INTERNATIONAL STANDARD ISO 2889

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION •МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

General principles for sampling airborne radioactive materials

Principes généraux pour le prélèvement des matières radioactives contenues dans l'air

First edition — 1975-05-01

UDC 614.876 : 614.71.001.4 **Ref. No. ISO 2889-1975 (E)**

Descriptors : air pollution, airborne wastes, radioactive materials, sampling, preparation of test specimens.

Price based on 25 pages

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2889 was drawn up by Technical Committee ISO/TC 85, *Nuclear energy*, and circulated to the Member Bodies in November 1972.

It has been approved by the Member Bodies of the following countries :

Australia	Hungary	Spain
Belgium	Ireland	Sweden
Canada	Italy	Switzerland
Czechoslovakia	Netherlands	Thailand
Egypt, Arab Rep. of	Portugal	Turkey
France	Romania	United Kingdom
Germany	South Africa, Rep. of	U.S.A.

No Member Body expressed disapproval of the document.

CONTENTS

This page intentionally left blank

General principles for sampling airborne radioactive materials

0 INTRODUCTION

The potential hazard from breathing airborne radioactive materials must be evaluated and controlled through measurements of the levels and nature of the airborne radioactive materials. In zones occupied, or to be occupied, by workers, the levels of airborne radioactive materials must be determined and compared with the applicable control level to ensure that workers are not exposed to concentrations exceeding those considered safe. Levels necessitating improved facility design, isolation of source of contamination, control of exposure time, or the wearing of approved respirators may thus be identified.

Although the most important and ultimate objective of sampling is to protect individuals from excessive exposure to internally deposited radioactive materials, other desirable objectives are realized in a well-developed sampling and evaluation programme. Some of these are :

1) to provide the supporting documentation of working environments to demonstrate compliance with regulations. Well-kept records of air contamination levels along with other data may assist in supporting or refuting claims of radiation injury by workers or others;

2) to call attention to deteriorating equipment, faulty processes, or other conditions leading to loss of effective control of airborne materials in an operation and subsequently to determine the effectiveness of corrective measures;

3) to measure the release of radioactive materials to the environment through sampling near the point of release. Sampling of effluents will assist in evaluating and controlling the exposure of the worker to radiation at the installation, but the results of effluent sampling are generally of greater importance in ensuring that people in the environment are not exposed to levels of airborne materials exceeding established levels. In non-routine incidents, effluent samples are of material worth in estimating the possible consequences and the necessary corrective action, or in some cases in determining cause and sequence of abnormal events.

Sampling should permit integrated radioactive contamination release to the environment to be measured over various time periods.

Recommendations by a panel of experts on air sampling included the following specific goals to be achieved through sampling[1] :

1) a detailed study should be made to characterize the nature of aerosols in different types of working environments;

2) the general levels in working spaces should be measured and controlled as a matter of routine;

3) provision should be made for rapid detection of high levels of contamination during accidental release;

4) evaluation of individual inhalation should be stressed.

1 SCOPE

This International Standard sets forth the general principles which apply in obtaining representative samples of airborne radioactive materials and prescribes acceptable methods and materials for gas and particle sampling.

2 FIELD OF APPLICATION

These general principles are limited to the collection of samples and do not embrace the area of measurement of the radioactive materials collected. Exclusion of radiochemical measurement from the field of application must not be construed to mean that the measurement and evaluation of samples are of lesser importance than sampling. Accurate measurement and evaluation are vitally necessary, but these are valid only to the extent that the sample obtained reflects the existing conditions.

These general principles are further limited to guides for sampling airborne radioactive materials in installations where work with radioactive materials is conducted, with the primary emphasis on the need to protect the radiation worker. However, they do include sampling effluent gases prior to, or at, the point of release to the atmosphere from the installation. Although this therefore exludes certain sampling techniques such as, for example, those used in environmental and free atmosphere sampling, the principles defined and most of the methods discussed are in most cases generally applicable.

These general principles do not deal in detail with the application of various collectors to specific problems. The specific and detailed application of charcoal for iodine sampling, for example, is felt to be beyond the scope of this International Standard.

