front head of the rockdrill, and fogging produced at the exhaust ports of the machine as a result of excessive moisure in the compressed air supply.

k. ***Rockdrill Number:*** This is recorded for report purposes.

l. ***Atomisation at steep upholes:*** When steep upholes are being drilled, observers should check and report whether sludge is being atomised by the air from the exhaust ports.

m. ***Air Pressure:*** The same method is used as that used to measure water pressure, except that both dynamic and static air pressures are measured ie. Pressures with both machine stopped and running.

n. ***Silencers:*** The noise levels associated with compressed air driven rockdrills are higher than the noise levels associated with hydropower or electro-pneumatic rockdrills. Compressed air driven rockdrills are “silenced” by placing a baffle over the exhaust ports of the rockdrill. Older types of rockdrill can be retrofitted with silencers, newer generations of rockdrill are manufactured with silencers as standard. See fig. 6, for examples of silenced compressed air driven rockdrills, note the “round” topped and “flat” topped baffles over the exhaust ports.

Observers should note whether or not pneumatic rockdrills are fitted with silencers. The observer must also note whether or not persons working within the vicinity of the rockdrill are wearing hearing protection devices. Persons not wearing hearing protection devices should be counseled by the observer (and their crew leader).

o. ***Power supply cables and connection:*** In the case of electro-pneumatic rockdrill, where 220/240V electrical current is supplied to explosion protected machines on the workface. The observer must check by inspection, that there are no “tape joints” or unauthorized joints in the power supply cables to the rockdrills. Fig. 7 shows an “authorized” explosion protected electrical cable connector.

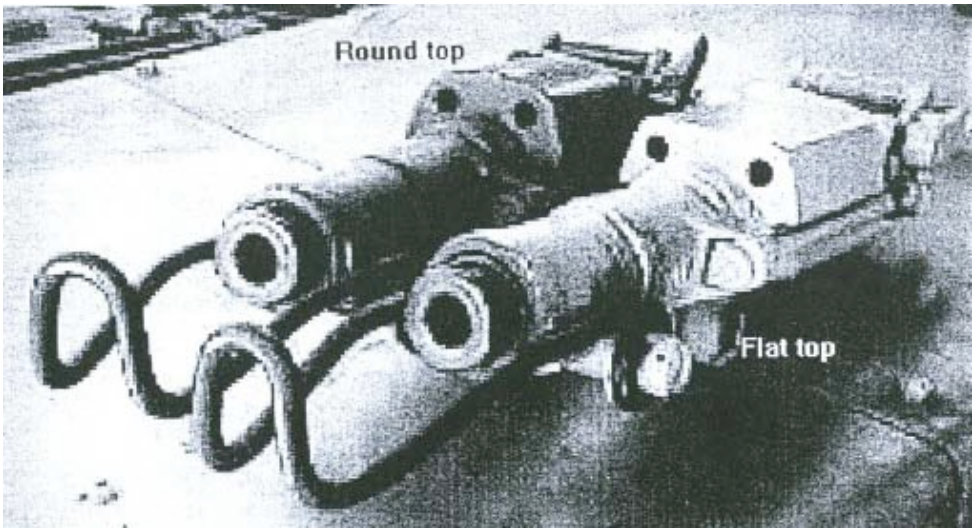

Figure 25.6 Typical pneumatic rockdrills with silenced exhaust ports

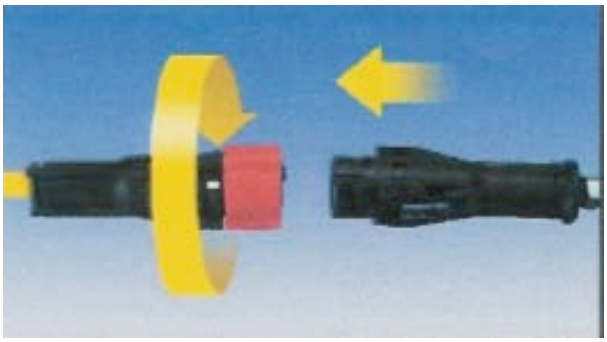

Figure 25.7 Explosion protected cable connector

25.3 Action to be Taken if a Fualty Drill is Detected

If the fault is such that the observer can remedy it himself, eg by tightening up the water bend or by cleaning out the front head release ports, this should be done. Any defect in the drill, particularly a damaged or defective water tube must be reported immediately to the miner (or crew leader in charge) who is responsible for sending the machine to surface and having the defect remedied. The defect should also be reported by the observer.

25.4 Bibliography

1. Cilliers, P.F. The routine examination of rockdrills. Demonstration and discussion of routine ventilation measurements. J.Mine Vent. Soc.S. Afr.,Vol 11, 1958.p.71 – 73

2. Mine Health and Safety Act (Act 29 of 1996) and regulations.

Glossary

Adapted with permission from the glossary used in the manual for the Occupational Hygiene: Basic Measuring Techniques course at Tshwane University of Technology (TUT).

A

Abrasive blasting: A process for cleaning metal and other surfaces using material in a high-pressure stream.The material is blasted against a surface to remove paint or contaminants. If silica sand is used as the material, this process is called sandblasting.

Acute effect: An effect that occurs immediately or shortly after a single, high-level exposure.

Aerosols: Liquid droplets or solid particles dispersed in air, that are of fine enough particle size (0.01 to 100 micrometers) to remain so dispersed for a period of time.

AIHA: American Industrial Hygiene Association.

Air: The mixture of gases that surrounds the earth; its major components are as follows; 78.08 percent nitrogen, 20.95 percent oxygen, 0.03 percent carbon dioxide, and 0.93 percent argon. Water vapour (humidity) varies. See Standard air.

Airborne contaminant: An airborne contaminant is a potentially harmful substance that is either normally absent from air, or present in an unnaturally high concentration, and to which workers may be exposed in their working environment.

Airborne micro organisms: Biologically active contaminants suspended in the air either as free floating particles surrounded by a film or organic or inorganic material, or attached to the surface of other suspended particulates.

Airborne pollutants: Any substance in the air that is harmful to health, including dust, fumes, aerosols, gases, fibres, vapours or mists.

Air cleaner: A device designed to remove atmospheric airborne impurities, such as dusts, gases, vapours, fumes, and smokes.

Air conditioning: The process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet requirements of the conditioned space.

Air filter: An air cleaning device to remove light particulate matter from normal atmospheric air.

Air monitoring: The use of specialised equipment to measure types of pollutants and their concentrations in the atmosphere.

Air mover: Any device which is capable of causing air to be moved from one space to another. Such device are generally used to exhaust, force, or draw gases through specific assemblies.

Air-regulating valve: An adjustable valve used to regulate airflow to the face piece, helmet, or hood of an airline respirator.

Air purifying respirator: Respirators that use filters or absorbents to remove harmful substances from the air.

Air-supplied respirator: Respirator that provides a supply of breathable air from a clean source outside of the contaminated word area.

Alpha quartz: Polymorphic form of crystalline silica (for other forms see crystalline silica). In nature, the alpha (or low) form of quartz is the most common. This form is so abundant that the term quartz is often used in place of the general term crystalline silica.

