PROJECT ADMINISTRATION DATA SHEET

Project No. A-3323

Project Director: J. L. Burson

Sponsor: GEMCO Construction Company

Type Agreement: Standard Research Agreement No. A-3323

Award Period: From 8/6/82 To 6/30/84

Sponsor Amount: $44,007

Cost Sharing: (Performance) (Reports)

Contracted through: GTRI/GRK

Title: Asbestos Sampling - GEMCO Construction Company

ADMINISTRATIVE DATA

1) Sponsor Technical Contact:

J. Wayne Simpson Sr., President

GEMCO Construction Company

P.O. Box 187

Trilby, FL 33593

2) Sponsor Admin/Contractual Matters:

J. Wayne Simpson Sr., President

GEMCO Construction Company

P.O. Box 187

Trilby, FL 33593

Defense Priority Rating: N/A

Security Classification: N/A

REstrictions

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with N/A

COMMENTS:

COPY TO: Research Administrative Network

Research Security Services

Research Property Management

Research Administration

Computer Input

EES Public Relations (2)

EES Public Relations

Project File: 08/25/82
GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date: 8/22/84

Project No. A-3323

Includes Subproject No(s):

Project Director(s) W. M. Ewing

Sponsor Gemco Construction Co.

Title Asbestos Sampling - Gemco Construction Co.

Effective Completion Date: 6/30/84 (Performance) 6/30/84 (Reports)

Grant/Contract Closeout Actions Remaining:

☐ None

☒ Final Invoice or Final Fiscal Report

☐ Closing Documents

☐ Final Report of Inventions

☐ Govt. Property Inventory & Related Certificate

☐ Classified Material Certificate

☐ Other

Continues Project No. Continued by Project No.

COPIES TO:

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services

Library
GTRI
Research Communications (2)
Project File
Other I. Newton
Mr. J. Wayne Simpson  
President  
Gemco Construction Co.  
P. O. Box 187  
Trilby, Florida 33593

Subject: Asbestos Sampling, University of Georgia, Athens, Georgia

Dear Wayne:

Enclosed are two copies of the report concerning the air monitoring conducted at Creswell and Bolton Halls, University of Georgia, Athens, Georgia. We have not forwarded a copy of this report to the University. If you need additional copies, please let me know.

It was a pleasure to work with you again. If you have any questions concerning the report, please contact our office.

Sincerely,

Kenneth E. Johnson  
Safety & Health Consultant

KEJ:rm  
Enclosures
AIR SAMPLING SURVEY
BOLTON AND CRESWELL HALLS
UNIVERSITY OF GEORGIA
ATHENS, GEORGIA
PROJECT NO. A-3323-001

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Occupational Safety and Health Branch
Atlanta, Georgia
August 31, 1982
INTRODUCTION

The Georgia Tech Research Institute performed industrial hygiene air sampling during the removal of existing acoustical ceiling material in Bolton Hall and floors 2, 3, and 4 of Creswell Hall for Gemco Construction Company. In addition, samples were taken on the ninth floor after removal and cleaning and samples were taken during the removal of acoustical material from an apartment on the first floor of Creswell Hall. Air sampling was performed by Mr. Kenneth E. Johnson, Ms. Nancy Zakraysek, and Mr. William M. Ewing of Georgia Tech, on July 21 - August 6, 1982, at the request of Mr. J. Wayne Simpson of Gemco Construction Company on July 20, 1982. All analyses were performed by Mr. Johnson, Ms. Zakraysek, or Mr. Ewing within 12 hours of sampling and the results reported daily to Mr. Bill Willis of Gemco Construction Company. The following report summarizes the results of sampling and analyses including conclusions and discussion of findings. The results of air sampling are included in Appendix A (Tables A-1 through A-10). A copy of the analytical method employed is attached as Appendix B. Appendix C contains copies of the Occupational Safety and Health Administration (OSHA) asbestos standard and the Environmental Protection Agency (EPA) asbestos standard.

CONCLUSIONS AND RECOMMENDATIONS

1. Work area samples taken during the removal of asbestos containing acoustical ceiling material indicated fiber concentrations that were not in excess of the OSHA asbestos standard of 2 fibers*/cc but did exceed the NIOSH recommended standard of 0.1 fibers* per cc. Eleven work area samples were taken with an average fiber* count of 0.38 fibers*/cc. This average is not a time-weighted average but is a result of adding all fiber* counts and dividing by the total number of samples.

2. The results of the area samples taken outside the work area but inside the building ranged from less than 0.01 to 0.03 fibers* per cc. The results of the area sample taken outside the building were 0.01 fibers* per cc and under.

3. Air sampling conducted, after all removal and clean-up activities were completed in each work area, indicated fiber concentrations below the OSHA asbestos standard and the NIOSH recommended standard.

4. The OSHA asbestos standard contains a requirement for full-shift personal monitoring to determine the 8-hour, time-weighted average airborne concentrations and ceiling concentrations of asbestos fibers*. On future asbestos abatement projects, it is recommended that full-shift personal monitoring be conducted.

*Fibers greater than 5 micrometers in length.
5. The NIOSH method P&CAM No. 239 was used to analyze the fiber* concentrations listed in this report. This method does not determine a fiber concentration for fibers shorter than 5 micrometers in length or thinner than 0.3 micrometers. Strong evidence exists that these short or thin fibers present the greatest threat to those people exposed. To determine the concentration of fibers such as these, analysis must be conducted using an electron microscope. While the cost of this analysis ($300 - $400 per sample) is prohibitive for analyzing all samples, it is suggested that, on future asbestos abatement projects, the University have samples taken before and after removal and analyzed by electron microscopy, to determine the fiber count of fibers less than 5 micrometers in length or thinner than 0.3 micrometers in addition to those fibers greater than 5 micrometers.

DESCRIPTION OF FACILITY

Creswell and Bolton Halls are located on the campus of the University of Georgia in Athens, Georgia. Creswell Hall is a dormitory with approximately 64 bedrooms on each floor. Bolton Hall is a cafeteria located adjacent to Creswell Hall. Figure 1 is a sketch of Bolton Hall and typical plans of floors 2, 3, 4, and 9 of Creswell Hall.

Acoustical ceiling material was to be removed from floors 2, 3, 4, and 9 of Creswell Hall. The work area was located on these floors with waste material and personnel transport provided by an elevator with access to the ground floor and an exit on the east side of the building. All these areas were considered "contaminated" areas.

DISCUSSION OF FINDINGS

A survey protocol was designed to meet the requirements of the asbestos removal contract between Gemco Construction Company and the University of Georgia. Air sampling was conducted during and after removal activities to determine airborne fiber concentrations. All air samples were collected and analyzed as described in the National Institute for Occupational Safety and Health (NIOSH) Method P&CAM No. 239. To provide prompt results, samples were analyzed within 12 hours at Georgia Tech's Engineering Experiment Station in Atlanta, Georgia.

During removal activities, 21 work area samples were taken, generally two per floor on each day of sampling. Six (6) samples were taken outside the building while removal was in progress. Nine (9) samples were taken inside the building but outside the work area to determine if a significant number of fibers were being emitted from the work area.

*Fibers greater than 5 micrometers in length.
CRESWELL HALL DORMITORY
TYPICAL PLAN, FLOORS 2,3,4,9
NO SCALE
After removal and clean-up, 17 samples were taken to determine the post-work fiber* count. The level of less than 0.05 fibers*/cc had been established by the University as acceptable for re-entry and occupancy. Three (3) of the 17 sample results exceeded this count and the areas were cleaned a second time. Repeat samples, afterwards, indicated fiber* counts had been reduced below 0.05 fibers*/cc.

This report prepared by: Kenneth E. Johnson
Safety & Health Consultant

This report approved by: James L. Burson, Program Manager
Safety & Health Services Branch

*Fibers greater than 5 micrometers in length.
APPENDIX A

RESULTS OF AIR SAMPLING
<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration Fibers per Filter</th>
<th>Fibers per cc air</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/21</td>
<td>122</td>
<td>Personal Sample - Buddy Logden</td>
<td>0937 - 1004</td>
<td>54</td>
<td>27</td>
<td>7,000</td>
<td>0.13</td>
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<tr>
<td></td>
<td></td>
<td>Scraping &amp; bagging - 4th floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/21</td>
<td>137</td>
<td>Same as above (#122)</td>
<td>1004 - 1041</td>
<td>74</td>
<td>37</td>
<td>14,000</td>
<td>0.19</td>
</tr>
<tr>
<td>7/21</td>
<td>128</td>
<td>Personal Sample - Tom Merchant</td>
<td>0936 - 1004</td>
<td>56</td>
<td>28</td>
<td>5,600</td>
<td>0.10</td>
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<tr>
<td></td>
<td></td>
<td>Scraping &amp; bagging - 4th floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/21</td>
<td>120</td>
<td>Same as above (#128)</td>
<td>1004 - 1037</td>
<td>66</td>
<td>33</td>
<td>7,000</td>
<td>0.11</td>
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<tr>
<td>7/21</td>
<td>140</td>
<td>Area Sample - Outside Bldg.</td>
<td>0839 - 1116</td>
<td>311</td>
<td>157</td>
<td>none noted</td>
<td>&lt;0.01</td>
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<tr>
<td></td>
<td></td>
<td>15' from decontam. trailer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/21</td>
<td>144</td>
<td>Area Sample - Outside Work Area</td>
<td>0843 - 1117</td>
<td>311</td>
<td>154</td>
<td>1,400</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Near Maint. Shop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/21</td>
<td>145</td>
<td>Area Sample - 4th floor-Rm457</td>
<td>0949 - 1050</td>
<td>121</td>
<td>61</td>
<td>38,000</td>
<td>0.31</td>
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<tr>
<td></td>
<td></td>
<td>Removal in process</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/21</td>
<td>132</td>
<td>Area Sample - 4th floor-Rm465</td>
<td>0952 - 1053</td>
<td>123</td>
<td>61</td>
<td>22,000</td>
<td>0.18</td>
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<td></td>
<td></td>
<td>Removal in process</td>
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</table>
**INDUSTRIAL HYGIENE SAMPLING SUMMARY**

Gemco Construction Company

University of Georgia, Athens, Georgia

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration Fibers per Filter</th>
<th>Concentration Fibers per cc Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/22</td>
<td>146</td>
<td>Area Sample - Outside Bldg. 15' from Decontam. Trailer</td>
<td>0836 - 1053</td>
<td>271</td>
<td>137</td>
<td>1,400</td>
<td>0.01</td>
</tr>
<tr>
<td>7/22</td>
<td>130</td>
<td>Area Sample - Inside bldg. near Maint. shop</td>
<td>0837 - 1054</td>
<td>273</td>
<td>137</td>
<td>none noted</td>
<td>&lt; 0.01</td>
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<tr>
<td>7/22</td>
<td>125</td>
<td>Area Sample - Room 307 3rd floor-no work in progress</td>
<td>0917 - 1037</td>
<td>163</td>
<td>80</td>
<td>1,400</td>
<td>0.01</td>
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<tr>
<td>7/22</td>
<td>147</td>
<td>Area Sample - Room 351 - no removal in progress</td>
<td>0914 - 1036</td>
<td>163</td>
<td>82</td>
<td>none noted</td>
<td>&lt; 0.01</td>
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<tr>
<td>7/22</td>
<td>123</td>
<td>Area Sample - 2nd floor - no removal in progress</td>
<td>0906 - 1029</td>
<td>164</td>
<td>83</td>
<td>none noted</td>
<td>&lt; 0.01</td>
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<tr>
<td>7/22</td>
<td>133</td>
<td>Area Sample - Work Area - lounge near elevator</td>
<td>0931 - 1043</td>
<td>142</td>
<td>72</td>
<td>20,000</td>
<td>0.14</td>
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<td>7/22</td>
<td>135</td>
<td>Area Sample - Work Area - Room 429</td>
<td>0923 - 1040</td>
<td>155</td>
<td>77</td>
<td>34,000</td>
<td>0.22</td>
</tr>
</tbody>
</table>
### INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant** University of Georgia, Creswell Hall

**Materials** Fibers greater than 5 micrometers in length

**Athens, Georgia**

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (L)</th>
<th>Sample Time (Min.)</th>
<th>Concentration Fibers per Filter</th>
<th>Concentration Fibers per cc air</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/24</td>
<td>AA-112</td>
<td>Area sample, outside building, 15 ft W of south entrance (decon)</td>
<td>1304-1515</td>
<td>261</td>
<td>131</td>
<td>3000</td>
<td>0.01</td>
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<tr>
<td>7/24</td>
<td>AA-116</td>
<td>Area sample, inside 1st floor elevator lobby (outside worksite)</td>
<td>1322-1450</td>
<td>173</td>
<td>88</td>
<td>5600</td>
<td>0.03</td>
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<tr>
<td>7/24</td>
<td>AA-76</td>
<td>Area sample, work area, 3rd floor Dolphin lounge (scraping)</td>
<td>1329-1445</td>
<td>150</td>
<td>76</td>
<td>140,000</td>
<td>0.91</td>
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<td>7/24</td>
<td>AA-102</td>
<td>Area sample, work area, 3rd floor Comet lounge (bagging)</td>
<td>1330-1446</td>
<td>151</td>
<td>76</td>
<td>69,000</td>
<td>0.45</td>
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</tbody>
</table>
**INDUSTRIAL HYGIENE SAMPLING SUMMARY**

**Plant** University of Georgia, Creswell Hall  
**Materials** Fibers greater than 5 micrometers in length  
**Athens, Georgia**

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/25</td>
<td>AA-134</td>
<td>Area sample, outside building, on loading dock</td>
<td>0915-1119</td>
<td>250</td>
<td>124</td>
<td>2800</td>
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<tr>
<td>7/25</td>
<td>AA-114</td>
<td>Area sample, inside 1st floor, elevator lobby</td>
<td>0924-1125</td>
<td>246</td>
<td>121</td>
<td>2800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(outside worksite)</td>
<td></td>
<td></td>
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<tr>
<td>7/25</td>
<td>AA-143</td>
<td>Area sample, work area, 3rd floor room 329</td>
<td>0927-1128</td>
<td>240</td>
<td>121</td>
<td>14,000</td>
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<tr>
<td></td>
<td></td>
<td>(bagging)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7/25</td>
<td>AA-99</td>
<td>Area sample, work area, 3rd floor room 317</td>
<td>0929-1130</td>
<td>247</td>
<td>121</td>
<td>22,400</td>
</tr>
</tbody>
</table>
## INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant:** Gemco Construction Co.

**University of Georgia, Creswell Hall**

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>7/26/82</td>
<td>149</td>
<td>Area sample, outside building, on loading dock</td>
<td>0844 1044</td>
<td>241</td>
<td>120</td>
<td>2800</td>
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<td></td>
<td></td>
<td></td>
<td>0.01</td>
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<tr>
<td>7/26/82</td>
<td>117</td>
<td>Area sample, inside building, loading area near barriers</td>
<td>0850 1051</td>
<td>244</td>
<td>121</td>
<td>2800</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>7/26/82</td>
<td>115</td>
<td>Area sample, work area, 2nd floor room 258 (scraping)</td>
<td>0858 1000</td>
<td>123</td>
<td>62</td>
<td>32,000</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.26</td>
</tr>
<tr>
<td>7/26/82</td>
<td>142</td>
<td>Area sample, work area, 2nd floor room 263 (bagging)</td>
<td>0901 1001</td>
<td>122</td>
<td>60</td>
<td>34,000</td>
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<td></td>
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<td>0.28</td>
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**Materials:** Fibers greater than 5 micrometers in length
<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Sample Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/27</td>
<td>155</td>
<td>Area Sample, Clean Air Test, Cafeteria, East End</td>
<td>0900 1252</td>
<td>457</td>
<td>232</td>
<td>8,400 0.02</td>
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<tr>
<td>7/27</td>
<td>157</td>
<td>Area Sample, Clean Air Test, Cafeteria, West End</td>
<td>0902 1254</td>
<td>SAMPLE VOIDED - PUMP NOT FUNCTIONING PROPERLY</td>
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<td>7/27</td>
<td>156</td>
<td>Area Sample, Work Area, 2nd Floor, Room 220</td>
<td>0928 1028</td>
<td>119</td>
<td>60</td>
<td>32,000 0.27</td>
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<tr>
<td>7/27</td>
<td>154</td>
<td>Area Sample, Work Area, 2nd Floor, Room 219</td>
<td>0933 1033</td>
<td>119</td>
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<td>7/27</td>
<td>139</td>
<td>Area Sample, Outside Building, Loading Deck</td>
<td>0946 1231</td>
<td>452</td>
<td>225</td>
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<tr>
<td>7/27</td>
<td>158</td>
<td>Area Sample, Outside Work Area, In Loading Area Near Barriers</td>
<td>0948 1234</td>
<td>450</td>
<td>226</td>
<td>4,200 0.01</td>
</tr>
</tbody>
</table>

Plant: Gemco Construction Co.
Materials: Fibers greater than 5 micrometers in length

University of Georgia, Athens, Georgia
<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>7/30</td>
<td>161</td>
<td>Area sample, clean air test, 9th floor, room 927</td>
<td>0928 1257</td>
<td>416</td>
<td>209</td>
<td>2800</td>
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<tr>
<td>7/30</td>
<td>159</td>
<td>Area sample, clean air test, 9th floor, room 902</td>
<td>0932 1259</td>
<td>414</td>
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<tr>
<td>7/30</td>
<td>160</td>
<td>Area sample, clean air test, 9th floor, room 948</td>
<td>0923 1254</td>
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<td>211</td>
<td>2800</td>
</tr>
<tr>
<td>Date 1982</td>
<td>Sample Number</td>
<td>Description</td>
<td>Sampling Period</td>
<td>Sample Volume (Liters)</td>
<td>Sample Time (Min.)</td>
<td>Concentration Fibers per filter</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------</td>
<td>-------------</td>
<td>-----------------</td>
<td>------------------------</td>
<td>--------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>8/4</td>
<td>163</td>
<td>Area sample, clean air, 4th floor room 449</td>
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<td>420 210 9800</td>
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<tr>
<td>8/4</td>
<td>164</td>
<td>Area sample, clean air, 4th floor room 426</td>
<td>0902 1233</td>
<td>433 211 28,000</td>
<td>0.06</td>
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</tr>
<tr>
<td>8/4</td>
<td>165</td>
<td>Area sample, 3rd floor, room 365, cleaning in progress</td>
<td>0911 1115</td>
<td>246 124 2800</td>
<td>0.01</td>
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</tr>
<tr>
<td>8/4</td>
<td>167</td>
<td>Area sample, 3rd floor, room 326, sweeping in progress</td>
<td>0917 1247</td>
<td>418 210 42,000</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>8/4</td>
<td>162</td>
<td>Area sample, 2nd floor, room 264, plastic removal</td>
<td>0926 1256</td>
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<td>Concentration Fibers per Filter</td>
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### INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant:** Gemco Construction Co.  
**University of GA, Cresswell Hall, Athens, Georgia**  
**Materials:** Fibers greater than 5 micrometers in length

<table>
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<th>Description</th>
<th>Sampling Period</th>
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<td>170</td>
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APPENDIX B

NATIONAL INSTITUTE FOR
OCCUPATIONAL SAFETY AND HEALTH
METHOD P & CAM 239
SAMPLE PREPARATION

Preparation of the Mounting Solution

Combine in a one-to-one ratio (by volume) dimethyl phthalate and diethyl oxalate and pour into a Wheaton balsam bottle. The viscosity of the solution must then be adjusted; if the mixture is too "thin" the solution will cause the movement of the fibers on the filter; if it is too "thick" the filters will not dissolve completely. The viscosity is adjusted by adding blank filters to the solution. The number of filters to add is based on the amount of solution prepared; approximately 0.05 ± 0.005 grams of new membrane filter per milliliter of solution. Use 10 ml each reagent, 1.2 g of MCEF membranes. The resulting solution should appear about as viscous as molasses. The normal shelf life of the solution is about three months. Twenty ml of mounting solution will prepare approximately 300 samples.

Sample Mounting

1. Clean the slides and cover slips with lens tissue. Lay each slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.

2. Wipe all the mounting tools clean with lens tissue and place them on a clean surface (such as lens tissue). All tools should be wiped clean prior to mounting each sample.

3. Using the glass rod supplied with the Wheaton balsam bottle, apply a drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of the solution so that after the cover slip has been placed on top, the solution extends only slightly beyond the filter boundary. If the quantity is greater than this particle migration may occur.

4. Using another glass rod, spread the mounting media into a triangular shape. The size of the triangle should coincide with the dimension of the filter wedge.

5. Separate the middle and bottom sections of the cassette to expose the filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface. The filter should not be removed from the cassette for cutting.

6. Grasp the filter wedge with the tweezers on the perimeter of the filter which was clamped between the cassette sections. DO NOT TOUCH THE FILTER WITH YOUR FINGERS. Place the wedge, SAMPLE SIDE UP, upon the mounting solution.

7. Pick up a clean cover slip with tweezers and carefully place it on the filter wedge. Once contact has been made, DO NOT REPOSITION THE COVER SLIP.
8. Label the slide with the sample number before proceeding to the next filter. On the bottom (backside) of the slide, trace the perimeter of the filter wedge with a felt tip marking pen. This will enable the counter, after the filter has become transparent, to stay within the filter perimeter when counting.

9. The sample should become transparent within about 15 minutes. If the filter appears cloudy, it may be necessary to press VERY LIGHTLY, on the cover slip. This is rarely necessary; however, counting should not be started until an hour after the mounting.

10. Samples should be counted within two days of mounting. Crystals appearing similar to asbestos fibers may begin to grow at the mounting media/air interfaces.

COUNTING OF FIBERS

1. Place the slide on the mechanical stage of the microscope and position the center of the wedge under the objective lens and focus upon the sample. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from perimeter to filter tip). Stay away from the filter's edges when counting and sizing. Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.

2. It is essential to continually scan over a range of focal planes (generally the upper 10 to 15 micrometers of the filter surface) with the fine focus control during each field count. This is especially necessary for asbestos fibers due to their impaction into the filter matrix.

3. On most airborne samples, asbestos fibers will generally have fiber diameters less than one micrometer. Therefore, it is necessary to look carefully for faint fiber images.

4. Regularly check the phase ring alignment.

5. When a mass of material covers a significant portion of the field of view (about one-sixth or greater) reject the field and select another. (Do not include in the number of fields counted.) However, report the fact as it may have meaning on other data collection.

6. Bundles of fibers are counted as one fiber unless both ends of the fiber can be clearly resolved.

7. Count only fibers with a length to width ratio greater than or equal to 3:1.

8. Count only fibers greater than 5 micrometers in length. Measure curved fibers along the curve to estimate the total length.