3 DEFINITIONS

For the purposes of this International Standard the following definitions are applicable :

3.1 absorbent : A material which takes up a constituent through the action of diffusion allowing the constituent to penetrate into the structure of the absorbent, if a solid, or to dissolve in it, if a liquid. When chemical reaction takes place during absorption, the process is called chemisorption.

3.2 adsorbent : A material, generally a solid, which retains a substance contacting it through the short-range molecular forces which bind the adsorbed material at the surface of the adsorbent.

3.3 aerodynamic diameter : Particles of the same diameter but of different densities will have different terminal settling velocities. Two particles of different densities are said to have equivalent "aerodynamic diameters" if their densities and diameters are such that the terminal settling velocities are equal, or that they are acted upon by air drag to an equal degree. Since comparisons with unit density materials are frequently made, "aerodynamic diameter" is the diameter of a unit density sphere with the same settling velocity as the particle in question irrespective of shape.

3.4 aerosol : A dispersion of solid or liquid particles in air or other gases.

3.5 anisokinetic : A condition which prevails when the velocity of air entering a sampling probe or the collector when held in the airstream is different from the velocity of the airstream being sampled at that point.

3.6 breathing zone : That region adjacent to a worker's mouth and nostrils from which air is drawn into the lungs while he performs his assigned work. Air taken from this region will truly represent the air the worker is breathing while he works, whether standing, sitting or moving.

3.7 burial : The embedding of a particle in a filter medium.

3.8 collection efficiency : The percentage retained by the filter of the total amount of particles initially in a known volume of air passed through the filter.

3.9 droplet : A very small quantity of a liquid in the general form of a sphere.

3.10 impaction : A process by which a particle or droplet is removed from an airstream by striking an object in the airstream.

3.11 isokinetic : A condition which prevails when the velocity of air entering a sampling probe or the collector, when held in the airstream, is identical to the velocity of the airstream being sampled at that point.

3.12 membrane filter : A filter medium consisting generally of very thin organic-based film having a porosity and composition controlled within a selected range. (Very thin porous metallic filters are also known as membrane filters.)

3.13 monitor : 1) To measure an airborne radioactive constituent or the gross content of radioactive material continuously or at a frequency which permits an evaluation of the concentration over an interval of time. 2) The instrumentation or device used in monitoring.

3.14 particle : An aggregate of molecules forming a solid or liquid of size ranging from a few molecular diameters to some tenths of a millimetre (several hundred micrometres).

3.15 penetration : The passage of airborne contaminants completely through a filter or other collector.

3.16 permissible level (as used in this International Standard) : That concentration of airborne material which has been established as a local guide or regulation, compliance with which will limit the quantity of radioactive materials inhaled. Permissible level may be different depending upon the nature of the airborne material, the duration of anticipated exposure, and the protection afforded by special clothing or other barriers.

3.17 "pseudo-coincidence" counting : A method for measuring the concentration of long-lived α-particle emitters, say plutonium or its compounds, collected on a filter, with differentiation of the α-particle emitters occurring naturally as the decay products of ^{222}Rn (radon) and ^{220}Rn (thoron). The detector senses and records the "pseudo-coincidence" of ^{214}Bi β-decay and its daughter, ^{214}Po α-decay, thus providing an index to the quantity of ^{222}Rn present. The ^{214}Po decays with a half-life of 150 μs; hence, the parent-daughter decay is regarded and utilized as a "pseudo-coincidence". The same consideration holds true for the ^{212}Bi to ^{212}Po decay. These are members of the ^{220}Rn decay chain.

3.18 representative sample : A portion of the medium of interest, or one or more separated constituents from this medium, which has the same quality and characteristics as possessed by the whole medium.

3.19 scrubber : A device for allowing air and liquid to achieve intimate contact to effect a transfer of gases, liquids, or solids carried in the gas to the liquid stream. The liquid may be a static pool through which the gas rises, or may be sprayed into a column or passed through packing.

3.20 "spot" sample : A randomly taken, single sample removed from a stream over a short interval of time.

3.21 sub-isokinetic : A condition which prevails when the velocity of air entering a sampling probe or the collector, when held in the airstream, is less than the velocity of the airstream being sampled at that point.

