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Sampling and Analysis of Compressed Air to be used for Breathing Purposes

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The B.O.H.S. Technology Committee

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CONTENTS

1 INTRODUCTION

The general quality requirements for compressed air to be used for breathing purposes have been considered in a number of national standards. Fairly typical specifications are those included in BS 4275: 1974,[1] which requires that air supplied to users should not contain impurities in excess of the following limits:

carbon monoxide: 5 parts per million (5.5 $mg.m^{-3}$),
carbon dioxide: 500 parts per million (900 $mg.m^{-3}$).

The air must also be free from odour and contamination by dust, dirt or metallic particles and should not contain hygienically "significant" amounts of other toxic, harmful or irritating substances. "Significant" here might be concentrations greater than one tenth of the U.K. recommended exposure limits[2] (measured at atmospheric pressure) for common air contaminants such as nitric oxide, nitrogen dioxide and hydrocarbons etc., but some caution is needed in accepting arbitrarily defined limits.

Further requirements are that air should be delivered to the user at a reasonable temperature, free from condensed water but with an acceptable relative humidity. In this context, temperatures in the range 15 - 25 °C and relative humidity of not more than 80% may be acceptable limits.

Very little practical guidance has been made available hitherto to users of compressed air as to how the quality of the air should be determined. Recognizing the value of having available a convenient source of reference, a working group set up by the Technology Committee of the British Occupational Hygiene Society has produced this Technical Guide on suitable sampling and analytical procedures. In preparing the text, the working group has drawn upon industrial and naval experience and published information.

2 SCOPE

The procedures and analytical methods described are primarily intended for the sampling and analysis of compressed atmospheric or reconstituted air used under normal industrial conditions for breathing purposes. The procedures and methods may require modification when used for special purposes e.g. the provision of biologically sterile air, certain medical gas mixtures, submarine air for long-term breathing, gas mixtures to be used at pressures equivalent to diving depths greater than 50 metres and breathing gases for crews of high altitude aircraft.

The compressed air for breathing purposes is usually air of the lower atmosphere compressed by suitable equipment for delivery to the work enclosure, to the breathing apparatus or to storage cylinders. Alternatively, reconstituted air is employed - this being a gaseous mixture of oxygen and nitrogen to produce the nominal proportions of 21% oxygen and 79% nitrogen by volume, to which water vapour can be added to give the required humidity.

3 PREPARATION OF SYSTEMS FOR SAMPLING

The main objective of the preparation procedure is to ensure that the air which is to be sampled will be representative of that which is going to be breathed. Before sampling, sufficient air must be allowed to flow through the system to purge it of existing atmospheric air and to ensure that any contaminants which may be present in the air are brought to the sampling position. This is particularly important where long air supply lines are involved when the purging process may take several minutes.

Where reasonably practicable, the sampling position should be where the breathing air is delivered to the user. During sampling, the air flow rate should ideally be similar to the delivery rate when in use, but it is recognized that this may not always be practicable. Sampling is normally undertaken from the low pressure side of supply regulators.

4 ON-LINE ANALYSIS

Commercial equipment is available for carrying out analyses for a number of contaminants (see the list of suppliers in the Appendix). This equipment requires the use of regulating devices and flow meters which are coupled directly to the compressed air line, compressor or cylinder. They have to be used with careful attention to the manufacturer's instructions.

Particulate contamination (including oil mists) requires sampling to be undertaken directly at the air supply point. The particulate is collected by filtration from a known volume of air. The contaminated air should not be collected for subsequent analysis because losses of aerosol can occur on the walls of sampling containers such as flexible sample bags. On-line connexion is also required when conventional long-term detector tubes are used, and again a suitable regulator/flow meter system is required.

5 GRAB SAMPLES

The collecting of a representative grab sample of the compressed air in a suitable container for subsequent analysis is a convenient and practical approach, but applicable only for gaseous constituents. Two basic methods are available, one employing flexible bags and the other rigid containers.