9. Count as many fields as necessary to yield a total count of at least 100 fibers. EXCEPTIONS: a). count at least 20 fields even if you count more than 100 fibers, and b). stop at 100 fields even if you haven't reached 100 fibers.
10. Rules for selecting fibers to be counted: a). COUNT any fiber greater than 5 micrometers in length, that lies entirely within the counting area, b). COUNT as \( \frac{1}{2} \) fiber any fiber with only one end lying within the counting area, and c). DO NOT COUNT any fiber crossing any two sides of the counting area.

CALCULATIONS AND RECORDKEEPING

1. The following data must be recorded in the microscopy data book: a). name of client, b). date of analysis, c). sample number, d). initials of person performing the analysis, e). total number of fibers counted, f). total number of fields counted, g). air volume (if supplied), h). fibers per filter, and i). fibers per cubic centimeter of air (if applicable). Additionally, any comments or notes should be recorded. Also a notation should be made if any deviations from the standard procedure were made.

2. To calculate total fibers per filter:

\[
\text{fiber/filter} = \frac{\text{# of fibers counted}}{\text{number of fields}} \times \frac{\text{fields/filter}}{}
\]

3. To calculate fibers per cubic centimeter of air:

\[
\text{fibers/cc} = \frac{\text{# of fibers per filter}}{\left(\frac{\text{liters of air sampled}}{1000}\right)}
\]

QUALITY CONTROL

1. Approximately one blank should be submitted for every 20 samples.

2. Approximately one filter out of every ten should be selected for recounting. For a pair of counts on the same filter, reject both values because one might be biased if:

\[
(FB_2 - FB_1) \text{ exceeds } 2.77 (FB)(CV_{FB})
\]

Where:

\( FB_1 = \) lower fiber count (total fibers)  
\( FB_2 = \) higher fiber count (total fibers)  
\( FB = \) average of the two total fiber counts  
\( CV_{FB} = CV_T \) for the value FB. Use the relation in figure 1.
Total coefficient of variation as a function of total fiber count
ASBESTOS FIBERS IN AIR
National Institute for Occupational Safety and Health
Analytical Method

<table>
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<tr>
<th>Analyte:</th>
<th>Asbestos fibers</th>
<th>Method No.:</th>
<th>P&amp;CAM 239</th>
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<tr>
<td>Matrix:</td>
<td>Air</td>
<td>Range:</td>
<td>0.1-60 fibers/cm³</td>
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<td>Filter collection, microscopic count</td>
<td>Precision (CV₂):</td>
<td>0.24 to 0.38</td>
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<tr>
<td>Date Issued:</td>
<td>3/30/77</td>
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1. Principle of the Method

1.1 This method describes the equipment and procedures for collecting, mounting, and counting asbestos fibers on cellulose ester membrane filters in the evaluation of personal samples of airborne asbestos fibers. The purpose of the method is to determine an employee's index of exposure to airborne asbestos fibers. The method is primarily a personal monitoring technique, but can be used for area monitoring.

1.2 The sample is collected by drawing air through a membrane filter by means of a battery powered personal sampling pump. The filter is transformed from an opaque solid membrane to a transparent optically homogeneous gel. The fibers are sized and counted using a phase-contrast microscope at 400-450X magnification.

1.3 Definitions. Asbestos fiber, for counting purposes, means a particulate which has a physical dimension longer than 5 micrometers and with a length to diameter ratio of 3 to 1 or greater. Asbestos includes chrysotile, cummingtonite-grunerite (amosite), crocidolite, fibrous tremolite, fibrous anthophyllite, and fibrous actinolite.

1.4 Any laboratory attempting to use this procedure should have at least one counter attend a training course conducted by an experienced, proficient laboratory. Novice, untutored counters, using only published instructions, can easily obtain counts of half those performed by experienced, proficient counters. Large differences between laboratories can be caused by: 1) differences in technique and observing ability among counters and 2) small, but significant, differences between microscopes meeting the basic specifications of Section 6.2. The following procedures are recommended:

1.4.1 All microscopists who perform asbestos counting should meet together for an “asbestos counting workshop” at least quarterly. This is best accomplished with counters from several laboratories using their own microscopes.

1.4.2 Each microscopist should count the same series of slides and with the results being compared.

1.4.3 Differences between counters should be resolved with side-by-side counting of the fields by the different counters.

1.4.4 Individuals who are found to be persistent outliers over several sessions should be encouraged to seek other tasks in their respective laboratories.
2. Range and Sensitivity

2.1 The usable range is primarily a function of sample volume, microscope count field area, and background airborne particulates. The influence of these variables is discussed in 8.1.3. For a microscope count field area of 0.003 mm² (see Figure 1) and a pump flow rate of 1.7 lpm, the optimal fiber densities would be produced over the range of 0.4 fiber/cm² (8-hour sample) to about 60 fibers/cm² (15-minute sample). For a field area of 0.006 mm² (see Figure 2) and a pump flow rate of 1.7 lpm, the optimal range is 0.2 fiber/cm² (8-hour sample) to about 30 fibers/cm² (15-minute sample). In each case, the optimal detection limits are inversely proportional to pump flow rate.

The upper detection limit can be extended by using sample times less than 15 minutes or using lower flow rates. The lower detection limit can be extended by increasing the flow rate up to about 2.5 lpm. Filter surface fiber densities less than optimal (less than about 0.5 to 1.0 fiber per count field) are still adequate, but will lead to decreased precision for the method (increased coefficient of variation, see Section 4).

The minimum total fiber count in 100 fields considered adequate for reliable quantitation is 10 fibers. Thus, the Tower limit of reliable quantitation is 0.1 fiber/cm³ (100,000 fibers/m³). For this level, a flow rate of about 2.5 lpm is recommended. For a field area of 0.003 mm², the minimum sample time would be about 2 hours. For a field area of 0.006 mm², the minimum sample time would be about 1 hour.

2.2 This method considers only fibers with a length to diameter ratio of 3 to 1 or greater and a length greater than 5 micrometers.

3. Interferences

In an atmosphere known to contain asbestos, all particulates with a length to diameter ratio of 3 to 1 or greater, and a length greater than 5 micrometers should, in the absence of other information, be considered to be asbestos fibers and counted as such.

4. Precision and Accuracy

4.1 In the past decade, there have appeared a number of articles examining sources of variation in the asbestos sampling and counting procedure. These include: Lynch et al. (11.1), Weidner and Ayer (11.2), Conway and Holland (11.3), Leidel and Busch (11.4), Beckett and Artfield (11.5), and Rajhans and Bragg (11.6). The sources of variation will be discussed by stages in the membrane filter evaluation procedure.

4.2 Sources of Variation in the Sampling Process. These include variations in pump flow rate, proximity of the filter to the employee's body, and filter location (left to right) in the employee's breathing zone.

4.2.1 Section 9.1 requires that the personal sampling pump be calibrated with sufficient accuracy such that the 95% confidence limits on the flow rate are ±10%. This is equivalent to a coefficient of variation (CV) of about 5%. However, this CV makes a negligible contribution to the total CV for the method due to the relatively large CV of the counting procedure.

4.2.2 Conway and Holland (11.3) concluded that positioning of the filter cassette on the wearer (regarding the angular portions of the filter and their proximity to the wearer) is not a significant factor in determining the fiber distribution on filters.

4.2.3 Weidner and Ayer (11.2) concluded that there is no appreciable difference between samples collected on either the right or left sides of a breathing zone or between samples collected side-by-side, especially for samples with concentrations less than 2.5 fibers/cm³.
4.3 Sources of Variation in the Counting Procedure

4.3.1 Random variations exist in the fiber distribution on a filter wedge (intra-wedge variability). The industrial hygiene literature has seen considerable debate in the last 20 years concerning whether or not the distribution of mineral dust or asbestos fibers on a filter surface is adequately described by a Poisson distribution probability density function. Leidel and Busch (11.4) found excellent agreement between empirical error variance and theoretical variance calculated from the assumption of Poisson distributed true counts. They concluded that there was not excessive variation among count fields for a filter wedge and that clumping of fibers (non-random coalescence) did not occur.

4.3.2 Variations exist in the fiber distribution on the total filter surface (inter-wedge variability) due to the random or non-random distribution of fibers across the total surface of the filter. This type of variation is easily confused with intra-wedge variations. The count procedure does not require counting of multiple sectors of the filter. There may be significant differences between average counts for different wedges, or the fiber distribution variations for the total filter surface may be greater than the variations of the Poisson distribution. If either of these occur experimentally, one must use the experimental variations to estimate the minimum precision of the count procedure. The minimum precision is governed by the variations of the fiber distribution on the total surface of the filter.

Conway and Holland (11.3) concluded the distribution of fibers on filters is not uniform and the distribution of fiber counts is more disperse than Poisson. For their filters which had significant variations in fiber concentrations between sectors (as much as 50-60% of the total filter mean), they described the following relation for the standard deviation of the total number of fibers counted on a wedge (N):

\[ \text{empirical } \sigma(N) = 1.6 \sqrt{N} \]

where \( N \) is about 100. The Poisson standard deviation would be:

\[ \text{Poisson } \sigma(N) = \sqrt{N} \]

Rajhans and Bragg (11.6) in Series I of their study found significant variation between filter segments and rejected the Poisson distribution for the total filter surface. However, in Series II of their study, utilizing various experimental modifications, they found no significant variation between filter segments and no reason to reject the assumption of Poisson distributed fiber counts.

4.3.3 Systematic variations due to differences between microscopes were studied by Leidel and Busch (11.4). In their study using five different brands of microscopes, they found no significant differences among four, but the fifth gave counts approximately 45% higher on the average than the other four.

4.3.4 Variations due to differences between counters should be examined at three levels: experienced counters occasionally counting, experienced counters routinely counting, and inexperienced (new or untutored) counters. Leidel and Busch (11.4) studied five experienced counters, with one counting only occasionally. There were no significant differences among three of the counters, but the fourth was 16% lower than the first three. The fifth, who occasionally counted, averaged 27% higher than the first three. Conway and Holland (11.3) studied three experienced counters and three inexperienced counters. They found statistically significant differences between the means of both the experienced and inexperienced counters that typically were in the range plus or minus 5 to 15%. They concluded that experience as a fiber counter is not a significant parameter affecting intercounter variations.
Rajhans and Bragg (11.6) found no significant differences among means of five experienced counters in Series I of their study. But in their carefully controlled Series II, an analysis of variance showed significant variations between counters that were plus or minus 1 to 15%.

4.3.5 Variations between laboratories are most likely due to systematic biases and are not a significant additional source of random variations. Any additional variations are most likely due to differences in counting technique. Beckett and Attfield (11.5) observed that standard counters improved greatly after personal instruction; also new counters, after instruction, tended to overcompensate and get exceedingly high counts. Additionally, they found that counts from an experienced laboratory that had not had contact with other laboratories performing the same analysis were as far from the standard values as were the counts by new counters.

4.4 Sources of variations between samples taken at different times on one employee during one work shift can affect the exposure estimate for that employee. These are primarily due to a) differences in exposure concentrations during the day, b) differences in location of the employee within the plant, and c) differences in work operation performed by the employee during the day. These sources of variation can be controlled by proper choice of sampling strategy. Refer to Leidel and Busch (11.7) and Leidel, Busch, and Lynch (11.8) for an extended discussion of sampling strategies. Interday temporal variations can affect the exposure estimates obtained on different days. Refer to Leidel, Busch, and Crouse (11.9) for a discussion of this type of variation.

4.5 Until recently, the total coefficient of variation (CV) for the sampling and counting procedure was best estimated from the work of Conway and Holland (11.3). The conclusions of their study included:

4.5.1 The precision of their procedure for filters not containing an abundance of fine fibers can be estimated by a coefficient of variation of 16.2%. This value includes variation among counters and observed interaction effects.

4.5.2 The accuracy of the procedure for similar filters may be estimated for a 100-fiber count by a coefficient of variation of 21.4%. This assumes that the contribution of the overall variance from the nonuniform fiber distribution is additive.

4.5.3 A high percentage of very fine fibers on the filter can significantly affect the standard deviation and confidence limits for counts by different counters. After combining variations in fiber concentrations over the entire filter with those for different counters, it was concluded:

a. For filters with a low concentration of fine fibers, the coefficient of variation is estimated at 21% and the 95% confidence interval is ± 43%.

b. For filters with a high concentration of fine fibers, the coefficient of variation is estimated at 25% and the 95% confidence interval is ± 50%.

Lynch, Kronoveter, and Leidel (11.11) have also reported on variations of the method. Their intralaboratory study utilized the data from a large number of dust counts made by different methods by experienced counters over a period of years in an epidemiologic study of the asbestos products industry. They concluded that the standard deviation of counts of fibers longer than 5 micrometers on membrane filters could be estimated from the relation \( \sigma = (N)^{0.43} \). Thus for counts of about 100 fibers, the coefficient of variation could be estimated at about 15.2% and the 95% confidence limits at ± 30.4%. These values are lower than the values reported by Conway and Holland (11.3). Recently, the Johns-Manville Corporation conducted an in-house investigation of the asbestos count method (11.10). The study data contained total fiber counts for over 239-4
100 filters with each filter counted by two to five counters. From the Johns-Manville data, NIOSH calculated over 100 estimates of the count CV for the method (11.11). The NIOSH CV estimates included random intrafilter variations and intercounter variations, but did not include random pump flow rate variations. It was found that the count coefficient of variation (all random variations except for pump variations) was a function of the total fiber count. NIOSH then included a CV of 0.05 for random pump variations (see Section 9.1) in the CV-estimator equation to obtain a CVT-estimator. The CVT-estimator line is plotted on Figure 3 for total fiber counts in the range 10 to 100 fibers. Or the following equation can be used:

\[ CV_T = \left[ \text{antilog}_{10}(-0.215 - 0.203 \log_{10} FB) + 0.0025 \right]^2 \]

where FB is total fiber count as discussed in Section 10.

Figure 3 demonstrates that for a total fiber count of 100, the best CVT is attainable with the appropriate sampling times given in 8.1.3 and the count rules in 8.3.9. When making decisions regarding compliance with the OSHA asbestos exposure standards in 29 CFR 1910.1001, the statistical procedures given in Leidel et al. (11.11) should be followed. The procedures are based on statistical theory and assumptions given in References 11.12, 11.13.

Because of the possibility of systematic biases due to differences between microscopes, counters, and laboratories as discussed above, it is strongly recommended that any laboratory counting asbestos should participate in an interlaboratory quality control program that includes the counting of standard reference filters. These standard filters are available from NIOSH through the Proficiency Analytical Testing (PAT) Program. The PAT Program is used by the American Industrial Hygiene Association (AIHA) as part of its Laboratory Accreditation Program. Each laboratory’s quality control program must include protocols for routinely adjusting and calibrating sampling and counting equipment plus training and evaluation programs for counters.

5. Advantages and Disadvantages of the Method

5.1 The method is intended to give an index of employee exposure to airborne asbestos fibers of specified dimensional characteristics.

5.2 It is not meant to count all asbestos fibers in all size ranges or to differentiate asbestos from other fibrous particulates.

6. Apparatus

6.1 Sampling Equipment

The personal sampling equipment train consists of 1) personal sampling pump, 2) tubing, 3) clothing spring clip, 4) tubing-to-field monitor metal adaptor, and 5) field monitor (filter and holder).

6.1.1 Personal Sampling Pump. The pump must be capable of sampling at 1.0 to 2.5 liters per minute (lpm) against a flow resistance of 7.5 inches of water (1.4 cm Hg) for 8 continuous hours on a fully charged battery.

6.1.2 Tubing. Laboratory tubing such as rubber or plastic with 6-mm bore and about 100 cm length.

6.1.3 Clothing Spring Clip. The clip attaches the rubber tubing to the lapel or shirt of the individual being monitored.

6.1.4 Tubing-to-field Monitor Adaptor. A short metal adaptor with ridges on one end to grip the inside of the tubing. The other end is designed for a pressure fit into the field monitor.

6.1.5 Field Monitor (Filter and Holder). The only field monitor currently considered acceptable by NIOSH is manufactured by the Millipore Corporation. The unit con-
sists of 1) a three section styrene plastic case designated Millipore Aerosol Monitor Case, 2) a 37-mm diameter plain white cellulose ester membrane filter designated Millipore AA (pore size of 0.8 micrometer), 3) a support pad, and 4) two plastic sealing caps. If a large number of samples are to be taken, it may be less expensive to reuse the plastic cases. Great care must be taken in the cleaning and reassembly process. The outside mating surfaces of the field monitors may be covered with a “shrink-fit” band to provide proper sealing and a writing surface for filter identification.

6.2 Optical Equipment and Microscope Features

6.2.1 Microscope body with binocular head.

6.2.2 10X Huygenian eyepieces are recommended. Other eyepieces can be substituted if necessary. Wide field eyepieces can be used; however, wide field eyepieces may yield a count field area less than 0.003 mm² with the Porton reticle. This is not always desirable from the standpoint of obtaining optimum sampling times (see Section 8.1.3). If wide field eyepieces are used, it is preferable to use the Patterson Globe and Circle reticle to obtain a larger count field area.

6.2.3 Koehler illumination (preferably built-in with provisions for adjusting light intensity).

6.2.4 A Porton reticle is recommended. Others such as the Patterson Globe and Circle can be substituted.

6.2.5 Mechanical stage.

6.2.6 Phase-Contrast condenser with a numerical aperture (N.A.) equal to or greater than the N.A. of the objective.

6.2.7 40-45X phase contrast achromatic objective (N.A. 0.65 to 0.75).

6.2.8 Phase-ring centering telescope or Bertrand lens.

6.2.9 Green or blue filter, if recommended by microscope manufacturer.

6.2.10 Stage micrometer with 0.01 mm subdivisions.

6.2.11 For general guidance on phase contrast microscopy, consult Needham (11.12), Clark (11.15) and McCrone (11.14).

6.3 Filter Mounting Equipment. Experience has shown that certain equipment is useful for efficient sample mounting. The following items are recommended for extracting and mounting a portion of the filter for counting.

6.3.1 Microscope slides. 2.5 by 7.5 cm glass slides are most commonly used. Sample number, data, initials, etc., can be conveniently written on a frosted end slide.

6.3.2 Cover Slips. Cover slips are a necessary part of the slide mount and optical system. The shape should be appropriate for the size of the filter wedge. The appropriate cover slip depends upon the objective to be used. Ordinarily, objectives are optically corrected for a #1½ (0.17 millimeter) thickness cover slip. Improper cover glass thickness will detract from the final image quality.

6.3.3 Scalpel. A scalpel is needed to cut out a portion of the filter to be examined. A number-ten curved blade scalpel is recommended.

6.3.4 Tweezers. A pair of fine-tipped tweezers is used to remove the membrane filter slice from the field monitor and place it upon the slide.

6.3.5 Lens Tissue. To insure cleanliness, a lint-free tissue is recommended. This tissue should also be used for wiping mounting tools and for cleaning slides and cover slips.

6.3.6 Glass Rod. A fire-polished glass rod may be used to spread the mounting solution on the slide.
6.3.7 Wheaton Balsam Bottle. This special glass container has a glass top which prevents contamination of the mounting solution. A glass rod is included for dispensing the solution.

Reagents
Chemicals should be reagent grade, free from particles and color, conforming to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

7.1 Dimethyl phthalate
7.2 Diethyl oxalate
Avoid getting the mounting solution on the skin. Wash skin promptly with soap and water if skin contact occurs.

Procedure
8.1 Sampling
8.1.1 General Information
Guidelines for the monitoring of employee exposures to industrial atmospheres are given in Reference 11.8. The Federal requirements for monitoring employee exposure to airborne asbestos are found in 29 CFR 1910.1001.

8.1.2 Mounting the Sampling Pump on the Worker
Fasten the sampling pump to the worker's belt and fasten the field monitor to the lapel or shirt front (as close to the breathing zone as is practical). Remove the top cover of the plastic monitor, then invert the monitor making certain the exposed filter is facing downward. Turn the pump on and adjust to the calibrated flow rate (1.0 to 2.5 lpm). Record the following information in a logbook.
1. Filter number
2. Pump start time and date
3. Flow rate
4. Subject's name and job title
5. Type of operation or process
6. Ventilation controls and is the worker wearing a respirator approved for asbestos?
The pump should be checked periodically during the sampling period for proper operation and flow rate.

8.1.3 Optimum Sampling Times
The requirement for the minimum count of 100 fibers or 20 fields in 8.3.9 was determined to be the best compromise to achieve adequate precision for the airborne fiber estimate and reasonable counting times. An optimum fiber density of about 1 to 5 fibers per microscope count field is recommended. To estimate appropriate sampling times for feasible counting and optimal counting, one must consider the following constraints:
1. microscope count field area (generally 0.003 to 0.006 mm²)
2. pump flow rate (typically 2.5 lpm maximum)
3. average airborne fiber concentrations
4. counting rule range of 20 to 100 fields
5. adequate fiber density to obtain a minimum count of 10 fibers in 100 fields, which is the least total fiber count that yields an acceptable count precision
6. background airborne particulate levels that can reduce the count precision due to an obscuring of fibers on the filter surface
The preceding constraints were considered in drawing Figures 1 and 2. These figures were developed from the following relationship:

\[
\text{sampling time} = \frac{(FB/FL) (ECA/MFA)}{(FR) (AC) (1000)} \text{ minutes}
\]

where:

- \( FB/FL = 1 \) to 5 fibers/field
- \( ECA = \) effective collecting area of filters (355 mm\(^2\) for 37-mm filter with effective diameter of 33 mm)
- \( MFA = \) microscope field area (generally 0.003 to 0.006 mm\(^2\))
- \( FR = \) Pump flow rate (generally 1.0 to 2.5 lpm)
- \( AC = \) Air concentration of fibers in fibers/cm\(^2\).

Figure 1 (microscope field area = 0.003 mm\(^2\)) and Figure 2 (microscope field area = 0.006 mm\(^2\)) show optimum and feasible sampling times for a pump flow rate of 1.7 lpm. Each individual responsible for sampling asbestos should prepare a similar chart for his particular pump flow rate and microscope field area before sampling is performed to aid in estimating proper sampling times. On Figures 1 and 2, the areas with solid shading lines are generally the optimum conditions for counting. The broken shading lines are for conditions very close to optimal. However, feasible counting conditions may extend down to about 0.1 fiber/field and above 5 fibers/field. Recommended sampling times are most strongly influenced by background airborne particulate levels, once all the other constraints have been estimated. For heavy particulate levels, it may be necessary to limit each filter to about 60 to 180 minutes sampling duration. Each individual responsible for sampling should work closely with the microscopist to attain as high as possible filter surface fiber densities (up to about 5 fibers/field), while avoiding filter surface background particulate levels that create very difficult or impossible counting conditions. If one has very little idea of airborne fiber and particulate levels, the best procedure is to take several long samples (as one 8-hour or two consecutive 4-hour samples) in conjunction with several short samples (as four consecutive 2-hour or eight consecutive 1-hour samples). If the longer samples prove very difficult to count, the microscopist will have the shorter samples to fall back on.