Alveoli: Thin-walled air sacs at the distal end of the conducting airways of the lungs, where gas exchange occurs between air and blood.

Ambient noise: The all encompassing noise associated with a given environment, being usually a composite of sounds from many sources near and far.

Amorphous: Noncrystalline.

Analysis methodology: Analysis techniques used to quantify a pollutant collected on or in sampling media (e.g. gas chromatography/mass spectrometry).

Anemometer: A device to measure air speed.

Anthropometry: The part of the anthropology having to do with measurement of the human body to determine differences in individuals or groups of individuals.

Approved: Tested and listed as satisfactory by an authority having jurisdiction, such as SABS or Department of Labour.

Approved Inspection Authority: An inspection authority approved by the Chief Inspector of the Department of Labour with respect to that service only. In other words, the Approved Inspection Authority for Occupational Hygiene stress factors (See the OSHAct. 83 of 1995).

Asbestos: A hydrated magnesium silicate in fibrous form.

Asbestosis: A disease of the lungs caused by the inhalation of fine airborne fibre's of asbestos.

Asphyxia: Suffocation from lack of oxygen. Chemical asphyxia is produced by a substance, such as carbon monoxide, that combines with haemoglobin to reduce the blood's capacity to transport oxygen. Simple asphyxia is the result of exposure to a substance, such as methane, that displaces oxygen.

Atmospheric pressure: The pressure exerted in all directions by the atmosphere. At sea level, mean atmospheric pressure is 29.92 inches Hg, 14.7 psi, or 407 inches w.g.

Attenuate: To reduce in amount. Usually refers to noise or ionising radiation.

Audible range: The frequency range over which normal ears hear - approximately 20 Hz through 20,000 Hz. Above the range of 20.000 Hz, the term ultrasonic is used. Below 20 Hz, the term subsonic is used.

Audible sound: Sound containing frequency components lying between 20 and 20.000 Hz.

Audit: Examination and verification.

Auditor: One who examines and verifies.

Auditory: Pertaining to, or involving, the organs of hearing or the sense of hearing.

B

Background noise: Noise coming from sources other than the particular noise source being monitored.

Bel: A unit of sound level based on a logarithmic scale.

Benign: Not malignant. A benign tumour is one which does not metastasise or invade tissue. Benign tumours may still be lethal, due to pressure on vital organs.

Benzene, C6H6: A major organic intermediate and solvent derived from coal or petroleum. The simplest member of the aromatic series of hydrocarbons.

Best practice: Can simply be explained as “the best way of doing things” and can be defined as the most practical and effective methodology that is currently in use or otherwise available.

Biomechanics: The study of the human body as a system operating under two sets of law: the laws of Newtonian mechanics and the biological laws of life.

Blood count: A count of the number of corpuscles per cubic millimetre of blood. Separate counts may be made for red and white corpuscles.

Body burden: The amount of noxious material in the body at a given time.

Breathing tube: A tube through which air or oxygen flows to the face piece, helmet, or hood.

Breathing zone: A person's breathing zone has been (arbitrarily) defined by a hemisphere of 300 mm radius extending in front of the face and measured from the midpoint of an imaginary line joining the ears.

Bronchial tubes: Branches or subdivisions of the trachea (windpipe). A bronchiole is a branch of a bronchus, which is a branch of the windpipe.

Bubble tube: A device used to calibrate air-sampling pumps.

C

Capture velocity: Air velocity at any point in front of the hood necessary to overcome opposing air currents and to capture the contaminated air by causing it to flow into the exhaust hood.

Cancer: A malignant tumour of an organ or tissue arising from the uncontrolled division of cells that can spread to other organs of the body either by direct growth or through transport channels (blood, lymph, etc.).This is distinct from a benign tumour, which cannot usually spread.

Carcinogenic: Cancer producing.

Carcinoma: Malignant tumours derived from epithelial tissues, that is, the outer skin, the membranes lining the body cavities, and certain glands.

Carpal tunnel syndrome: A common affliction caused by compression of the median nerve in the carpal tunnel. Often associated with tingling, pain, or numbness, in the thumb and first three fingers - may be job related.

Ceiling Limit (C): An airborne concentration of a toxic substance in the work environment, which should never be exceeded.

Celsius: The Celsius temperature scale is a designation of the scale previously known as the centigrade scale.

CFU: Colony forming units.

Chemical cartridge: The type of absorption unit used with a respirator for removal of low concentrations of specific vapours and gases.

Chromatograph: An instrument which can separate and analyse mixtures of chemical substances.

Chronic: Persistent, prolonged, repeated.

Chronic obstructive pulmonary (or airway) disease (COPD or COAD): Group of lung diseases involving limited airflow and varying degrees of air sac enlargement, airway inflammation, and lung tissue destruction. Emphysema and chronic bronchitis are the most common forms of COPD.

Chronic silicosis: The most common form of silicosis.Workers usually don't show symptoms for 10 years or more after an initial exposure.

Cilia: Tiny hair like "whips" in the bronchi and other respiratory passages that aid in the removal of dust trapped on these moist surfaces.

Clearly audible alarm: An audible alarm with a minimum sound pressure level of 80 dB when measured at a distance of 30 cm perpendicular to the sound transducer.

Clearly visible alarm: A flashing visual alarm visible to the user by direct line of sight, with the instrument being used in the normal prescribed manner.

Clearly visible alarm: A flashing visual alarm visible to the user by direct line of sight, with the instrument being used in the normal prescribed manner.

CM: Chamber of Mines of South Africa.

COAD/COPD: Chronic obstructive airways or pulmonary disease (i.e. chronic persistent airflow obstruction or limitation).

Cochlea: The auditory part of the internal ear, shaped like a snail shell. It contains the basilar membrane on which the end organs of the auditory nerve are distributed.

Collection efficiency: The percentage of a specific substance removed and retained from air by an air cleaning or sampling device. A measure of the cleaner or sampler performance.

Colorimetry (colorimetric): The term applied to all chemical analysis techniques involving reactions in which a colour is developed when a particular contaminant is present in the sample and reacts with the collection medium. The resultant colour intensity is measured to determine the contaminant concentration.

Combustible liquids: Combustible liquids are those having a flash point at or above 37.8 °C.

Comfort ventilation: Airflow intended to maintain comfort of room occupants (heat, humidity, and odour).

Comfort zone: Average - the range of effective temperatures over which the majority (50 percent or more) of adults feels comfortable.

Concentration: The amount of a given substance in a stated unit of measure. Common methods of stating concentration are percent by weight or by volume, weight per unit volume, normality, etc.

Confined space: An enclosure that is difficult to get out of and limited or no ventilation. Examples are storage tanks, boilers, sewers, and tank cars.

COP: Code of Practice.