5.1 Flexible bag sampling

Sampling using flexible bags is probably the most useful method since conventional, hand-pumped short-term detector tubes can then be used to measure many gaseous contaminants. Plastic bags of at least one litre capacity, but preferably of two or more litres, and fitted with a small bore tube (6 mm i.d.) are suitable. The bags should be filled and completely emptied at least three times to ensure that the previous contents are removed. The tube should be closed with a tap, pinch clip or stopper, until the analysis is performed.

To avoid significant changes in composition due to permeation through or adsorption onto the walls of the bag, analysis should be performed as soon as possible after sampling and preferably within 30 minutes. It should be noted that significant losses may occur when samples are stored in bags made of certain materials e.g. PVC,

polythene, natural and synthetic rubbers. Fluocarbon polymers (e.g. Tedlar or PTFE) and aluminium/polyester laminates are more reliable in this respect.

5.2 Rigid sample containers

Metal sample containers with a valve at either end are easily purged prior to filling to a suitable pressure. They may prove more practical to use than evacuated cylinders.

Care must be taken to ensure that the safe maximum pressure for rigid containers is not exceeded. Containers should be serviced and pressure tested at appropriate intervals.

Much caution needs to be exercised if glass sample containers are used, to prevent serious injury, and they are not generally recommended for obvious safety reasons.

6 ANALYSIS

All instruments and detectors used in the test procedures must be operated and adjusted in accordance with the manufacturers' instructions. Where applicable, they should be calibrated using a recognized procedure, e.g. against certified calibration gas mixtures.

6.1 Gaseous constituents

Many contaminants can be measured using detector tubes (e.g. those supplied by Draeger, Gastec etc.). They are inexpensive and are available for a wide range of gases and vapours - in particular, CO, CO_2, NO, NO_2, SO_2, - and some hydrocarbons. A practical method is to use hand-pumped detector tubes, taking the sample directly from the flexible bag. As the air is removed from the bag, atmospheric pressure collapses the bag and hence retains the sample of compressed air within the calibration pressure for the detector tubes. The general procedure is illustrated in Fig.1.

Gaseous constituents can also be determined using on-line sampling procedures and long-term detector tubes.[7,10] Using a regulator and flow meter, the compressed air is set to flow through the detector tube within the flow rate range specified by the detector tube manufacturer. After the appropriate timed sampling period, the concentration of the contaminant is calculated from the detector tube reading and the volume of air sampled.

Portable instruments are commercially available for measuring several gaseous contaminants. These include instruments using solid state or electrochemical sensors, para-magnetic detectors, chemiluminescent detectors and infrared spectrophotometers.

