

Asbestos

Analytical Monitoring

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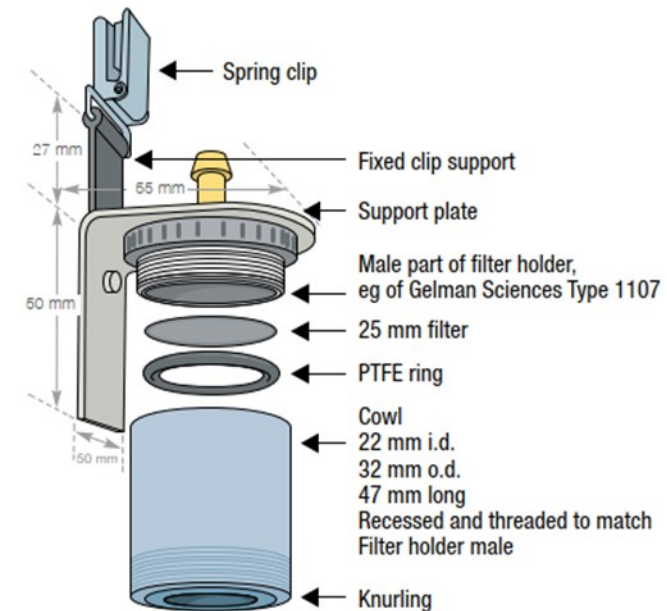
Principle

- A measured volume of air is drawn through a membrane filter (usually 480 litres for a static sample e.g. clearance)
- Filter is rendered transparent and mounted on to a slide
- Slide is analysed using a phase contrast microscope (PCM)
- Number of fibres in a known area (graticule) are counted
- Usually 200 graticules counted
- Concentration calculated for the volume of air sampled and presumed to be indicative of the fibre concentration generally

Types of Samples

- Static:
 - Background – Usually refers to monitoring carried out before an activity
 - Reassurance – Usually refers to monitoring carried out after an activity
 - Leak – Carried out outside an enclosure during removal to check confirm the integrity of an enclosure
 - Clearance – The 3rd Stage of 4-Stage Clearance
 - Near Source (new to me!) – Investigating sources of release e.g. power station
 - Far Source (also new to me) – Reassurance or checking purposes e.g. perimeter monitoring of contaminated land (Increased volume of air required as fibre concentration expected to be low)
- Personal:
 - Control Limit (4-hour)
 - Short-term exposure limit (10-min)
 - Assessment of suitability of RPE