Crystalline silica: Crystalline silica may be found in more than one form (polymorphism). The polymorphic forms of crystalline silica are alpha quartz , beta quartz, tridymite, cristobalite, keatite, coesite, stishovite, and moganite. Each polymorph is unique in its spacing, lattice structure, and angular relationship of the atoms. In nature, the alpha (or low) form of quartz is the most common. This form is so abundant that the term quartz is often used in place of the general term crystalline silica. When low temperature alpha quartz is heated at atmospheric pressure it changes to beta quartz at 573 °C. At 870 °C tridymite is formed and cristobalite is formed at 1 470 °C.The melting point of silica is 1 610 °C, which is higher than iron, copper and aluminium, and is one reason why it is used to produce moulds and cores for the production of metal castings.

Cubic centimetre (cc): Cubic centimetre, a volumetric measurement that is also equal to one millilitre (ml).

Cubic meter (m^3): A measure of volume in the metric system.

Cutaneous: Pertaining to or effecting the skin.

Cyclone separator: A dust collecting device which has the ability to separate particles by size. Typically used in respirable dust sampling to remove non-respirable dust.

D

Damage risk criterion: The suggested base line of noise tolerance, which if not exceeded, should result in no hearing loss due to noise. A damage risk criterion may include in its statement a

specification of such factors as time of exposure, noise level, and frequency, amount of hearing loss that is considered significant, percentage of the population to be protected, and method of measuring the noise.

Dangerous to life or health, immediately (IDLH): Used to describe very hazardous atmospheres where employee exposure can cause serious injury or death within a short time or serious delayed effects.

dBA: Sound level in decibels read on the A-scale of a sound level meter. The A scale discriminates against very low frequencies (as does the human ear) and is, therefore, better for measuring general sound levels. See also Decibel.

Decibel (dB): A unit used to express sound power level (Lw). Sound power is the total acoustic output of a sound source in watts (W).

Dermatitis: Inflammation of the skin from any cause.

Dermatosis: A broader term than dermatitis; it includes any cutaneous abnormality, thus encompassing folliculitis, acne, pigmentary changes, and nodules and tumours.

Diatomaceous earth: A soft, gritty amorphous silica composed of minute siliceous skeletons of small aquatic plants. Used on filtration and decolorization of liquids, insulation, filter in dynamite, wax, textiles, plastics, paint, and rubber. Calcined and flux-calcined diatomaceous earth contains appreciable amounts of cristobalite, and dust levels should be controlled the same as for cristobalite.

Diesel particulate matter (DPM): The portion of diesel exhaust which is made up of solid carbon particles and the attached chemicals including organic chemicals sich as polycyclic aromatic hydrocarbons (PAHs) and inorganics such as sulphate compounds.

Diffuse sound field: One in which the time average of the mean-square sound pressure is everywhere the same and the flow of energy in all directions is equally probable.

Dilution ventilation: See General ventilation.

Direct exhaust sampling: Diret sampling of diesel exhaust contaminants in the tailpipe of a vehicle as opposed to sampling in air.

Direct-reading instrumentation: Those instruments that give an immediate indication of the concentration of aerosols, gases, or vapours or magnitude of physical hazard by some means such as a dial or meter.

Disease: A departure from a state of health, usually recognised by a sequence of signs and symptoms.

DME: Department of Minerals and Energy, South Africa.

DEAT: Department of Environmental Affairs and Tourism, South Africa.

DoL: Department of Labour, South Africa.

DoH: Department of Health, South Africa

Dose: A term used:

a) to express the amount of a chemical or of ionising radiation energy absorbed in a unit volume or an organ or individual. Dose rate is the dose delivered per unit of time. Unit = Gray.
b) Used to express amount of exposure to a chemical substance.

Dose equivalent, maximum permissible (MPD): The largest equivalent received within a specified period which is permitted by a regulatory agency or other authoritative group on the assumption that receipt of such dose equivalent creates no appreciable somatic or genetic injury. Different levels of MPD may be set for different groups within a population. (By popular usage, "dose, maximum permissible," is an accepted synonym.) Unit = Sievert.

Dose-response relationship: Correlation between the amount of exposure to an agent to toxic chemical and the resulting effect on the body.

Dosimeter (dose meter): An instrument used to determine the full shift exposure a person has received to a hazard.

Dry-bulb thermometer: An ordinary mercury thermometer, not dependent on atmospheric humidity. Reading is the dry-bulb temperature. Usually shielded from radiation/ solar loads.

Duct: A conduit used for conveying air at low pressures.

Duct velocity: Air velocity through the duct cross section. When solid particulate material is present in the air stream, the duct velocity must exceed the minimum transport velocity.

Dust collection: An air-cleaning device to remove heavy particulate loadings from exhaust systems before discharge to outdoors.

Dusts: Solid particles generated and dispersed into the air by handling, crushing and grinding of organic or inorganic materials such as rock, ore, metal, coal, wood or grain.

E

Ear: The entire hearing apparatus, consisting of three parts: external ear, the middle ear or tympanic cavity, and the inner ear or labyrinth. Sometimes the pinna (shell) is called the ear.

ECF: Exposure classification factor

Effective temperature: An arbitrary index that combines into a single value the effect of temperature, humidity, and air movement on the sensation of warmth and cold on the human body.

Effective temperature index: An empirically determined index of the degree of warmth perceived on exposure to different combinations of temperature, humidity, and air movement. The determination of effective temperature requires simultaneous determinations of dry bulb and wet bulb temperatures.

Efficiency, fractional: The percentage of particles of a specified size which are removed and retained by a particular type collector or sampler. A plot of fractional efficiency values versus the respective sized particles yield a fractional efficiency curve which may be related to the total collecting efficiency of air-cleaning or -sampling equipment.

Electrical precipitators: A device which removes particles from an air stream by charging the particles and collecting the charged particles on a suitable surface.

Elemental carbon (EC): The pure carbon particles that are the basic building blocks of diesel particulate.

Elutriator: A device used to separate particles according to mass and aerodynamic size by maintaining a laminar flow system at a rate which permits the particles of greatest mass to settle rapidly while the smaller particles are kept airborne by the resistance force of the flowing air for longer times and distances. The various times and distances of deposit may be used to determine representative fractions of particle mass and size.

Employer: Means any person whomsoever who employs or provides work for any person and remunerates that person.

Engineering controls: Methods of controlling employee exposures by modifying the source or reducing the quantity of contaminants released into the workroom environment.

Ergonomics: Ergonomics is the science and practice of designing systems to fit people so that the tasks required of the human user are within their limitations, but also to ensure that best use is made of their functional capabilities. Unhealthy, unsafe or inefficient situations at work could be avoided by taking into account the physiological and psychological capabilities and limitations of humans.

Exhalation valve: A device that allows exhaled air to leave a respirator and prevents outside air to leave a respirator and prevents outside air from entering through the valve.

Exhaust ventilation: The removal of air usually by mechanical means from any space. The flow of air between two points is due to the occurrence of a pressure difference between the two points. This pressure difference will cause air to flow from the high pressure to the low pressure zone.

Exposure: Contact with a chemical, biological, or physical hazard.

Exposure control: A means of eliminating or reducing workplace hazards. Examples include engineering, work-practice, and administrative controls.