3.22 super-isokinetic : A condition which prevails when the velocity of air entering a sampling probe or the collector, when held in the airstream, is greater than the velocity of the airstream being sampled at that point.

3.23 vapour; vapor /USA/ : The gaseous form of materials which are liquids or solids at room temperature, as distinguished from non-condensable gases. (Vapours are gases but carry the connotation of having been released or volatilized from liquids or solids.)

3.24 volatile : Having a high vapour pressure at room temperature.

4 PRINCIPLES

Certain principles must be recognized and used as guides if effective sampling is to be realized. These are discussed in this clause.

4.1 REPRESENTATIVE SAMPLES

A sample must be representative of the bulk stream or volume from which it is taken. "Representative" embodies various qualities of the sample.

4.1.1 Representative according to spatial location

4.1.1.1 *Sampling in a zone occupied by workers*

The sample should ideally be drawn from a point or series of points within the "breathing zone" of the worker.[2] The actual sampling point would ideally be closely adjacent to the man's nostrils and mouth throughout all the worker's activities. For routine monitoring this is impracticable and some compromises are usually necessary. For many purposes a battery-operated sampler with a collector fastened near the breathing zone is an acceptable compromise, provided that adequate sensitivity can be achieved and worker comfort and safety are not jeopardized by wearing the device.

In the interests of simplicity, air samples are frequently taken with fixed position samplers. When fixed sampling positions are used, care must be taken in the selection of the position and number of samplers in a given work area. The location should be selected to be as close to the breathing zone as is practical without interfering with the work and the worker. Sampling with fixed position samplers compromises to a degree the principle of a sample being representative according to spatial location of the sampling point; however, with judicious placing of the sampling point and correlation with true breathing zone samplers the fixed position sampler can be useful.

Routinely obtained samples from fixed locations will signal changes in general air concentrations and help in determining the source of the contamination. When room ventilation arrangement is such that room air is exhausted through a single or a few ducts, samplers placed at the ventilation duct exits prior to filtration may provide a better integrated average of the air concentration, but could be unrepresentative of actual air breathed. This would be particularly true if the source were an isolated leak from one point in the room near a breathing zone, or if the particles concerned had a large aerodynamic diameter since these will tend to settle out over a relatively short path length. Several studies have called attention to the problems of obtaining a representative sample from fixed position samplers.[3, 4, 5, 6]

Air samplers may be installed slightly above head height and in front of the worker, or they may be installed at the front face of the hood, gloved box or other enclosure used to contain the radioactive material processed. The collector filter is most frequently oriented in a vertical plane to reduce the potential for the collection of larger particles by gravity settling. Although the principle of isokinetic sampling is not achieved in fixed room air samplers, the particles of interest are almost always of sizes sufficiently small that anisokinetic sampling errors are not of serious concern.

Due consideration should be given to the number, location, and air-moving requirements of samplers during the design of a facility in which radioactive materials are to be processed.

4.1.1.2 *Sampling from a duct or exhaust stack*

To withdraw representative samples from a duct or stack requires attention to the placement and number of entry nozzles and the configuration of the nozzle used. Arrangements in which the collector can be held in the air stream are to be preferred over those in which delivery lines between sampling points and collector are used. (See 4.1.2.) Some recommended probe configurations and guides locating exhaust points in ducts and stacks are given in annex A.

The sampling point for a reasonable degree of mixing should be a minimum of five duct diameters (or five times the major dimension for rectangular ducts) downstream from abrupt changes in flow direction or prominent transitions. Although these guidelines are generally applicable, it is recommended that velocity traverses also be taken to confirm that fully developed flow has been achieved at the sampling section.

4.1.2 Representative with respect to physical and chemical composition

4.1.2.1 *Sampling without differentiation or bias as to particle size or kind*

A representative sample must have the same radiochemical and physical composition as the air which would be contacted by the worker in the area sampled. In addition to the requirement of correct spatial location is the requirement that the sampler does not fractionate by particle size, or in other ways distort the physical and chemical properties of the airborne radioactive constituents. This requirement is difficult — often impossible — to accomplish perfectly. Any delivery line through which the sample is carried to the collection device will preferentially remove large particles, either through gravitational settling when the flow is too low, or through turbulent impaction when the flow is too high. Density of the particles in the air is also of importance in the fractionation by particle size. Some guides are presented in annex B to allow estimates to be made of particle loss in sampling lines due to gravity settling and turbulent flow.