Taking a Sample - Preparation of Filter



Taking a Sample

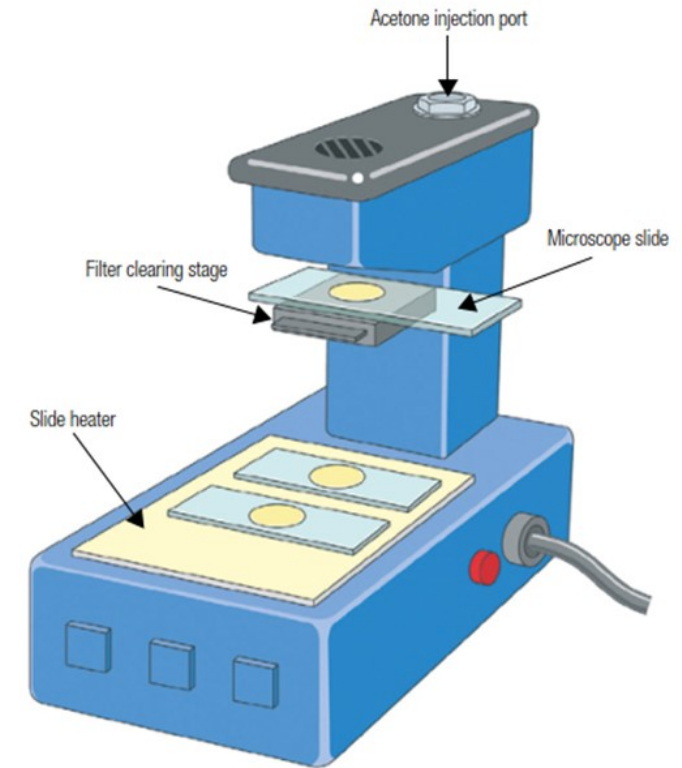
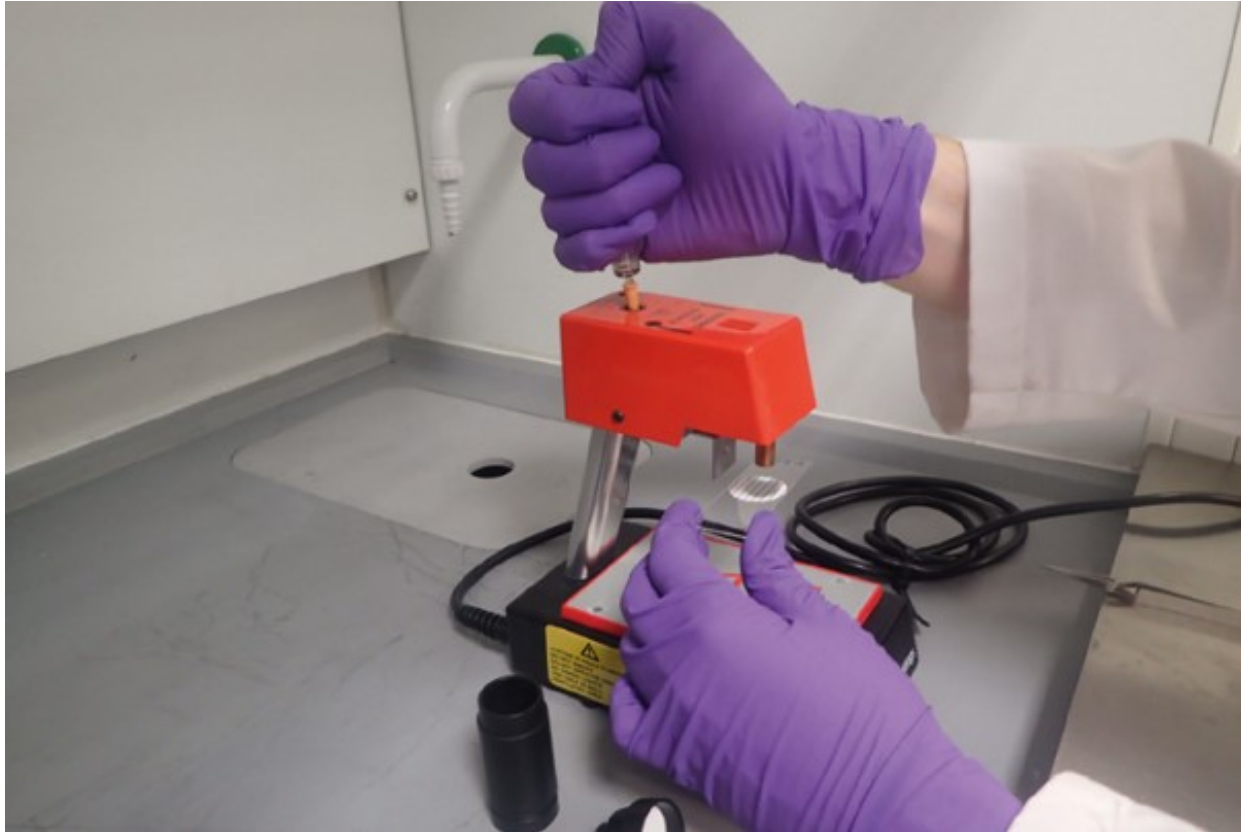


- Record:
 - Sample reference number
 - Cowl and pump reference
 - Location of sample
 - Name of operative and activity for personal samples
 - Sample start time and flow rate
 - Sample end time and flow rate
 - (i.e. to calculate volume)
 - Older samples may have recorded temperature and pressure for variation in air density and therefore flow rate – no longer required under normal operating conditions in UK

Recommended Sampling Parameters

Application	Sampling rate (litres/min)	Minimum volume of air to be sampled onto 25 mm diameter filter (litres)	Minimum number of graticule areas to be examined	Calculated airborne concentration at the LOQ (20 fibres counted) (f/ml)
Personal sampling				
4-hour control limit	1–2	240	100	0.04
10-minute short-term exposure limit	4	40	100	0.24
Specific short-duration activities ¹	2–4	120	100	0.08
Assessment of suitability of RPE ²	>0.2–4	40	100	0.24
Static sampling				
Clearance indicator ³	0.5–16	480	200	0.010
Background ⁴				
Leak ⁴				
Reassurance ⁴				
Near source ⁴				
Far source/perimeter ⁴	0.5–16	960	200	0.005