From Figures 1 and 2, it can be seen that there are certain sampling times which will yield optimum fiber densities on the filter for almost all airborne fiber concentrations from 1 to 10 fibers/cm\(^2\). These optimum times have been calculated and are presented in Figure 4. Note that the optimum times given by Figure 4 are approximate and can be varied by as much as ± 25%. The nomogram is intended as a guide to be used where no prior knowledge of the air concentration is available.

8.1.4 End of Sampling Period
Remove the field monitor, replace the plastic top cover and the small end caps, and store the monitor. Always shut off the pump when changing monitors to avoid contaminating or damaging the pump. Record the pump shutoff time and flow rate in the logbook.

8.1.5 Blanks
With each batch (25 to 50 filters) of samples sent for analysis, submit two unopened field monitors which have been subjected to the same treatment as the samples except that they were not exposed to the sampling environment. Label these as blanks. If the blanks yield fiber counts greater than 5 fibers/100 fields, then the entire sampling procedure should be examined carefully for the cause of contamination. The
mounting solution of Section 8.2.1 should also be examined for contamination and/or crystal growth.

8.1.6 Shipping
The field monitors in which the samples are collected should be shipped in a rigid container with sufficient packing material to prevent crushing.

8.1.7 Numbers of Samples
When sampling for the Federal ceiling standard of 10 fibers (>5 μm)/cm², [29 CFR 1910.1001(b) (3), effective July 7, 1972], only one sample (15 minutes maximum duration) is necessary, theoretically. However, several samples should be taken during expected periods of peak air concentrations to allow for detection of gross sampling or counting errors.

When sampling for determination of noncompliance with the Federal 8-hour TWA standard of 2 fibers (>5 μm)/cm³, [29 CFR 1910.1001(b) (2)], one should continuously sample as large a portion of the work day as is feasible for airborne concentrations of about 2 to 10 fibers/cm³. However, for a lower airborne concentration such as 0.5 fiber/cm³, one sample might require 4 to 8 hours sampling time in order to get the proper filter fiber density (Section 8.1.3). For this situation, the 8-hour TWA exposure would be determined from one 8-hour or two 4-hour samples as appropriate.

8.2 Sample Preparation

8.2.1 Preparation of Mounting Solution
A very important part of the sample evaluation is the mounting process. This process involves a special mounting medium of prescribed viscosity. The proper viscosity is important in order to expedite filter dissolving and still minimize particle migration. After the sample has been mounted, an elapsed time of approximately sixty minutes is needed before the sample is ready for evaluation.

Combine the dimethyl phthalate and diethyl oxalate in a one to one ratio by volume and pour into a Wheaton balsam bottle. Add approximately 0.05 (= 0.005) grams of new membrane filter per milliliter of solution to reach the necessary viscosity. The mixture must be stirred periodically until the filters have dissolved and a homogeneous mixture is formed. The normal shelf life of the mounting solution is about three months. Twenty milliliters of mounting solution will prepare approximately 300 samples.

8.2.2 Sample Mounting
Cleanliness is important! A dirty working area may result in sample contamination and erroneous counts. The following steps should be followed when mounting a sample.

1. Clean the slides and cover slips with lens tissue. Lay each slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.

2. Wipe all the mounting tools clean with lens tissue and place them on a clean surface (such as lens tissue). All tools should be wiped clean prior to mounting each sample.

3. Using the glass rod supplied with the Wheaton balsam bottle, apply a drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of solution so that after the cover slip has been placed on top, the solution extends only slightly beyond the filter boundary. If the quantity is greater than this, particle migration may occur.
4. Using another glass rod, spread the mounting media into a triangular shape. The size of this triangle should coincide with the dimension of the filter wedge.

5. Separate the middle and bottom sections of the field monitor case to expose the filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface. The filter can be very carefully removed from the cassette for cutting, but this should only be done with great care.

6. Grasp the filter wedge with the tweezers on the perimeter of the filter which was clamped between the monitor case sections. Do not touch the filter with your fingers. Place the wedge, sample side up, upon the mounting medium.

7. Pick up a clean cover slip with tweezers and carefully place it on the filter wedge. Once this contact has been made, do not reposition the cover slip.

8. Label the slide with the sample number and current date before proceeding to the next filter. On the bottom (backside) of the slide, trace the perimeter of the filter wedge with a felt tip marking pen. This will enable the counter, after the filter has become transparent, to stay within the filter perimeter when counting.

9. The sample should become transparent within fifteen minutes. If the filter appears cloudy, it may be necessary to press very lightly on the cover slip. This is rarely necessary; however, counting should not be started until an hour after the mounting. This allows the microscopic texture of the filter to become invisible to microscope viewing.

10. Discard the sample mount after two days if it has not been counted. Crystals appearing similar to asbestos fibers may begin to grow at the mounting media/air interfaces. They seldom present any problems if the slide is examined before two days. In any case, stay away from the filter's edges when counting and sizing.

8.3 Counting of Fibers

8.3.1 Place the slide on the mechanical stage of the microscope and position the center of the wedge under the objective lens and focus upon the sample. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from perimeter to wedge tip). Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.

8.3.2 It is essential to continually scan over a range of focal planes (generally the upper 10 to 15 micrometers of the filter surface) with the fine focus control during each field count. This is especially necessary for asbestos fibers due to their impaction into the filter matrix.

8.3.3 On most airborne samples, asbestos fibers will generally have fiber diameters less than one micrometer. Therefore, it is necessary to look carefully for faint fiber images.

8.3.4 Regularly check phase ring alignment.

8.3.5 When an agglomerate (mass of material) covers a significant portion of the field of view (approx 1/6 or greater) reject the field and select another. (Do not include it in the number of fields counted.) However, report the fact as it may have meaning on other data collection.

8.3.6 Bundles of fibers are counted as one fiber unless both ends of the fiber can be clearly resolved.

8.3.7 Count only fibers with a length to width ratio greater than or equal to 3:1.

8.3.8 Count only fibers greater than 5 micrometers in length. (Be as accurate as possible in accepting fibers near this length.) Measure curved fibers along the curve to estimate the total length.
8.3.9 Count as many fields as necessary to yield a total count of at least 100 fibers. Exceptions: a) count at least 20 fields even if you count more than 100 fibers, and b) stop at 100 fields even if you haven’t reached 100 fibers.

8.3.10 For fibers that cross either one or two sides of the counting field, the following procedure is used to obtain a representative count.

COUNT any fiber greater than 5 micrometers in length, that lies entirely within the counting area. COUNT as “½ fiber” any fiber with only one end lying within the counting area. DO NOT COUNT any fiber crossing any two sides. Reject and do not count all other fibers. Refer to Figures 5 through 10. Note that the fibers in Figures 5 through 10 are not representative of the appearance of most asbestos fibers. Most fibers have a very faint image.

9. Calibration and Standards

9.1 Sampling Train Calibration

The accurate calibration of the sampling pump is essential to the correct calculation of the air volume sampled. The frequency of calibration is dependent on the use, care, and handling to which the pump is subjected. Pumps must be recalibrated if they have just been repaired, misused, or received from the manufacturer. If the pump receives hard usage, more frequent calibration may be necessary. Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples.

The accuracy of calibration is dependent upon the type of instrument used as a reference. The choice of a calibration instrument will depend largely on where the calibration is performed. For laboratory testing, a 1-liter buret used as a soap bubble flow meter or wet-test meter is recommended. Other standard calibrating instruments, such as a spirometer, Marriot’s bottle, or dry gas meter can be used. The calibration should be of sufficient precision that the 95% confidence limits on the flow rate are ± 10% (95% of the flow rates will fall within ± 10% of the calibrated value).

Instructions for calibration with the soap bubble flow meter follow. The sampling train used (pump, hose, filter cassette) in the pump calibration should be the same as the one used in the field.

9.1.1 Check the voltage of the pump battery with a voltmeter both with the pump off and while it is operating to assure adequate voltage for calibration. If necessary, charge the battery to manufacturer’s specifications.

9.1.2 Fill a beaker with 10 ml of soap solution.

9.1.3 Connect the filter cassette inlet to the top of the buret with a length of hose.

9.1.4 Turn the pump on and moisten the inside of the soap bubble meter by immersing the open end of the buret into the soap solution and drawing bubbles up the inside of the buret. Perform this task until the bubbles are able to travel the entire length of the buret without breaking.

9.1.5 Adjust the pump rotameter to provide a flow between 1.5 to 2.5 lpm.

9.1.6 With a water manometer, check that the pressure drop across the filter is less than 13 inches of water (about 1 inch of mercury).

9.1.7 Start a soap bubble up the buret and measure the time it takes for the bubble to travel a minimum volume of 1 liter.

9.1.8 Repeat the procedure in 9.1.7 at least three times, average the results, and calculate the calibrated flow rate by dividing the volume traveled by the soap bubble by the elapsed time. If the range between the highest and lowest of the three flow rates is greater than about 0.33 lpm, then the calibration should be repeated since it is likely that the precision is not adequate.
9.1.9 Data required for the calibration include the volume measured, elapsed time, pressure drop, air temperature, atmospheric pressure (or elevation), pump serial number, date, and name of person performing the calibration.

9.1.10 Corrections to the flow rate for pumps with rotameters may be necessary if the pressure (elevation) or temperature where the samples are collected (actual flow rate) differs significantly from that where the calibration was performed (indicated flow rate). Actual flow rates at time of sampling may be calculated for a linear scale rotameter by using the following correction formula:

\[ Q_{\text{actual}} = Q_{\text{indicated}} \sqrt{\frac{P_{\text{cal}}}{P_{\text{actual}}}} \cdot \frac{T_{\text{actual}}}{T_{\text{cal}}} \]

where both pressure (P) and temperature (T) are in absolute units such as:

- \text{psia} = \text{psig} + 14.7
- \text{deg Rankin} = \text{deg Fahrenheit} + 460
- \text{deg Kelvin} = \text{deg Celsius} + 273

9.2 Microscope Setup

9.2.1 Porton Reticle and the Counting Field
The asbestos fiber count procedure consists of comparing fiber length to the diameters of calibrated circles of a Porton reticle, and counting all fibers greater than 5 micrometers in length lying within a given counting field area. The Porton reticle is a glass plate inscribed with a series of circles and rectangles. The left half of the reticle is divided into six rectangles constituting the counting field. The counting field is illustrated in Figures 5 through 10.

9.2.2 Placement in Eyepiece
The Porton reticle is placed inside the Huygenian eyepiece where it rests on the field-limiting diaphragm. If other types of eyepieces are used, it may be necessary to insert a counting collar for retaining the reticle. The reticle should always be kept clean, since dirt on the reticle is in focus and could complicate the counting and sizing process.

9.2.3 Stage Micrometer
The Porton reticle cannot be used for counting until it has been properly calibrated with a stage micrometer. Most stage micrometer scales are approximately two millimeters long and are divided into units of one-hundredth of a millimeter (ten micrometers).

9.2.4 Microscope Adjustment
When adjusting the microscope, follow the manufacturer's instructions while observing the following guidelines.

1. The light source image must be in focus and centered on the condenser iris or annular diaphragm.
2. The particulate material to be examined must be in focus.
3. The illuminator field iris must be in focus, centered on the sample, and opened only to the point where the field of view is illuminated.
4. The phase rings (annular diaphragm and phase-shifting elements) must be concentric.

9.2.5 Porton Reticle Calibration Procedure
Each eyepiece-objective-reticle combination on the microscope must be calibrated. Should any of the three be changed (disassembly, replacement, zoom adjustment, etc.), the combination must be recalibrated. Calibration may change if interpupillary dis-
Distance is changed. For proper calibration, the following procedure should be followed closely.

With a 10X objective in place, place the stage micrometer on the mechanical stage, focus the millimeter scale, and center the image. Change to the 40-45X objective and adjust the first millimeter scale division to coincide with the left boundary of the Porton rectangle. Measure the distance between the left and extreme right boundaries of the Porton rectangle, estimating any portion of the final division. This measurement represents 200 L units. The rectangle is 100 L units on the short vertical dimension. The calculated "L" is inserted into the formula \( D = L(2^N)^{1/2} \) where "N" is the circle number (indicated on the reticle) and "D" is the circle diameter. Since the circle diameters vary logarithmically, every other circle doubles in diameter. For example, circle number three is twice the diameter of number one; number four is twice the diameter of number two. When the circle sizes have been determined, the counting field area which consists of the left six smaller rectangles can be calculated from the relation 10,000 L². This completes the reticle calibration for this specific objective-eyepiece-reticle combination.

Example for Porton Reticle

The following calibration was obtained for a pair of 10X Huygenian eyepieces and a 43X objective:

- \( 200 \text{ L} = 0.148 \text{ mm} = 148 \text{ micrometers} \)
- \( 100 \text{ L} = 0.074 \text{ mm} = 74 \text{ micrometers} \)
- One L-unit = 0.74 micrometers

Thus Circle #1 has a diameter \( D = L(2^N)^{1/2} = 0.74(2^1)^{1/2} = 0.74 \times 1.414 = 1.05 \) micrometers.

Thus fibers with a length greater than a distance halfway between the diameters of the #5 and #6 circles would be counted.

If a Patterson Globe and Circle reticle is used, a different calculation procedure is required. The circle diameters are related as follows. The #25 circle diameter is \( (0.1) \) (reticle length).

The circle diameters are proportional to the ratio of their numbers. Thus the #20 circle diameter is \( (20/25) \) or 0.8 times the #25 circle diameter.

10. Calculations

10.1 The average airborne asbestos fiber concentration estimated by the filter sample may be calculated from the following formula:

\[
AC = \frac{(FB/FL) - (BFB/BFL)}{(ECA)} \times \frac{1000}{(FR)(T)(MFA)}
\]
where:

\[ AC = \text{Airborne fiber concentration in (fibers > 5 } \mu\text{m)/cm}^3. \]

\[ BFB = \text{Total number of fibers counted in the BFL fields of the blank or control filters in fibers > 5 } \mu\text{m.} \]

\[ BFL = \text{Total number of fields counted on the blank or control filters.} \]

\[ ECA = \text{Effective collecting area of filter (855 mm}^2 \text{for a 37-mm filter with effective diameter of 33 mm).} \]

\[ FR = \text{Pump flow rate in liters/min (lpm).} \]

\[ FB = \text{Total number of fibers counted in the FL fields in fibers > 5 } \mu\text{m.} \]

\[ FL = \text{Total number of fields counted on the filter.} \]

\[ MFA = \text{Microscope count field area in mm}^2 \text{ (generally 0.003 to 0.006).} \]

\[ T = \text{Sample collection time in minutes.} \]

10.2 Recount criteria. It is very desirable for a counter to conduct a “blind recount” for about 1 in every 10 filter wedges (slides) counted. Alternatively, a second counter could perform the blind recount. In training sessions for novice counters, the trainee should conduct a blind recount for filter wedges counted by an experienced, proficient counter. In all cases, we will observe differences between the first and second counts of the same filter wedge. Most of these differences will be due to chance alone, that is, due to the random variability (precision) of the count method. Statistical recount criteria enable us to decide whether observed differences can reasonably be explained due to chance alone or are probably due to systematic differences between counters or microscopes or due to some other biasing factor.

The following recount criterion is for a pair of counts that estimate some airborne fiber concentration (AC) in fibers/cm³. The criterion is given at the type-I error level. That is, there is a 5% maximum risk that we will reject a pair of counts for the reason that one might be biased, when the large observed difference is really due to chance.

Reject a pair of counts because one might be biased if:

\[ (AC_2 - AC_1) \text{ exceeds } 2.77(AC)(CV_{FB}) \]

where:

\[ AC_1 = \text{lower estimated airborne fiber concentration} \]

\[ AC_2 = \text{higher estimated airborne fiber concentration} \]

\[ AC = \text{average of the two airborne concentration estimates} \]

\[ CV_{FB} = \text{average CV for the two concentration estimates which are a function of the total fiber count (FB) in each case. Use the relation in Section 4 or Figure 3.} \]

For a pair of counts on the same filter, reject the pair because one might be biased if:

\[ (FB_2 - FB_1) \text{ exceeds } 2.77(FB)(CV_{FB}) \]

where:

\[ FB_1 = \text{lower fiber count on the filter (total fibers)} \]

\[ FB_2 = \text{higher fiber count on the filter (total fibers)} \]

\[ FB = \text{average of the two total fiber counts} \]

\[ CV_{FB} = CV_T \text{ for the value FB. Use the relation in Section 4 or Figure 3.} \]

11. References


11.2 Weidner, R. B. and H. E. Ayer, “Dust Exposure in Asbestos Processing”, Transactions of the...


11.10 Comments of the Johns-Manville Corporation with Respect to the Notice of Proposed Rulemaking: Occupational Exposure to Asbestos, Federal Register, October 9, 1975. Submitted to the public record at the U. S. Department of Labor, Occupational Safety and Health Administration, April 1976.


FIGURE 1. Optimum Sampling Times for airborne asbestos where microscopic field area = 0.003 mm²
FIGURE 2. Optimum sampling times for airborne asbestos where microscopic field area = 0.006 mm$^2$. 

- OSHA CEILING STD.
- 1976 8hr. TWA STD.
- OSHA PROPOSED TWA STD.

**AVERAGE FIBERS/cc OF P-ANT AIR**

**SAMPLING TIME IN MINUTES @ 1.7 lpm**
FIGURE 3. Total coefficient of variation as a function of total fiber count.
FIGURE 4. Nomogram of optimum sampling times for airborne asbestos fibers in concentrations of 1 to 10 fibers/cm³
LIST OF FIGURES
(5 through 10)

FIGURE 5. DO NOT COUNT. Fiber crosses top and bottom sides.

FIGURE 6. COUNT. One fiber.

FIGURE 7. COUNT. One-half fiber. Fiber crosses left side and one end lies within count area.

FIGURE 8. COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.

FIGURE 9. DO NOT COUNT. Fiber crosses two sides.

FIGURE 10. DO NOT COUNT. Fiber crosses two sides (bottom left corner).
COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.
COUNT. One fiber (top right corner).
APPENDIX C

1) OSHA ASBESTOS STANDARD 29 CFR 1910.1001

2) EPA ASBESTOS STANDARD 40 CFR 61
OSHA

1910.1001 - ASBESTOS

(a) Definitions

For the purpose of this section.

(1) "Asbestos" includes chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite.

(2) "Asbestos fibers" means asbestos fibers longer than 5 micrometers.

(b) PERMISSIBLE EXPOSURE TO AIRBORNE CONCENTRATIONS OF ASBESTOS FIBERS

(1) Standard effective July 7, 1972. The 8-hour, time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed five fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(2) Standard effective July 1, 1976. The 8-hour, time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed two fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(3) Ceiling concentration. No employee shall be exposed at any time to airborne concentration of asbestos fibers in excess of 10 fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(c) METHODS OF COMPLIANCE

(1) ENGINEERING METHODS

(i) Engineering controls. Engineering controls, such as but not limited to, isolation, enclosure, exhaust ventilation, and dust collection, shall be used to meet the exposure limits prescribed in paragraph (b) of this section.

(ii) LOCAL EXHAUST VENTILATION

(a) Local exhaust ventilation and dust collection systems shall be designed, constructed, installed, and maintained in accordance with the American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971, which is incorporated by reference herein.
(b) See Section 1910.6 concerning the availability of ANSI-A9.2-1971, and the maintenance of a historic file in connection therewith. The address of the American National Standards Institute is given in Section 1910.100.

(iii) PARTICULAR TOOLS

All hand-operated and power-operated tools which may produce or release asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, such as, but not limited to, saws, scorers, abrasive wheels, and drills, shall be provided with local exhaust ventilation systems in accordance with subdivision (ii) of this subparagraph.

(2) WORK PRACTICES

(i) Wet methods. Insofar as practicable, asbestos shall be handled, mixed, applied, removed, cut, scored, or otherwise worked in a wet state sufficient to prevent the emission of airborne fibers in excess of the exposure limits prescribed in paragraph (b) of this section, unless the usefulness of the product would be diminished thereby.

(ii) Particular products and operations. No asbestos cement, mortar, coating, grout, plaster, or similar material containing asbestos shall be removed from bags, cartons, or other containers in which they are shipped, without being either wetted, or enclosed, or ventilated so as to prevent effectively the release of airborne asbestos fibers in excess of the limits prescribed in paragraph (b) of this section.

(iii) Spraying, demolition, or removal. Employees engaged in the spraying of asbestos, the removal, or demolition of pipes, structures, or equipment covered or insulated with asbestos, and in the removal or demolition of asbestos insulation or coverings shall be provided with respiratory equipment in accordance with paragraph (d) (2) (iii) of this section and with special clothing in accordance with paragraph (d) (3) of this section.

(d) PERSONAL PROTECTIVE EQUIPMENT

(1) Compliance with the exposure limits prescribed by paragraph (b) of this section may not be achieved by the use of respirators or shift rotation of employees, except:

(i) During the time period necessary to install the engineering controls and to institute the work practices required by paragraph (c) of this section;

(ii) In work situations in which the methods prescribed in paragraph (c) of this section are either technically not feasible or feasible to an extent insufficient to reduce the airborne concentrations of asbestos fibers below the limits prescribed by paragraph (b) of this section; or
(iii) In emergencies.

(iv) Where both respirators and personnel rotation are allowed by subdivision (i) and (ii), or (iii) of this subparagraph, and both are practicable, personnel rotation shall be preferred and used.

(2) Where a respirator is permitted by subparagraph (i) of this paragraph, it shall be selected from among those approved by the Bureau of Mines, Department of the Interior, or the National Institute for Occupational Safety and Health Department, of Health, Education, and Welfare, under the provisions of 30 CFR Part 11 (37 P.R. 6244, March 25, 1972), and shall be used in accordance with subdivisions (i), (ii), (iii), and (iv) of this subparagraph.

(i) Air purifying respirators. A reusable or single use air purifying respirator, or a respirator described in subdivision (ii) or (iii) of this subparagraph, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour, time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed no more than 10 times those limits.

(ii) Powered air purifying respirators. A full facepiece powered air purifying respirator, or a powered air purifying respirator, or a respirator described in subdivision (iii) of this subparagraph, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour, time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed 10 times, but not 100 times, those limits.

(iii) Type "C" supplied-air respirators, continuous flow or pressure-demand class. A type "C" continuous flow or pressure-demand, supplied air respirator shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour, time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed 100 times those limits.

(iv) ESTABLISHMENT OF A RESPIRATOR PROGRAM

(a) The employer shall establish a respirator program in accordance with the requirements of the American National Standard Practices for respiratory Protection, ANSI Z88.2-1969, which is incorporated by reference herein.