A sample obtained with a delivery line and collector which do not discriminate between particles of various sizes can be evaluated accurately as to radiological significance only after knowledge of the physical and chemical properties of the airborne material is obtained. Separate study may be necessary to establish in given circumstances the size distribution and chemical nature of the airborne material.

Changes in the nature of airborne materials must be anticipated with changes in operations. Characterization of the airborne constituents must be performed frequently enough to ensure statistically significant information of the nature of the airborne material.

4.1.2.2 *Sampling with deliberate differentiation as to the particle sizes*

Because knowledge of particle size distribution is important to a correct evaluation of radiological effects, samplers and collectors may be deliberately designed to identify two or more size fractions of the airborne material. Measurement of the radioactivity associated with each size fraction will permit a determination of the radioactivity which will be preferentially retained in various portions of the respiratory tract.* Although not capable of high resolution, these devices can reasonably well distinguish radioactivity associated with particles which will be retained in the upper respiratory passage, and the much smaller particles which would be accessible to the alveoli of the lung. These sampling devices have considerable merit and, in the absence of knowledge of particle sizes in the air sampled, are recommended. References[3], [9], [10], [11], [12] and [13] describe some of these.

4.1.2.3 *Particle size fractionation due to anisokinetic sampling*

Distortion in particle size distributions may occur when the velocity of the sampled air entering the sample probe (or collector, when supported directly in the stream to be sampled) is significantly different from the velocity of the air in the stream sampled. When the air drawn through the sampler or collector in the stream is at a much lower velocity than the stream velocity, larger particles will be preferentially collected. When the air velocity through the sample probe and collector is greater than the stream velocity, smaller particles will be collected preferentially. The degree to which the fractionation occurs is a function of particle size, density, the particle size distribution, and the difference between the isokinetic velocity and the anisokinetic velocity employed. Except in very unusual situations, particles smaller than aerodynamic diameter of about 5 μm are able to follow the streamlines of the air and the fractionation error is not great. Annex C presents data showing the error which would be made for various conditions of anisokinetic sampling. Obviously, the sizes and density of particles being sampled must be known before this error can be evaluated. In applications in which particle sizes may be expected to vary, particularly when particles larger than 5 μm are anticipated, it is recommended that the sampler arrangement be designed to permit near-isokinetic flow into the sampler entry probe or through the collector when the collector is facing into the stream sampled. A potential source of non-representative sampling may thus be avoided.

4.1.2.4 *Sample distortion due to chemical reactions and related effects*

Extreme care must be exercised in extracting a sample from an airstream when the air may contain chemically reactive forms of radionuclides. Reactive vapours such as radioiodine may be largely adsorbed on, or react with, materials which might be considered for sampling lines, for example rubber, copper and some plastics materials.

Some collectors, such as impingers, trap materials in a liquid with varying efficiency, depending upon the solubility and particle size. Condensate on the inner surfaces of sampling lines may form pockets and act as traps, or provide wetted surfaces to which the material of interest may adhere. In extreme situations traps and pockets may act as effective scrubbers for the radioactive material transported. Sampling lines must also be free from dust, oil or grease, all of which may lead to increased deposition of transported radioactive material.

When the air to be sampled is nearly saturated with water vapour, condensation may occur on the collector itself. Excessive moisture may destroy filter media usefulness either by blocking the air passageways through the pores, or by weakening it to a point that it tears or breaks easily. When heavy moisture loadings are anticipated, heated sampling lines will be required to prevent condensation in the lines to raise the collector temperature well above the dewpoint.

All possible interactions which may change the sample quality from the point where it is diverted to the collector must be carefully considered. The chemical form as well as the physical nature of the airborne constituents to be sampled must be known before a representative sample can be ensured.