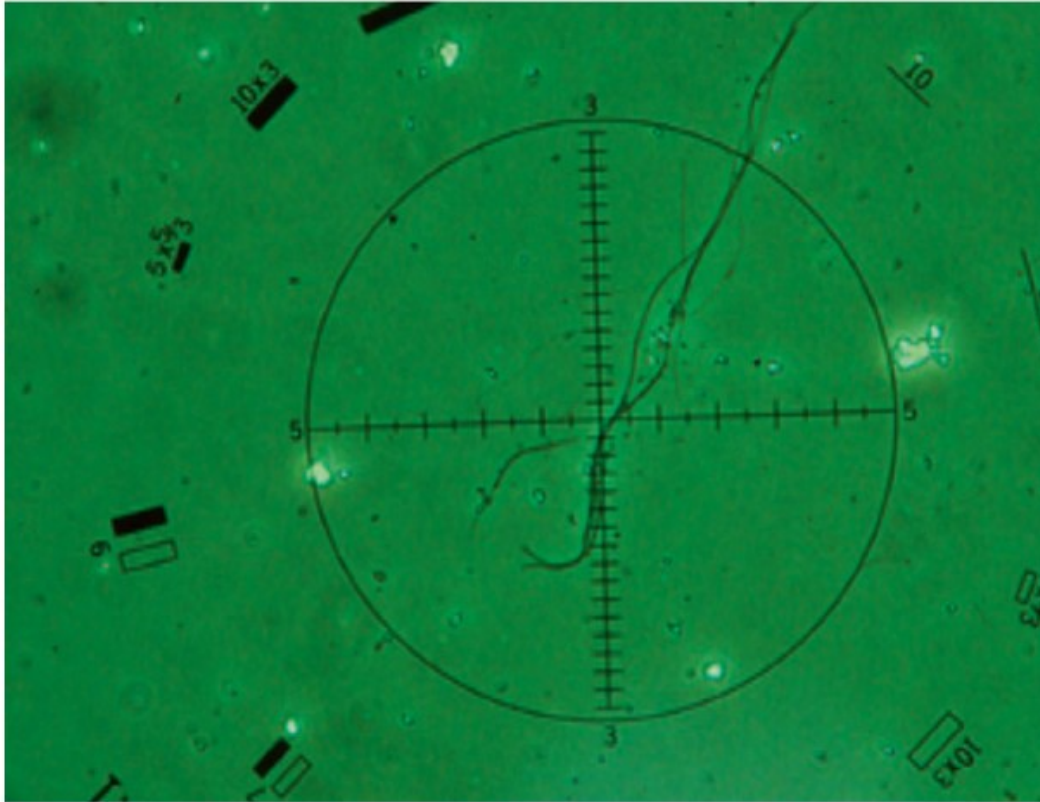
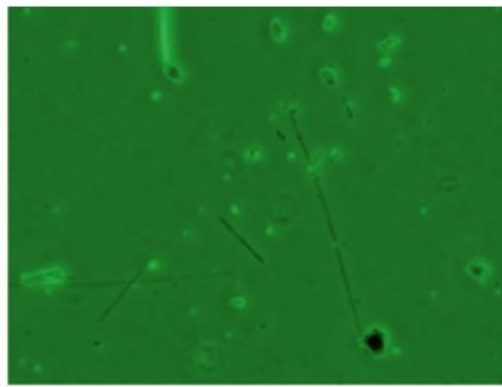
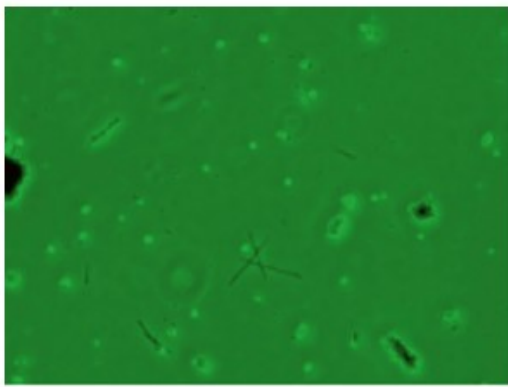
Mounting the Filter



Analysing the Sample - PCM

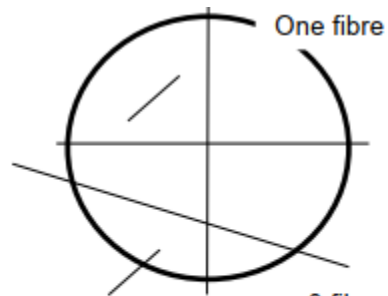


- Counter in each hand, recording number of fields counted on one and number of fibre ends on the other
- HSE advise it may take 10 – 15 minutes to count one sample with a sparse dust deposit, but longer for 'more difficult samples'
- HSE advise one analyst should not exceed 2400 fields in one day, equivalent to 12 samples if counting 200 fields