Exposure Limit Values: A value of the maximum concentration in the air to which persons may be exposed without any adverse health effect. (See TLV's)

NB E8hEV. Equivalent eight hour exposure value meaning the time weighted average exposure of an employee in any 24 hour period to airborne substances for a period of 8 hours and if the period of exposure is more or less than 8 hours, the exposure calculated by multiplying the measured concentration by a factor equal to the period of exposure divided by 8 hours.

Excursion: A deviation from a definite path. A movement above or below a norm (TLV).

F

Face velocity: Average air velocity into the exhaust system measured at the opening into the hood or booth.

Facepiece: That portion of a respirator that covers the wearer's nose and mouth in a half-mask face piece or nose, mouth, and eyes in a full face piece. It is designed to make a gastight fit with the face and includes the headbands, exhalation valve(s), and connections for air-purity device or respirable gas source or both.

Far field (free field): In noise measurement, this refers to the distance from the noise source where the sound pressure level decreases 6 dBA for each doubling of distance (inverse square law).

Fibrosis: Scarring of the lungs because of breathing harmful dusts or chemicals such as crystalline silica. As the disease develops, the lungs begin to stiffen and become less flexible, making breathing more difficult.

Fibrogenic dust: A dust (e.g. crystalline silica or asbestos) that causes the formation of fibrotic (scar) tissue after its deposition in the gas-exchange region of the lung.

Field blanks: Filter cassettes, used in quality control, that are identical to those used for sampling dust, except that these are not used in sampling. They are brought to the sampling site, handled as the regular sample cassettes would be and are sent back for analysis It is expected that these cassettes will show little, or no trace of contamination, otherwise, the results from exposure measurement using the regular sampling cassettes could be questioned.

Filter:

a) A device for separating components of a signal on the basis of its frequency. It allows components in one or more frequency bands to pass relatively not attenuated, and it attenuates greatly components in other frequency bands,
b) a fibrous media used in respirators to remove solid or liquid particles from the air stream entering the respirator,
c) a sheet of material that is interposed between patient and the source of x-rays to absorb a selective part of the x-rays, a fibrous or membrane media used to collect dust, fume, or mist air samples.

Filter efficiency: The efficiency of various filters can be established on the basic of entrapped particles; i.e., collection efficiency, or on the basis of particles passed through the filter, i.e., penetration efficiency.

Filter, HEPA: High efficiency particulate air filter that is at least 99.97 percent efficient in removing thermally generated mono disperse dioctylphthalate smoke particles with a diameter of 0.3 μm.

Flammable gas: Means either methane or hydrogen or a mixture of both in air.

Flammable Gas Measuring Instrument (FGMI): A lightweight, portable hand-held battery operated spot or continuous-duty measuring instrument which allows the user to measure at roof and hanging wall positions the presence and concentration of flammable gas (CH_4/H_2) in the range of 0 % - 5 % v/v as methane (CH_4). The instrument gives a clearly audible and clearly visible alarm should it be placed in an atmosphere containing a concentration of flammable gas, which equals or exceeds the alarm set point. Continuous-duty instruments do not have a facility allowing the user to turn the instrument off or to disable its operation in the working place. (Also known as a type A instrument).

Flammable Gas Warning Device (FGWD): A portable battery operated, continuous-duty device designed to give a clearly audible and a clearly visible alarm, should it be placed in an atmosphere containing a concentration of flammable gas, which equals or exceeds the alarm set point. The device does not have a facility allowing the user to turn the device off or to disable its operation in the working place and is able to monitor and alarm even if the lamp, if fitted, is turned off. (Also known as a type C device).

Flammable limits: Flammables have a minimum concentration below which propagation of flame does not occur on contact with a source of ignition. This is known as the lower flammable explosive limit (LEL). There is also a maximum concentration of vapour or gas in air above which propagation of flame does not occur. This is known as the upper flammable explosive limit (UEL). These units are expressed in percent of gas or vapour in air by volume.

Flammable liquid: Any liquid having a flash point below 37.8 °C.

Flow meter: An instrument for measuring the rate of flow of a liquid or gas.

Fly ash: Finely divided particles of ash entrained in flue gases arising from the combustion of fuel.

Force: That which changes the state of rest or motion in matter. The SI (International System) unit of measurement is the Newton (N).

Free sound field (free field): A field in a homogeneous, isotropic medium free from boundaries. In practice it is a field in which the effects of the boundaries are negligible over the region of interest. (see Far field.)

Frequency (in hertz or Hz): Rate at which pressure oscillations are produced. One hertz is equivalent to one cycle per second. A subjective characteristic of sound related to frequency is pitch.

Fume: Airborne particulate formed by the evaporation of solid materials, e.g., metal fume emitted during welding. Usually less than one micron in diameter.

Fume fever: Metal fume fever is an acute condition caused by a brief high exposure to the freshly generated fumes of metals, such as zinc or magnesium, or their oxides.

G

Gas: A state of matter in which the material has very low density and viscosity; can expand and contract greatly in response to changes in temperature and pressure; easily diffuses into other gases; readily and uniformly distributes itself throughout any container. A gas can be changed to the liquid or solid state only by the combined effect of increased pressure and decreased temperature (below the critical temperature).

Gas chromatography: A gaseous detection technique which involves the separation of mixtures by passing them through a column that will enable the components to be held up for varying periods of time before they are detected and recorded.

General Atmosphere (flammable gas): Any point in the atmosphere of a working place with the exception of a distance of 150 mm from a known source of flammable gas.

General ventilation: System of ventilation consisting of either natural or mechanically induced fresh air movements to mix with and dilute contaminants in the workroom air. This is not the recommended type of ventilation to control contaminants that are toxic.

Genetic effects: Mutations or other changes which are produced by irradiation of the germ plasma.

Globe thermometer: A thermometer set in the centre of a metal sphere that has been painted black in order to measure radiant heat.

Grab sample: A sample which is taken within a very short time period. The sample is taken to determine the constituents at a specific time.

Gram (g): A metric unit of weight. One ounce equals 28.4 grams.

Gravimetric: Of or pertaining to measurement by weight.

Gravimetric method: A procedure dependent upon the formation or use of a precipitate or residue, which is weighed to determine the concentration of a specific contaminant in a previously collected sample.

H

Hand-held instrument: An instrument that is designed to be held and supported by the hand, and that may, with ease, be elevated to shoulder height.

Hazard: The intrinsic ability of an agent or process to produce adverse effects on health.

Hazardous location (flammable gas):

In respect of hardrock mines:

- Any area where, under normal operating conditions, there is a continuous presence of flammable gas concentration of 0.5% or more in the general body of the air.

In respect of coal mines:

- Any area where, under normal operating conditions, there is a continuous presence of flammable gas concentration of 0.5% or more in the general body of the air.
- A return airway.
- An area within 180 metres outbye of any working face.

Hazardous material: Any substance or compound that has the capability of producing adverse effects on the health and safety of humans.

HCP: Hearing conservation programme.

Health: State of complete physical, mental and social well-being and not merely the absence of disease or impairment.

Hearing conservation: The prevention or minimising of noise induced deafness through the use of hearing protection devices, the control of noise through engineering methods, annual audiometric tests, and employee training.