* The Task Group on Lung Dynamics for Committee I of the International Commission on Radiological Protection has developed and recommended a dust deposition model which utilizes and depends upon knowledge of particle sizes obtained through air samples.[7] When particle size distributions are known, the fractional deposition in each of three regions of the respiratory tract can be estimated from this model. When specific particle size data are lacking, the ICRP earlier recommended that inhaled particles be assumed to be 25 % exhaled, 50 % deposited in the upper respiratory passages (and subsequently swallowed) and that 25 % would be deposited in the lungs.[8] In either case it is also necessary to know in some detail the physico-chemical properties of the particles to estimate the rate of clearance from the deposition site.

4.1.2.5 *Qualification of sampling methods and equipment*

In each case, the sampling methods and equipment used should be carefully studied and tested to make certain that, in use, they will perform as intended. Leaktightness, general integrity, and general methods for sample handling must be thoroughly reviewed.

4.2 SAMPLE PROGRAMMING

Many factors enter into the design of a sampling programme. The sampling programme includes the frequency, duration, and volume rate of sampling. In most cases the selection of these three elements in programming will be a compromise between ideal values and those which provide adequate information for the evaluation of operational safety and yet are technically, economically, and conveniently achieved.

4.2.1 Sensitivity of detection and measurement

The sensitivity and accuracy of the analytical or counting method will determine the minimum volume of air which must be sampled to obtain the requisite accuracy and precision of results.

4.2.2 Permissible levels at point of sampling

The permissible concentration of the radionuclides of interest will also determine the minimum volume to be sampled. If possible, the sample should be large enough to permit one-tenth the permissible level to be determined with reliability. In some cases the sample must be sufficiently large to permit the effective measurement of activity levels equal to or less than the ambient levels (see also 4.2.4).

4.2.3 Radioactivity decay

The radioactive half-life of the nuclide to be measured is an important consideration. For short half-life materials the sampling period may be short with a large volume throughout and rapid measurement. An alternative procedure is to sample until the radioactive material collected has reached equilibrium. At such time the decay rate is equal to the accumulation rate. Evaluation requires a method of quantitation during or immediately following collection. Long-lived materials, being low in radioactivity per unit of mass, may require sampling of large volumes to achieve the necessary degree of accuracy using radiometric analyses.

4.2.4 Natural radioactive materials

The presence of natural radioactive materials of short half-life may mask the presence of significant quantities of longer-lived materials, necessitating delays between collection and counting, repeated counting at subsequent times, or special methods — for example, energy discrimination, pseudo-coincidence counting, or particle size discrimination sampling methods such as the annular impactor and particle size selective filter technique.[13, 14, 15, 16] (See 5.1.2.2.)

4.2.5 Specific nature of the operation or process

The nature of the operation which creates the potential for airborne radioactive materials may influence the sampling programme. An operation or process being instituted for the first time may require more frequent and extensive sampling than one which is well established and proven. The potential for release of radioactive material and the consequences of accidental air contamination must be considered in establishing frequency and duration of sampling.

When the purpose of sampling is to establish the total release of radioactive materials to the environment, the sampling programme must be designed to ensure obtaining an adequate sample during accidental releases. Under normal operations, intermittent, relatively infrequent sampling may be adequate, but when due account is taken of the off-standard or accident situation, it may be necessary to sample continuously. The relative levels of radioactivity contained in the sample during an accidental release must be anticipated. This consideration may influence the volume rate of sample withdrawal for non-standard situations. In some cases, two separate sampling systems may be justified, one to obtain a sample during non-routine high level releases, the other for day-to-day release evaluation. The collection method may also be different for the two purposes.

The unusual conditions following a serious radiation incident must be anticipated when sampling is required for assessing the levels of airborne radioactive materials present in an area affected by the incident. Representative samples from a contained atmosphere following a reactor accident must be obtained, for example. Sampling under adverse conditions must be anticipated and the necessary provisions designed into the system.

5 METHODS

The two forms of airborne radioactive materials are particles and gases; the particles can be solid or liquid, although particles are more generally considered to be very small fragments of solids. The sampling methods for airborne radioactive material can be discussed according to the application to gases or particulate material.

5.1 PARTICLES

5.1.1 Sample delivery

Principles concerning the removal of a representative portion of a contained stream as from a large duct have been presented. The sample line designed according to these principles will deliver a representative sample to the collector. For samples drawn from an atmosphere such as room air, delivery lines are not required.