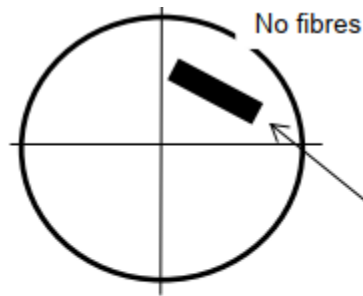


- Filter should be scanned under low power objective to ensure even distribution of fibres
- 40X objective then used to count fibres (with a 12.5X eyepiece) giving a total magnification of 500X

Counting Rules



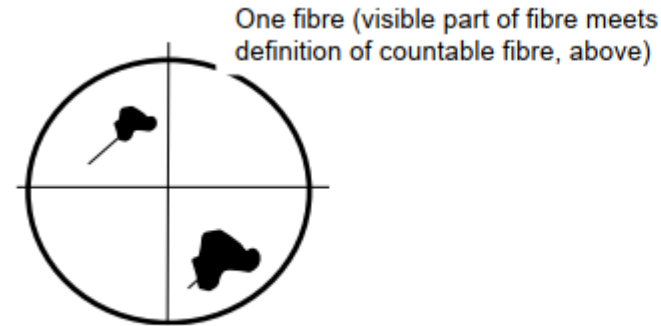
1/2 fibre
(only one
fibre end
in)



0 fibres (no
fibre ends in)

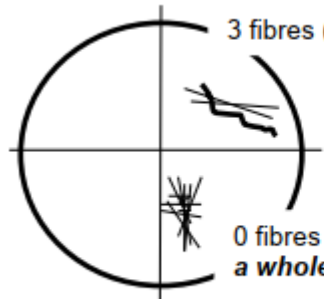
A countable fibre
must be:
>5µm long;
<3µm wide;
>3 times longer,
than it is wide.

This fibre is too
wide!

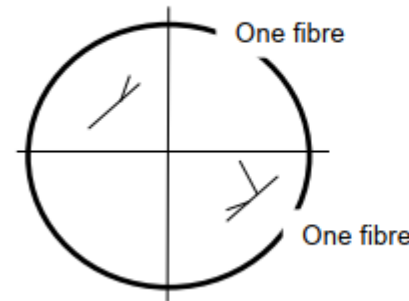


0 fibres (visible part of fibre does
not meet definition of countable
fibre, above)

More than 1/8 of the graticule area is
obscured by an agglomerate of fibre
and/or particles – **REJECT FIELD**



0 fibres (fibres not reasonably individually distinguishable, and **bundle as a whole** does not meet the definition of a countable fibre).



Split fibre – a **countable** fibre (as above) that at one or more points of its length appears undivided, but at other points appears to divide into separate strands.

The width is measured across the undivided part.

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Airborne Fibre Monitoring Results

Sample No.	Cowl No.	Pump No.	Test Type	Location/Name	Time On	Time Off	Start Flow (l/min)	Final Flow (l/min)	Average Flow (l/min)	Volume Sampled (Litres)
	369		FB	FIELD BLANK						
1	354	21	BT	Adjacent works on the ground floor during the removal of fire door	09:24	10:24	8.0	8.2	8.1	486
2	266	70	BT	Adjacent works on the first floor during the removal of fire door	09:28	10:28	8.0	8.0	8.0	480
3	368	82	BT	Adjacent works on the first floor during the removal of fire door	09:31	10:31	8.0	8.0	8.0	480
4	356	56	PM	On [REDACTED] during the removal of fire door on the first floor	09:33	10:33	2.0	2.0	2.0	120
5	366	21	RT	Adjacent works on the ground floor following the removal of fire door	11:21	12:21	8.0	8.0	8.0	480
6	367	70	RT	Adjacent works on the first floor following the removal of fire door	11:25	12:25	8.0	8.4	8.2	492
7	371	82	RT	Adjacent works on the first floor following the removal of fire door	11:28	12:28	8.0	8.0	8.0	480
							END OF TESTS			

- Fibre counts are typically recorded in tabular format as shown here
- Generally handwritten until the last few years
- Be cautious where all samples start exactly on the hour, are exactly 60 minutes and 480 litres

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Recording the Results

Airborne Fibre Monitoring Results										
Sample No.	Cowl No.	Pump No.	Test Type	Location/Name	Time On	Time Off	Start Flow (l/min)	Final Flow (l/min)	Average Flow (l/min)	Volume Sampled (Litres)
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							END OF TESTS			

- Fibre counts are typically recorded in tabular format as shown here
- Generally handwritten until the last few years
- Be cautious where all samples start exactly on the hour, are exactly 60 minutes and 480 litres

