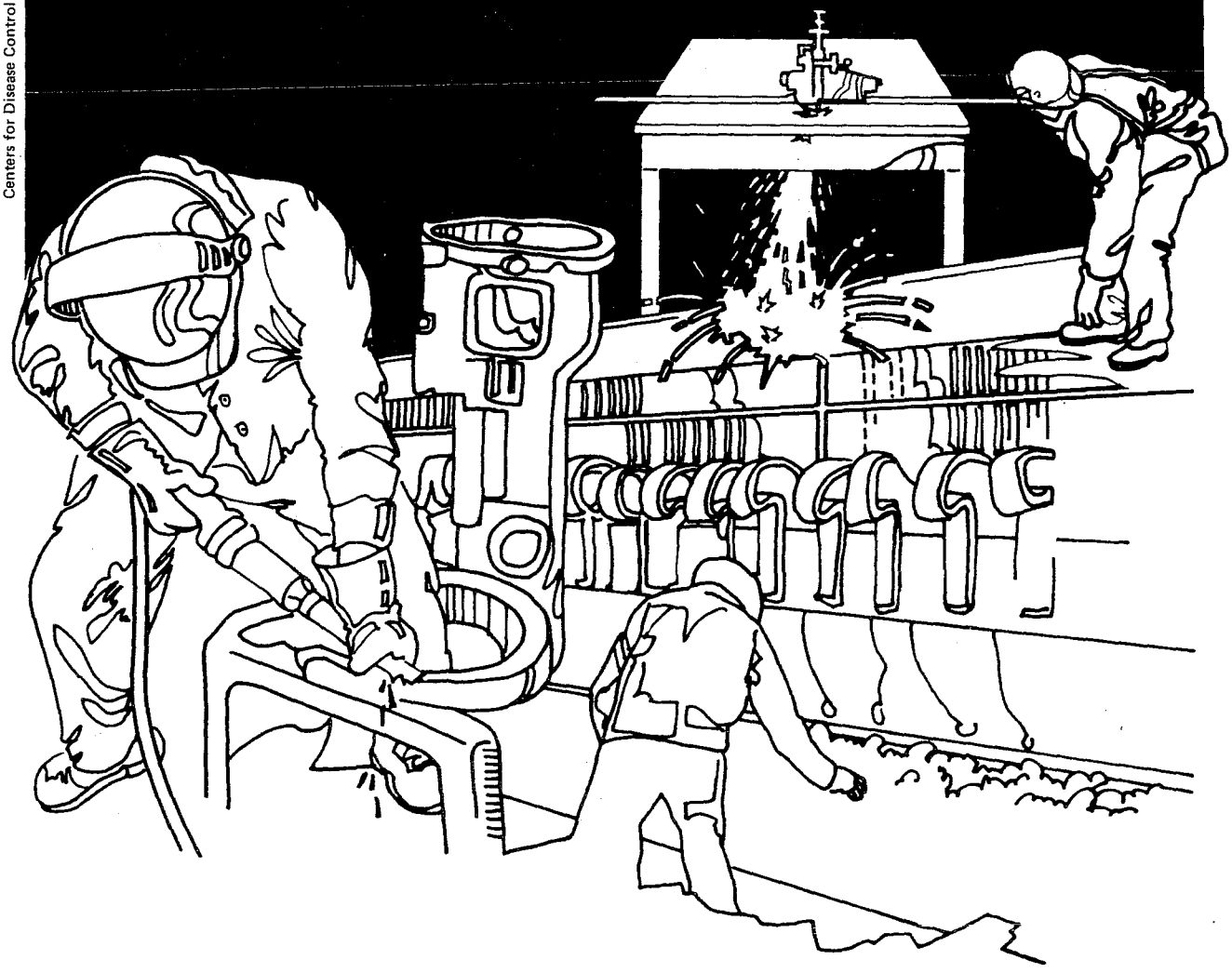
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

NIOSH



Health Hazard Evaluation Report

HETA 84-408-1522
U.S. FOREST SERVICE
REDDING, CALIFORNIA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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OCTOBER, 1984
U.S. FOREST SERVICE
REDDING, CALIFORNIA

NIOSH INVESTIGATOR:
PIERRE L. BELANGER, I.H.