(b) See Section 1910.6 concerning the availability of ANSI Z88.2-1969 and the maintenance of an historic file in connection therewith. The address of the American National Standards Institute is given in Section 1910.100.
(c) No employee shall be assigned to tasks requiring the use of respirators if, based upon his most recent examination, an examining physician determines that the employee will be unable to function normally wearing a respirator, or that the safety or health of the employee or other employees will be impaired by his use of the respirator. Such employee shall be rotated to another job or given the opportunity to transfer to a different position whose duties he is able to perform with the same employer, in the same geographical area and with the same seniority, status, and rate of pay he had just prior to such transfer, if such a different position is available.

(3) Special Clothing: The employer shall provide, and require the use of, special clothing, such as coveralls or similar whole body clothing, head coverings, gloves, and foot coverings for any employee exposed to airborne concentrations of asbestos fibers, which exceed the ceiling level prescribed in paragraph (b) of this section.

(4) Change rooms:

(i) At any fixed place of employment exposed to airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, the employer shall provide change rooms for employees working regularly at the place.

(ii) Clothes lockers: The employer shall provide two separate lockers or containers for each employee, so separated or isolated as to prevent contamination of the employee's street clothes from his work clothes.

(iii) Laundering:

(a) Laundering of asbestos-contaminated clothing shall be done so as to prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(b) Any employer who gives asbestos-contaminated clothing to another person for laundering shall inform such person of the requirement in (a) of this subdivision to effectively prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(c) Contaminated clothing shall be transported in sealed impermeable bags, or other closed, impermeable bags, or other closed, impermeable containers, and labeled in accordance with paragraph (g) of this section.

(e) METHOD OF MEASUREMENT

All determinations of airborne concentrations of asbestos fibers shall be made by the membrane filter method at 400-450 x (magnification) (4 millimeter objective) with phase contrast illumination.
(f) MONITORING

(1) Initial determinations. Within 6 months of the publication of this section, every employer shall cause every place of employment where asbestos fibers are released to be monitoried in such a way as to determine whether every employee’s exposure to asbestos fibers is below the limits prescribed in paragraph (b) of this section. If the limits are exceeded, the employer shall immediately undertake a compliance program in accordance with paragraph (c) of this section.

(2) Personal Monitoring

(i) Samples shall be collected from within the breathing zone of the employees, on membrane filters of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour, time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(ii) Sampling frequency and patterns. After the initial determinations required by subparagraph (I) of this paragraph, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of employees. In no case shall the sampling be done at intervals greater than 6 months for employees whose exposure to asbestos may reasonably be foreseen to exceed the limits prescribed by paragraph (b) of this section.

(3) Environmental monitoring

(i) Samples shall be collected from areas of a work environment which are representative of the airborne concentrations of asbestos fibers which may reach the breathing zone of employees. Samples shall be collected on a membrane filter of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour, time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(ii) Sampling frequency and patterns. After the initial determinations required by subparagraph (I) of this paragraph, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of the employees. In no case shall sampling be at intervals greater than 6 months for employees whose exposures to asbestos may reasonably be foreseen to exceed the exposure limits prescribed in paragraph (b) of this section.

(4) Employee observation of monitoring. Affected employees, or their representatives, shall be given a reasonable opportunity to observe any monitoring required by this paragraph and shall have access to the records thereof.
(g) CAUTION SIGNS AND LABELS

(1) Caution Signs

(i) Posting. Caution signs shall be provided and displayed at each location where airborne concentrations of asbestos fibers may be in excess of the exposure limits prescribed in paragraph (b) of this section. Signs shall be posted at such a distance from such a location so that an employee may read the signs and take necessary protective steps before entering the area marked by the signs. Signs shall be posted at all approaches to areas containing excessive concentrations of airborne asbestos fibers.

(ii) Sign specifications. The warning signs required by subdivision (i) of this subparagraph shall conform to the requirements of 20'' x 14'' vertical format signs specified in Section 1910.145(d)(4), and to this subdivision. The signs shall display the following legend in the lower panel, with letter sizes and styles of a visibility at least equal to that specified in this subdivision.

LEGEND

<table>
<thead>
<tr>
<th>NOTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos</td>
</tr>
<tr>
<td>Dust Hazard</td>
</tr>
<tr>
<td>Avoid Breathing Dust</td>
</tr>
<tr>
<td>Wear Assigned Protective Equipment</td>
</tr>
<tr>
<td>Do Not Remain in Area Unless Your Work Requires It</td>
</tr>
<tr>
<td>Breathing Asbestos Dust May be Hazardous to Your Health</td>
</tr>
</tbody>
</table>

Spacing between lines shall be at least equal to the height of the upper of any two lines.

(2) Caution Labels

(i) Labeling. Caution labels shall be affixed to all raw materials, mixtures, scrap, waste, debris, and other products containing asbestos fibers, or to their containers, except that no label is required where asbestos fibers have been modified by a bonding agent, coating, binder, or other material so that during any reasonably foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section will be released.
(ii) Label specifications. The caution labels required by subdivision (i) of this subparagraph shall be printed in letters of sufficient size and contrast as to be readily visible and legible. The label shall state:

CAUTION
Contains Asbestos Fibers
Avoid creating Dust
Breathing Asbestos Dust May Cause
Serious Bodily Harm

(h) HOUSEKEEPING

(1) Cleaning. All external surfaces in any place of employment shall be maintained free of accumulations of asbestos fibers if, with their dispersion, there would be an excessive concentration.

(2) Waste disposal. Asbestos waste, scrap, debris, bags, containers, equipment, and asbestos-contaminated clothing, consigned for disposal, which may produce in any reasonably foreseeable use, handling, storage, processing, disposal or transportation airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section shall be collected and disposed of in sealed impermeable bags, or other closed, impermeable containers.

(i) Recordkeeping

(1) Exposure records. Every employer shall maintain records of any personal or environmental monitoring required by this section. Records shall be maintained for a period of at least 20 years and shall be made available upon request to the Assistant Secretary of Labor for Occupational Safety and Health, the Director of the National Institute for Occupational Safety and Health, and to authorized representatives of either.

(2) Employee access. Every employee and former employee shall have reasonable access to any record required to be maintained by subparagraph (i) of this paragraph, which indicates the employee's own exposure to asbestos fibers.

(3) Employee notification. Any employee found to have been exposed at any time to airborne concentrations of asbestos fibers in excess of the limits prescribed in paragraph (b) of this section shall be notified in writing of the exposure as soon as practicable but not later than 5 days of the finding. The employee shall also be timely notified of the corrective action being taken.

(j) MEDICAL EXAMINATIONS

(1) General. The employer shall provide or make available at his cost, medical examinations relative to exposure to asbestos required by this paragraph.
(2) Preplacement. The employer shall provide or make available to each of his employees, within 30 calendar days following his first employment in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination, which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(3) Annual examinations. On or before January 31, 1973, and at least annually thereafter, every employer shall provide, or make available, comprehensive medical examinations to each of his employees engaged in occupations exposed to airborne concentrations of asbestos fibers. Such annual examination shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(4) Termination of employment. The employer shall provide, or make available, within 30 calendar days before or after the termination of employment of any employee engaged in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(5) Recent examinations. No medical examination is required of any employee, if adequate records show that the employee has been examined in accordance with this paragraph within the past 1-year period.

(6) Medical records.

(i) Maintenance. Employers of employees examined pursuant to this paragraph shall cause to be maintained complete and accurate records of all such medical examinations. Records shall be retained by employers for at least 20 years.

(ii) Access. Records of the medical examinations required by this paragraph shall be provided upon request to employees, designated representatives, and the Assistant Secretary in accordance with 29 CFR 1910.20(a)-(e) and (g)-(l). These records shall also be provided upon the request of the Director of NIOSH. Any physician who conducts a medical examination required by this paragraph shall furnish to the employer of the examined employee all the information specifically required by this paragraph, and any other medical information related to occupational exposure to asbestos fibers.
§ 61.25 Waste disposal sites.

In order to be an acceptable site for disposal of asbestos-containing waste material under § 61.22(i) and (k), an active waste disposal site shall meet the requirements of this section.

(a) There shall be no visible emissions to the outside air from any active waste disposal site where asbestos-containing waste material has been deposited, except as provided in paragraph (e) of this section.

(b) Warning signs shall be displayed at all entrances, and along the property line of the site, or along the perimeter of the site, where asbestos-containing waste material has been deposited, except as specified in paragraph (d) of this section.

(c) The perimeter of the disposal site shall be fenced in order to adequately deter access to the general public, except as specified in paragraph (d) of this section.

(d) Warning signs and fencing shall be required where the requirements of paragraph (e)(1) of this section are met, or where a natural barrier inadequately deters access to the general public. Upon request and supply of appropriate information, the Administrator will determine whether a fence or a natural barrier adequately deters access to the general public.

(e) Rather than meet the requirement of paragraph (a) of this section, an owner or operator may choose to meet the requirements of paragraph (e)(1) or a natural barrier adequately deters access to the general public.

(f) Spacing between lines shall be at least equal to the height of the upper of the two lines.

(g) The perimeter of the disposal site shall be fenced in order to adequately deter access to the general public, except as specified in paragraph (d) of this section.

(h) Warning signs and fencing are not required where the requirements of paragraph (e)(1) of this section are met, or where a natural barrier adequately deters access to the general public. Upon request and supply of appropriate information, the Administrator will determine whether a fence or a natural barrier adequately deters access to the general public.

(i) The perimeter of the disposal site shall be fenced in order to adequately deter access to the general public. Upon request and supply of appropriate information, the Administrator will determine whether a fence or a natural barrier adequately deters access to the general public.

(j) The perimeter of the disposal site shall be fenced in order to adequately deter access to the general public. Upon request and supply of appropriate information, the Administrator will determine whether a fence or a natural barrier adequately deters access to the general public.
§ 61.52(d).

Sec. 116, Clean Air Act as amended (42 U.S.C. 7416).


Subpart B—National Emission Standards for Asbestos

§ 61.20 Applicability.

The provisions of this subpart are applicable to those sources specified in § 61.22.

§ 61.21 Definitions.

(a) “Asbestos” means actinolite, amosite, anthophyllite, chrysotile, crocidolite, tremolite.

(b) “Asbestos material” means asbestos or any material containing asbestos.

(c) “Particulate asbestos material” means finely divided particles of asbestos material.

(d) “Asbestos tailings” means any solid waste product of asbestos mining or milling operations which contains asbestos.

(e) “Outside air” means the air outside buildings and structures.

(f) “Visible emissions” means any emissions which are visually detectable without the aid of instruments and which contain particulate asbestos material.

(g) “Asbestos mill” means any facility engaged in the conversion of any intermediate step in the conversion of asbestos or into commercial asbestos.

(h) “Commercial asbestos” means any variety of asbestos which is produced by extracting asbestos from asbestos ore.

(i) “Manufacturing” means the combining of commercial asbestos, or in the case of woven friction products the combining of textiles containing commercial asbestos, with any other materials, including commercial asbestos, and the processing of this combination into a product as specified in § 61.22(i).

(j) “Demolition” means the wrecking or taking out of any load-supporting asbestos or any material that contains more than 1 percent asbestos by weight and that can be crumbled, pulverized, or reduced to powder, when dry, by hand pressure.

(k) “Control device asbestos waste” means any asbestos-containing waste material that is collected in a pollution control device.

(l) “Renovation” means the removing or stripping of friable asbestos material used on pipe, duct, boiler, tank, reactor, turbine, furnace, or structural member. Operations in which load-supporting structural members are removed or taken out are excluded.

(m) “Emergency renovation” means a renovation operation, or a number of such operations, in which the amount of friable asbestos material that will be removed or stripped within a given period of time can be predicted. Operations that are individually non-scheduled are included, provided a number of such operations can be predicted to occur during a given period of time based on operating experience.

(n) “Emergency renovation” means a renovation operation that results from sudden, unexpected event, and is not scheduled renovation. Operations necessary to prevent dust emissions are included.

(o) “Adequately wetted” means sufficiently mixed or coated with water or an aqueous solution to prevent dust emissions.

(p) “Removal” means taking out friable asbestos materials used on any pipe, duct, boiler, tank, reactor, turbine, furnace, or structural member from any building, structure, facility, or installation.

(q) “Stripping” means taking off friable asbestos materials from any pipe, duct, boiler, tank, reactor, turbine, furnace, or structural member.

(r) “Emergency renovation” means a renovation operation that results from sudden, unexpected event, and is not scheduled renovation. Operations necessary to prevent dust emissions are included.

(s) “Manufacturing” means the combining of commercial asbestos, or in the case of woven friction products the combining of textiles containing commercial asbestos, with any other materials, including commercial asbestos, and the processing of this combination into a product as specified in § 61.22(h).

(t) “Demolition” means the wrecking or taking out of any load-supporting asbestos or any material that contains more than 1 percent asbestos by weight and that can be crumbled, pulverized, or reduced to powder, when dry, by hand pressure.

(u) “Active waste disposal site” means any disposal site other than an inactive site.

(v) “Roadways” means surfaces on which vehicular traffic travels, and which contain commercial asbestos and is generated by a source subject to the provisions of this subpart.

§ 61.22 Emission standards.

(a) Asbestos mills: There shall be no visible emissions to the outside air from any asbestos mill except as provided in paragraph (f) of this section.

(b) Roadways: The surfacing of roadways with asbestos tailings or waste containing asbestos is prohibited, except for temporary roadways on an area of asbestos ore deposits. The deposition of asbestos tailings or waste containing asbestos on roadways covered with snow or ice is considered surfacing.

(c) Manufacturing: There shall be no visible emissions to the outside air, except as provided in paragraph (f) of this section, from any of the following operations if they use commercial asbestos or from any building or structure in which such operations are conducted.

(d) The manufacture of cloth, cord, wicks, tubing, tape, twine, rope,
The manufacture of paper, millboard, and felt.

The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

The manufacture of plastics and rubber materials.

The manufacture of asphaltic products.

The manufacture of concrete or masonry products.

The manufacture of paper, millboard, and felt.

The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

The manufacture of plastics and rubber materials.

The manufacture of asphaltic products.

The manufacture of concrete or masonry products.

The manufacture of paper, millboard, and felt.

The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

The manufacture of plastics and rubber materials.

The manufacture of asphaltic products.

The manufacture of concrete or masonry products.

The manufacture of paper, millboard, and felt.

The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

The manufacture of plastics and rubber materials.

The manufacture of asphaltic products.

The manufacture of concrete or masonry products.

The manufacture of paper, millboard, and felt.

The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

The manufacture of plastics and rubber materials.

The manufacture of asphaltic products.

The manufacture of concrete or masonry products.

The manufacture of paper, millboard, and felt.

The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

The manufacture of plastics and rubber materials.

The manufacture of asphaltic products.

The manufacture of concrete or masonry products.

The manufacture of paper, millboard, and felt.

The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

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The manufacture of asphaltic products.

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The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

The manufacture of plastics and rubber materials.

The manufacture of asphaltic products.

The manufacture of concrete or masonry products.

The manufacture of paper, millboard, and felt.

The manufacture of floor tile.

The manufacture of paints, coatings, caulks, adhesives, sealants.

The manufacture of plastics and rubber materials.

The manufacture of asphaltic products.

The manufacture of concrete or masonry products.
extent possible, should be removed as units or in sections prior to wrecking. In no case shall the requirements of paragraphs (d)(4)(iv) or (d)(4)(v) be suspended due to freezing temperatures.

(vii) For renovation operations, local exhaust ventilation and collection systems may be used, instead of wetting as specified in paragraph (d)(4)(vii), to prevent emissions of particulate asbestos material to outside air when damage to equipment resulting from the wetting would be unavoidable. Such local exhaust ventilation systems shall be designed and operated to capture the asbestos particulate matter produced by the stripping and removal of friable asbestos material. There shall be no visible emissions to the outside air from such local exhaust ventilation and collection systems, except as provided in paragraph (f) of this section.

(5) Sources subject to this paragraph are exempt from the requirements of § 61.05(a), § 61.07, and § 61.09.

(6) The demolition of a building, structure, facility, or installation, pursuant to an order of an authorized representative of a State or local governmental agency, because that building is structurally unsound and in danger of imminent collapse is exempt from all but the following requirements of paragraph (d) of this section:

(i) The notification requirements specified by paragraph (d)(2) of this section;

(ii) The requirements on stripping of friable asbestos materials from previously removed units or sections as specified in paragraph (d)(4)(vii) of this section;

(iii) The wetting, as specified by paragraph (d)(4)(ix) of this section, of friable asbestos materials that have been removed or stripped;

(iv) The portion of the structure being demolished that contains friable asbestos materials shall be adequately wetted during the wrecking operation.
§ 61.21 Reporting.

The owner or operator of any existing waste disposal site subject to this paragraph must report the following information:

(a) A description of the emission control equipment used for each process.

(b) If a fabric filter device is used to control emissions, the pressure drop across the fabric filter in inches water gage.

(c) If the fabric filter device utilizes a woven fabric, the airflow permeability in ft²/min/ft² and, if the fabric is synthetic, indicate whether the fill yarn is spun or not spun.

(d) If the fabric filter device utilizes a felted fabric, the density in oz/yd²; the minimum thickness in inches, and the airflow permeability in ft²/min/ft².

(e) For sources subject to §§ 61.22(j) and 61.22(k).

§ 61.22 Fabric filter collection devices.

Fabric filter collection devices must be used, except as noted in paragraphs (a) and (b) of this section.

(a) Fabric filter collection devices need not be used where the requirements of paragraphs (a) and (b) of this section are met, or where a natural barrier and the general public. Upon request and supply of appropriate information, the administrator will determine whether such a barrier is adequate to protect the general public.

(b) If the fabric filter device utilizes a woven fabric, the airflow permeability in ft²/min/ft² and, if the fabric is synthetic, indicate whether the fill yarn is spun or not spun.

(c) If the fabric filter device utilizes a felted fabric, the density in oz/yd²; the minimum thickness in inches, and the airflow permeability in ft²/min/ft².
August 20, 1982

Mr. J. W. Simpson
Gemco Construction Company
P. O. Box 187
Trilby, Florida  33593

Subject:  Report on Fulton County Schools Asbestos Abatement Projects

Dear Wayne:

Enclosed are two copies of the report on the air sampling performed in conjunction with your recent project with the Fulton County School system in Atlanta, Georgia. Per your request, a copy will be sent to Mr. Joseph Shilling of the Fulton County School system unless directed otherwise.

It was a pleasure to work with you, Mr. Robert Walker and Gemco Construction on this important project. Should you have any questions regarding any aspect of this report please do not hesitate to contact us.

Respectfully,

William M. Ewing
Industrial Hygienist

WME:rm
xc: James L. Burson, Program Manager
AIR SAMPLING SURVEYS
at
SELECTED FULTON COUNTY SCHOOLS
for
GEMCO CONSTRUCTION COMPANY
TRILBY, FLORIDA

PROJECT NO. A-3323-002

Georgia Institute of Technology
Engineering Experiment Station
Occupational Safety and Health Branch
Atlanta, Georgia
August 20, 1982
AIR SAMPLING SURVEYS
at
SELECTED FULTON COUNTY SCHOOLS
for
GEMCO CONSTRUCTION COMPANY
TRILBY, FLORIDA

1.0 INTRODUCTION

The GEORGIA TECH RESEARCH INSTITUTE was retained by Mr. J. W. Simpson of the Gemco Construction Company to conduct air sampling in conjunction with their project to remove asbestos-containing materials from five Fulton County, Georgia schools. The air sampling was conducted during the period from July 26, 1982, to August 2, 1982, by Messrs. William M. Ewing and Kenneth E. Johnson of Georgia Tech. The following report summarizes the results of air sampling for all locations. The individual results have been compiled in Appendix A, Tables 1-11. A copy of the sampling and analytical method is enclosed as Appendix B.

2.0 WESTWOOD HIGH SCHOOL

The work area at Westwood High School was limited to the boiler room located on the ground level. All work at this location was completed between July 25 and July 26, 1982, with the actual removal operations performed on the 26th. The work consisted of removing asbestos (amosite) containing insulation from the hot water tank. Air samples were collected inside and outside the work area during the removal process.

Two air samples (AA-202 and AA-203) were collected inside the work area. One of these samples, AA-203, was a personal sample collected in the breathing zone of a Gemco employee. The results of these samples were 42 and 31 fibers* per cubic centimeter (fibers*/cc) of air sampled. The sample indicated values in excess of the current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 2.0 fibers*/cc (8-hour, time-weighted average (TWA)) and the current OSHA ceiling concentration of 10 fibers*/cc for 15 minutes. It was noted that all Gemco employees wore powered-air purifying full-face respirators equipped with high efficiency particulate absolute (HEPA) filters. Each employee also wore full body covering, including head and foot covers.

Several methods were employed by Gemco personnel to minimize the generation of airborne fibers. These included the use of water (with a wetting agent), a microtrap, and work practices designed to reduce fiber emissions. The microtrap creates a negative pressure within the work area (with respect to all areas immediately outside the plastic barriers). This aids in reducing the emission of fibers to other areas of the building. The use of water to wet the material may have proved more effective if the material was wetted a day or so before the removal took place. This would allow for the absorption of more water, reducing fiber emissions.

*greater than 5 micrometers in length
One sample collected in the hallway immediately outside the plastic barrier indicated 0.01 fibers*/cc. This indicates that fibers* were predominantly contained in the work area and not in the building. Outside the building, however, one sample indicated 0.12 fibers*/cc. This sample, collected 3 feet from the exhaust of the microtrap, indicates that the HEPA filter did not successfully trap all fibers*. The sample results suggest the filters were 99.7% efficient in stopping fibers greater than 5 micrometers in length. Many more samples would be necessary to gain a better determination on the efficiency of the filter. Electron microscopy would need to be employed to determine penetration of the filter by those fibers shorter than 5 micrometers in length.

Two samples were collected on July 27, 1982, and analyzed for fibers* by phase-contrast microscopy. The results of analyses indicated less than 0.01 and 0.01 fibers*/cc, respectively. These samples were taken after all work and clean-up activities were completed.

3.0 BRIARWOOD HIGH SCHOOL

Air sampling was conducted on July 27 and 28, 1982, during and following the asbestos abatement project at Briarwood High School in Atlanta, Georgia. The results of these samples are included in Tables A-3 and A-4 of Appendix A. The work area consisted of the boiler room. The abatement project consisted of removing lagging material from the hot water tank. Two area samples collected during the removal operation, inside the enclosed work area, indicated 15 and 18 fibers*/cc, respectively. The microtrap, water with a wetting agent, and work practices to limit dust dispersal were employed during this work. All Gemco employees were observed wearing full body covering and powered-air purifying respirators equipped ith HEPA filters.