Heat cramps: Painful muscle spasms as a result of exposure to excess heat.

Heat exhaustion: A condition usually caused by loss of body water because of exposure to excess heat. Symptoms include headache, tiredness, nausea, and sometimes fainting.

Heat stress: Relative amount of thermal strain from the environment.

Heat stress index: Index which combines the environmental factors into a single figure which can be compared to a standard.

Heat stroke: A serious disorder resulting from exposure to excess heat. It results from sweat suppression and increased storage of body heat. Symptoms include hot dry skin, high temperature, mental confusion, convulsions, and coma. Heat stroke is fatal if not treated promptly.

HEG: Homogeneous exposure group.

Homogeneous exposure group: A group of employees who experience pollutant exposures similar enough that monitoring exposures of any representative subgroup of employees in the group provides data useful for predicting exposures of the remaining employees.

Helmet: A device that shield the eyes, face, neck, and other parts of the head.

Hertz: The frequency measured in cycles per second. 1 cps = 1 Hz.

Hazard: Probability of impairment of health following exposure to a specific substance. The level depends on toxicity of the substance, time of exposure, its use and absorption rate.

Hazardous material: Any substance or compound that has the capability of producing adverse effects on the health and safety of humans.

Hood:

a) enclosure, part of a local exhaust system;
b) a device that completely covers the head, neck and portions of the shoulders.

HPD: Hearing protection device

HSE: Health and Safety Executive (UK).

HVAC: Heating, ventilation and air-conditioning.

Hz: Hertz (cycles per second, as a measure of audio frequency).

I

IARC: International Agency for Research on Cancer, a subsidiary of the World Health Organisation.

ILO: International Labour Organization, a specialised agency of the United Nations to deal with labour issues.

Inhalable fraction: The amount of dust capable of entering and depositing in the upper respiratory tract (<100 μm in diameter).

Inorganic: Term used to designate compounds that generally do not contain carbon. Source: matter, other than vegetable or animal. Examples: sulphuric acid and salt. Exceptions are carbon monoxide, carbon dioxide.

Irritant: A substance that produces an irritating effect when it contacts skin, eyes, nose, or respiratory system.

Inspection Authority: Means any person who, with the aid of specialised knowledge or equipment or after such investigations, tests, sampling or analysis as he may consider necessary, renders a service by making special findings, purporting to be objective findings, as to:

a) the safety of any article or of a condition prevalent on or in any premises.
b) whether or not any particular standard has been or is being complied with, with respect to any article or to a condition prevalent on or in any premises or with respect to any other matter, and
c) by issuing a certificate, stating such finding to a person to whom the service is rendered.

ISO/CEN: International Organisation for Standardisation (ISO)/ European Committee for Standardisation (CEN).

K

Kilogram (kg): A unit of weight in the metric system equal to 2.2 lb.

Kelvin (K): An absolute temperature scale which incorporates absolute zero. 0 °K = -273 °C.

L

Latched (flammable gas): A condition that once activated requires a deliberate manual action to deactivate. When an instrument/device is exposed to flammable gas above full scale, then

a) all flammable gas indications shall be latched to full scale or over-range, and;
b) the alarm set point signal, previously activated, shall be latched on.

Latent period: The time that elapses between exposure and the first manifestation of damage.

Lead poisoning: Lead compounds can produce poisoning when they are swallowed or inhaled. Inorganic lead compounds commonly cause symptoms of lead colic and lead anaemia. Organic lead compounds can attack the nervous system.

Limit of detection (LOD): The lowest concentration of substance, e.g. crystalline silica, that can be determined to be statistically different from a sample that contains none of that substance.

Litre (L): A measure of capacity - one quart equals 0.9 L.

Litres per minute (L/min): Measure of the rate of flow of a gas or a liquid. For example a pump that moves 60 litres of air in one hour (60 minutes), pumps at a flow rate of 1 litre per minute or 1 L/min.

Local exhaust ventilation: An air movement system for capturing pollutants in the air directly where they are produced and carrying them away before they can spread throughout the work area.

Loudness: The intensive attribute of an auditory sensation, in terms of which sounds may be ordered on a scale extending from soft to loud. Loudness depends primarily upon the sound pressure of the stimulus, but it also depends upon the frequency and wave form of the stimulus.

Loudness level: A sound, in phones, is numerically equal to the median sound pressure level, in decibels, relative to 0.0002 microbar, of a free progressive wave of frequency 1,000 Hz presented to listeners facing the source, which in a number of trials is judged by the listeners to be equally loud.

Lower explosive limit (LEL): The lowest percentage, by volume, of flammable gas in air that will support combustion.

M

MAC: Maximum allowable concentration.

Manometer: Instrument for measuring pressure; essentially a U-tube partially filled with a liquid (usually water, mercury, or a light oil), so constructed that the amount of displacement of the liquid indicates the pressure being exerted on the instrument.

Mass: Quantity of matter. The units are the gram and the pound.

Matter: Anything that has mass or occupies space.

Membrane filter: A filter medium made from various polymeric materials such as cellulose, polyethylene, or tetrapolyethylene. Membrane filters usually exhibit narrow ranges of effective pore diameters and, therefore, are very useful in collecting and sizing microscopic and sub microscopic particles and in sterilising liquids.

Mesothelioma: Cancer of the membranes that line the chest and abdomen.

Metal fume fever: A flu like condition caused from inhaling of the fumes of heated metal.

MHSA: Mine Health and Safety Act (Act No. 29 of 1996), South Africa.

MHSC: Mine Health and Safety Council (South Africa)

Micron, micrometre (µm): One thousandth of a millimetre.

Microphone: An electro-acoustic transducer that responds to sound waves and delivers essentially equivalent electric waves.

Milligram (mg): A unit of weight in the metric system. One thousand milligrams equals one gram.

Milligrams per cubic meter (mg/m^3): Unit used to measure air concentrations of dusts, gases, mists, and fumes.

Millilitre (ml): A metric unit used to measure volume. One millilitre equals one cubic centimetre.

Millimetre of mercury (mm Hg): The unit of pressure equal to the pressure exerted by a column of liquid mercury one millimetre high at a standard temperature.

Mists: Suspended liquid droplets generated by condensation from the gaseous to the liquid state or by breaking up a liquid into a dispersed state, such as by splashing, foaming, or atomising. Mist is formed when a finely divided liquid is suspended in air.

Mixture: A combination of two or more substances that may be separated by mechanical means. The components may not be uniformly dispersed. See also Solution.

MOHAC: Mining Occupational Health Advisory Committee, South Africa

Monitoring: A continuing program of observation, measurement and judgement all of which are necessary to recognise the potential hazards and to judge the adequacy of existing control measures. It is the systematic surveillance of hazards in the workplace to which workers may be exposed.

MSHA: Mine Safety and Health Administration. In all American mines, MSHA is the safety and health regulator, similar to the DME in South Africa.

Mutagen: Anything that can cause a change (mutation) in the genetic material of a living cell.