I. SUMMARY

In June, 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the U.S. Forest Service. The forest ranger at the Shasta-Trinity National Forest was concerned that forestry personnel who periodically drive on Parks Creek road may be exposed to asbestos. The road was resurfaced in 1983 using a serpentine aggregate material. Bulk quarry samples of the aggregate material were analyzed by NIOSH during the re-surfacing and found to contain 1-10 percent chrysotile asbestos.

On July 10, 1984, NIOSH conducted an environmental survey at the Shasta-Trinity National Forest along Parks Creek Road. Six personal asbestos air samples (ceiling) were collected during a simulation in which an engineer drove along the ten mile road. Two of the six air samples detected asbestos at a concentration of 0.17 and 0.18 fibers per cubic centimeter of air, greater than 5 microns in length (fibers/cc and greater than 5 um length) based on a 22 minute sampling period. NIOSH recommends that asbestos exposures be maintained at the lowest feasible limit based on the carcinogenicity of asbestos. The Federal Occupational Safety and Health Administration (OSHA) ceiling standard is 10 fibers/cc greater than 5 um in length based on a 15-minute sample.

Based on the environmental survey conducted along Parks Creek road low level asbestos exposures were measured, however, it should be noted that these exposures were near the analytical limit of detection. Given the presence of chrysotile asbestos in the bulk quarry samples previously analyzed by NIOSH, a potential health hazard exists to workers who drive along the road. Recommendations are included in Section VIII of the report.

KEYWORDS: SIC 1610 (Highway and Street Construction), serpentine, asbestos, U. S. Forest Service, aggregate, road building.

II. INTRODUCTION

In June, 1984, a request for technical assistance was submitted to NIOSH by the Staff Engineer for the U. S. Department of Agriculture, in San Francisco, California. The requestor wanted NIOSH to determine whether forest service personnel were exposed to asbestos fibers whenever they periodically drive along the Parks Creek Road located in the Shasta-Trinity National Forest.

III. BACKGROUND

In November, 1983, the U.S. Forest Service requested NIOSH to analyze two quarry samples of serpentine aggregate for percentage and type of asbestos. The aggregate was going to be used to re-surface Parks Creek road. The serpentine aggregate was found to contain from 1-10 percent chrysotile asbestos.

In June, 1984, NIOSH was requested to evaluate worker exposure when driving along Parks Creek Road. The 10 mile road was re-surfaced and re-shaped during the summer and fall of 1983 using 6 to 8 inches of crushed serpentine aggregrate which contained chrysotile asbestos. In addition, the road was sprayed with lignin sulfonate which compacts the soil, controls dust and absorbs water quickly; however, the primary purpose was for dust control.

The road is primarily used by loggers for hauling timber, but the logging company is required to water the road during logging operations. Recreationists and local residents use the road to access the Trinity river area, and rangers use the road to access other jobs. It was reported that the rangers use the road about once per week which takes about 22 minutes to drive.

On July 10, 1984, the NIOSH industrial hygienist met with the Shasta-Trinity District Ranger to learn more about the work regime and the frequency of exposure to road dust. None of the Forestry service personnel were going to be driving on Parks Creek Road during the day of the study, thus the operation had to be simulated by having one of the engineers drive along the Road. In order to simulate the worst possible conditions, the driver left his window down on each of the trips up and down the hill.

IV. ENVIRONMENTAL DESIGN

Personal air samples were collected for asbestos using a MSA Model G battery-operated pump and a mixed cellulose ester membrane filter (Type AA). Samples were collected at 1.5 liters per minute using open-face cassettes. The air samples were collected for the duration of the ten mile trip which averaged 22 minutes. The air samples were analyzed according to NIOSH Method Physical and Chemical Analytical Method (P&CAM) 239 utilizing Phase Contrast Microscopy(1). The limit of detection was determined to be 0.03 fibers/field or 5000 fibers/filter.

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures. NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criteria. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease.

In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet only those levels specified by an OSHA standard. The reader should recognize that evaluation criteria may change in the future as new information on the toxic effects of a physical agent or chemical substance become available.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

TABLE A

Concentration/Exposure Period

Contaminant	8-Hour TWA	Ceiling	Source
asbestos (fibers/cc)(1)	CA(2)	---	NIOSH
	2.0	10.0	OSHA

1. fibers/cc- asbestos fibers per cubic centimeter of air. The fibers must be greater than 5 microns in length.