One sample, AA-208, collected in the hallway east of the work area indicated less than 0.01 fibers*/cc. This sample was collected during the actual removal process. Two samples were collected outside the work area and outside the building. These samples indicated 0.01 and 0.03 fibers*/cc each. The fibers* detected probably resulted from some leakage through the HEPA filter of the microtrap.

On July 28, 1982, two area air samples were collected after all work had been completed inside the work area. These samples indicated 0.01 fibers*/cc each.

4.0 BROOKVIEW ELEMENTARY SCHOOL

Area air samples were collected during insulation removal from the hot water tank on July 28, 1982, at the Brookview Elementary School. The work area was confined to the boiler room at this location. It should be noted that the actual insulation removal and gross clean-up required 14 minutes, although preparation and final clean-up required approximately 10 hours. The results of the two samples taken in the work area during removal were 2.0 and 3.3

*greater than 5 micrometers in length
fibers*/cc, respectively. One sample, collected in the kitchen, outside the work area indicated less than 0.01 fibers*/cc. Another sample, AA-211, was collected outside the building and indicated 0.01 fibers*/cc. The work practices employed and protective equipment used at this location were similar to those previously discussed. The results of the individual air samples are included as Tables A-6 and A-9 in Appendix 9 of this report.

Two days following the removal (and clean-up) air samples were collected in the work area. The results of the two area air samples were 0.01 and 0.02 fibers*/cc.

5.0 CAMPBELL HIGH SCHOOL

Area air sampling was conducted before, during and after an asbestos abatement project at Campbell High School in Fairburn, Georgia. These results are included as Tables A-5, A-7, and A-11 in Appendix A of this report. The work area consisted of the wood shop (west side only) where sprayed-on fireproofing was removed from a portion of the ceiling. The east side of the wood shop was not a part of the project and therefore still contains fireproofing with asbestos.

Prior to the start of the project, two area samples were collected in the wood shop to estimate pre-existing fiber concentrations. The sample results were 0.07 and 0.14 fibers*/cc. It was noted that the wood shop had just been cleaned prior to sampling and visible dust was in the air. It is likely that many of the fibers* found in these samples were the result of interference from wood dust present. However, it should be noted that some of the fibers* may have been settled asbestos fibers which were re-entrained into the wood shop air during the cleaning process.

One additional sample was collected in the musical instrument storage room to estimate airborne fiber concentrations. Since the school was not in session, activity was simulated during the first 5 minutes of sampling by brushing out several instrument storage bins. The results of this sample was 0.06 fibers*/cc. It should be noted that this value exceeds the 0.04 fibers*/cc "clean air" limit established for schools in Massachusetts. Georgia currently does not have such a limit.

The two area air samples collected in the work area during removal activities indicated 2.5 and 2.8 fibers*/cc, respectively. One sample collected outside the work area, in the wood shop indicated 0.17 fibers*/cc. One area air sample collected outside the building indicated 0.04 fibers*/cc. It should be noted that these last two samples may have exhibited interference from wood dust. The interference could have been eliminated by performing analysis by electron microscopy, however, due to the increased cost, this was not permitted.

After the completion of the final clean-up and spray-back with another acoustical insulation, two area air samples were collected in the east side of the wood shop. The results of the air sampling and analyses indicated less than 0.01 fibers*/cc for each sample. It was noted that the new insulation

*greater than 5 micrometers in length
was a non-fibrous, styrofoam insulation. Further, the sampling was conducted with no activity which reduced the chance of wood dust interference, but also reduced the chance of collecting any settled asbestos fibers.

6.0 ROSWELL HIGH SCHOOL

Area air sampling was conducted during and following an asbestos abatement project at the Roswell High School in Roswell, Georgia. The work area was confined to the boiler room and consisted of removing insulation from two boilers, the hot water tank, and several pipes. The type of asbestos and content, as reported by the Fulton County Schools, was approximately 50% amosite. This was similar to that encountered at the Westwood High School (see section 2.0 of this report). The removal practices at Roswell were similar to those used at Westwood except the wetting agent was added directly to water through an in-hose connection. The type of wetting agent was also produced by a different manufacturer. It was also noted that the water with the wetting agent was allowed to soak into the insulation for a longer period of time (approximately 1 hour as opposed to 10 minutes at Westwood).

Two area air samples were collected in the work area during removal activities on July 29, 1982. The results of these samples were 4.5 and 6.5 fibers*/cc, respectively. Two area samples were collected outside the work area in the hallway northeast of the boiler room and outside the building, 10 feet west of the boiler room. Each of these samples indicated a fiber* concentration of 0.02 fibers*/cc. The following day, after final clean-up two air samples collected in the work area indicated less than 0.01 and 0.01 fibers*/cc.

The work area samples indicated an order-of-magnitude reduction in fiber concentrations when compared with the similar work performed at Westwood High School. Since more than one variable was present between the two work sites the exact reason cannot be determined with certainty. It is probable, however, that the longer time allowed for the insulation to absorb the water and the direct introduction of the wetting agent into the water hose played a significant role in reducing fiber* emissions into the work area.

This report prepared by:  
William M. Ewing  
Industrial Hygienist

This report approved by:  
James L. Burson, CIH  
Manager, Occupational Safety and Health Branch

*greater than 5 micrometers in length
APPENDIX A

Results of Air Sampling
# INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant:** WESTWOOD HIGH SCHOOL  
**Materials:** Fibers greater than 5 micrometers in length  

1370 Union Rd., SW, Atlanta, Georgia

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/26</td>
<td>AA-200</td>
<td>Area sample, outside building in airstream of microtrap exhaust</td>
<td>1328-1508</td>
<td>254</td>
<td>150</td>
<td>29,000</td>
</tr>
<tr>
<td>7/26</td>
<td>AA-201</td>
<td>Area sample, inside building, outside enclosed work area</td>
<td>1403-1522</td>
<td>161</td>
<td>79</td>
<td>3000</td>
</tr>
<tr>
<td>7/26</td>
<td>AA-202</td>
<td>Area sample, work area, far side of boiler, on support</td>
<td>1424-1507</td>
<td>84*</td>
<td>42</td>
<td>3,200,000</td>
</tr>
<tr>
<td>7/26</td>
<td>AA-203</td>
<td>M. Cain, removing boiler lagging and bagging waste in work area</td>
<td>1422-1453</td>
<td>63*</td>
<td>31</td>
<td>2,040,000</td>
</tr>
</tbody>
</table>

* NOTE: Air volume was reduced to prevent overloading of the sampling medium with particulate matter.
### Industrial Hygiene Sampling Summary

**Plant:** Westwood High School  
1370 Union Road, SW, Atlanta, Georgia  

**Materials:** Fibers greater than 5 micrometers in length

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/27</td>
<td>AA-204</td>
<td>Area sample, clean air test, in boiler room, east end on pipe</td>
<td>1123 to 1432</td>
<td>380</td>
<td>189</td>
<td>3000 Fibers per Filter</td>
</tr>
<tr>
<td>7/27</td>
<td>AA-205</td>
<td>Area sample, clean air test, in boiler room, west end</td>
<td>1123 to 1432</td>
<td>386</td>
<td>189</td>
<td>4000 Fibers per Filter</td>
</tr>
</tbody>
</table>
**Engineering Experiment Station**  
*Safety & Health Services*  
**INDUSTRIAL HYGIENE SAMPLING SUMMARY**

**Plant**  
Briarwood High School  
Briarwood Road, SW., Atlanta, Georgia

**Materials**  
Fibers greater than 5 micrometers in length

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration Fibers per Filter</th>
<th>Concentration Fibers per cc Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/27</td>
<td>AA-206</td>
<td>Area sample, outside building, 50 ft downwind of microtrap exhaust</td>
<td>1202 1406</td>
<td>247</td>
<td>124</td>
<td>7000</td>
<td>0.03</td>
</tr>
<tr>
<td>7/27</td>
<td>AA-207</td>
<td>Area sample, outside building, 4 feet from microtrap exhaust</td>
<td>1204 1407</td>
<td>246</td>
<td>123</td>
<td>3000</td>
<td>0.01</td>
</tr>
<tr>
<td>7/27</td>
<td>AA-208</td>
<td>Area sample, inside hallway east of work area, on door to b-room</td>
<td>1220 1403</td>
<td>205</td>
<td>103</td>
<td>≤3000</td>
<td>≤0.01</td>
</tr>
<tr>
<td>7/27</td>
<td>AA-209</td>
<td>Area sample, work area, boiler room, north end of tank</td>
<td>1344 1354</td>
<td>20.1</td>
<td>10</td>
<td>303,000</td>
<td>15.</td>
</tr>
<tr>
<td>7/27</td>
<td>AA-210</td>
<td>Area sample, work area, boiler room, south end of tank</td>
<td>1344 1354</td>
<td>19.8</td>
<td>10</td>
<td>350,000</td>
<td>18.</td>
</tr>
</tbody>
</table>
## INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant**: Briarwood High School  
**Briarwood Road, SW., Atlanta, Georgia**

**Materials**: Fibers greater than 5 micrometers in length

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/28</td>
<td>AA-215</td>
<td>Area sample, boiler room clean air test, west side</td>
<td>1234 1507</td>
<td>303</td>
<td>153</td>
<td>3000 0.01</td>
</tr>
<tr>
<td>7/28</td>
<td>AA-216</td>
<td>Area sample, boiler room clean air test, east side</td>
<td>1233 1507</td>
<td>314</td>
<td>154</td>
<td>3000 0.01</td>
</tr>
</tbody>
</table>
**Plant**  
Campbell High School  
Fairburn, Georgia

**Materials**  
Fibers greater than 5 micrometers in length

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/28</td>
<td>AA-220</td>
<td>Area sample, outside building entrance to wood shop</td>
<td>1600 1800</td>
<td>241</td>
<td>120</td>
<td>10,000</td>
</tr>
<tr>
<td>7/28</td>
<td>AA-221</td>
<td>Area sample, outside work area enclosure, in wood shop</td>
<td>1607 1758</td>
<td>131</td>
<td>65</td>
<td>22,000</td>
</tr>
<tr>
<td>7/28</td>
<td>AA-222</td>
<td>Area sample, work area, west end of wood shop during removal</td>
<td>1719 1750</td>
<td>63.2</td>
<td>31</td>
<td>160,000</td>
</tr>
<tr>
<td>7/28</td>
<td>AA-223</td>
<td>Area sample, work area, north end of wood shop during removal</td>
<td>1719 1750</td>
<td>61.4</td>
<td>31</td>
<td>170,000</td>
</tr>
</tbody>
</table>

*Note: Suspected interference from wood dust present in the wood shop. All fibers counted may not be asbestos as stated in the NIOSH method P & CAM 239.*

---

**Date**  
1982

**Sample Number**  
AA-220, AA-221, AA-222, AA-223
**INDUSTRIAL HYGIENE SAMPLING SUMMARY**

**Plant:** Roswell High School  
**Materials:** Fibers greater than 5 micrometers in length

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration Fibers per Filter</th>
<th>Fibers per cc Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/29</td>
<td>AA-224</td>
<td>Area sample, outside building, 10 ft. west of boiler room door</td>
<td>1406-1730</td>
<td>410</td>
<td>204</td>
<td>10,000</td>
<td>0.02</td>
</tr>
<tr>
<td>7/29</td>
<td>AA-225</td>
<td>Area sample, outside work area, in hall NE of boiler room</td>
<td>1532-1729</td>
<td>230</td>
<td>117</td>
<td>6000</td>
<td>0.02</td>
</tr>
<tr>
<td>7/29</td>
<td>AA-226</td>
<td>Area sample, work area, east end of boiler room</td>
<td>1643-1715</td>
<td>63</td>
<td>32</td>
<td>290,000</td>
<td>4.5</td>
</tr>
<tr>
<td>7/29</td>
<td>AA-227</td>
<td>Area sample, work area, west end of boiler room</td>
<td>1643-1715</td>
<td>65</td>
<td>32</td>
<td>420,000</td>
<td>6.5</td>
</tr>
</tbody>
</table>
**Plant**
Brookview Elementary School

**Materials**
Fibers greater than 5 micrometers in length

**East Point, Georgia**

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/30</td>
<td>AA-229</td>
<td>Area sample, clean air test, in boiler room above tele. box</td>
<td>1114-1356</td>
<td>327</td>
<td>162</td>
<td>3000, 0.01</td>
</tr>
<tr>
<td>7/30</td>
<td>AA-228</td>
<td>Area sample, clean air test, in boiler room, storage rack</td>
<td>1113-1358</td>
<td>328</td>
<td>165</td>
<td>6000, 0.02</td>
</tr>
</tbody>
</table>
Plant: Roswell High School  
Roswell, Georgia

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/30</td>
<td>AA-240</td>
<td>Area sample, clean air test, east side of boiler room</td>
<td>1308 1612</td>
<td>375</td>
<td>184</td>
<td>&lt;3000 &lt;0.01</td>
</tr>
<tr>
<td>7/30</td>
<td>AA-241</td>
<td>Area sample, clean air test, west side of boiler room</td>
<td>1308 1612</td>
<td>364</td>
<td>184</td>
<td>3000 0.01</td>
</tr>
</tbody>
</table>
Plant | Campbell High School  
---|---  
Location | Fairburn, Georgia  

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration Fibers per filter</th>
<th>Concentration Fibers per cc air</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/2</td>
<td>AA-230</td>
<td>Area Sample - Clean air test - in small work room - wood shop</td>
<td>1037 - 1401</td>
<td>404</td>
<td>204</td>
<td>&lt;3,000</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>8/2</td>
<td>AA-231</td>
<td>Area Sample - Clean air test - at sink in wood shop</td>
<td>1040 - 1400</td>
<td>408</td>
<td>200</td>
<td>&lt;3,000</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>
APPENDIX B

Sampling and Analytical Method
PROCEDURES FOR FIBER COUNTING BY MICROSCOPY

SAMPLE PREPARATION

Preparation of the Mounting Solution

Combine in a one-to-one ratio (by volume) dimethyl phthalate and diethyl oxalate and pour into a Wheaton balsam bottle. The viscosity of the solution must then be adjusted; if the mixture is too "thin" the solution will cause the movement of the fibers on the filter; if it is too "thick" the filters will not dissolve completely. The viscosity is adjusted by adding blank filters to the solution. The number of filters to add is based on the amount of solution prepared; approximately 0.05 ± 0.005 grams of new membrane filter per milliliter of solution. Use 10 ml each reagent, 1.2 g of MCEF membranes. The resulting solution should appear about as viscous as molasses. The normal shelf life of the solution is about three months. Twenty ml of mounting solution will prepare approximately 300 samples.

Sample Mounting

1. Clean the slides and cover slips with lens tissue. Lay each slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.

2. Wipe all the mounting tools clean with lens tissue and place them on a clean surface (such as lens tissue). All tools should be wiped clean prior to mounting each sample.

3. Using the glass rod supplied with the Wheaton balsam bottle, apply a drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of the solution so that after the cover slip has been placed on top, the solution extends only slightly beyond the filter boundary. If the quantity is greater than this particle migration may occur.

4. Using another glass rod, spread the mounting media into a triangular shape. The size of the triangle should coincide with the dimension of the filter wedge.

5. Separate the middle and bottom sections of the cassette to expose the filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface. The filter should not be removed from the cassette for cutting.

6. Grasp the filter wedge with the tweezers on the perimeter of the filter which was clamped between the cassette sections. DO NOT TOUCH THE FILTER WITH YOUR FINGERS. Place the wedge, SAMPLE SIDE UP, upon the mounting solution.

7. Pick up a clean cover slip with tweezers and carefully place it on the filter wedge. Once contact has been made, DO NOT REPOSITION THE COVER SLIP.
8. Label the slide with the sample number before proceeding to the next filter. On the bottom (backside) of the slide, trace the perimeter of the filter wedge with a felt tip marking pen. This will enable the counter, after the filter has become transparent, to stay within the filter perimeter when counting.

9. The sample should become transparent within about 15 minutes. If the filter appears cloudy, it may be necessary to press VERY LIGHTLY, on the cover slip. This is rarely necessary; however, counting should not be started until an hour after the mounting.

10. Samples should be counted within two days of mounting. Crystals appearing similar to asbestos fibers may begin to grow at the mounting media/air interfaces.

**COUNTING OF FIBERS**

1. Place the slide on the mechanical stage of the microscope and position the center of the wedge under the objective lens and focus upon the sample. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from perimeter to filter tip). Stay away from the filter's edges when counting and sizing. Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.

2. It is essential to continually scan over a range of focal planes (generally the upper 10 to 15 micrometers of the filter surface) with the fine focus control during each field count. This is especially necessary for asbestos fibers due to their impaction into the filter matrix.

3. On most airborne samples, asbestos fibers will generally have fiber diameters less than one micrometer. Therefore, it is necessary to look carefully for faint fiber images.

4. Regularly check the phase ring alignment.

5. When a mass of material covers a significant portion of the field of view (about one-sixth or greater) reject the field and select another. (Do not include in the number of fields counted.) However, report the fact as it may have meaning on other data collection.

6. Bundles of fibers are counted as one fiber unless both ends of the fiber can be clearly resolved.

7. Count only fibers with a length to width ratio greater than or equal to 3:1.

8. Count only fibers greater than 5 micrometers in length. Measure curved fibers along the curve to estimate the total length.

9. Count as many fields as necessary to yield a total count of at least 100 fibers. **EXCEPTIONS:** a). count at least 20 fields even if you count more than 100 fibers, and b). stop at 100 fields even if you haven't reached 100 fibers.
10. Rules for selecting fibers to be counted: a). COUNT any fiber greater than 5 micrometers in length, that lies entirely within the counting area, b). COUNT as "1 fiber" any fiber with only one end lying within the counting area, and c). DO NOT COUNT any fiber crossing any two sides of the counting area.

CALCULATIONS AND RECORDKEEPING

1. The following data must be recorded in the microscopy data book: a). name of client, b). date of analysis, c). sample number, d). initials of person performing the analysis, e). total number of fibers counted, f). total number of fields counted, g). air volume (if supplied), h). fibers per filter, and i). fibers per cubic centimeter of air (if applicable). Additionally, any comments or notes should be recorded. Also a notation should be made if any deviations from the standard procedure were made.

2. To calculate total fibers per filter:

\[
\text{fiber/filter} = \frac{\# \text{ of fibers counted}}{\text{number of fields}} \times \frac{\text{fields/filter}}{\text{fields}}
\]

3. To calculate fibers per cubic centimeter of air:

\[
\text{fibers/cc} = \frac{\# \text{ of fibers per filter}}{\left(\frac{\text{liters of air sampled}}{1000}\right)}
\]

QUALITY CONTROL

1. Approximately one blank should be submitted for every 20 samples.

2. Approximately one filter out of every ten should be selected for recounting. For a pair of counts on the same filter, reject both values because one might be biased if:

\[
(FB_2 - FB_1) \text{ exceeds } 2.77 (FB)(CV_{FB})^3
\]

Where:

- \(FB_1\) = lower fiber count (total fibers)
- \(FB_2\) = higher fiber count (total fibers)
- \(FB\) = average of the two total fiber counts
- \(CV_{FB}\) = \(CV_T\) for the value \(FB\). Use the relation in figure 1.
Total coefficient of variation as a function of total fiber count

TOTAL FIBER COUNT - FD (fibers in FL fields)
ASBESTOS FIBERS IN AIR
National Institute for Occupational Safety and Health
Analytical Method

<table>
<thead>
<tr>
<th>Analyte:</th>
<th>Asbestos fibers</th>
<th>Method No.:</th>
<th>P&amp;CAM 239</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrix:</td>
<td>Air</td>
<td>Range:</td>
<td>0.1-60 fibers/cm³</td>
</tr>
<tr>
<td>Procedure:</td>
<td>Filter collection, microscopic count</td>
<td>Precision (CV):</td>
<td>0.24 to 0.38</td>
</tr>
<tr>
<td>Date Issued:</td>
<td>3/30/77</td>
<td>Classification:</td>
<td>D (Operational)</td>
</tr>
<tr>
<td>Date Revised:</td>
<td></td>
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</tr>
</tbody>
</table>

1. Principle of the Method

1.1 This method describes the equipment and procedures for collecting, mounting, and counting asbestos fibers on cellulose ester membrane filters in the evaluation of personal samples of airborne asbestos fibers. The purpose of the method is to determine an employee's index of exposure to airborne asbestos fibers. The method is primarily a personal monitoring technique, but can be used for area monitoring.

1.2 The sample is collected by drawing air through a membrane filter by means of a battery powered personal sampling pump. The filter is transformed from an opaque solid membrane to a transparent optically homogeneous gel. The fibers are sized and counted using a phase-contrast microscope at 400-450X magnification.

1.3 Definitions. Asbestos fiber, for counting purposes, means a particulate which has a physical dimension longer than 5 micrometers and with a length to diameter ratio of 3 to 1 or greater. Asbestos includes chrysotile, cummingtonite-grunerite (amosite), crocidolite, fibrous tremolite, fibrous anthophyllite, and fibrous actinolite.

1.4 Any laboratory attempting to use this procedure should have at least one counter attend a training course conducted by an experienced, proficient laboratory. Novice, untutored counters, using only published instructions, can easily obtain counts of half those performed by experienced, proficient counters. Large differences between laboratories can be caused by: 1) differences in technique and observing ability among counters and 2) small, but significant, differences between microscopes meeting the basic specifications of Section 6.2. The following procedures are recommended:

1.4.1 All microscopists who perform asbestos counting should meet together for an “asbestos counting workshop” at least quarterly. This is best accomplished with counters from several laboratories using their own microscopes.

1.4.2 Each microscopist should count the same series of slides and with the results being compared.

1.4.3 Differences between counters should be resolved with side-by-side counting of the fields by the different counters.

1.4.4 Individuals who are found to be persistent outliers over several sessions should be encouraged to seek other tasks in their respective laboratories.
2. Range and Sensitivity

2.1 The usable range is primarily a function of sample volume, microscope count field area, and background airborne particulates. The influence of these variables is discussed in 8.1.3. For a microscope count field area of 0.003 mm² (see Figure 1) and a pump flow rate of 1.7 lpm, the optimal fiber densities would be produced over the range of 0.4 fiber/cm² (8-hour sample) to about 60 fibers/cm² (15-minute sample). For a field area of 0.006 mm² (see Figure 2) and a pump flow rate of 1.7 lpm, the optimal range is 0.2 fiber/cm² (8-hour sample) to about 30 fibers/cm² (15-minute sample). In each case, the optimal detection limits are inversely proportional to pump flow rate.

The upper detection limit can be extended by using sample times less than 15 minutes or using lower flow rates. The lower detection limit can be extended by increasing the flow rate up to about 2.5 lpm. Filter surface fiber densities less than optimal (less than about 0.5 to 1.0 fiber per count field) are still adequate, but will lead to decreased precision for the method (increased coefficient of variation, see Section 4).