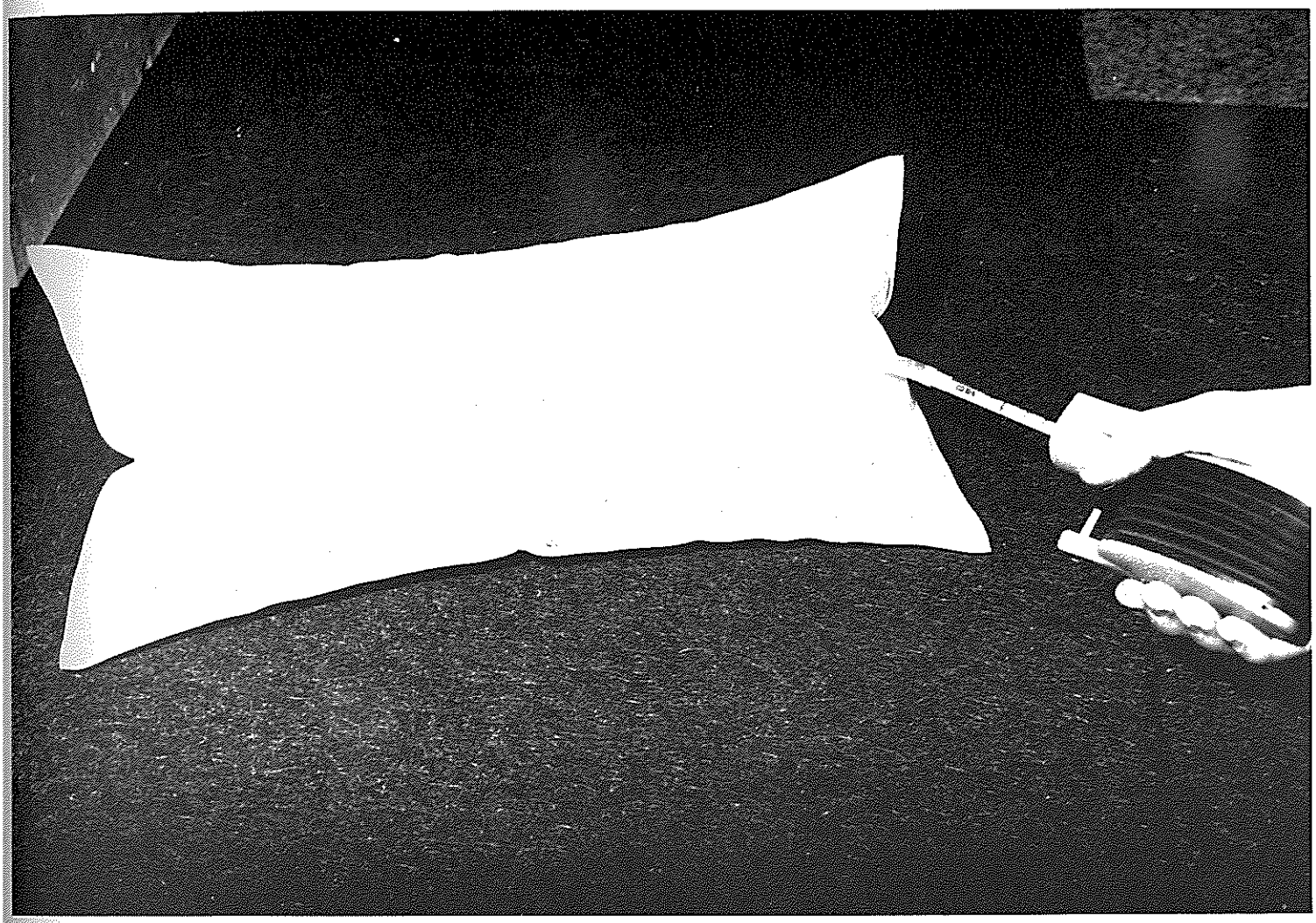

Fig.1. Analysis of a sample of compressed air using a detector tube.

Laboratory analysers such as gas chromatographs (GC) and infrared spectrophotometers (IR)[8] can be used to analyse for most gases and organic vapours. For measuring carbon monoxide at low levels, in-line catalytic conversion to methane followed by flame ionization detection is the GC method usually employed. Oxygen can also be determined by GC using a molecular sieve or similar column to separate it from nitrogen (but not usually from argon) and a thermal conductivity detector. Standard volumetric absorption analysers, such as the Orsatt or Haldane, can be used for oxygen and carbon dioxide.

6.2 Particulates, including oil mists

Particulates and oil mists must be sampled directly from the compressed air line, cylinder or breathing apparatus - usually at the point where air enters the user's environment. Loss of particulate will occur if attempts are made to take preliminary samples in bags or cylinders. The following procedure is based upon that developed by The Institute of Petroleum Hygiene Sub-Committee (1974).[3]

Air is passed through a tared glass fibre filter supported in a suitable, closed, in-line, filter holder. Flow rates of the order 2 - 100 litres of air min^{-1} are theoretically possible, depending upon the diameter of the filter. The flow should be measured with a flow meter or integrated gas meter downstream of the filter.

Particulate measurement can be integrated with temperature and humidity measurement, as indicated in Section 7 of this guide. When a suitable volume of air has been sampled (not less than 1 $metre^3$) the total particulates are determined gravimetrically. Sintered silver filters have also been used for this measurement.