2. CA- lowest feasible limit (suspect or confirmed carcinogen), use best control technology.

A. Toxicological Effects

Asbestos(2,3) - Asbestos is a generic term applied to a number of hydrated silicate minerals, including chrysotile, amosite, crocidolite, tremolite, and anthophyllite. The most toxic route of entry is inhalation.

Overexposure to asbestos fibers can cause asbestosis as well as other lung ailments. Asbestosis is a chronic lung ailment which can result in shortness of breath due to fibrotic changes and scarring of lung tissue. Usually there is a period of 10 to 35 years before this chronic lung ailment will become manifest. Other effects from inhalation of asbestos fibers are the asbestos related neoplasms. A high incidence of lung cancer is associated with persons who are exposed to asbestos and smoke cigarettes. Additionally, mesothelioma (a cancer of the thin membranes which line the chest and abdomen) are associated with asbestos exposure.

VI. RESULTS AND DISCUSSION

Six personal air samples (ceiling) were collected for asbestos (Table 1) while simulating the condition of exposure to road dust. In order to simulate the worst possible condition, the operator drove with his window open. Asbestos was identified on two filters collected during the morning drive up and down the mountain road. The air concentrations were measured to be 0.17 and 0.18 fibers per cubic centimeter of air. This is above the NIOSH recommended criterion of lowest feasible limit, but below the Federal OSHA standard mentioned in Table A. It is important to note that the analytical limit of detection is 0.03 fibers/field. If the asbestos air concentrations were to be

expressed in another manner, it could be said that 0.036 fibers/field were measured in the airborne samples which is extremely low, i.e. at a concentration close to the limit of detection. There was no other traffic on the road when these two air samples were collected except for a watering truck which was encountered as we approached the top of the hill and the same watering truck when we drove back down the hill. During the afternoon the watering truck and three logging trucks were using the road, but no asbestos was collected on the filters. During the final drive down the hill, we followed another ranger vehicle, but no asbestos was identified on that filter.

VII. CONCLUSIONS

In conclusion, the conditions which were observed and monitored on the dates of this evaluation are the worst conditions that could have been evaluated based on my discussions with the district ranger and the engineer who simulated the test. Asbestos exposures were measured in the morning when there were no other vehicles on the road other than the watering truck which appeared to be driving along the road slowly. No asbestos exposures were measured in the afternoon when dusty road conditions were clearly evident. In view of the following facts: that the asbestos exposures were measured to be very similiar to the analytical limit of detection, that the sample volume was very small due to the short exposure period, and the fact that environmental air monitoring was done for only one day, the following recomendations are included in the next section to help better evaluate and reduce the potential risk of exposure.

VIII. RECOMMENDATIONS

1. Environmental air monitoring should be done by the U.S. Forest Service in the spring when the road surface is dry to evaluate workers exposure to airborne asbestos. It is recommended that the new NIOSH sampling and analytical method No. 7400 (attached) be used which will allow the investigator to collect a larger air volume which will be more helpful in evaluating the risk of exposure.

2. Environmental air monitoring should be done periodically to assure that workers are not exposed to asbestos due to the general deterioration of the road.

3. Employees should be instructed to drive along the road with the windows rolled up to prevent potential exposures to asbestos.

4. It is recommended that the asbestos abatement measures listed in the Forest Service Manual Title 2100-Environmental Management, be closely followed to assure that future exposures be prevented. Some of these abatement measures include: dust palliatives (water or chemical) applied to the road surface, traffic control such as speed reduction, the application of a layer of asbestos-free aggregate on top of the existing asbestos-contaminated surface, and asphalt surface treatment or paving of the road.

IX. REFERENCES

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3. International Labour Office. Encyclopedia of Occupational Health and Safety. Geneva: International Labour Office,1983

4. National Institute of Health. Asbestos: An information Resource. Bethesda, Maryland: National Cancer Institute, National Institutes of Health, 1978, DHEW (NIH) Publication No. 79-1681.

X. AUTHORSHIP AND ACKNOWLEDGEMENTS

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XI. DISTRIBUTION AND AVAILABILITY

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office, at the Cincinnati address.

Copies of this report have been sent to:

1. U. S. Department of Agriculture.
2. U. S. Forest Service District Ranger, Shasta-Trinity National Forest.
3. U. S. Department of Labor/OSHA- Region IX.
4. NIOSH-Region IX.
5. Environmental Protection Agency-Region IX, Regional Asbestos Coordinator.