5.1.2 Collectors

Various collectors are applicable to sampling airborne radioactive particulate material. Two general categories are :

1) gross particle collectors without significant size differentiation;

2) particle collectors with size differentiation.

5.1.2.1 *Collectors without significant particle size differentiation*

The careful evaluation of the radiological significance of airborne particles requires a knowledge of particle sizes and chemical nature of the material. This information may be determined in other than routine sampling. After such special studies have characterized the airborne material, subsequent particle collection without particle size differentiation may be performed provided that the operation creating the potential for airborne contamination is not changed significantly. At regular intervals and when any change is anticipated, the airborne material should be characterized as to physical and chemical nature. This procedure should also be adopted in the case of incidents because of the likelihood of a change in the general characteristics of the airborne contaminant and much higher levels leading to a risk of significant exposure.

5.1.2.1.1 FILTERS

Air filtration is most frequently employed in sampling atmospheres for radioactive particles. Filters are preferred because of the simplicity of the procedure and the equipment required. Filter media with a wide range of performance characteristics are commercially available so that a filter suitable to most air sampling programmes can usually be found. Collection of particles by a filter is achieved through one or more of the following mechanisms : direct interception, impaction, diffusion and electrostatic attraction. Although properties of the particles, filters and the sampling conditions determine which of these collection factors may be involved, for most filters impaction and diffusion are the predominant mechanisms to be considered. Collection by impaction increases with particle size and velocity, whereas diffusion (Brownian motion) is more effective for very small particles in air at low velocities.

For a given filter and a given face velocity there is theoretically a particle size for maximum penetration; particles larger or smaller than this size may be more efficiently collected. Filter efficiencies reported by filter manufacturers are usually based on tests with approximately 0,3 μm particles. This size aerosol can be larger by a factor of 2 to 5 than the most penetrating aerosol for some media and flow conditions. Reported efficiencies must be regarded as nominal values and in critical situations, more definitive efficiency measurements may be required. Since collection efficiencies so determined may differ from the efficiency for the actual aerosol, attention should be given to possible inaccuracies arising from this source. A filter efficiency of 100 % is not required, but it is necessary to know the efficiency for the particle size and flow rate selected, or to know that the efficiency will be equal to or greater than some minimum acceptable efficiency. In general, if a filter is reported to have a "high" efficiency, say greater than 99 %, it is less likely that its efficiency will be as sensitive to changes in particle sizes as a lower efficiency filter will be. Although there appear to be some different efficiencies reported by different experimenters, the ranking is frequently the same.

TABLE 1 — **Collection efficiency and flow resistance of selected air sampling filter media***

Filter class	Filter designation	Collection efficiency, % for retaining 0,3 μm DOP				Flow resistance, mmHg			
		velocity, cm/s				velocity, cm/s			
		10,7	26,7	53	106	35	53	71	106
Cellulose	Supplier A	64	72	84	98	24	36	48	72
	Supplier B	46	56	66	80	18	27	37	56
	Supplier C	62	74	86	98	23	40	48	81
Cellulose-asbestos	Supplier D	99,18	99,28	99,52	99,75	38	57	75	112
	Supplier E	96,6	98,2	99,2	99,8	44	64	87	127
Glass	Supplier F	99,968	99,932	99,952	99,978	20	30	40	61
	Supplier G	99,974	99,964	99,970	99,986	19	28	38	57
Membrane	Supplier H (Pore size 0,8 μm)	99,992	99,985	99,980	–	98	142	195	285
	Supplier G (Pore size 5 μm)	88	88	92	95	56	84	117	190

* L.B. Lockhart *et al.*, "Characteristics of Air Filter Media Used For Monitoring Airborne Radioactivity," NRL Report 6054, March 20, 1964.

In addition to differing in collection efficiency, filter media differ with respect to air flow resistance, wet and dry strength, surface roughness, and ease of chemical dissolution in leaching. These properties may be of greater or lesser significance and the particular application must be carefully considered in a choice of filter media. Often the choice of filter must represent a compromise among these factors. Filter selection is usually made from five filter classes : cellulose, cellulose-asbestos, glass fibre, synthetic fibre, and membrane. Characteristics of some typical filter media are shown in table 1.