The minimum total fiber count in 100 fields considered adequate for reliable quantitation is 10 fibers. Thus, the lower limit of reliable quantitation is 0.1 fiber/cm² (100,000 fibers/m²). For this level, a flow rate of about 2.5 lpm is recommended. For a field area of 0.003 mm², the minimum sample time would be about 2 hours. For a field area of 0.006 mm², the minimum sample time would be about 1 hour.

2.2 This method considers only fibers with a length to diameter ratio of 3 to 1 or greater and a length greater than 5 micrometers.

3. Interferences

In an atmosphere known to contain asbestos, all particulates with a length to diameter ratio of 3 to 1 or greater, and a length greater than 5 micrometers should, in the absence of other information, be considered to be asbestos fibers and counted as such.

4. Precision and Accuracy

4.1 In the past decade, there have appeared a number of articles examining sources of variation in the asbestos sampling and counting procedure. These include: Lynch et al. (11.1), Weidner and Ayer (11.2), Conway and Holland (11.3), Leidel and Busch (11.4), Beckett and Atfield (11.5), and Rajhans and Bragg (11.6). The sources of variation will be discussed by stages in the membrane filter evaluation procedure.

4.2 Sources of Variation in the Sampling Process. These include variations in pump flow rate, proximity of the filter to the employee's body, and filter location (left to right) in the employee's breathing zone.

4.2.1 Section 9.1 requires that the personal sampling pump be calibrated with sufficient accuracy such that the 95% confidence limits on the flow rate are ± 10%. This is equivalent to a coefficient of variation (CV) of about 5%. However, this CV makes a negligible contribution to the total CV for the method due to the relatively large CV of the counting procedure.

4.2.2 Conway and Holland (11.3) concluded that positioning of the filter cassette on the wearer (regarding the angular portions of the filter and their proximity to the wearer) is not a significant factor in determining the fiber distribution on filters.

4.2.3 Weidner and Ayer (11.2) concluded that there is no appreciable difference between samples collected on either the right or left sides of a breathing zone or between samples collected side-by-side, especially for samples with concentrations less than 2.5 fibers/cm².
4.3 Sources of Variation in the Counting Procedure

4.3.1 Random variations exist in the fiber distribution on a filter wedge (intra-wedge variability). The industrial hygiene literature has seen considerable debate in the last 20 years concerning whether or not the distribution of mineral dust or asbestos fibers on a filter surface is adequately described by a Poisson distribution probability density function. Leidel and Busch (11.4) found excellent agreement between empirical error variance and theoretical variance calculated from the assumption of Poisson distributed true counts. They concluded that there was not excessive variation among count fields for a filter wedge and that clumping of fibers (non-random coalescence) did not occur.

4.3.2 Variations exist in the fiber distribution on the total filter surface (inter-wedge variability) due to the random or non-random distribution of fibers across the total surface of the filter. This type of variation is easily confused with intra-wedge variations. The count procedure does not require counting of multiple sectors of the filter. There may be significant differences between average counts for different wedges, or the fiber distribution variations for the total filter surface may be greater than the variations of the Poisson distribution. If either of these occur experimentally, one must use the experimental variations to estimate the minimum precision of the count procedure. The minimum precision is governed by the variations of the fiber distribution on the total surface of the filter.

Conway and Holland (11.3) concluded the distribution of fibers on filters is not uniform and the distribution of fiber counts is more disperse than Poisson. For their filters which had significant variations in fiber concentrations between sectors (as much as 50-60% of the total filter mean), they described the following relation for the standard deviation of the total number of fibers counted on a wedge (N)

\[
\text{empirical } \sigma(N) = 1.6 \sqrt{N}
\]

where N is about 100. The Poisson standard deviation would be:

\[
\text{Poisson } \sigma(N) = \sqrt{N}
\]

Rajhans and Bragg (11.6) in Series I of their study found significant variation between filter segments and rejected the Poisson distribution for the total filter surface. However, in Series II of their study, utilizing various experimental modifications, they found no significant variation between filter segments and no reason to reject the assumption of Poisson distributed fiber counts.

4.3.3 Systematic variations due to differences between microscopes were studied by Leidel and Busch (11.4). In their study using five different brands of microscopes, they found no significant differences among four, but the fifth gave counts approximately 45% higher on the average than the other four.

4.3.4 Variations due to differences between counters should be examined at three levels: experienced counters occasionally counting, experienced counters routinely counting, and inexperienced (new or untutored) counters. Leidel and Busch (11.4) studied five experienced counters, with one counting only occasionally. There were no significant differences among three of the counters, but a fourth was 16% lower than the first three. The fifth, who occasionally counted, averaged 27% higher than the first three. Conway and Holland (11.3) studied three experienced counters and three inexperienced counters. They found statistically significant differences between the means of both the experienced and inexperienced counters that typically were in the range plus or minus 5 to 15%. They concluded that experience as a fiber counter is not a significant parameter affecting intercounter variations.
Rajhans and Bragg (11.6) found no significant differences among means of five experienced counters in Series I of their study. But in their carefully controlled Series II, an analysis of variance showed significant variations between counters that were plus or minus 1 to 15%.

4.3.5 Variations between laboratories are most likely due to systematic biases and are not a significant additional source of random variations. Any additional variations are most likely due to differences in counting technique. Beckett and Attfield (11.5) observed that standard counters improved greatly after personal instruction; also new counters, after instruction, tended to overcompensate and get exceedingly high counts. Additionally, they found that counts from an experienced laboratory that had not had contact with other laboratories performing the same analysis were as far from the standard values as were the counts by new counters.

4.4 Sources of variations between samples taken at different times on one employee during one work shift can affect the exposure estimate for that employee. These are primarily due to a) differences in exposure concentrations during the day, b) differences in location of the employee within the plant, and c) differences in work operation performed by the employee during the day. These sources of variation can be controlled by proper choice of sampling strategy. Refer to Leidel and Busch (11.7) and Leidel, Busch, and Lynch (11.8) for an extended discussion of sampling strategies. Interday temporal variations can affect the exposure estimates obtained on different days. Refer to Leidel, Busch, and Crouse (11.9) for a discussion of this type of variation.

4.5 Until recently, the total coefficient of variation (CV) for the sampling and counting procedure was best estimated from the work of Conway and Holland (11.3). The conclusions of their study included:

4.5.1 The precision of their procedure for filters not containing an abundance of fine fibers can be estimated by a coefficient of variation of 16.2%. This value includes variation among counters and observed interaction effects.

4.5.2 The accuracy of the procedure for similar filters may be estimated for a 100-fiber count by a coefficient of variation of 21.4%. This assumes that the contribution of the overall variance from the nonuniform fiber distribution is additive.

4.5.3 A high percentage of very fine fibers on the filter can significantly affect the standard deviation and confidence limits for counts by different counters. After combining variations in fiber concentrations over the entire filter with those for different counters, it was concluded:

a. For filters with a low concentration of fine fibers, the coefficient of variation is estimated at 21% and the 95% confidence interval is ± 43%.

b. For filters with a high concentration of fine fibers, the coefficient of variation is estimated at 25% and the 95% confidence interval is ± 50%.

Lynch, Kronoveter, and Leidel (11.1) have also reported on variations of the method. Their intralaboratory study utilized the data from a large number of dust counts made by different methods by experienced counters over a period of years in an epidemiologic study of the asbestos products industry. They concluded that the standard deviation of counts of fibers longer than 5 micrometers on membrane filters could be estimated from the relation \[ \sigma = (N)^{0.31}. \] Thus for counts of about 100 fibers, the coefficient of variation could be estimated at about 15.2% and the 95% confidence limits at ± 30.4%. These values are lower than the values reported by Conway and Holland (11.3).

Recently, the Johns-Manville Corporation conducted an in-house investigation of the asbestos count method (11.10). The study data contained total fiber counts for over
100 filters with each filter counted by two to five counters. From the Johns-Manville data, NIOSH calculated over 100 estimates of the count CV for the method (11.11). The NIOSH CV estimates included random intrafilter variations and intercounter variations, but did not include random pump flow rate variations. It was found that the count coefficient of variation (all random variations except for pump variations) was a function of the total fiber count. NIOSH then included a CV of 0.05 for random pump variations (see Section 9.1) in the CV-estimator equation to obtain a CVT-estimator. The CVT-estimator line is plotted on Figure 3 for total fiber counts in the range 10 to 100 fibers. Or the following equation can be used:

$$CV_T = \left[ \text{antilog}_{10}(-0.215 - 0.203 \log_{10} FB) + 0.0025 \right]^2$$

where FB is total fiber count as discussed in Section 10.

Figure 3 demonstrates that for a total fiber count of 100, the best CVT is attainable with the appropriate sampling times given in 8.1.3 and the count rules in 8.3.9. When making decisions regarding compliance with the OSHA asbestos exposure standards in 29 CFR 1910.1001, the statistical procedures given in Leidel et al. (11.11) should be followed. The procedures are based on statistical theory and assumptions given in References 11.12, 11.13.

Because of the possibility of systematic biases due to differences between microscopes, counters, and laboratories as discussed above, it is strongly recommended that any laboratory counting asbestos should participate in an interlaboratory quality control program that includes the counting of standard reference filters. These standard filters are available from NIOSH through the Proficiency Analytical Testing (PAT) Program. The PAT Program is used by the American Industrial Hygiene Association (AIHA) as part of its Laboratory Accreditation Program. Each laboratory's quality control program must include protocols for routinely adjusting and calibrating sampling and counting equipment plus training and evaluation programs for counters.

5. Advantages and Disadvantages of the Method

5.1 The method is intended to give an index of employee exposure to airborne asbestos fibers of specified dimensional characteristics.

5.2 It is not meant to count all asbestos fibers in all size ranges or to differentiate asbestos from other fibrous particulates.

6. Apparatus

6.1 Sampling Equipment

The personal sampling equipment train consists of 1) personal sampling pump, 2) tubing, 3) clothing spring clip, 4) tubing-to-field monitor metal adaptor, and 5) field monitor (filter and holder).

6.1.1 Personal Sampling Pump. The pump must be capable of sampling at 1.0 to 2.5 liters per minute (lpm) against a flow resistance of 7.5 inches of water (1.4 cm Hg) for 8 continuous hours on a fully charged battery.

6.1.2 Tubing. Laboratory tubing such as rubber or plastic with 6-mm bore and about 100 cm length.

6.1.3 Clothing Spring Clip. The clip attaches the rubber tubing to the lapel or shirt of the individual being monitored.

6.1.4 Tubing-to-field Monitor Adaptor. A short metal adaptor with ridges on one end to grip the inside of the tubing. The other end is designed for a pressure fit into the field monitor.

6.1.5 Field Monitor (Filter and Holder). The only field monitor currently considered acceptable by NIOSH is manufactured by the Millipore Corporation. The unit con-
sists of 1) a three section styrene plastic case designated Millipore Aerosol Monitor Case, 2) a 37-mm diameter plain white cellulose ester membrane filter designated Millipore AA (pore size of 0.8 micrometer), 3) a support pad, and 4) two plastic sealing caps. If a large number of samples are to be taken, it may be less expensive to reuse the plastic cases. Great care must be taken in the cleaning and reassembly process. The outside mating surfaces of the field monitors may be covered with a “shrink-fit” band to provide proper sealing and a writing surface for filter identification.

6.2 Optical Equipment and Microscope Features

6.2.1 Microscope body with binocular head.

6.2.2 10X Huygenian eyepieces are recommended. Other eyepieces can be substituted if necessary. Wide field eyepieces can be used; however, wide field eyepieces may yield a count field area less than 0.003 mm² with the Porton reticle. This is not always desirable from the standpoint of obtaining optimum sampling times (see Section 8.1.3). If wide field eyepieces are used, it is preferable to use the Patterson Globe and Circle reticle to obtain a larger count field area.

6.2.3 Koehler illumination (preferably built-in with provisions for adjusting light intensity).

6.2.4 A Porton reticle is recommended. Others such as the Patterson Globe and Circle can be substituted.

6.2.5 Mechanical stage.

6.2.6 Phase-Contrast condenser with a numerical aperture (N.A.) equal to or greater than the N.A. of the objective.

6.2.7 40-45X phase contrast achromatic objective (N.A. 0.65 to 0.75).

6.2.8 Phase-ring centering telescope or Bertrand lens.

6.2.9 Green or blue filter, if recommended by microscope manufacturer.

6.2.10 Stage micrometer with 0.01 mm subdivisions.

6.2.11 For general guidance on phase contrast microscopy, consult Needham (11.12), Clark (11.15) and McCrone (11.14).

6.3 Filter Mounting Equipment. Experience has shown that certain equipment is useful for efficient sample mounting. The following items are recommended for extracting and mounting a portion of the filter for counting.

6.3.1 Microscope slides. 2.5 by 7.5 cm glass slides are most commonly used. Sample number, data, initials, etc., can be conveniently written on a frosted end slide.

6.3.2 Cover Slips. Cover slips are a necessary part of the slide mount and optical system. The shape should be appropriate for the size of the filter wedge. The appropriate cover slip depends upon the objective to be used. Ordinarily, objectives are optically corrected for a #1½ (0.17 millimeter) thickness cover slip. Improper cover glass thickness will detract from the final image quality.

6.3.3 Scalpel. A scalpel is needed to cut out a portion of the filter to be examined. A number-ten curved blade scalpel is recommended.

6.3.4 Tweezers. A pair of fine-tipped tweezers is used to remove the membrane filter slice from the field monitor and place it upon the slide.

6.3.5 Lens Tissue. To insure cleanliness, lint-free tissue is recommended. This tissue should also be used for wiping mounting tools and for cleaning slides and cover slips.

6.3.6 Glass Rod. A fire-polished glass rod may be used to spread the mounting solution on the slide.
6.3.7 Wheaton Balsam Bottle. This special glass container has a glass top which prevents contamination of the mounting solution. A glass rod is included for dispensing the solution.

Reagents
Chemicals should be reagent grade, free from particles and color, conforming to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

7.1 Dimethyl phthalate
7.2 Diethyl oxalate

Avoid getting the mounting solution on the skin. Wash skin promptly with soap and water if skin contact occurs.

Procedure
8.1 Sampling
8.1.1 General Information
Guidelines for the monitoring of employee exposures to industrial atmospheres are given in Reference 11.8. The Federal requirements for monitoring employee exposure to airborne asbestos are found in 29 CFR 1910.1001.

8.1.2 Mounting the Sampling Pump on the Worker
Fasten the sampling pump to the worker's belt and fasten the field monitor to the lapel or shirt front (as close to the breathing zone as is practical). Remove the top cover of the plastic monitor, then invert the monitor making certain the exposed filter is facing downward. Turn the pump on and adjust to the calibrated flow rate (1.0 to 2.5 lpm). Record the following information in a logbook.
1. Filter number
2. Pump start time and date
3. Flow rate
4. Subject's name and job title
5. Type of operation or process
6. Ventilation controls and is the worker wearing a respirator approved for asbestos?
The pump should be checked periodically during the sampling period for proper operation and flow rate.

8.1.3 Optimum Sampling Times
The requirement for the minimum count of 100 fibers or 20 fields in 8.3.9 was determined to be the best compromise to achieve adequate precision for the airborne fiber estimate and reasonable counting times. An optimum fiber density of about 1 to 5 fibers per microscope count field is recommended. To estimate appropriate sampling times for feasible counting and optimal counting, one must consider the following constraints:
1. microscope count field area (generally 0.003 to 0.006 mm²)
2. pump flow rate (typically 2.5 lpm maximum)
3. average airborne fiber concentrations
4. counting rule range of 20 to 100 fields
5. adequate fiber density to obtain a minimum count of 10 fibers in 100 fields, which is the least total fiber count that yields an acceptable count precision
6. background airborne particulate levels that can reduce the count precision due to an obscuring of fibers on the filter surface
The preceding constraints were considered in drawing Figures 1 and 2. These figures were developed from the following relationship:

\[
\text{sampling time} = \frac{(FB/FL) (ECA/MFA)}{(FR) (AC) (1000)} \text{ minutes}
\]

where:
- \(FB/FL\) = 1 to 5 fibers/field
- \(ECA\) = effective collecting area of filters (855 mm\(^2\) for 37-mm filter with effective diameter of 33 mm)
- \(MFA\) = microscope field area (generally 0.003 to 0.006 mm\(^2\))
- \(FR\) = Pump flow rate (generally 1.0 to 2.5 lpm)
- \(AC\) = Air concentration of fibers in fibers/cm\(^2\).

Figure 1 (microscope field area = 0.003 mm\(^2\)) and Figure 2 (microscope field area = 0.006 mm\(^2\)) show optimum and feasible sampling times for a pump flow rate of 1.7 lpm. Each individual responsible for sampling asbestos should prepare a similar chart for his particular pump flow rate and microscope field area before sampling is performed to aid in estimating proper sampling times. On Figures 1 and 2, the areas with solid shading lines are generally the optimum conditions for counting. The broken shading lines are for conditions very close to optimal. However, feasible counting conditions may extend down to about 0.1 fiber/field and above 5 fibers/field. Recommended sampling times are most strongly influenced by background airborne particulate levels, once all other constraints have been estimated. For heavy particulate levels, it may be necessary to limit each filter to about 60 to 180 minutes sampling duration. Each individual responsible for sampling should work closely with the microscopist to attain as high as possible filter surface fiber densities (up to about 5 fibers/field), while avoiding filter surface background particulate levels that create very difficult or impossible counting conditions. If one has very little idea of airborne fiber and particulate levels, the best procedure is to take several long samples (as one 8-hour or two consecutive 4-hour samples) in conjunction with several short samples (as four consecutive 2-hour or eight consecutive 1-hour samples). If the longer samples prove very difficult to count, the microscopist will have the shorter samples to fall back on.

From Figures 1 and 2, it can be seen that there are certain sampling times which will yield optimum fiber densities on the filter for almost all airborne fiber concentrations from 1 to 10 fibers/cm\(^2\). These optimum times have been calculated and are presented in Figure 4. Note that the optimum times given by Figure 4 are approximate and can be varied by as much as \(\pm 25\%\). The nomogram is intended as a guide to be used where no prior knowledge of the air concentration is available.

8.1.4 End of Sampling Period

Remove the field monitor, replace the plastic top cover and the small end caps, and store the monitor. Always shut off the pump when changing monitors to avoid contaminating or damaging the pump. Record the pump shutoff time and flow rate in the logbook.

8.1.5 Blanks

With each batch (25 to 50 filters) of samples sent for analysis, submit two unopened field monitors which have been subjected to the same treatment as the samples except that they were not exposed to the sampling environment. Label these as blanks. If the blanks yield fiber counts greater than 5 fibers/100 fields, then the entire sampling procedure should be examined carefully for the cause of contamination.
mounting solution of Section 8.2.1 should also be examined for contamination and/or crystal growth.

8.1.6 Shipping
The field monitors in which the samples are collected should be shipped in a rigid container with sufficient packing material to prevent crushing.

8.1.7 Numbers of Samples
When sampling for the Federal ceiling standard of 10 fibers (>5μm)/cm³, [29 CFR 1910.1001(b) (3), effective July 7, 1972], only one sample (15 minutes maximum duration) is necessary, theoretically. However, several samples should be taken during expected periods of peak air concentrations to allow for detection of gross sampling or counting errors.
When sampling for determination of noncompliance with the Federal 8-hour TWA standard of 2 fibers (>5μm)/cm³, [29 CFR 1910.1001(b) (2)], one should continuously sample as large a portion of the work day as is feasible for airborne concentrations of about 2 to 10 fibers/cm³. However, for a lower airborne concentration such as 0.5 fiber/cm³, one sample might require 4 to 8 hours sampling time in order to get the proper filter fiber density (Section 8.1.3). For this situation, the 8-hour TWA exposure would be determined from one 8-hour or two 4-hour samples as appropriate.

8.2 Sample Preparation

8.2.1 Preparation of Mounting Solution
A very important part of the sample evaluation is the mounting process. This process involves a special mounting medium of prescribed viscosity. The proper viscosity is important in order to expedite filter dissolving and still minimize particle migration.
After the sample has been mounted, an elapsed time of approximately sixty minutes is needed before the sample is ready for evaluation.
Combine the dimethyl phthalate and diethyl oxalate in a one to one ratio by volume and pour into a Wheaton balsam bottle. Add approximately 0.05 (= 0.005) grams of new membrane filter per milliliter of solution to reach the necessary viscosity. The mixture must be stirred periodically until the filters have dissolved and a homogeneous mixture is formed. The normal shelf life of the mounting solution is about three months. Twenty milliliters of mounting solution will prepare approximately 300 samples.

8.2.2 Sample Mounting
Cleanliness is important! A dirty working area may result in sample contamination and erroneous counts. The following steps should be followed when mounting a sample.
1. Clean the slides and cover slips with lens tissue. Lay each slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.
2. Wipe all the mounting tools clean with lens tissue and place them on a clean surface (such as lens tissue). All tools should be wiped clean prior to mounting each sample.
3. Using the glass rod supplied with the Wheaton balsam bottle, apply a drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of solution so that after the cover slip has been placed on top, the solution extends only slightly beyond the filter boundary. If the quantity is greater than this, particle migration may occur.
4. Using another glass rod, spread the mounting media into a triangular shape. The size of this triangle should coincide with the dimension of the filter wedge.

5. Separate the middle and bottom sections of the field monitor case to expose the filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface. The filter can be very carefully removed from the cassette for cutting, but this should only be done with great care.

6. Grasp the filter wedge with the tweezers on the perimeter of the filter which was clamped between the monitor case sections. Do not touch the filter with your fingers. Place the wedge, sample side up, upon the mounting medium.

7. Pick up a clean cover slip with tweezers and carefully place it on the filter wedge. Once this contact has been made, do not reposition the cover slip.

8. Label the slide with the sample number and current date before proceeding to the next filter. On the bottom (backside) of the slide, trace the perimeter of the filter wedge with a felt tip marking pen. This will enable the counter, after the filter has become transparent, to stay within the filter perimeter when counting.

9. The sample should become transparent within fifteen minutes. If the filter appears cloudy, it may be necessary to press very lightly on the cover slip. This is rarely necessary; however, counting should not be started until an hour after the mounting. This allows the microscopic texture of the filter to become invisible to microscope viewing.

10. Discard the sample mount after two days if it has not been counted. Crystals appearing similar to asbestos fibers may begin to grow at the mounting media/air interfaces. They seldom present any problems if the slide is examined before two days. In any case, stay away from the filter’s edges when counting and sizing.

8.3 Counting of Fibers

8.3.1 Place the slide on the mechanical stage of the microscope and position the center of the wedge under the objective lens and focus upon the sample. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from perimeter to wedge tip). Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.

8.3.2 It is essential to continually scan over a range of focal planes (generally the upper 10 to 15 micrometers of the filter surface) with the fine focus control during each field count. This is especially necessary for asbestos fibers due to their impaction into the filter matrix.