TABLE 1.
PERSONAL AIR CONCENTRATIONS
OF ASBESTOS FIBERS FOR
VEHICLE OPERATOR

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE
SHASTA-TRINITY NATIONAL FOREST
July 10, 1984

Sample Number	Sampling Period	Volume liters	Conc.(1)	Comments(2)
1	0950-1012	33	0.18	No road traffic encountered.
2.	1036-1059	34.5	0.17	No road traffic encountered.
3.	1254-1318	36	ND(3)	Three logging trucks on road.
4.	1320-1341	31.5	ND	Three logging trucks on road.
5.	1357-1418	31.5	ND	Three logging trucks on road.
6.	1419-1451	48	ND	Followed another vehicle down hill Stopped car to remove falling rocks.

1. Conc.- The concentration is fibers/cc and greater than 5um in length.

2. It should be noted that the vehicle operator drove the road with the window down for the entire sampling period.

3. ND- None detected (limit of detection is 0.03 fibers/field)

ATTACHMENT

FORMULA: various

M.W.: various

FIBERS
METHOD: 7400
ISSUED: 2/15/84

OSHA: 0.5 asbestos fibers (> 5 μm long)/mL
NIOSH: 0.1 asbestos f/mL [1]; 3 glass fibers (>10 μm x <3.5 μm)/mL [2]
ACGIH: 0.2 crocidolite; 0.5 amosite; 2 chrysotile and other asbestos, f/mL

PROPERTIES: solid, fibrous

SYNONYMS: asbestos (actinolite [CAS #77536-66-4], grunerite (amosite) [CAS #12172-73-5], anthophyllite [CAS #77536-67-5], chrysotile [CAS #12001-29-5], crocidolite [CAS #12001-28-4], tremolite [CAS #77536-68-6]); fibrous glass.

SAMPLING

SAMPLER: FILTER
(0.8-1.2 μm cellulose ester membrane, 25-mm diameter)

FLOW RATE*: ≥ 0.5 L/min

VOL-MIN*: 400 L @ 0.1 fiber/mL
-MAX*: 1920 L @ 0.1 fiber/mL
*Adjust for 100 to 1300 fibers/mm² (step 4)

SHIPMENT: routine

SAMPLE STABILITY: indefinite

BLANKS: 10% of samples (minimum 2) [3]

ACCURACY

RANGE STUDIED: 80 to 100 fibers counted

BIAS: see EVALUATION OF METHOD

OVERALL PRECISION (s_r): 0.115 to 0.13 [3] (A Rules)

MEASUREMENT

TECHNIQUE: MICROSCOPY, PHASE CONTRAST

ANALYTE: fibers (manual count)

SAMPLE PREPARATION: acetone/triacetin method

COUNTING RULES: Set A (P&CAM 239 [3,4]) or Set B (modified CRS [5])

EQUIPMENT: 1. phase-contrast microscope
2. Walton-Beckett graticule (100 μm field diameter): A Rules use G-22; B Rules use Type G-24
3. phase-shift test slide (HSE/NPL)

CALIBRATION: phase-shift detection limit about 3 degrees [7]

RANGE: 100 to 1300 fibers/mm² filter area [6]

ESTIMATED LOD: 7 fibers/mm² filter area

PRECISION: 0.10 to 0.12 [3] (A Rules)

APPLICABILITY: The working range is 0.02 fiber/mL (1920-L air sample) to 1.25 fibers/mL (400-L air sample). The method gives an index of airborne asbestos fibers but may be used for other materials such as fibrous glass by inserting suitable parameters into the counting rules. The method does not differentiate between asbestos and other fibers. Asbestos fibers less than ca. 0.25 μm diameter will not be detected by this method [7].

INTERFERENCES: Any other airborne fiber may interfere since all particles meeting the counting criteria are counted. Chain-like particles may appear fibrous. High levels of non-fibrous dust particles may obscure fibers in the field of view and raise the detection limit.

OTHER METHODS: This method introduces changes for improved sensitivity and reproducibility and replaces P&CAM 239 [3,4].

REAGENTS:

1. Acetone.*
2. Triacetin (glycerol triacetate), reagent grade.

*See Special Precautions.