To measure the oil mists, the filter should be extracted with trichlorotrifluoroethane (Halocarbon 113).[4] The absorbance of the resultant solution, made up to some convenient volume (say 20 ml), can be measured on a UV spectrophotometer. Peak absorbance occurs at wavelengths around 240 nanometres. Absorbance can also be measured on an IR spectrophotometer at 2.1 micrometres. Quantitative assessment is obtained by comparison of absorbance with that for prepared standards using known weights of the lubricating oil used in the compressor. When the type of oil is unknown, a typical compressor oil should be used as a standard. A detector tube (Draeger) is available which responds to both oil mist and oil vapour. If a significant response is obtained, separate measurements will be required to confirm the proportions of mist and vapour present.

6.3 Hydrocarbon vapours

Hydrocarbon vapours can be collected on solid absorbants (e.g. activated charcoal, porous polymers) placed downstream of a filter to remove particulates. The particulates in the compressed air may contain liquid hydrocarbons (oils). These would also be collected by an absorbant if not filtered out first. The collected hydrocarbons can be desorbed and then analysed chromatographically. The collection of hydrocarbon vapours can be integrated with a particulate measurement.

7 CONDENSED WATER, HUMIDITY, TEMPERATURE

The presence of water may sometimes be detected by passing air gently through a wad of dry tissue paper or filter paper. Excess oil will also be revealed. The presence of water produced by adiabatic cooling can frequently be observed when the compressed air is passed through a transparent tube. The tube must be capable of withstanding the pressures involved. Polycarbonate is a suitable material for this application.

Temperature and humidity can be measured in the observation tube

using a wet and dry bulb thermometer or other suitable sensors. This facility can be conveniently integrated into a unit to enable particulate, hydrocarbon vapour and even gaseous constituents to be measured, as illustrated in Fig.2.

To ensure that readings are meaningful, the air flow past the wet bulb or other humidity sensor should be of the order 3 metres sec^{-1} (600 feet min^{-1}).[5,6]

8 ODOUR

The assessment of odour is a purely subjective test.[12,13] Since ability to make judgements of odour varies considerably, it is advisable to employ persons of proven capability. Caution is advised in using new plastics or rubber tubing to bring air from the sampling point to the place where odour is to be assessed. The tubing may introduce odours.