8.3.3 On most airborne samples, asbestos fibers will generally have fiber diameters less than one micrometer. Therefore, it is necessary to look carefully for faint fiber images.

8.3.4 Regularly check phase ring alignment.

8.3.5 When an agglomerate (mass of material) covers a significant portion of the field of view (approx 1/6 or greater) reject the field and select another. (Do not include it in the number of fields counted.) However, report the fact as it may have meaning on other data collection.

8.3.6 Bundles of fibers are counted as one fiber unless both ends of the fiber can be clearly resolved.

8.3.7 Count only fibers with a length to width ratio greater than or equal to 3:1.

8.3.8 Count only fibers greater than 5 micrometers in length. (Be as accurate as possible in accepting fibers near this length.) Measure curved fibers along the curve to estimate the total length.

239-10
8.3.9 Count as many fields as necessary to yield a total count of at least 100 fibers. Exceptions: a) count at least 20 fields even if you count more than 100 fibers, and b) stop at 100 fields even if you haven't reached 100 fibers.

8.3.10 For fibers that cross either one or two sides of the counting field, the following procedure is used to obtain a representative count. COUNT any fiber greater than 5 micrometers in length, that lies entirely within the counting area. COUNT as “½ fiber” any fiber with only one end lying within the counting area. DO NOT COUNT any fiber crossing any two sides. Reject and do not count all other fibers. Refer to Figures 5 through 10. Note that the fibers in Figures 5 through 10 are not representative of the appearance of most asbestos fibers. Most fibers have a very faint image.

9. Calibration and Standards

9.1 Sampling Train Calibration

The accurate calibration of the sampling pump is essential to the correct calculation of the air volume sampled. The frequency of calibration is dependent on the use, care, and handling to which the pump is subjected. Pumps must be recalibrated if they have just been repaired, misused, or received from the manufacturer. If the pump receives hard usage, more frequent calibration may be necessary. Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples.

The accuracy of calibration is dependent upon the type of instrument used as a reference. The choice of a calibration instrument will depend largely on where the calibration is performed. For laboratory testing, a 1-liter buret used as a soap bubble flow meter or wet-test meter is recommended. Other standard calibrating instruments, such as a spirometer, Marriott's bottle, or dry gas meter can be used. The calibration should be of sufficient precision that the 95% confidence limits on the flow rate are ± 10% (95% of the flow rates will fall within ± 10% of the calibrated value).

Instructions for calibration with the soap bubble flow meter follow. The sampling train used (pump, hose, filter cassette) in the pump calibration should be the same as the one used in the field.

9.1.1 Check the voltage of the pump battery with a voltmeter both with the pump off and while it is operating to assure adequate voltage for calibration. If necessary, charge the battery to manufacturer's specifications.

9.1.2 Fill a beaker with 10 ml of soap solution.

9.1.3 Connect the filter cassette inlet to the top of the buret with a length of hose.

9.1.4 Turn the pump on and moisten the inside of the soap bubble meter by immersing the open end of the buret into the soap solution and drawing bubbles up the inside of the buret. Perform this task until the bubbles are able to travel the entire length of the buret without breaking.

9.1.5 Adjust the pump rotameter to provide a flow between 1.5 to 2.5 lpm.

9.1.6 With a water manometer, check that the pressure drop across the filter is less than 13 inches of water (about 1 inch of mercury).

9.1.7 Start a soap bubble up the buret and measure the time it takes for the bubble to travel a minimum volume of 1 liter.

9.1.8 Repeat the procedure in 9.1.7 at least three times, average the results, and calculate the calibrated flow rate by dividing the volume traveled by the soap bubble by the elapsed time. If the range between the highest and lowest of the three flow rates is greater than about 0.33 lpm, then the calibration should be repeated since it is likely that the precision is not adequate.
9.1.9 Data required for the calibration include the volume measured, elapsed time, pressure drop, air temperature, atmospheric pressure (or elevation), pump serial number, date, and name of person performing the calibration.

9.1.10 Corrections to the flow rate for pumps with rotameters may be necessary if the pressure (elevation) or temperature where the samples are collected (actual flow rate) differs significantly from that where the calibration was performed (indicated flow rate). Actual flow rates at time of sampling may be calculated for a linear scale rotameter by using the following correction formula:

\[
Q_{\text{actual}} = Q_{\text{indicated}} \sqrt{\frac{P_{\text{cal}}}{P_{\text{actual}}} \cdot \frac{T_{\text{actual}}}{T_{\text{cal}}}}
\]

where both pressure (P) and temperature (T) are in absolute units such as:

- psia = psig + 14.7
- deg Rankin = deg Fahrenheit + 460
- deg Kelvin = deg Celsius + 273

9.2 Microscope Setup

9.2.1 Porton Reticle and the Counting Field

The asbestos fiber count procedure consists of comparing fiber length to the diameters of calibrated circles of a Porton reticle, and counting all fibers greater than 5 micrometers in length lying within a given counting field area. The Porton reticle is a glass plate inscribed with a series of circles and rectangles. The left half of the reticle is divided into six rectangles constituting the counting field. The counting field is illustrated in Figures 5 through 10.

9.2.2 Placement in Eyepiece

The Porton reticle is placed inside the Huygenian eyepiece where it rests on the field-limiting diaphragm. If other types of eyepieces are used, it may be necessary to insert a counting collar for retaining the reticle. The reticle should always be kept clean, since dirt on the reticle is in focus and could complicate the counting and sizing process.

9.2.3 Stage Micrometer

The Porton reticle cannot be used for counting until it has been properly calibrated with a stage micrometer. Most stage micrometer scales are approximately two millimeters long and are divided into units of one-hundredth of a millimeter (ten micrometers).

9.2.4 Microscope Adjustment

When adjusting the microscope, follow the manufacturer’s instructions while observing the following guidelines.

1. The light source image must be in focus and centered on the condenser iris or annular diaphragm.
2. The particulate material to be examined must be in focus.
3. The illuminator field iris must be in focus, centered on the sample, and opened only to the point where the field of view is illuminated.
4. The phase rings (annular diaphragm and phase-shifting elements) must be concentric.

9.2.5 Porton Reticle Calibration Procedure

Each eyepiece-objective-reticle combination on the microscope must be calibrated. Should any of the three be changed (disassembly, replacement, zoom adjustment, etc.), the combination must be recalibrated. Calibration may change if interpupillary dis-
tance is changed. For proper calibration, the following procedure should be followed closely.

With a 10X objective in place, place the stage micrometer on the mechanical stage, focus the millimeter scale, and center the image. Change to the 40-45X objective and adjust the first millimeter scale division to coincide with the left boundary of the Porton rectangle. Measure the distance between the left and extreme right boundaries of the Porton rectangle, estimating any portion of the final division. This measurement represents 200 L units. The rectangle is 100 L units on the short vertical dimension. The calculated "L" is inserted into the formula D = L(2^N)^1/2 where "N" is the circle number (indicated on the reticle) and "D" is the circle diameter. Since the circle diameters vary logarithmically, every other circle doubles in diameter. For example, circle number three is twice the diameter of number one; number four is twice the diameter of number two. When the circle sizes have been determined, the counting field area which consists of the left six smaller rectangles can be calculated from the relation 10,000 L^2. This completes the reticle calibration for this specific objective-eyepiece-reticle combination.

Example for Porton Reticle

The following calibration was obtained for a pair of 10X Huygenian eyepieces and a 43X objective:

200 L = 0.148 mm = 148 micrometers
100 L = 0.074 mm = 74 micrometers
One L-unit = 0.74 micrometers

Thus Circle #1 has a diameter D = L(2^N)^1/2 = 0.74(2^1)^1/2 = 0.74 (1.414) = 1.05 micrometers.

Then our circle diameter calibration table looks like:

Diameter of Circle #1 = 1.05 micrometers
#2 = 1.48
#3 = 2.09
#4 = 2.96
#5 = 4.19
#6 = 5.92

Field area = (10,000) (L^2) = (100 L) (100 L) = (0.074) (0.074) = 0.0055 mm^2

Thus fibers with a length greater than a distance halfway between the diameters of the #5 and #6 circles would be counted.

If a Patterson Globe and Circle reticle is used, a different calculation procedure is required. The circle diameters are related as follows. The #25 circle diameter is (0.1) (reticle length).

The circle diameters are proportional to the ratio of their numbers. Thus the #20 circle diameter is (20/25) or 0.8 times the #25 circle diameter.

10. Calculations

10.1 The average airborne asbestos fiber concentration estimated by the filter sample may be calculated from the following formula:

\[
AC = \frac{[(FB/FL) - (BFB/BFL)] (ECA)}{(1000) (FR) (T) (MFA)}
\]

239-13
where:

- **AC** = Airborne fiber concentration in (fibers > 5 μm)/cm³.
- **BF** = Total number of fibers counted in the BFL fields of the blank or control filters in fibers > 5 μm.
- **BFL** = Total number of fields counted on the blank or control filters.
- **ECA** = Effective collecting area of filter (855 mm² for a 37-mm filter with effective diameter of 33 mm).
- **FR** = Pump flow rate in liters/min (lpm).
- **FB** = Total number of fibers counted in the FL fields in fibers > 5 μm.
- **FL** = Total number of fields counted on the filter.
- **MFA** = Microscope count field area in mm² (generally 0.003 to 0.006).
- **T** = Sample collection time in minutes.

10.2 Recount criteria. It is very desirable for a counter to conduct a "blind recount" for about 1 in every 10 filter wedges (slides) counted. Alternatively, a second counter could perform the blind recount. In training sessions for novice counters, the trainee should conduct a blind recount for filter wedges counted by an experienced, proficient counter. In all cases, we will observe differences between the first and second counts of the same filter wedge. Most of these differences will be due to chance alone, that is, due to the random variability (precision) of the count method. Statistical recount criteria enable us to decide whether observed differences can reasonably be explained due to chance alone or are probably due to systematic differences between counters or microscopes or due to some other biasing factor.

The following recount criterion is for a pair of counts that estimate some airborne fiber concentration (AC) in fibers/cm³. The criterion is given at the type-I error level. That is, there is a 5% maximum risk that we will reject a pair of counts for the reason that one might be biased, when the large observed difference is really due to chance. Reject a pair of counts because one might be biased if:

\[(AC_2 - AC_1) > 2.77(AC)(CV_{FB})\]

where:
- **AC₁** = lower estimated airborne fiber concentration
- **AC₂** = higher estimated airborne fiber concentration
- **AC** = average of the two airborne concentration estimates
- **CV_{FB}** = average CV for the two concentration estimates which are a function of the total fiber count (FB) in each case. Use the relation in Section 4 or Figure 3.

For a pair of counts on the same filter, reject the pair because one might be biased if:

\[(FB_2 - FB_1) > 2.77(FB)(CV_{FB})\]

where:
- **FB₁** = lower fiber count on the filter (total fibers)
- **FB₂** = higher fiber count on the filter (total fibers)
- **FB** = average of the two total fiber counts
- **CV_{FB}** = CV for the value FB. Use the relation in Section 4 or Figure 3.

11. References


11.2 Weidner, R. B. and H. E. Ayer, “Dust Exposure in Asbestos Processing”, Transactions of the


11.10 Comments of the Johns-Manville Corporation with Respect to the Notice of Proposed Rulemaking: Occupational Exposure to Asbestos, Federal Register, October 9, 1975. Submitted to the public record at the U. S. Department of Labor, Occupational Safety and Health Administration, April 1976.


FIGURE 1. Optimum Sampling Times for airborne asbestos where microscopic field area = 0.003 mm$^2$
FIGURE 2. Optimum sampling times for airborne asbestos where microscopic field area = 0.006 mm²
FIGURE 3. Total coefficient of variation as a function of total fiber count.
FIGURE 4. Nomogram of optimum sampling times for airborne asbestos fibers in concentrations of 1 to 10 fibers/cm³.

EXAMPLE = 1.7 1pm
A = 0.00302 mm²
READ: OPTIMUM TIME = 120 min
(± 25 %)
LIST OF FIGURES
(5 through 10)

FIGURE 5. DO NOT COUNT. Fiber crosses top and bottom sides.

FIGURE 6. COUNT. One fiber.

FIGURE 7. COUNT. One-half fiber. Fiber crosses left side and one end lies within count area.

FIGURE 8. COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.

FIGURE 9. DO NOT COUNT. Fiber crosses two sides.

FIGURE 10. DO NOT COUNT. Fiber crosses two sides (bottom left corner).

COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.

COUNT. One fiber (top right corner).
ASBESTOS SAMPLING
at
POLK COMMUNITY COLLEGE
for
GEMCO CONSTRUCTION COMPANY
Trilby, Florida

PROJECT NO. A-3323-003

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Occupational Safety and Health Branch
Atlanta, Georgia
September 9, 1982
ASBESTOS SAMPLING
at
POLK COMMUNITY COLLEGE
for
GEMCO CONSTRUCTION COMPANY
Trilby, Florida

INTRODUCTION

The Georgia Tech Research Institute was retained by Mr. J. W. Simpson of the Gemco Construction Company to conduct air sampling during the removal of asbestos-containing materials from selected buildings at Polk Community College in Winter Haven, Florida. Air sampling was performed for a total of eleven days between August 9, 1982 and August 21, 1982 by Ms. Nancy Zakraysek of Georgia Tech. The following report summarizes results for all locations sampled. Individual air sampling results have been compiled in Appendix A, Tables 1-11. A copy of the sampling and analytical method is contained in Appendix B.

SURVEY PROTOCOL

As a minimum a survey protocol designed to meet the requirements of the Gemco Construction Company, project no. 3323, was followed. This protocol requested that each day during the removal of asbestos containing acoustical materials the following area air samples be collected and analyzed as described in the National Institute for Occupational Safety and Health (NIOSH) method P & CAM 239 (see Appendix B).

- Two area air samples will be collected within the work area each day of an asbestos abatement project after the actual removal of asbestos containing materials has begun. The sampling duration will vary depending on several factors including estimated airborne dust concentrations, contract specifications for the particular project, and the duration of the work in progress.

- Each day of an asbestos abatement project a minimum of one sample will be collected outside the work area but inside the structure (if feasible). If an entire building is considered the work area then this sample will be collected outside the building at the worker's entrance/exit. The minimum sampling duration will be 60 minutes, although we anticipate collecting this sample over a 120-minute duration in most cases.

- Each day of an asbestos abatement project one sample will be collected outside the building. The minimum duration of sampling will be 120 minutes for this sample. It should be noted that this sample and the previous one will be collected on days during actual removal or abatement operations.

- Upon completion of each work area renovation activities a minimum of two area air samples will be collected (minimum air volume of 240 liters) and analyzed.
In addition, eleven area air samples were collected before or during preparation of areas for work. Five of these were collected in intended work areas, four of the samples were collected inside the building but outside the work area, and two samples were collected outside the building.

Personal samples to determine individual worker exposure were also taken in addition to the minimum survey protocol. A total of four personal samples were collected. The personal exposures of two individual workers were determined.

Usually between four and six area air samples were collected during actual removal. As required by the survey protocol, at least two work area samples were collected on each day removal activities took place.

All area air samples and personal air samples were analyzed by Ms. Zakraysek and results reported to the Gemco Construction Company site supervisor within 24 hours of collection.

**DISCUSSION OF FINDINGS**

Prior to the start of the removal of asbestos-containing accoustical materials area air samples were collected inside and outside the building both while the intended work areas were being prepared for removal and with no activity in progress. The results of two area air samples collected outside the Learning Resources (LR) building indicated fiber* concentrations ranging from less than 0.01 fibers*/cc to 0.02 fibers*/cc. Three of the samples taken outside the intended work area and inside the building indicated fiber* concentrations of less than 0.01 fibers*/cc. An area air sample taken inside the lobby leading to auditoriums 1A and 1B in the Learning Resources (LR) building indicated a fiber* concentration of 0.13 fibers*/cc. Two area air samples collected in the intended work area auditorium 1B indicated 0.23 fibers*/cc and 0.10 fibers*/cc. Prior to removal activities in auditorium 1A, a concentration of 0.02 fibers*/cc was indicated. During preparation for removal activities sheet rock was torn down in auditorium 1B in order to expose a ceiling area of asbestos-containing accoustical material. This may have presented a positive interference in the analysis of samples from auditorium 1B and the auditorium lobby.

A copy of the sampling and analytical method in Appendix B lists several limitations of the NIOSH analytical method which are amplified here. It should be noted that the method is only capable of analyzing for any fibers which are longer than 5 micrometers in length, have an aspect ratio of 3:1, and are no thinner than approximately 0.3 micrometers. The method does not distinguish between asbestos fibers and other fibrous materials. Electron microscopy would be the only currently available method of analysis to distinguish between asbestos and other fibers and to analyze for thin fibers and fibers less than 5 micrometers in length. Due to the high cost of analysis by electron microscopy (approximately 20 times the NIOSH method) this was not permitted.

A total of 4 personal air samples were collected within the work area during actual removal of asbestos-containing materials. The concentration of fibers*

*fibers greater than 5 micrometers in length
ranged from 3.6 fibers*/cc to 8.2 fibers*/cc with an average fiber* concentration of 5.7 fibers*/cc. This average is not a time-weighted average but is a result of adding all fiber* counts and dividing by the total number of samples.

A total of 24 area air samples were collected during removal activities within the work area. These samples ranged from 1.2 fibers*/cc to 8.6 fibers*/cc. The average fiber* concentration was 3.5 fibers*/cc.

A total of 7 samples were collected inside the building but outside the work area during removal activities. Fiber* concentrations were in most cases less than 0.01 fibers*/cc. One sample had a fiber* concentration of 0.09 fibers*/cc. One sample had a fiber* concentration of 0.17 fibers*/cc. These unusually high fiber* concentrations were probably due to the placement of sampling equipment during removal work. In each case, pumps were placed in areas being prepared for removal activities. These areas were not inhabited by Polk Community College personnel.

A total of 8 samples were collected outside the building where removal activities were occurring. The concentration of fibers* ranged from less than 0.01 fibers*/cc to 0.05 fibers*/cc.

Upon completion of each phase of removal final area air samples were collected in the work area. The results of these samples are included in Appendix A of this report.

This Report Prepared By: Nancy J. Zakrzewski
Industrial Hygienist

This Report Approved By: James L. Burson, Program Manager
Occupational Safety and Health Consultation Program

NJZ:JLB:sek

*fibers greater than 5 micrometers in length
APPENDIX A

Air Sampling Results
## INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant**: GEMCO CONSTRUCTION COMPANY  
**Materials**: Fibers greater than 5 micrometers in length  
**Location**: Polk Community College, Winter Haven, Florida

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/9</td>
<td>341</td>
<td>Area sample, preparing to work, auditorium 1B, sheet rock being torn out, Learning Resources Building (LR)</td>
<td>0832 1037</td>
<td>248</td>
<td>125</td>
<td>56,000</td>
</tr>
<tr>
<td>8/9</td>
<td>343</td>
<td>Area sample, prepping, auditorium 1B (LR)</td>
<td>0834 1037</td>
<td>247</td>
<td>123</td>
<td>24,000</td>
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<tr>
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<td>342</td>
<td>Area sample, prepping, lobby outside of auditoriums 1A &amp; 1B</td>
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<td>240</td>
<td>120</td>
<td>32,000</td>
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<tr>
<td>8/9</td>
<td>344</td>
<td>Area sample, outside of building to right of auditorium lobby (LR)</td>
<td>0845 1045</td>
<td>239</td>
<td>120</td>
<td>5,600</td>
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<tr>
<td>8/9</td>
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<td>Area sample, prepping, auditorium 1A (LR)</td>
<td>1125 1452</td>
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<tr>
<td>8/9</td>
<td>348</td>
<td>Area sample, pre-work, auditorium 1C (LR)</td>
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<tr>
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<td>Area sample, pre-work, auditorium 1D (LR)</td>
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<td>&lt;3,000</td>
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<td>Description</td>
<td>Sampling Period</td>
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<td>Sample Time (Min.)</td>
<td>Concentration Fibers per Filter</td>
</tr>
<tr>
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<tr>
<td>8/10</td>
<td>383</td>
<td>Area sample, prepping, audio-visual storage area (LR)</td>
<td>1322 1525</td>
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<tr>
<td>8/10</td>
<td>374</td>
<td>Area sample, pre-work, room 1A (Classroom Maintenance)</td>
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<td>120</td>
<td>&lt; 3,000</td>
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<td>8/10</td>
<td>378</td>
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<td>272</td>
<td>136</td>
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<tr>
<td>8/10</td>
<td>BSK-08</td>
<td>Area sample, outside of work area, north stairwell (LR)</td>
<td>1259 1515</td>
<td>270</td>
<td>136</td>
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</tbody>
</table>
## Industrial Hygiene Sampling Summary

**Plant:** GEMCO CONSTRUCTION COMPANY  
**Location:** Polk Community College, Winter Haven, Florida  
**Materials:** Fibers greater than 5 micrometers in length

<table>
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<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
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<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
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<tr>
<td>8/11</td>
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<td>Personal sample, Mark Cain, AV storage, scraping (LR)</td>
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<td>340,000 5.1</td>
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<td>Personal sample, Mark Cain, AV storage, scraping (LR)</td>
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<td>Personal sample, John McClelland AV storage, bagging (LR)</td>
<td>1300 1331</td>
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<td>220,000 3.6</td>
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<td>8/11</td>
<td>BSK-05</td>
<td>Personal sample, John McClelland AV storage, bagging (LR)</td>
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<td>57*</td>
<td>29</td>
<td>340,000 5.9</td>
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<tr>
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<td>354</td>
<td>Area sample, work area, AV storage (LR), upper level</td>
<td>1255 1355</td>
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<td>470,000 4.0</td>
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<td>Area sample, work area, AV storage (LR), lower level</td>
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<td>59</td>
<td>240,000 2.0</td>
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<td>377</td>
<td>Area sample, outside of building, east of auditorium lobby</td>
<td>1217 1617</td>
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<tr>
<td>8/11</td>
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<td>Area sample, outside of work area, north stairwell</td>
<td>1221 1623</td>
<td>484</td>
<td>242</td>
<td>&lt;3,000 &lt;0.01</td>
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</table>

*NOTE: Air volume was reduced to prevent overloading of the sampling medium with particulate matter.*


<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration Fibers per Filter</th>
<th>Fibers per cc air</th>
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<tr>
<td>8/12</td>
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<td>Area sample, work area, auditorium 1B, scraping</td>
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<td>47</td>
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<td>50*</td>
<td>25</td>
<td>150,000</td>
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<td>Area sample, work area, auditorium 1B, bagging</td>
<td>0945 1025</td>
<td>80*</td>
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<td>Area sample, work area, auditorium 1A, scraping (LR)</td>
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<td>1.7</td>
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<td>Area sample, work area, auditorium 1A, scraping (LR)</td>
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<tr>
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<td>363</td>
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<td>&lt;3,000</td>
<td>&lt;0.01</td>
</tr>
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*NOTE: Air volume was reduced to prevent overloading of the sampling medium with particulate matter.
# Engineering Experiment Station
## Safety & Health Services
### INDUSTRIAL HYGIENE SAMPLING SUMMARY