MVS: Mine Ventilation Society of South Africa

N

Narcosis: Stupor or unconsciousness produced by chemical substances.

Near field: In noise measurement this refers to a field in the immediate vicinity of the noise source where the sound pressure level does not follow the inverse square law.

Neurotoxin: Chemicals which produce their primary effect on the nervous system.

NIHL: Noise-induced hearing loss.

90th percentile: The value which must be used to determine when HEG's need to be re-classified. This value can be calculated by:

a) using Microsoft Excel programme (percentile function); or

b) first placing all sample results in order from the lowest concentration to the highest concentration (i.e., concentration of specific contaminants). Next, assign each sample result a number, starting with the number 1 for the lowest concentration result up to the highest concentration being given the number equal to the total number of samples collected in that HEG. Multiply the total number

of samples collected by 0.9. The sample result with the number corresponding to this calculated value is the 90th percentile.

NIOH: National Institute for Occupational Health, National Health Laboratory Service, South Africa.

NIOSH: The National Institute for Occupational Safety and Health is a federal agency. It conducts research on health and safety concerns, tests, and certifies respirators, and trains occupational health and safety professionals in the USA.

NPES: National Programme for the Elimination of Silicosis.

O

OB: Octave-band (method for predicting HPD attenuation).

Occupational Health and Safety Act (Act No. 83 of 1995_: Replaced the Machinery and Occupational Safety Act of 1983 (South Africa)..

Occupational exposure limit (OEL): The time weighted average concentration for a 8 hour work day and a 40 hour work week to which nearly all workers may be repeatedly exposed without adverse health effects.

Occupational exposure limit - Ceiling limit (OEL - C): An instantaneous value which must never be exceeded during any part of the working exposure.

Occupational exposure limit - Short term exposure limit (OELSTEL): A 15-minute TWA exposure which should not be exceeded at any time during a workday even if the 8-hour TWA is within the OEL-TWA. Exposures above the OEL-TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There should be at least 60 minutes between successive exposures in this range.

Octave: The interval between two sounds having a basic frequency ration of two.

Octave band: An arbitrary spread of frequencies. The top frequency in an octave band is always twice the bottom one. The octave band may be referred to by a centre frequency.

Odour: That property of a substance that affects the sense of smell.

Odour threshold: The minimum concentration of a substance at which a majority of test subjects can detect and identify the characteristic odour of a substance.

OH: Ooccupational hygiene.

Organ of Corti: An aggregation of nerve cells in the ear lying on the basilar membrane that picks up vibrations and converts them to electrical energy, which is sent to the brain and interpreted as sound.

Organic: Term used to designate chemicals that contain carbon. To date nearly one million organic compounds have been synthesised or isolated. Many occur in nature; others are produced by chemical synthesis. See also Inorganic.

Organic carbon (OC): The complex carbon compounds found in diesel particulate, including hydrocarbons such as aldehydes and polycyclic aromatic hydrocabons (PAHs). Organic carbons do not inlude elemental carbon and inorganic substances such as sulphates.

Over-exposure: Exposure beyond the specified limits.

P

Particle: A small discrete mass of solid or liquid matter.

Particle concentration: Concentration expressed in terms of number of particles per unit volume of air or other gas. Note: When expressing particle concentrations the method of determining the concentration should be stated.

Particle size: The measured dimension of liquid or solid particles usually in units of microns.

Particle size distribution: The statistical distribution of the sizes or ranges of size of a population of particles.

Particulate matter: A suspension of fine solid or liquid particles in air, such as dust, fog, fume, mist, smoke or sprays. Particulate matter suspended in air is commonly known as an aerosol.

Personal protective equipment (PPE): Devices worn by the worker to protect against hazards in the environment. Respirators, gloves, and hearing protectors are examples.

Personal sample: An atmospheric sample collected from within the breathing zone of an individual.

Personal sampling: A method whereby air is sampled from within employees' breathing zones to evaluate personal exposure to airborne contaminants.

Pinna: Ear flap (part of ear that projects from the head); also known as the auricle.

Pitch: That attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high. Pitch depends primarily upon the frequency of the sound stimulus, but it also depends upon the sound pressure and wave form of the stimulus.

Pitot tube: A device consisting of two concentric tubes, one serving to measure the total or impact pressure existing in the air stream, the other to measure the static pressure only. When the annular space between the tubes and the interior of the centre tube are connected across a pressure measuring device, the pressure difference automatically nullifies the static pressure, and the velocity pressure alone is registered.

Pneumo-(Greek) and pulmo-(Latin)(prefix): Both terms pertain the lungs.

Pneumoconiosis: Dusty lungs, as a result of the continued inhalation of various kinds of dusts or other particles.

Pneumoconiosis-producing dust: Dust, which when inhaled, deposited, and retained in the lungs, may produce signs, symptoms and findings of pulmonary disease.

Portal: Place of entrance.

ppb: Parts per billion.

Poison (flammable gas): Substances, which lead to temporary or permanent loss of sensitivity of the sensors.

PPE, Personal Protective Equipment: Includes items such as gloves goggles, respirators, and protective clothing.

ppm: Parts per million parts of air by volume of vapour or gas or other contaminant.

Pre-separator: In a sampling train, the pre-separator removes a portion of the airborne dust that does not need to be collected. In the case of respirable dust, a cyclone used as a pre-separator removes the larger, non-respirable dust.

Probe: A tube used for sampling or for measuring pressures at a distance from the actual collection or measuring apparatus. It is commonly used for reaching inside stacks or ducts.

Protection factor (PF): With respiratory protective equipment - the ratio of the ambient airborne concentration of the contaminant to the concentration inside the face piece.

Psychrometer: An instrument consisting of wet and dry bulb thermometers for measuring relative humidity.

Psychrometric chart: A graphical representation of the thermodynamic properties of moist air.

Pulmonary: Pertaining to the lungs.

Pure tone: The sound wave characterised by its singleness of frequency.

Q

Quartz: The most common type of crystalline silica. Quartz occurs as two polymorphs, alpha quartz (or low quartz) and beta quartz (or high quartz). Beta quartz is stable only at temperatures above 573 °C and converts to alpha quartz on cooling. The quartz form is so abundant that the term quartz is often used in place of the general term crystalline silica.

R

Radiant temperature: The temperature resulting from the body absorbing radiant energy.

Random noise: A sound or electrical wave whose instantaneous amplitudes occur as a function of time, according to a normal (Gaussian) distribution curve. Random noise is an oscillation whose instantaneous magnitude is not specified for any given instant of time. The instantaneous magnitudes of a random noise are specified only by probability functions giving the fraction of the total time that the magnitude, or some sequence of the magnitudes, lies within a specific range.

Raynaud's syndrome, phenomenon: Abnormal constriction of the blood vessels of the fingers on exposure to cold temperature.

Reference Testing: A system of reference testing as referred to in SABS 0215 Code of Practice and will be administered by the Approved Inspection Authority.

Relative humidity: The ratio of the quantity of water vapour present in the air to the quantity that would saturate it at any specific temperature.

Reliability: The degree to which an instrument, component, or system retains its performance characteristics over a period of time.