Early References to Limit of Quantification

- No limit of quantification given in ARC Technical Note 1.
 - Said to be *“generally only suitable for measuring concentrations in factories, workshops and constructions sites”*
 - Does this imply not suitable for lower concentrations?
- EH 10 (1984)
 - Lower limit of measurement about 0.01 fibres/ml for phase contrast microscopy
 - No explanation as to why this is about the lower limit
- MDHS 39 (1984)
 - Provides some information in relation to accuracy and precision but this guidance was *“intended for personal sampling measurements in relation to the control limits and is not necessarily suitable for other purposes”* (0.2 fibres/ml 4-hour TWA for crocidolite/amosite, 0.5 fibres/ml for chrysotile)

Limit of Detection and Limit of Quantification HSE

A1.7 Particles sampled onto a filter have at best a random distribution. This means that the precision of the count is limited by the underlying Poisson statistics. The precision is usually expressed in terms of the confidence interval, which defines the upper and lower limits expected for a defined percentage of repeat counts. For example, 95% confidence limits mean that on average 19 of the 20 values from repeat counts on different areas of the same filter would be within the upper and lower limits. For low counts the lower confidence limit is 0, so a one-sided upper

95% confidence interval is used. For a count of 0 it is 95% probable that the true number is <3 fibres. Using the formula given in A1.41, the analytical sensitivity (based on counting one half-fibre in 200 graticule areas (the lowest count possible above zero), a sample volume of at least 480 litres and an effective diameter greater than 20 mm) is between 0.0002 and 0.0003 f/ml. However, due to the presence of some fibres on blank tested filters, the limit of detection (LOD) is ~0.003 f/ml and the limit of quantification (LOQ) of the method is 0.010 f/ml. This is equivalent to a count of 40 fibre ends (20 fibres) in 200 graticule areas on a 480-litre sample. In dusty

environments it may only be possible to sample one-tenth of the volume of air so these values will be increased by a factor of 10. In clean environments with very low levels of dust it may be possible to sample a factor of 10 or more and reduce these values accordingly.

Confusing guidance on LOD and LOQ...

HSG248 (2021):

Box A1.4 Examples of limit of detection calculations for airborne asbestos concentrations

Example 1

A sample with a volume of 120 litres and 200 graticule areas counted has a detection limit of:

$$\frac{96,000}{120 \times 200} \times 0.01 = 0.04 \text{ f/ml}$$

Example 2

A sample with a volume of 240 litres and 200 graticule areas counted has a detection limit of:

$$\frac{96,000}{240 \times 200} \times 0.01 = 0.02 \text{ f/ml}$$

Example 3

Fifteen fibres were counted in 100 graticule areas, the graticule diameter was 98 µm, the exposed filter diameter was 22.0 mm and the sample volume was 240 litres.

The fibre concentration is calculated as:

$$1000 \times 15 \times 22^2 / 240 \times 100 \times 98^2 = 0.031 = 0.03 \text{ f/ml}$$

The detection limit for this sample is calculated as:

$$\frac{96,000}{120 \times 200} \times 0.01 = 0.04 \text{ f/ml}$$

A1.49 The analytical report or certificate should include the information listed in Table A1.1.

Table A1.1 Information to be included in the analytical report

Area	Details to be included
General details	Name or letterhead of the organisation carrying out the work
	Full postal address of the organisation and other electronic contacts
	UKAS accreditation symbol and number (and any appropriate disclaimer)
	Printed name(s) of the person(s) who carried out the work
	Printed name and signature of the person who authorised the release of the report (this may be the same person who carried out the work)
	Date the report was authorised for release
	A suitable report identifier or number
Sampling information	Location/s of the sampling (eg name and address)
	Date of sampling
	Type of sampling being carried out
	Sampling information for each sample including: <ul style="list-style-type: none"> ■ a unique identifier (eg sample number) ■ type of sample (eg personal or static and compliance, background, clearance) ■ position of the sample (eg the name of the person or location) ■ sampling time started and ended for each period ■ sampling flow rate ■ calculated volume of air sampled ■ reference to any specific activities or events taking place during the sampling (eg during demolition, immediately after demolition) ■ for personal sampling, contextual information is also required (see paragraphs 5.6–5.7). Personal data should be collected on template A6.3
Other details	Method of analysis used and for each sample
	Sample number
	Volume of each sample (if not given elsewhere)
	Number of fibres counted
	Number of graticule areas counted
	Calculated fibre concentration to three decimal places
	Reported fibre concentration (rounded down as appropriate)
	Limit of quantification

Confusing guidance on LOD and LOQ...