EQUIPMENT:

1. Sampler: field monitor, 25 mm, three-piece cassette with 50-mm extension cowl with cellulose ester filter, 0.8 to 1.2-µm pore size and backup pad.
   NOTE: Analyze representative filters for fiber background before use and discard the filter lot if more than 5 fibers/100 fields are found.
2. Personal sampling pump, $\geq$ 0.5 L/min (see step 4 for flow rate), with flexible connecting tubing.
3. Microscope, phase contrast, with green or blue filter, 8 to 10X eyepiece, and 40 to 45X phase objective (total magnification ca. 400X); numerical aperture = 0.65 to 0.75.
4. Slides, glass, single-frosted, pre-cleaned, 25 x 75 mm.
5. Cover slips, 25 x 25 mm, no. 1-1/2, unless otherwise specified by microscope manufacturer.
6. Knife, #10 surgical steel, curved blade.
7. Tweezers.
8. Flask, Guth-type, insulated neck, 250 to 500 mL (with single-holed rubber stopper and elbow-jointed glass tubing, 16 to 22 cm long).
9. Hotplate, spark-free, stirring type; heating mantle; or infrared lamp and magnetic stirrer.
10. Syringe, hypodermic, with 22-gauge needle.
11. Graticule, Walton-Beckett type with 100 µm diameter circular field at the specimen plane (area = 0.00785 mm^2) (Type G-22 for A Rules; Type G-24 for B Rules). Available from Graticules Ltd., Morley Road, Tonbridge TN9 1RN, Kent, England (Telephone 011-44-732-359061).
    NOTE: The graticule is custom-made for each microscope. Specify disc diameter needed to fit exactly the ocular of the microscope and the diameter (mm) of the circular counting area (see step 11).
12. HSE/NPL phase contrast test slide, Mark II. Available from PTR Optics Ltd., 145 Newton Street, Waltham, MA 02154 (Telephone (617) 891-6000).
13. Telescope, ocular phase-ring centering.
14. Stage micrometer (0.01 mm divisions).

SPECIAL PRECAUTIONS: Acetone is an extremely flammable liquid and precautions must be taken not to ignite it. Heating of acetone must be done in a ventilated laboratory fume hood using a flameless, spark-free heat source.

SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line [3].
2. Fasten the sampler to the worker's lapel as close as possible to the worker's mouth. Remove the top cover from the end of the cowl extension (open face) and orient face down. Wrap the joint between the extender and monitor body with shrink tape to prevent air leaks.

3. Submit at least two field blanks (or 10% of the total samples, whichever is greater) for each set of samples. Remove the caps from the field blank cassettes and store the caps and cassettes in a clean area (bag or box) during the sampling period. Replace the caps in the cassettes when sampling is completed.
4. Sample at 0.5 L/min or greater [8]. Do not exceed 1 mg total dust loading on the filter. Adjust sampling flow rate, Q (L/min), and time to produce a fiber density, E (fibers/mm^2), of 100 to 1300 fibers/mm^2 [3.85 • 10^4 to 5 • 10^5 fibers per 25-mm filter with effective collection area (A_c= 385 mm^2)] for optimum counting precision (see step 21). Calculate the minimum sampling time, t_{min} (min), at the action level (one-half the current standard), L (fibers/mL), of the fibrous aerosol being sampled:

$$t_{min} = \frac{(A_c)(E)}{(Q)(L)10^3}.$$

5. Remove the field monitor at the end of sampling, replace the plastic top cover and small end caps, and store the monitor.
6. Ship the samples in a rigid container with sufficient packing material to prevent jostling or damage.

   NOTE: Do not use polystyrene foam in the shipping container because of electrostatic forces which may cause fiber loss from the sampler filter.

SAMPLE PREPARATION:

NOTE: The object is to produce samples with a smooth (non-grainy) background in a medium with a refractive index equal to or less than 1.46. The method below collapses the filter for easier focusing and produces permanent mounts which are useful for quality control and interlaboratory comparison. Other mounting techniques meeting the above criteria may also be used (e.g., the non-permanent field mounting technique used in P&CAM 239 [1,3,4]).

7. Ensure that the glass slides and cover slips are free of dust and fibers.
8. Place 40 to 60 mL of acetone into a Guth-type flask. Stopper the flask with a single-hole rubber stopper through which a glass tube extends 5 to 8 cm into the flask. The portion of the glass tube which exits the top of the stopper (8 to 10 cm) is bent downward in an elbow which makes an angle of 20 to 30° with the horizontal.
9. Place the flask on a stirring hotplate or wrap in a heating mantle. Heat the acetone gradually to its boiling temperature (ca. 58 °C).