Replication: A fold or folding back, the act or process of duplicating or reproducing something.

Resistance:

a) Opposition to the flow of air, as through a canister, cartridge, particulate filter, or orifice.
b) A property of conductors depending on their dimensions, material, and temperature which determines the current produced by a given difference in electrical potential.

Resonance: Each object or volume of air will "resonate" or strengthen a sound at one or more particular frequencies. The frequency depends on the size and construction of the object or air volume.

Respirable combustible dust (RCD): The portion of a respirable dust sample that can be burned off a silver membrane filter when exposed to a temperature of 400 °C for two hours.

Respirable dust: Dust that contains particles small enough to enter the gas exchange region of the human lung (less than 10 microns in accordance with the ISO/CEN curve).

Respirable particulates: The respirable fraction of airborne particulates.

Respirator: A device worn over the mouth and nose or entire head to protect a user from inhaling harmful agents.

Respiratory system: Consists of (in descending order) - the nose, mouth, nasal passages, nasal pharynx, pharynx, larynx, trachea, bronchi, bronchioles, air sacs (alveoli) of the lungs, and muscles of respiration.

Reticule: A scale or grid or other pattern located in the focus of the eyepiece of the microscope.

Risk: The potential for a hazard to cause bodily harm or injury.

Risk Area: High risk > Exposure limit Medium risk Action level Low risk < Action level

Rotameter: A flow meter, consisting of a precision bored, tapered, transparent tube with a solid float inside.

RRN: Risk rating for noise.

RTA: Real-time sound analyser.

S

SAMOHP: South African Mines Occupational Hygiene Programme Codebook.

SAS: Surface air sampler.

SAIOH: Southern African Institute for Occupational Hygiene

Sampling: A process consisting of the withdrawal or isolation of a fractional part of a whole. In air analysis, the separation of a portion of an ambient atmosphere for subsequent analysis to determine concentration.

Sampling areas: An area derived from the breakdown of a mine into a ventilation district or combination of ventilation districts with a common intake and return of which the return is not used as an intake to another vent area.

Sampling train (dust): The complete assembly of what is required to perform dust sampling. It includes: a self-regulating pump, plastic/rubber tubing, lapel clips and a filtration medium in a sampling cassette to collect the dust sample. It may or may not include a pre-separator. In the case of respirable dust sampling, a cyclone is used as a pre-separator to remove the coarse, non-respirable dust.

SCBA: Self contained breathing apparatus.

Scanning Electron Microscopy: Optical method of dust identification, the aim of which is to determine concentration; sizing and surface characteristics.

Sensitivity: The minimum amount of contaminant that can repeatedly be detected by an instrument.

SCFH: Standard cubic foot per hour.

Short-term exposure limit (STEL): Maximum concentration to which workers can be exposed for a short period of time (15 minutes) for only four times throughout the day with at least one hour between exposures.

SI: The International System of Units, the metric system that is being adopted throughout the world. It is a modern version of the MKSA (meter, kilogram, second, ampere) system whose details are published and controlled by an international treaty organisation financed by the Member States of the Metre Convention, of which the United States is a member.

Siderosis: The deposition of iron pigments in the lung - can be associated with disease.

Significant airborne pollutant: Any airborne pollutant to which any employee is exposed in concentrations equal to or exceeding the hazard limits contemplated in Regulation 9.2.1 under the MHSA.

Silica gel: A regenerative absorbent consisting of the amorphous silica manufactured by the action of HC1 on sodium silicate. Hard, glossy, quartz like in appearance. Used in dehydrating and in drying and as a catalyst carrier.

Silicates: Compounds of silicon, oxygen, and one or more metals with or without hydrogen. These dusts cause non-specific dust reactions, but generally do not interfere with pulmonary function or result in disability.

Silicosis: A disease of the lungs caused by the inhalation of silica dust.

SIMRAC: Safety in Mines Research Advisory Committee, South Africa

SLM: Sound level meter.

Smoke: An air suspension (aerosol) of particles, originating from combustion or sublimation. Carbon or soot particles resulting from incomplete combustion of carbonaceous materials such as coal or oil. Smoke generally contains droplets as well as dry particles. Tobacco, for instance, produces a wet smoke composed of minute tarry droplets.

Sorbent:

a) A material that removes toxic gases and vapours from air inhaled through a canister or cartridge.

b) Material used to collect gases and vapours during air-sampling.

Sound: An oscillation in pressure, stress, particle displacement, particle velocity, etc., which is propagated in an elastic material, in a medium with internal forces (e.g., elastic, viscous), or the superposition of such propagated oscillations. Sound is also the sensation produced through the organs of hearing - usually by vibrations transmitted in a material medium, commonly air.

Sound absorption: The change of sound energy into some other form, usually heat, in passing through a medium or on striking a surface. In addition, sound absorption is the property possessed by materials and objects, including air, of absorbing sound energy.

Sound analyzer: A device for measuring the band pressure level or pressure spectrum level of a sound as a function of frequency.

Sound level: A weighted sound pressure level, obtained by the use of metering characteristics and the weighting A, B or C.

Sound-level meter and octave-band analyzer: Instruments for measuring sound pressure levels in decibels referenced to 0.0002 microbars. Readings can also be made in specific octave bands, usually beginning at 75 Hz and continuing through 10,000 Hz.

Sound pressure level, Lp: The level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. The reference pressure must be explicitly stated.

$Lp = 20 \log Pa/Po \qquad Po = 20 \times 10^{-6} Pa.$

Sound transmission: The work "sound" usually means sound waves travelling in air. However, sound waves also travel in solids and liquids. These sound waves may be transmitted to air to make sound we can hear.

Sound transmission loss: A barrier's ability to block transmission is indicated by its transmission loss (TL) rating, measured in decibels.

SPL: Sound pressure level.

Specificity: The degree to which an instrument or detection method is capable of accurately detecting or measuring the concentration of a single contaminant in the presence of other contaminants.

Spectrography - spectral emission: An instrumental method for detecting trace contaminants utilising the formation of a spectrum by exciting the contaminants under study by various means,

causing characteristic radiation to be formed, which is dispersed by a grating or a prism and photographed.

Spectrophotometer: An instrument used for comparing the relative intensities of the corresponding colours produced by chemical reactions.

Spectroscopy: Observation of the wavelength and intensity of light, or other electromagnetic waves, absorbed or emitted by various materials. When excited by an arc or spark, each element emits light of certain well defined wave-lengths.

Spectrum: The distribution in frequency of the magnitudes (and sometimes phases) of the components of the wave. Spectrum also is used to signify a continuous range of frequencies, usually wide in extent, within which waves have some specified common characteristics. Also, the pattern of red-to-blue light observed when a beam of sunlight passes through a prism and then projects upon a surface.

Speech interference level (SIG): The speech interference level of a noise is the average, in decibels, of the sound pressure levels of the noise in the three octave bands of frequency 600 - 1 200, 1 200 - 2 400 and 2 400 - 4 800 Hz.

Standard air: Air at standard temperature and pressure. The most common values are 21.1 °C and 101.3 kPa. Also, air with a density of 1.2 kg/m^3 .