HSG248 (2021):

Box A1.4 Examples of limit of detection calculations for airborne asbestos concentrations

Example 1

A sample with a volume of 120 litres and 200 graticule areas counted has a detection limit of:

$$\frac{96,000}{120 \times 200} \times 0.01 = 0.04 \text{ f/ml}$$

Example 2

A sample with a volume of 240 litres and 200 graticule areas counted has a detection limit of:

$$\frac{96,000}{240 \times 200} \times 0.01 = 0.02 \text{ f/ml}$$

Example 3

Fifteen fibres were counted in 100 graticule areas, the graticule diameter was 98 µm, the exposed filter diameter was 22.0 mm and the sample volume was 240 litres.

The fibre concentration is calculated as:

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4-hour control limit	1–2	240	100	0.04
10-minute short-term exposure limit	4	40	100	0.24
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Assessment of suitability of RPE ²	>0.2–4	40	100	0.24
Static sampling				
Clearance indicator ³	0.5–16	480	200	0.010
Background ⁴				
Leak ⁴				
Reassurance ⁴				
Near source ⁴				
Far source/perimeter ⁴	0.5–16	960	200	0.005

A1.49 The analytical report or certificate should include the information listed in Table A1.1.

- If 480 litres and 200 fields (graticules) provides a limit of quantification of 0.01 fibres/ml, then the following equation (ratio?) is derived to calculate limit of quantification for different volumes and/or graticule counts:

- $\frac{96,000}{480 \times 200} \times 0.01 = 0.01$

- $\frac{960}{\text{Volume} \times \text{Graticules}} = \text{limit of quantification}$

Calculating the Limit of Quantification

Airborne Fibre Monitoring Results										
Sample No.	Cowl No.	Pump No.	Test Type	Location/Name	Time On	Time Off	Start Flow (l/min)	Final Flow (l/min)	Average Flow (l/min)	Volume Sampled (Litres)
	369		FB	FIELD BLANK						
1	354	21	BT	Adjacent works on the ground floor during the removal of fire door	09:24	10:24	8.0	8.2	8.1	486
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3	368	82	BT	Adjacent works on the first floor during the removal of fire door	09:31	10:31	8.0	8.0	8.0	480
4	356	56	PM	On [REDACTED] during the removal of fire door on the first floor	09:33	10:33	2.0	2.0	2.0	120
5	366	21	RT	Adjacent works on the ground floor following the removal of fire door	11:21	12:21	8.0	8.0	8.0	480
6	367	70	RT	Adjacent works on the first floor following the removal of fire door	11:25	12:25	8.0	8.4	8.2	492
7	371	82	RT	Adjacent works on the first floor following the removal of fire door	11:28	12:28	8.0	8.0	8.0	480
							END OF TESTS			

- Volume = 486 litres
- To achieve a limit of quantification of 0.01:
- $960/(\text{volume} \times \text{graticules}) = 0.01$
- $960/(486 \times 0.01) = \text{number of graticules} = 197.5$
- Therefore, rather than 200 graticules, 198 graticules are needed to be counted to achieve a limit of quantification of 0.01 fibres/ml

Airborne Fibre Monitoring Results													
Sample No.	Cowl No.	Pump No.	Test Type	Location/Name	Time On	Time Off	Start Flow (l/min)	Final Flow (l/min)	Average Flow (l/min)	Volume Sampled (Litres)	Fibres Counted	Fields Counted	Limit of Detection (fibres/ml)
	369		FB	FIELD BLANK							*	*	
1	354	21	BT	Adjacent works on the ground floor during the removal of fire door	09:24	10:24	8.0	8.2	8.1	486	1.5	198	0.010
2	266	70	BT	Adjacent works on the first floor during the removal of fire door	09:28	10:28	8.0	8.0	8.0	480	2.0	200	0.010
3	368	82	BT	Adjacent works on the first floor during the removal of fire door	09:31	10:31	8.0	8.0	8.0	480	0.5	200	0.010
4	356	56	PM	On [REDACTED] during the removal of fire door on the first floor	09:33	10:33	2.0	2.0	2.0	120	3.5	200	0.010
5	366	21	RT	Adjacent works on the ground floor following the removal of fire door	11:21	12:21	8.0	8.0	8.0	480	1.0	200	0.010
6	367	70	RT	Adjacent works on the first floor following the removal of fire door	11:25	12:25	8.0	8.4	8.2	492	0.5	196	0.010
7	371	82	RT	Adjacent works on the first floor following the removal of fire door	11:28	12:28	8.0	8.0	8.0	480	1.0	200	0.010
							END OF TESTS						