5.1.2.1.1.1 Cellulose

Cellulose filters of the type common to analytical chemistry are made from purified cellulose pulp. Consequently, such filters have a low ash content and are easily decomposed by chemical treatment (oxidizing acids). They have a relatively low resistance to air flow but are susceptible to increase in flow resistance due to dust loading. Collection efficiency is velocity-dependent and these filters must be operated at a velocity yielding the required efficiency. High velocities are required for best performance. Burial of radioactive particles within the filter medium is significant and, as a result, the cellulose papers are not well suited for detection of α-emitting radionuclides by direct counting. Cellulose filters are strong and are not easily damaged in handling. Among the five filter groups they are the least expensive.

5.1.2.1.1.2 Cellulose-asbestos

When mineral fibres such as asbestos are mixed with cellulose, the resulting filter exhibits improved collection efficiency and greater chemical resistance.

Because the asbestos content is significant, special chemical treatment is required for filter dissolution. Consequently, cellulose-asbestos filters are usually restricted to those air monitoring programmes where radiochemical separations are not involved. The cellulose-asbestos filters are not easily damaged in handling and are widely used in air sampling.

5.1.2.1.1.3 Glass fibre

Filter mats of fine glass fibres can have high collection efficiency and lower burial losses than do the cellulose-asbestos filters. An outstanding feature of these filters is that this increased collection efficiency is not accompanied by increased air flow resistance. Glass filters may be used at higher temperatures than cellulose or cellulose-asbestos filters. Relative fragility and low resistance to hydrofluoric acid are the principal shortcomings of this medium. Their general chemical inertness is an advantage when digestion is required since the collection material may be dissolved without dissolving the filter.

Small amounts of ^{40}K may be found in glass fibre filters. For extremely low levels of α-emitters, account should be taken of possible contribution from this source.

5.1.2.1.1.4 Synthetic fibre

Various organic-based fibres are available and these may be incorporated into filters having specific properties determined by the fibre composition and diameter. Fluorocarbons, polypropylene, nylon, and other fibres may find application as filter media.

5.1.2.1.1.5 Membrane filters

Membrane filters are porous dry gels of cellulose esters, usually produced as the acetate or nitrate. Structure and pore size can be controlled over a wide range by the production processes. Filters are commercially available in pore sizes (diameters) ranging from about 10 nm to 10 μm. These filters are completely soluble in many organic solvents and can be decomposed easily by oxidizing acids. Membrane filters with sub-micrometre pore diameters have the highest collection efficiency of the four filter surfaces, so that burial losses are minimal. Because of the fragility of membrane filters, they require special support in the filter holder and must be handled with care during sample changing. The principal shortcoming of these filters is their relatively high resistance to air flow, and to obtain the required sample volume may require unreasonably long sampling periods, or air movers of a type or size that are impractical for the programme.

Large-pore membrane filters — those with pore diameters greater than 1 μm — retain the high surface collection efficiency of the sub-micrometre filters, but offer considerably lower flow resistance. Particle penetration through the large-pore filters is higher than through cellulose-asbestos or glass-fibre filters. However, large-pore membrane filters are well suited to sampling of α-particle emitting radionuclides, because lower collection efficiency is more than offset by the fact that those particles that are retained are not lost by burial in the medium.

5.1.2.1.1.6 Metallic filters

Filters are available which are very thin films of porous metal. These will find use in special applications; for example, a pure silver filter may be used to trap particles and molecular iodine simultaneously.

5.1.2.1.1.7 Related equipment for filter sampling

5.1.2.1.1.7.1 Filter support

The filter media must be supported in a well-designed filter holder.

Features to be included in the design :

1) A porous backing screen or plate. The filter contacting surface should be smooth, flat, and free from burrs and sharp edges. In some instances of small area filters when the strength of the filter medium is adequate, the porous backing plate may be omitted. This will be the exceptional case rather than the rule.

2) A compression sealing ring designed to press the perimeter of the filter against the backing support and ensure an airtight seal is an important requirement. Various compressible materials, such as plastics and rubber, are useful. Pressure on the seal must be uniform through using well-designed clamps, cams, or other compression closure mechanisms.