Static Sampling: The measurement of contaminant concentrations in a special work area and the sampling device is placed in a fixed location.

Stress: A physical, chemical, or psychological factor that causes bodily or mental tension and may be a factor in disease causation or fatigue.

Stressor: Any agent causing a condition of stress.

Supplied-air respirator: A protective device that delivers fresh (uncontaminated) air to a user through a supply hose connected to the face mask or enclosure.

Supplied-air suit: A one- or two-piece suit that is impermeable to most particulate and gaseous contaminants and is provided with an adequate supply of respirable air.

Suspect carcinogen: A material which is believed to be capable of causing cancer but for which there is limited scientific evidence.

Sweating:

a) Visible perspiration;

b) the process of uniting metal parts by heating solder so that it runs between the parts.

Symptom: Evidence from a patent indicating illness; the subjective feelings of the patient.

Syndrome: A collection, constellation, or concurrence of signs and symptoms, usually of disease.

Synergism: Co-operative action of substances whose total effect is greater than the sum of their separate effects.

Synergistic: Pertaining to an action of two or more substances, organs or organisms to achieve an effect of which is greater than the additive effects of each alone.

T

Temperature: The condition of a body which determined the transfer of heat to or from other bodies. Specifically, it is a manifestation of the average conductive kinetic energy of the molecules of a substance due to heat agitation. See Celsius and Kelvin scale.

Temperature, mean radiant (MRT): The temperature of a uniform black bulb temperature in which a solid body or occupant would exchange the same amount of radiant heat as in the existing non-uniform environment.

Temperature wet-bulb: Thermodynamic wet-bulb temperature is the temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature (without qualification) is the temperature indicated by a wet-bulb psychrometer.

Temporary threshold shift (TTS): The hearing loss suffered as the result of noise exposure, all or part of which is recovered during an arbitrary period of time when one is removed from the noise. It accounts for the necessity of checking hearing acuity at least 16 hours after a noise exposure.

Teratogen: An agent or substance that may cause physical defects in the developing embryo or fetus when a pregnant female is exposed to that substance.

Thermogram: The graphical summary of the analysis from the software used in the NIOSH 5040 method for carbon analysis. This graph shows the relative amounts of elemental and organic carbon and analytical conditions inluding oven temperature and time settings.

Threshold: The level where the first effects occur; also the point at which a person just begins to notice the tone is becoming audible.

Timbre: The quality given to a sound by its overtones; the tone distinctive of a singing voice or a musical instrument. Pronounced tamber or timber.

Time-weighted average concentration (TWA): Refers to concentrations of airborne toxic materials which have been weighted for a certain time duration, usually 8 hours.

Tinnitus: A ringing sound in the ears.

TLV. Threshold Limit Value: A time-weighted average concentration under which most people can work consistently for 8 hours a day, day after day, with no harmful effects. A table of these values and accompanying precautions is published annually by the American Conference of Governmental Industrial Hygienists. (ACGIH)

Tone deafness: The inability to make a close discrimination between fundamental tones close together in pitch.

Total carbon: The combination of organic and elemental carbon found in diesel emissions. This excludes inorganic substances such as sulphates and usually makes up about 85% of diesel particulate matter.

Toxicity: A relative property of a chemical agent and refers to a harmful effect on some biologic mechanism and the condition under which this effect occurs.

Transmission loss: The ratio, expressed in decibels, of the sound energy incident on a structure to the sound energy that is transmitted. The term is applied both to building structures (walls, floors, etc.) and to air passages (muffler, ducts, etc.).

U

Ultrasonics: The technology of sound at frequencies above the audio range.

Ultraviolet: Those wavelengths of the electromagnetic spectrum which are shorter than those of visible light and longer than x-rays, 10^{-5} cm to 10^{-6} cm wavelength.

Upper explosive limit (UEL): The highest concentration (expressed in percent vapour or gas in the air by volume) of a substance that will burn or explode when an ignition source is present.

Unsatisfactory Conditions (Substandard): Substandard refers to any condition which does not conform to legal requirements, or any other requirements which may pose a threat to the health of workers and/or pollution to the environment.

V

Vapours: The gaseous form of substances that are normally in the solid or liquid state (at room temperature and pressure). The vapour can be changed back to the solid or liquidstate either by increasing the pressure or decreasing the temperature alone. Vapours also diffuse. Evaporation is the process by which a liquid is changed into the vapour state and mixed with the surrounding air. Solvents with low boiling points will volatile readily.

Velometer: A device for measuring air velocity.

Ventilation: One of the principal methods to control health hazards, may be defined as "causing fresh air to circulate to replace foul air simultaneously removed".

Ventilation, dilution: Airflow designed to dilute contaminants to acceptable levels.

Ventilation district: Such part of a mine as has an independent intake commencing from a main intake air-course and an independent return airway terminating at a main air-course.

Ventilation, mechanical: Air movement caused by a fan or other air moving device.

Ventilation, natural: Air movement caused by wind, temperature difference or other non-mechanical factors.

Verification: The process of confirming the correctness of any results by means of independent examination or demonstration of any statement, procedure, program including figures, calculations and references by an accredited party.

Vibration: An oscillation motion from an equilibrium position produced by a disturbing force.

Volume flow rate: The quantity (measured in units of volume) of a fluid flowing per unit of time, as cubic feet per minute, gallons per hour, or cubic meters per second.

Volume ratio (v/v): Ratio of the volume of a component gas to the volume of the gas mixture under specified conditions of temperature and pressure.

W

Wavelength: The distance in the line of advance of a wave from any point to a like point on the next wave. It is usually measured in angstrom, micron, micrometer, or nanometer.

Weighting network (sound): Electrical networks (A, B, C) associated with sound level meters. The C network provides a flat response over the frequency range 20 - 10,000 Hz while the B and A networks selectively discriminate against low (less than 1 kHz) frequencies. The A weighting network represent responses equivalent to human hearing.

Wet-bulb globe temperature index: An index of the heat stress in humans when work is being performed in a hot environment. Commonly referred to as WBGT.

Wet-bulb temperature: Temperature as determined by the wet bulb thermometer or a standard sling psychrometer or its equivalent. This temperature is influenced by the evaporation rate of the water, which in turn depends on the humidity (amount of water vapour) in the air.

Wet-bulb thermometer: A mercury thermometer having the bulb covered with a cloth saturated with distilled water.

Wet methods: The use of water or another suitable liquid with industrial processes (cutting, sanding, grinding) to reduce dust concentrations in the air.

White noise: A noise whose spectrum density (or spectrum level) is substantially independent of frequency over a specified range.

WHO: World Health Organization.

Workplace: Place/site where employees work on a permanent or temporary basis.

Work practices: The procedures followed by employers and workers to control hazards in the workplace (for example, use of wet methods to control dust).

X

X-ray diffraction: Since all crystals act as three-dimensional grating for x-rays, the pattern of diffracted rays is characteristic for each crystalline material. This method is of particular value in determining the presence or absence of crystalline silica in an industrial dust.