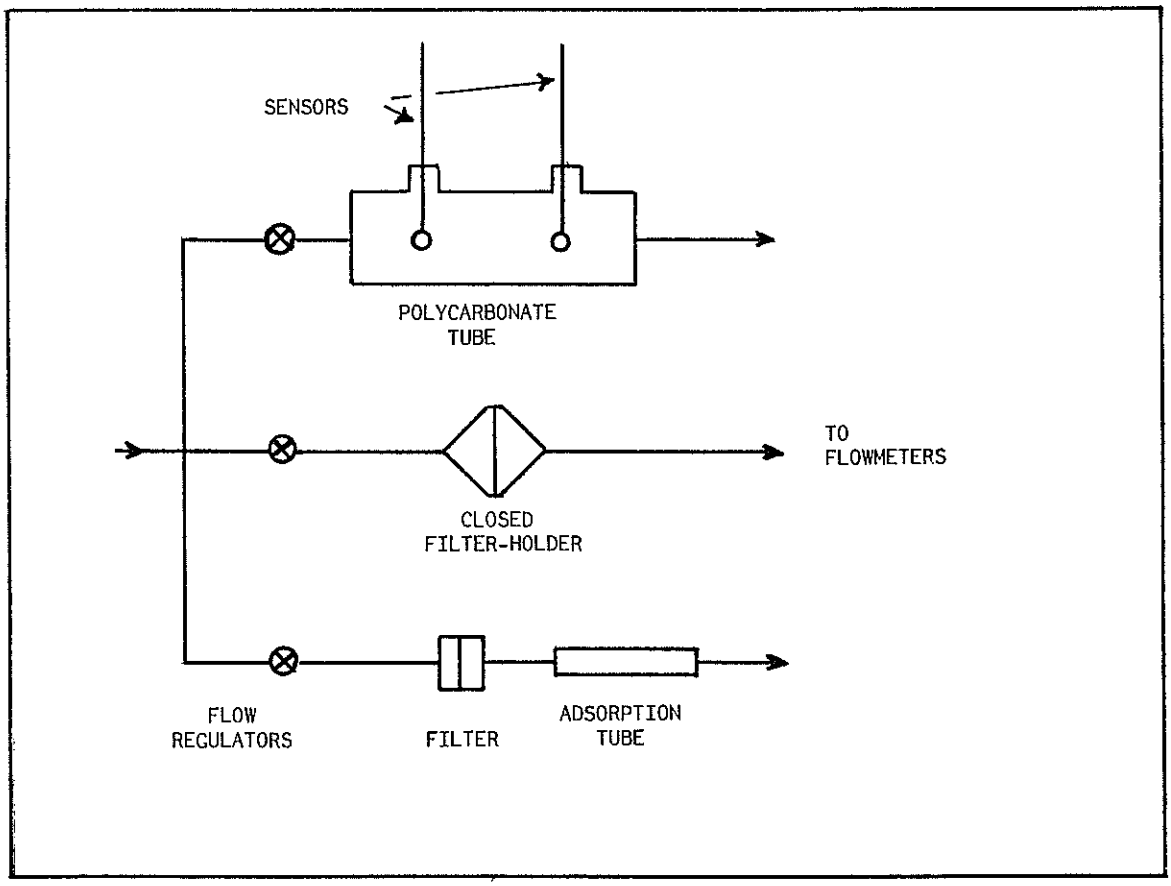

Fig.2. Measurement of humidity, particulates etc.

9 FREQUENCY OF TESTING

All new installations should be tested before the air is used for breathing purposes. Thereafter, breathing air should be tested at intervals, not greater than 6 months. Whenever a breakdown of plant, refit or incident likely to cause deterioration in air quality arises, testing should be repeated. Similarily, testing should be carried out when systems have been out of use for prolonged periods.

The testing procedures for the quality control of the air stored in cylinders should be organized in the full knowledge of the production procedures and equipment used for filling the cylinders. Thus, where electrically driven compressors are used with air inlets at positions where contamination of air is unlikely to be significant, it is not necessary to test so frequently.

The special problem relating to the toxicity of carbon monoxide will usually require more frequent testing. When cylinders are filled from electrically driven installations, the checking of one cylinder per batch filled could be the quality control procedure. When internal combustion engines are used to drive compressors with air inlets close to the sources of exhaust gas contamination or where other contamination risk is likely, more frequent testing is needed.

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APPENDIX:

SOME SUPPLIERS OF SAMPLING EQUIPMENT

1. Draeger Safety, Draeger House, Sunnyside, Chesham, Bucks HP5 2AR - detector tubes, the Aerotest Breathing Air Tester, oxygen analysers and charcoal tubes.
2. Detectawl (Gastec), Unit 61, Garamonde Drive, Wymbush, Milton Keynes, Bucks MK8 8DE - detector tubes.
3. SKC Ltd, Hamworthy Trading Estate, Dawkins Road, Poole, Dorset BH15 4JW - charcoal tubes, flow meters, filters, Tedlar sample bags and accessories.
4. Whatman Ltd, Springfield Mill, Maidstone, Kent, England - filters.
5. G.A. Platon Ltd, Flowbits, Freepost, Basingstoke RG22 4AQ - flow meters.
6. Gelman Sciences Ltd, 10 Harrowden Road, Brackmills, Northampton NN4 OEZ - filters and in-line filter holders.
7. Casella London Ltd, Regent House, Britannia Walk, London N1 7ND - thermometers, wicks, hygrometers etc.
8. Foxboro Analytical, 28 Heathfield, Stacey Bushes, Milton Keynes, Bucks MK12 6HR - portable infra-red analysers.

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Contents: Introduction, scope, preparation of systems for sampling, on-line analysis, grab samples, analysis, condensed water humidity and temperature, odour, frequency of testing, suppliers of sampling equipment.

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Contents: Introduction, biological effects on animals, biological effects on man, threshold limit values, occupational and domestic exposure, methods of determining ozone in air.

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