3) The filter support must be easily opened and closed to facilitate filter changes.

4) Material of the filter support must be corrosion resistant to the atmosphere where the sample is to be taken.

5) A sampler with a filter strip moved continuously or intermittently will require a more complex filter support and sealing mechanism. Commercial designs anticipated for use should be carefully reviewed for the integrity of the filter media sealing, the filter advance mechanism, and the flexibility in programming.

6) In special circumstances it may be necessary to provide a mesh screen preceding the filter. The screen will collect from the air insects, leaves, or other debris not representative of the aerosol of interest.

5.1.2.1.1.7.2 Air movers

Air samples may be drawn through the collector by any of a variety of air movers. The prime requirement is that the air mover deliver the necessary air flow against the resistance of the sampling system. Positive displacement pumps such as the rotary vane type or the lobe (gear type) impeller pumps find great favour since they will maintain a more nearly constant flow even when the pressure drop changes. When the pressure drop across the collector is quite small, centrifugal blowers or high speed turbine blowers will prove useful. This type of air mover must be selected and used with regard for the flow-pressure drop characteristics of this unit. By nature of the design, these air movers will displace large volumes of air when free-running (very little pressure drop) but the flow will decrease materially when they operate against a pressure drop. Increased pressure drop resulting from ambient dust clogging the filter will rapidly reduce the flow rate.

Venturi-type, air driven aspirators find use in special applications. In locations in which electrical power may not be available, cylinders of compressed air or other gas may be used to operate the air aspiration sampler. In applications in which mechanical pumps may prove expensive and difficult to maintain, for example where highly corrosive gases are to be sampled, a steam jet ejector for obtaining the pressure drop for sampling proves very practical.

In applications for which a self-contained air mover is desirable, for example for personal air sampling, positive displacement pumps powered by rechargeable batteries have proved to be very suitable.

In an installation in which sampling from many locations is anticipated, a central vacuum system designed exclusively for this purpose is recommended. The vacuum system should be engineered to provide a vacuum pump and receiver large enough to provide for simultaneous sampling at the design rate from all sample collectors on the system.

An important consideration is the noise in the work location resulting from the air and the air mover itself. Due attention should be given to noise specifications and permissible levels at the work location.

5.1.2.1.1.7.3 Flow-measuring devices

The flow rate must be measured to determine the airborne radioactive material concentration and to ensure that the collector is being operated at its design flow rate. The most frequently used flow instrument is probably the "rotameter", a variable orifice device. Venturi meters, fixed orifices, vane anemometers and pitot tubes may be used within their limitations. Flow integrators, such as displacement meters, prove useful when variable sampling rates during long periods are anticipated. All devices should be calibrated to the requisite accuracy under the conditions of use, using a standard instrument.

Flow-measuring instruments should in every case possible be located on the downstream (lower pressure) side of the collector. With this location, particles and vapour deposition in the flow-measuring instrument will not lower the apparent concentration, and the flow meter will be maintained essentially clean. In these cases the flow meter will be metering air at less than atmospheric pressure. Proper correction to the volume through the collector may thus be required, or accounted for in the calibration.

5.1.2.1.1.7.4 Flow rate control

Provisions must be made for adjusting the sampling rate to the required value. In most instances, a control valve placed in the line between the air mover and the collector will serve this purpose. A by-pass valve may be needed when the air mover is operating well below its rating and the additional air intake is required for cooling the pump. The by-pass valve can be manually controlled or may be a ball check valve with adjustable tension on the check valve seating spring.

Critical orifices placed in the line downstream of the collector act to provide a fixed flow and can be used. Adequate pressure drop to achieve critical flow through the orifice must be ensured by the air mover selected.

In some cases rates can be varied and controlled by changing the pump motor speed. This can be accomplished by adjusting the input voltage on universal type motors.

The gradual build-up of dust on a filter during a long sampling period acts to decrease the flow through the filter. The significance of this decrease is a function of air mover characteristics and the dust loading on the filter. Averaging the initial and final flow rates during a sampling period may give a reasonably accurate average if it can be shown that the increase has been linear with time. Flow rate recorders and integrators can be used to establish total sample size and are recommended. Flow integrators are particularly useful during long sampling periods during which flow may