Calculating the Concentration

- Earliest documented method for calculating asbestos concentrations in guidance (that I am aware of) was the ARC's Technical Note 1 (1969).
- Method for calculating the dust concentration is essentially the same as defined by the ARC in the late 1960s (difference being due to units of volume):

8 Evaluation of Results

8.1 Dust concentration is determined from the total fibre count above 5 μ in length.

8.2 If the diameter of the dust deposit = D and the diameter of each field of

view = d, then the dust concentration = $\frac{D^2}{d^2} \times \frac{N}{n} \times \frac{1}{V}$ (fibres per cc),

where V = volume of sample (cc),

N = number of fibres counted,

n = number of fields examined.

$$C = 1000 N D^2 / V n d^2 \text{ (Equation 1)}$$

Where: N is the number of fibres counted;
n is the number of graticule areas examined;
D (mm) is the diameter of the exposed filter area;
d (μ m) is the diameter of the Walton-Beckett graticule;
V (litres) is the volume of air sampled through the filter.

ARC Technical Note 1 (Revised 1969)

HSE HSG248 (2021)

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- Although difference between parameters:

ARC 1969

- Advised to count fields until “about 200” fibres are counted or 100 fields in sparse distribution of fibres
- Advised to sample:
 - 10 – 20 litres where concentration is expected to be less than 2 fibres/ml
 - 5 – 10 litres for 2 – 4 fibres/ml
 - 2 – 5 litres for 4 – 12 fibres/ml
 - “pro rata” for greater than 12 fibres/ml

HSE 2021

- Count 200 fields or 100 fibres (and at least 20 fields)
- Must sample:
 - 480 litres for static samples
 - 240 litres for personal sample to measure against 4-hour control limit
 - 40 litres for personal sample to measure against 10-min exposure limit
- Number of fields counted can be increased to increase sensitivity but *“the occurrence of blank PCM fibre count and counter fatigue means that it is often a better strategy to adjust the volume of air sampled to give an appropriate filter loading”*.

Calculating the Concentrations

Airborne Fibre Monitoring Results													
Sample No.	Cowl No.	Pump No.	Test Type	Location/Name	Time On	Time Off	Start Flow (l/min)	Final Flow (l/min)	Average Flow (l/min)	Volume Sampled (Litres)	Fibres Counted	Fields Counted	Limit of Detection (fibres/ml)
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2	266	70	BT	Adjacent works on the first floor during the removal of fire door	09:28	10:28	8.0	8.0	8.0	480	2.0	200	0.010
3	368	82	BT	Adjacent works on the first floor during the removal of fire door	09:31	10:31	8.0	8.0	8.0	480	0.5	200	0.010
4	356	56	PM	On 2nd floor during the removal of fire door on the first floor	09:33	10:33	2.0	2.0	2.0	120	3.5	200	0.010
5	366	21	RT	Adjacent works on the ground floor following the removal of fire door	11:21	12:21	8.0	8.0	8.0	480	1.0	200	0.010
6	367	70	RT	Adjacent works on the first floor following the removal of fire door	11:25	12:25	8.0	8.4	8.2	492	0.5	196	0.010
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							END OF TESTS						

Calculating the Concentrations

Sample No.	Cowl No.	Pump No.	Test Type	Location/Name	Time On	Time Off	Start Flow (l/min)	Final Flow (l/min)	Average Flow (l/min)	Volume Sampled (Litres)	Fibres Counted	Fields Counted	Limit of Detection (fibres/ml)
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$$C = 1000 N D^2 / V n d^2 \text{ (Equation 1)}$$

Where: N is the number of fibres counted;
 n is the number of graticule areas examined;
 D (mm) is the diameter of the exposed filter area;
 d (µm) is the diameter of the Walton-Beckett graticule;
 V (litres) is the volume of air sampled through the filter.

$$C = \frac{1000 \times 1.5 \times 22^2}{486 \times 198 \times 100^2}$$

$$= 0.0003 \text{ fibres/ml}$$

However, limit of quantification is 0.01 fibres/ml

Therefore, reported result is <0.01 fibres/ml

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Calculating all concentrations, you end up with a report that looks something like this:

Technical Measurement Data				Equipment variations(additions to kit number - strike through where not applicable)								Key:Test Type		
Air Monitoring Kit Number				Equipment	URN	Equipment	URN	Equipment	URN			FB	Field Blank	
Site Temperature (°K)		*		Microscope	*	Tally Counter	*	Static Pump	*			CT	Clearance	
Atmospheric pressure (mbar)		*		Stage Micrometer	*	Tally Counter	*	Static Pump	*			RT	Reassurance	
Walton Beckett Graticule Diameter (µm)		100		NPL Test Slide	*	Flow Meter	*	Static Pump	*			BT	Background	
Exposed filter diameter (mm)		22		Stop Watch	*	Flow Meter	*	Static Pump	*			LT	Leak	
NPL test slide blocks required / observed		5/5		Barometer	*	Personal Pump	*	Static Pump	*			PM	Personal	
Airborne Fibre Monitoring Results														
Sample No.	Cowl No.	Pump No.	Test Type	Location/Name	Time On	Time Off	Start Flow (l/min)	Final Flow (l/min)	Average Flow (l/min)	Volume Sampled (Litres)	Fibres Counted	Fields Counted	Limit of Detection (fibres/ml)	Fibre Concentration (fibres/ml)
	369		FB	FIELD BLANK							*	*		
1	354	21	BT	Adjacent works on the ground floor during the removal of fire door	09:24	10:24	8.0	8.2	8.1	486	1.5	198	0.010	<0.01
2	266	70	BT	Adjacent works on the first floor during the removal of fire door	09:28	10:28	8.0	8.0	8.0	480	2.0	200	0.010	<0.01
3	368	82	BT	Adjacent works on the first floor during the removal of fire door	09:31	10:31	8.0	8.0	8.0	480	0.5	200	0.010	<0.01
4	356	56	PM	On Zach Jenkins of LAR during the removal of fire door on the first floor	09:33	10:33	2.0	2.0	2.0	120	3.5	200	0.010	<0.04
5	366	21	RT	Adjacent works on the ground floor following the removal of fire door	11:21	12:21	8.0	8.0	8.0	480	1.0	200	0.010	<0.01
6	367	70	RT	Adjacent works on the first floor following the removal of fire door	11:25	12:25	8.0	8.4	8.2	492	0.5	196	0.010	<0.01
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							END OF TESTS							

Be wary of potential errors when reviewing analytical monitoring records...

Technical Measurement Data		Equipment variations (additions to kit number - strike through where not applicable)						Key: Test Type	
Air Monitoring Kit Number		Equipment	URN	Equipment	URN	Equipment	URN	FB	Field Blank
Site Temperature (°K)	*	Microscope	*	Tally Counter	*	Static Pump	*	CT	Clearance
Atmospheric pressure (mbar)	*	Stage Micrometer	*	Tally Counter	*	Static Pump	*	RT	Reassurance
Walton Beckett Graticule Diameter (µm)	100	NPL Test Slide	*	Flow Meter	*	Static Pump	*	BT	Background
Exposed filter diameter (mm)	22	Stop Watch	*	Flow Meter	*	Static Pump	*	LT	Leak
NPL test slide blocks required / observed	5/5	Barometer	*	Personal Pump	*	Static Pump	*	PM	Personal

Airborne Fibre Monitoring Results														
Sample No.	Cowl No.	Pump No.	Test Type	Location/Name	Time On	Time Off	Start Flow (l/min)	Final Flow (l/min)	Average Flow (l/min)	Volume Sampled (Litres)	Fibres Counted	Fields Counted	Limit of Detection (fibres/ml)	Fibre Concentration (fibres/ml)
	369		FB	FIELD BLANK							*	*		
1	354	21	BT	Adjacent works on the ground floor during the removal of fire door	09:24	10:24	8.0	8.2	8.1	486	1.5	198	0.010	<0.01
2	266	70	BT	Adjacent works on the first floor during the removal of fire door	09:28	10:28	8.0	8.0	8.0	480	2.0	200	0.010	<0.01
3	368	82	BT	Adjacent works on the first floor during the removal of fire door	09:31	10:31	8.0	8.0	8.0	480	0.5	200	0.010	<0.01
4	356	56	PM	On during the removal of fire door on the first floor	09:33	10:33	2.0	2.0	2.0	120	3.5	200	0.010	<0.04
5	366	21	RT	Adjacent works on the ground floor following the removal of fire door	11:21	12:21	8.0	8.0	8.0	480	1.0	200	0.010	<0.01
6	367	70	RT	Adjacent works on the first floor following the removal of fire door	11:25	12:25	8.0	8.4	8.2	492	0.5	196	0.010	<0.01
7	371	82	RT	Adjacent works on the first floor following the removal of fire door	11:28	12:28	8.0	8.0	8.0	480	1.0	200	0.010	<0.01
END OF TESTS														

Should include column of calculated result before reporting fibre concentration