   CAUTION: The acetone vapor must be generated in a ventilated fume hood away from all open flames and spark sources. Alternate heating methods can be used, providing no open flame or sparks are present.
10. Mount either the whole sample filter or a wedge cut from the sample filter on a clean glass slide.
    a. Cut wedges of ca. 25% of the filter area with a curved blade steel surgical knife using a rocking motion to prevent tearing.
    b. Place the filter or wedge, dust side up, on the slide. Static electricity will usually keep the filter on the slide until it is cleared.
    c. Hold the glass slide supporting the filter approximately 1 to 2 cm from the glass tube port where the acetone vapor is escaping from the heated flask. The acetone vapor stream should cause a condensation spot on the glass slide ca. 2 to 3 cm in diameter. Move the glass slide gently in the vapor stream. The filter should clear in 2 to 5 sec. If the filter curls, distorts or is otherwise rendered unusable, the vapor stream is probably not strong enough. Periodically wipe the outlet port with tissue to prevent liquid acetone dripping onto the filter.

d. Using the hypodermic syringe with a 22-gauge needle, place 1 to 2 drops of triacetin on the filter. Gently lower a clean 25-mm square cover slip down onto the filter at a slight angle to reduce the possibility of forming bubbles. If too many bubbles form or the amount of triacetin is insufficient, the cover slip may become detached within a few hours.

e. Glue the edges of the cover slip to the glass slide using a lacquer or nail polish [9].

NOTE: If clearing is slow, the slide preparation may be heated on a hotplate (surface temperature 50 °C) for 15 min to hasten clearing. Counting may proceed immediately after clearing and mounting are completed.

CALIBRATION AND QUALITY CONTROL:

11. Calibration of the Walton-Beckett graticule. The diameter, d_c (mm), of the circular counting area and the disc diameter must be specified when ordering the graticule.
    a. Insert any available graticule into the eyepiece and focus so that the graticule lines are sharp and clear.
    b. Set the appropriate interpupillary distance and, if applicable, reset the binocular head adjustment so that the magnification remains constant.
    c. Install the 40 to 45X phase objective.
    d. Place a stage micrometer on the microscope object stage and focus the microscope on the graduated lines.
    e. Measure the magnified grid length, L_o (µm), using the stage micrometer.
    f. Remove the graticule from the microscope and measure its actual grid length, L_a (mm). This can best be accomplished by using a stage fitted with verniers.
    g. Calculate the circle diameter, d_c (mm), for the Walton-Beckett graticule:

$$d_c = \frac{L_a}{L_o} \times D.$$

    Example: If L_o = 108 µm, L_a = 2.93 mm and D = 100 µm, then d_c = 2.71 mm.
    h. Check the field diameter, D(acceptable range 100 µm ± 2 µm) with a stage micrometer upon receipt of the graticule from the manufacturer. Determine field area (mm^2).
12. Microscope adjustments. Follow the manufacturer's instructions and also the following:
    a. Adjust the light source for even illumination across the field of view at the condenser iris.
    NOTE: Köhler illumination is preferred, where available.
    b. Focus on the particulate material to be examined.
    c. Make sure that the field iris is in focus, centered on the sample and open only enough to fully illuminate the field of view.
    d. Use the telescope ocular supplied by the manufacturer to ensure that the phase rings (annular diaphragm and phase-shifting elements) are concentric.
13. Check the phase-shift detection limit of the microscope periodically.
    a. Remove the HSE/NPL phase-contrast test slide from its shipping container and center it under the phase objective.
    b. Bring the blocks of grooved lines into focus.
    NOTE: The slide consists of seven sets of grooves (ca. 20 grooves to each block) in descending order of visibility from sets 1 to 7. The requirements for asbestos counting are that the microscope optics must resolve the grooved lines in set 3 completely, although they may appear somewhat faint, and that the grooved lines in sets 6 and 7 must be invisible. Sets 4 and 5 must be at least partially visible but may vary slightly in visibility between microscopes. A microscope which fails to meet these requirements has either too low or too high a resolution to be used for asbestos counting.

c. If the image quality deteriorates, clean the microscope optics and if the problem persists, consult the microscope manufacturer.

14. Quality control of fiber counts.
    a. Prepare and count field blanks along with the field samples. Report the counts on each blank. Calculate the mean of the field blank counts and subtract this value from each sample count before reporting the results.
       NOTE 1: The identity of the blank filters should be unknown to the counter until all counts have been completed.
       NOTE 2: If a field blank yields fiber counts greater than 7 fibers/100 fields, report possible contamination of the samples.
    b. Perform blind recounts by the same counter on 10% of filters counted (slides relabeled by a person other than the counter).
15. Use the following test to determine whether a pair of counts on the same filter should be rejected because of possible bias. This statistic estimates the counting repeatability at the 95% confidence level. Discard the sample if the difference between the two counts exceeds $2.77\ (F)s_r$, where F = average of the two fiber counts and s_r = relative standard deviation, which should be derived by each laboratory based on historical in-house data.
    NOTE: If a pair of counts is rejected as a result of this test, recount the remaining samples in the set and test the new counts against the first counts. Discard all rejected paired counts.
16. Enroll each new counter in a training course which compares performance of counters on a variety of samples using this procedure.
    NOTE: To ensure good reproducibility, all laboratories engaged in asbestos counting should participate in an asbestos proficiency testing program such as the NIOSH Proficiency Analytical Testing (PAT) Program and routinely participate with other asbestos fiber counting laboratories in the exchange of field samples to compare performance of counters.

MEASUREMENT:

17. Place the slide on the mechanical stage of the calibrated microscope with the center of the filter under the objective lens. Focus the microscope on the plane of the filter.
18. Regularly check phase-ring alignment and Köhler illumination [7].
19. Select one of the following sets of counting rules:
    NOTE: The two sets of rules have been demonstrated to produce equivalent mean counts on a variety of asbestos sample types [5] and must be strictly followed in order to obtain valid results. No hybridizing of the two sets of rules is permitted. The calibration of the microscope with the HSE/NPL test slide determines the minimum detectable fiber diameter (ca. 0.25 µm).
    a. A Rules (same as P&CAM 239 rules [1,3,4]).
       NOTE: The A Rules are required for monitoring asbestos for compliance purposes under OSHA or NIOSH standards.
       1. Count only fibers longer than 5 µm. Measure the length of curved fibers along the curve.
       2. Count only fibers with a length-to-width ratio equal to or greater than 3:1.
       3. For fibers which cross the boundary of the graticule field, do the following:
          a. Count any fiber longer than 5 µm which lies entirely within the graticule area.
          b. Count as 1/2 fiber any fiber with only one end lying within the graticule area.
          c. Do not count any fiber which crosses the graticule boundary more than once.
          d. Reject and do not count all other fibers.

4. Count bundles of fibers as one fiber unless individual fibers can be identified by observing both ends of a fiber.
5. Count enough graticule fields to yield 100 fibers. Count a minimum of 20 fields. Stop at 100 fields regardless of fiber count.

b. B Rules

NOTE: The B Rules are preferred analytically because of their demonstrated ability to improve the reproducibility of fiber counts [5].

1. Count only ends of fibers. Each fiber must be longer than 5 µm and less than 3 µm diameter.
2. Count only ends of fibers with a length-to-width ratio equal to or greater than 5:1.
3. Count each fiber end which falls within the graticule area as one end, provided that the fiber meets rules b.1 and b.2.
4. Count visibly free ends which meet rules b.1 and b.2 when the fiber appears to be attached to another particle, regardless of the size of the other particle.
5. Count the free ends of fibers emanating from large clumps and bundles up to a maximum of 10 ends (5 fibers), provided that each segment meets rules b.1 and b.2.
6. Count enough graticule fields to yield 200 ends. Count a minimum of 20 fields. Stop at 100 fields, regardless of the fiber count.
7. Divide the total end count by 2 to yield fiber count.

NOTE: Split fibers will normally be counted as more than two ends if the free ends meet the rules b.1. and b.2.

20. Start counting from one end of the filter and progress along a radial line to the other end, shift either up or down on the filter and continue in the reverse direction [10]. Select fields randomly by looking away from the eyepiece briefly while advancing the mechanical stage. When an agglomerate covers ca. 1/6 or more of the field of view, reject the field and select another. Do not report rejected fields in the number of total fields counted.

NOTE: When counting a field, continuously scan a range of focal planes by moving the fine focus knob to detect very fine fibers which have become embedded in the filter. The small-diameter fibers will be very faint but are an important contribution to the total count.

CALCULATIONS:

21. Calculate and report fiber density on the filter, E (fibers/mm^2), by dividing the total fiber count, F, minus the mean field blank count, B, by the number of fields, n, and the field area, A_f (0.00785 mm^2 for a properly calibrated Walton-Beckett graticule):

$$E = \frac{(F - B)}{(n)(A_f)}, \text{ fibers/mm}^2.$$

22. Calculate the concentration, C (fibers/mL), of fibers in the air volume sampled, V (L), using the effective collection area of the filter, A_c (385 mm^2 for a 25-mm filter):

$$C = \frac{(E)(A_c)}{V \cdot 10^3}.$$

NOTE: Periodically check and adjust the value of A_c, if necessary.

EVALUATION OF METHOD:

This method is a revision of NIOSH Method P&CAM 239 [1,3,4]. A summary of the revisions is as follows:

A. Sampling

The change from a 37-mm to a 25-mm filter size was incorporated to improve sensitivity and reduce problems associated with non-uniform fiber loading reported on the 37-mm filters [10]. The change in flow rates allows for 2 m^3 full-shift samples to be taken, providing that the filter is not overloaded with non-fibrous particulates. The collection efficiency of the sampler is not affected by changes in flow rate in the range 0.5 to 16 L/min [8].

B. Sample Preparation Technique

The acetone vapor-triacetin preparation technique has been incorporated in the method as a faster, more permanent mounting technique than the dimethyl phthalate/diethyl oxalate method of P&CAM 239 [1,3,4,11].

C. Measurement

1. The inclusion of the Walton-Beckett graticule in the method was made to standardize the field area observed through the eyepiece [6,11].
2. The introduction of the HSE/NPL test slide was made to standardize microscope optics for sensitivity to fiber diameter [7,11].
3. A recent international collaborative study involved 16 laboratories using prepared slides from the asbestos, cement, milling, mining, textile, and friction material industries [5]. The relative levels of count by different counting rules were:

Sample Type	Number of Samples	Aspect Ratio > 3:1		Aspect Ratio > 5:1	
		AIA	Mod. CRS*	AIA	Mod. CRS*
Mining	10	100	127	74	92
Milling	10	100	112	84	95
Asbestos Cement	14	100	146	90	137
Textile Chrysotile	10	100	109	89	99
Friction Material	10	100	130	87	116
Others (Insulation, Amosite)	6	100	127	92	118
TOTAL:	60	MEAN: 100	125	86	110

*Arithmetic means of counts made by different laboratories relative to the AIA counts.

The modified CRS (NIOSH B) Rules were found to be more precise than the AIA (NIOSH A)* Rules. The ranges of relative standard deviations (s_r) which varied with sample type and laboratory were:

	s_r		
	Intralaboratory	Interlaboratory	Overall
AIA (NIOSH A Rules)*	0.12 to 0.40	0.27 to 0.85	0.46
Modified CRS (NIOSH B Rules)	0.11 to 0.29	0.20 to 0.35	0.25

*Under AIA rules, only fibers having a diameter less than 3 μm are counted and fibers attached to particles larger than 3 μm are not counted. NIOSH A Rules are otherwise similar to the AIA rules.

The B Rules have also been favorably received by analysts as less ambiguous and simpler to use; these rules also showed the least bias relative to AIA rules in the collaborative study. An independent NIOSH laboratory study using amosite fibers reported a relative standard deviation, including within- and between-sample

variability, of 0.157 for the B Rules [12]. Adding an estimated sampling pump error, s_r, of 0.05 [13] to the within-sample variability in this study results in an estimate of overall precision, s_r, of 0.102 for the B Rules.

4. Because of past inaccuracies associated with low fiber counts, the minimum loading has been increased to 100 fibers/mm^2 filter area (80 fibers total count). This level yields an overall $s_r = 0.13$, as indicated in Figure 3 (revised) of P&CAM 239 [3,4] which corresponds to a measurement $s_r = 0.12$ after removal of pump error [13]. Similarly, at the maximum count of 100 fibers, overall $s_r = 0.115$ and measurement $s_r = 0.10$ are obtained.

D. Evaluation of the method using the A and B counting rules will proceed on a continuing basis through the NIOSH Proficiency Analytical Testing (PAT) Program. The new PAT reporting form allows for reporting of results by either set of rules as of January, 1984.

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