<table>
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<tr>
<th>Plant</th>
<th>GEMCO CONSTRUCTION COMPANY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Polk Community College, Winter Haven, Florida</td>
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</tbody>
</table>

<table>
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<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
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<td>Fibers per Filter</td>
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<tr>
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<td>BSK-02</td>
<td>Area sample, work area, auditorium 1A (Learning Resources)</td>
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<td>0706</td>
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<td>122</td>
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## INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant**: GEMCO CONSTRUCTION COMPANY  
**Location**: Polk Community College, Winter Haven, Florida  

**Materials**: Fibers greater than 5 micrometers in length

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration Fibers per Filter</th>
<th>Concentration Fibers per cc air</th>
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<tr>
<td>8/14</td>
<td>360</td>
<td>Area sample, room 119, work area (Classroom Maintenance)</td>
<td>1419 1444</td>
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<td>240</td>
<td>121</td>
<td>41,000</td>
<td>0.17</td>
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*NOTE: Air volume was reduced to prevent overloading of the sampling medium with particulate matter.*
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<th>Date 1982</th>
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<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
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<td>333</td>
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<td>339</td>
<td>Area sample, outside of work area, hallway near 1A</td>
<td>1038 1444</td>
<td>497</td>
<td>246</td>
<td>43,000</td>
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Plant: GEMCO CONSTRUCTION COMPANY
Materials: Fibers greater than 5 micrometers in length
Polk Community College, Winter Haven, Florida
<table>
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<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
<th>Fibers per Filter</th>
<th>Fibers per cc air</th>
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<td>8/16</td>
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<td>Area sample, final air test, room 121 (Classroom Maintenance)</td>
<td>0736 1111</td>
<td>430</td>
<td>215</td>
<td>&lt;3,000</td>
<td>&lt;0.01</td>
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</tr>
</tbody>
</table>
## Engineering Experiment Station
### Safety & Health Services
### INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant**
GEMCO CONSTRUCTION COMPANY
Polk Community College, Winter Haven, Florida

**Materials**
Fibers greater than 5 micrometers in length

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/18</td>
<td>404</td>
<td>Area sample, work area, 2nd floor, north stairwell (LR)</td>
<td>1412 1514</td>
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<td>337</td>
<td>Area sample, work area, 1st floor, north stairwell (LR)</td>
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<td>Area sample, outside of building near north stairwell (LR)</td>
<td>1358 1623</td>
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<td>145</td>
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<td>403</td>
<td>Area sample, 2nd floor near north stairwell, outside work area</td>
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<tr>
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<td>336</td>
<td>Area sample, final air test, auditorium 1-A (at top) (LR)</td>
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<td>Area sample, final air test, audiovisual storage area (lower)</td>
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<td>Area sample, near outside building, room 1G, near ventilation (CM)</td>
<td>1130 1435</td>
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<td>185</td>
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</table>
## GEMCO CONSTRUCTION COMPANY

**Location:** Polk Community College, Winter Haven, Florida

### Materials
- Fibers greater than 5 micrometers in length

### Sampling Summary

<table>
<thead>
<tr>
<th>Date 1982</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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</thead>
<tbody>
<tr>
<td>8/20</td>
<td>310</td>
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<td>321</td>
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<td>8/20</td>
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<td>Area sample, inside LR, 1st floor lobby, outside worksite</td>
<td>1432 - 1703</td>
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<td>334</td>
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<td>151</td>
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<tr>
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<td>305</td>
<td>Area sample, final air test, north stairs, LR, 1st floor</td>
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<tr>
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<td>8/20</td>
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<td>Area sample, final air test, Classroom Maintenance, room 1-D</td>
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<td>8/20</td>
<td>406-NZ</td>
<td>Area sample, final air test, Classroom Maintenance, room 1-G</td>
<td>1518 - 1903</td>
<td>450</td>
<td>225</td>
<td>&lt;3,000</td>
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<tr>
<td>Date</td>
<td>Sample Number</td>
<td>Description</td>
<td>Sampling Period</td>
<td>Sample Volume (Liters)</td>
<td>Sample Time (Min.)</td>
<td>Concentration</td>
</tr>
<tr>
<td>-------</td>
<td>---------------</td>
<td>------------------------------------------</td>
<td>----------------</td>
<td>------------------------</td>
<td>--------------------</td>
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</tr>
<tr>
<td>8/21</td>
<td>406</td>
<td>Area sample, final air test, south staircase, LR, 2nd floor</td>
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<tr>
<td>8/21</td>
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<td>424</td>
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<td>7,000 0.02</td>
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<td>8/21</td>
<td>407</td>
<td>Area sample, final air test, room 1-C, (Classroom Maintenance)</td>
<td>0442 0804</td>
<td>400</td>
<td>202</td>
<td>&lt;3,000 0.01</td>
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APPENDIX B

Sampling and Analytical Method
ASBESTOS FIBERS IN AIR
National Institute for Occupational Safety and Health
Analytical Method

<table>
<thead>
<tr>
<th>Analyte:</th>
<th>Asbestos fibers</th>
<th>Method No.:</th>
<th>P&amp;CAM 239</th>
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<tbody>
<tr>
<td>Matrix:</td>
<td>Air</td>
<td>Range:</td>
<td>0.1-60 fibers/cm³</td>
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<tr>
<td>Procedure:</td>
<td>Filter collection,</td>
<td>Precision (CV₀):</td>
<td>0.24 to 0.38</td>
</tr>
<tr>
<td></td>
<td>microscopic count</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date Issued:</td>
<td>3/30/77</td>
<td>Classification:</td>
<td>D (Operational)</td>
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</table>

1. Principle of the Method

1.1 This method describes the equipment and procedures for collecting, mounting, and counting asbestos fibers on cellulose ester membrane filters in the evaluation of personal samples of airborne asbestos fibers. The purpose of the method is to determine an employee's index of exposure to airborne asbestos fibers. The method is primarily a personal monitoring technique, but can be used for area monitoring.

1.2 The sample is collected by drawing air through a membrane filter by means of a battery powered personal sampling pump. The filter is transformed from an opaque solid membrane to a transparent optically homogeneous gel. The fibers are sized and counted using a phase-contrast microscope at 400-450X magnification.

1.3 Definitions. Asbestos fiber, for counting purposes, means a particulate which has a physical dimension longer than 5 micrometers and with a length to diameter ratio of 3 to 1 or greater. Asbestos includes chrysotile, cummingtonite-grunerite (amosite), crocidolite, fibrous tremolite, fibrous anthophyllite, and fibrous actinolite.

1.4 Any laboratory attempting to use this procedure should have at least one counter attend a training course conducted by an experienced, proficient laboratory. Novice, untutored counters, using only published instructions, can easily obtain counts of half those performed by experienced, proficient counters. Large differences between laboratories can be caused by: 1) differences in technique and observing ability among counters and 2) small, but significant, differences between microscopes meeting the basic specifications of Section 6.2. The following procedures are recommended:

1.4.1 All microscopists who perform asbestos counting should meet together for an “asbestos counting workshop” at least quarterly. This is best accomplished with counters from several laboratories using their own microscopes.

1.4.2 Each microscopist should count the same series of slides and with the results being compared.

1.4.3 Differences between counters should be resolved with side-by-side counting of the fields by the different counters.

1.4.4 Individuals who are found to be persistent outliers over several sessions should be encouraged to seek other tasks in their respective laboratories.

239-1
2. Range and Sensitivity

2.1 The usable range is primarily a function of sample volume, microscope count field area, and background airborne particulates. The influence of these variables is discussed in 8.1.3. For a microscope count field area of 0.003 mm² (see Figure 1) and a pump flow rate of 1.7 lpm, the optimal fiber densities would be produced over the range of 0.4 fiber/cm² (8-hour sample) to about 60 fibers/cm² (15-minute sample). For a field area of 0.006 mm² (see Figure 2) and a pump flow rate of 1.7 lpm, the optimal range is 0.2 fiber/cm² (8-hour sample) to about 30 fibers/cm² (15-minute sample). In each case, the optimal detection limits are inversely proportional to pump flow rate.

The upper detection limit can be extended by using sample times less than 15 minutes or using lower flow rates. The lower detection limit can be extended by increasing the flow rate up to about 2.5 lpm. Filter surface fiber densities less than optimal (less than about 0.5 to 1.0 fiber per count field) are still adequate, but will lead to decreased precision for the method (increased coefficient of variation, see Section 4).

The minimum total fiber count in 100 fields considered adequate for reliable quantitation is 10 fibers. Thus, the lower limit of reliable quantitation is 0.1 fiber/cm² (100,000 fibers/m²). For this level, a flow rate of about 2.5 lpm is recommended. For a field area of 0.003 mm², the minimum sample time would be about 2 hours. For a field area of 0.006 mm², the minimum sample time would be about 1 hour.

2.2 This method considers only fibers with a length to diameter ratio of 3 to 1 or greater and a length greater than 5 micrometers.

3. Interferences

In an atmosphere known to contain asbestos, all particulates with a length to diameter ratio of 3 to 1 or greater, and a length greater than 5 micrometers should, in the absence of other information, be considered to be asbestos fibers and counted as such.

4. Precision and Accuracy

4.1 In the past decade, there have appeared a number of articles examining sources of variation in the asbestos sampling and counting procedure. These include: Lynch et al. (11.1), Weidner and Ayer (11.2), Conway and Holland (11.3), Leidel and Busch (11.4), Beckett and Attfield (11.5), and Rajhans and Bragg (11.6). The sources of variation will be discussed by stages in the membrane filter evaluation procedure.

4.2 Sources of Variation In the Sampling Process. These include variations in pump flow rate, proximity of the filter to the employee's body, and filter location (left to right) in the employee's breathing zone.

4.2.1 Section 9.1 requires that the personal sampling pump be calibrated with sufficient accuracy such that the 95% confidence limits on the flow rate are ±10%. This is equivalent to a coefficient of variation (CV) of about 5%. However, this CV makes a negligible contribution to the total CV for the method due to the relatively large CV of the counting procedure.

4.2.2 Conway and Holland (11.3) concluded that positioning of the filter cassette on the wearer (regarding the angular portions of the filter and their proximity to the wearer) is not a significant factor in determining the fiber distribution on filters.

4.2.3 Weidner and Ayer (11.2) concluded that there is no appreciable difference between samples collected on either the right or left sides of a breathing zone or between samples collected side-by-side, especially for samples with concentrations less than 2.5 fibers/cm².
4.3 Sources of Variation in the Counting Procedure

4.3.1 Random variations exist in the fiber distribution on a filter wedge (intra-wedge variability). The industrial hygiene literature has seen considerable debate in the last 20 years concerning whether or not the distribution of mineral dust or asbestos fibers on a filter surface is adequately described by a Poisson distribution probability density function. Leidel and Busch (11.4) found excellent agreement between empirical error variance and theoretical variance calculated from the assumption of Poisson distributed true counts. They concluded that there was not excessive variation among count fields for a filter wedge and that clumping of fibers (non-random coalescence) did not occur.

4.3.2 Variations exist in the fiber distribution on the total filter surface (inter-wedge variability) due to the random or non-random distribution of fibers across the total surface of the filter. This type of variation is easily confused with intra-wedge variations. The count procedure does not require counting of multiple sectors of the filter. There may be significant differences between average counts for different wedges, or the fiber distribution variations for the total filter surface may be greater than the variations of the Poisson distribution. If either of these occur experimentally, one must use the experimental variations to estimate the minimum precision of the count procedure. The minimum precision is governed by the variations of the fiber distribution on the total surface of the filter.

Conway and Holland (11.3) concluded the distribution of fibers on filters is not uniform and the distribution of fiber counts is more disperse than Poisson. For their filters which had significant variations in fiber concentrations between sectors (as much as 50-60% of the total filter mean), they described the following relation for the standard deviation of the total number of fibers counted on a wedge (N):

\[ \text{empirical } s(N) = 1.6 (N)^{1/2} \]

where N is about 100. The Poisson standard deviation would be:

\[ \text{Poisson } \sigma(N) = (N)^{1/2} \]

Rajhans and Bragg (11.6) in Series I of their study found significant variation between filter segments and rejected the Poisson distribution for the total filter surface. However, in Series II of their study, utilizing various experimental modifications, they found no significant variation between filter segments and no reason to reject the assumption of Poisson distributed fiber counts.

4.3.3 Systematic variations due to differences between microscopes were studied by Leidel and Busch (11.4). In their study using five different brands of microscopes, they found no significant differences among four, but the fifth gave counts approximately 45% higher on the average than the other four.

4.3.4 Variations due to differences between counters should be examined at three levels: experienced counters occasionally counting, experienced counters routinely counting, and inexperienced (new or untutored) counters. Leidel and Busch (11.4) studied five experienced counters, with one counting only occasionally. There were no significant differences among three of the counters, but a fourth was 16% lower than the first three. The fifth, who occasionally counted, averaged 27% higher than the first three. Conway and Holland (11.3) studied three experienced counters and three inexperienced counters. They found statistically significant differences between the means of both the experienced and inexperienced counters that typically were in the range plus or minus 5 to 15%. They concluded that experience as a fiber counter is not a significant parameter affecting intercounter variations.
Rajhans and Bragg (11.6) found no significant differences among means of five experienced counters in Series I of their study. But in their carefully controlled Series II, an analysis of variance showed significant variations between counters that were plus or minus 1 to 15%.

4.3.5 Variations between laboratories are most likely due to systematic biases and are not a significant additional source of random variations. Any additional variations are most likely due to differences in counting technique. Beckett and Atfield (11.5) observed that standard counters improved greatly after personal instruction; also new counters, after instruction, tended to overcompensate and get exceedingly high counts. Additionally, they found that counts from an experienced laboratory that had not had contact with other laboratories performing the same analysis were as far from the standard values as were the counts by new counters.

4.4 Sources of variations between samples taken at different times on one employee during one work shift can affect the exposure estimate for that employee. These are primarily due to a) differences in exposure concentrations during the day, b) differences in location of the employee within the plant, and c) differences in work operation performed by the employee during the day. These sources of variation can be controlled by proper choice of sampling strategy. Refer to Leidel and Busch (11.7) and Leidel, Busch, and Lynch (11.8) for an extended discussion of sampling strategies. Interday temporal variations can affect the exposure estimates obtained on different days. Refer to Leidel, Busch, and Crouse (11.9) for a discussion of this type of variation.

4.5 Until recently, the total coefficient of variation (CV T ) for the sampling and counting procedure was best estimated from the work of Conway and Holland (11.3). The conclusions of their study included:

4.5.1 The precision of their procedure for filters not containing an abundance of fine fibers can be estimated by a coefficient of variation of 16.2%. This value includes variation among counters and observed interaction effects.

4.5.2 The accuracy of the procedure for similar filters may be estimated for a 100-fiber count by a coefficient of variation of 21.4%. This assumes that the contribution of the overall variance from the nonuniform fiber distribution is additive.

4.5.3 A high percentage of very fine fibers on the filter can significantly affect the standard deviation and confidence limits for counts by different counters. After combining variations in fiber concentrations over the entire filter with those for different counters, it was concluded:

a. For filters with a low concentration of fine fibers, the coefficient of variation is estimated at 21% and the 95% confidence interval is ± 43%.

b. For filters with a high concentration of fine fibers, the coefficient of variation is estimated at 25% and the 95% confidence interval is ± 50%.

Lynch, Kronoveter, and Leidel (11.1) have also reported on variations of the method. Their intralaboratory study utilized the data from a large number of dust counts made by different methods by experienced counters over a period of years in an epidemiologic study of the asbestos products industry. They concluded that the standard deviation of counts of fibers longer than 5 micrometers on membrane filters could be estimated from the relation \( \sigma = (N)\sqrt{\bar{N}} \). Thus for counts of about 100 fibers, the coefficient of variation could be estimated at about 15.2% and the 95% confidence limits at ± 30.4%. These values are lower than the values reported by Conway and Holland (11.3).

Recently, the Johns-Manville Corporation conducted an in-house investigation of the asbestos count method (11.10). The study data contained total fiber counts for over
100 filters with each filter counted by two to five counters. From the Johns-Manville data, NIOSH calculated over 100 estimates of the count CV for the method (11.11). The NIOSH CV estimates included random intrafilter variations and intercounter variations, but did not include random pump flow rate variations. It was found that the count coefficient of variation (all random variations except for pump variations) was a function of the total fiber count. NIOSH then included a CV of 0.05 for random pump variations (see Section 9.1) in the CV-estimator equation to obtain a CVr-estimator. The CVr-estimator line is plotted on Figure 3 for total fiber counts in the range 10 to 100 fibers. Or the following equation can be used:

$$CV_r = \left( \text{antilog}_{10}(-0.215 - 0.203 \log_{10} FB) + 0.0025 \right)$$

where FB is total fiber count as discussed in Section 10.

Figure 3 demonstrates that for a total fiber count of 100, the best CVr is attainable with the appropriate sampling times given in 8.1.3 and the count rules in 8.3.9. When making decisions regarding compliance with the OSHA asbestos exposure standards in 29 CFR 1910.1001, the statistical procedures given in Leidel et al. (11.11) should be followed. The procedures are based on statistical theory and assumptions given in References 11.12, 11.13.

Because of the possibility of systematic biases due to differences between microscopes, counters, and laboratories as discussed above, it is strongly recommended that any laboratory counting asbestos should participate in an interlaboratory quality control program that includes the counting of standard reference filters. These standard filters are available from NIOSH through the Proficiency Analytical Testing (PAT) Program. The PAT Program is used by the American Industrial Hygiene Association (AIHA) as part of its Laboratory Accreditation Program. Each laboratory's quality control program must include protocols for routinely adjusting and calibrating sampling and counting equipment plus training and evaluation programs for counters.

5. Advantages and Disadvantages of the Method

5.1 The method is intended to give an index of employee exposure to airborne asbestos fibers of specified dimensional characteristics.

5.2 It is not meant to count all asbestos fibers in all size ranges or to differentiate asbestos from other fibrous particulates.

6. Apparatus

6.1 Sampling Equipment

6.1.1 Personal Sampling Pump. The pump must be capable of sampling at 1.0 to 2.5 liters per minute (lpm) against a flow resistance of 7.5 inches of water (1.4 cm Hg) for 8 continuous hours on a fully charged battery.

6.1.2 Tubing. Laboratory tubing such as rubber or plastic with 6-mm bore and about 100 cm length.

6.1.3 Clothing Spring Clip. The clip attaches the rubber tubing to the lapel or shirt of the individual being monitored.

6.1.4 Tubing-to-field Monitor Adaptor. A short metal adaptor with ridges on one end to grip the inside of the tubing. The other end is designed for a pressure fit into the field monitor.

6.1.5 Field Monitor (Filter and Holder). The only field monitor currently considered acceptable by NIOSH is manufactured by the Millipore Corporation. The unit con-
sists of 1) a three section styrene plastic case designated Millipore Aerosol Monitor Case, 2) a 37-mm diameter plain white cellulose ester membrane filter designated Millipore AA (pore size of 0.8 micrometer), 3) a support pad, and 4) two plastic sealing caps. If a large number of samples are to be taken, it may be less expensive to reuse the plastic cases. Great care must be taken in the cleaning and reassembly process. The outside mating surfaces of the field monitors may be covered with a "shrink-fit" band to provide proper sealing and a writing surface for filter identification.

6.2 Optical Equipment and Microscope Features

6.2.1 Microscope body with binocular head.

6.2.2 10X Huygenian eyepieces are recommended. Other eyepieces can be substituted if necessary. Wide field eyepieces can be used; however, wide field eyepieces may yield a count field area less than 0.003 mm² with the Porton reticle. This is not always desirable from the standpoint of obtaining optimum sampling times (see Section 8.1.3). If wide field eyepieces are used, it is preferable to use the Patterson Globe and Circle reticle to obtain a larger count field area.

6.2.3 Koehler illumination (preferably built-in with provisions for adjusting light intensity).

6.2.4 A Porton reticle is recommended. Others such as the Patterson Globe and Circle can be substituted.

6.2.5 Mechanical stage.

6.2.6 Phase-Contrast condenser with a numerical aperture (N.A.) equal to or greater than the N.A. of the objective.

6.2.7 40-45X phase contrast achromatic objective (N.A. 0.65 to 0.75).

6.2.8 Phase-ring centering telescope or Bertrand lens.

6.2.9 Green or blue filter, if recommended by microscope manufacturer.

6.2.10 Stage micrometer with 0.01 mm subdivisions.

6.2.11 For general guidance on phase contrast microscopy, consult Needham (11.12), Clark (11.15) and McCrone (11.14).

6.3 Filter Mounting Equipment. Experience has shown that certain equipment is useful for efficient sample mounting. The following items are recommended for extracting and mounting a portion of the filter for counting.

6.3.1 Microscope slides. 2.5 by 7.5 cm glass slides are most commonly used. Sample number, data, initials, etc., can be conveniently written on frosted end slide.

6.3.2 Cover Slips. Cover slips are a necessary part of the slide mount and optical system. The shape should be appropriate for the size of the filter wedge. The appropriate cover slip depends upon the objective to be used. Ordinarily, objectives are optically corrected for a #1½ (0.17 millimeter) thickness cover slip. Improper cover glass thickness will detract from the final image quality.

6.3.3 Scalpel. A scalpel is needed to cut out a portion of the filter to be examined. A number-ten curved blade scalpel is recommended.

6.3.4 Tweezers. A pair of fine-tipped tweezers is used to remove the membrane filter slice from the field monitor and place it upon the slide.

6.3.5 Lens Tissue. To insure cleanliness, a lint-free tissue is recommended. This tissue should also be used for wiping mounting tools and for cleaning slides and cover slips.

6.3.6 Glass Rod. A fire-polished glass rod may be used to spread the mounting solution on the slide.

239-6
6.3.7 Wheaton Balsam Bottle. This special glass container has a glass top which prevents contamination of the mounting solution. A glass rod is included for dispensing the solution.

Reagents
Chemicals should be reagent grade, free from particles and color, conforming to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

7.1 Dimethyl phthalate
7.2 Diethyl oxalate

Avoid getting the mounting solution on the skin. Wash skin promptly with soap and water if skin contact occurs.

Procedure
8.1 Sampling

8.1.1 General Information
Guidelines for the monitoring of employee exposures to industrial atmospheres are given in Reference 11.8. The Federal requirements for monitoring employee exposure to airborne asbestos are found in 29 CFR 1910.1001.

8.1.2 Mounting the Sampling Pump on the Worker
Fasten the sampling pump to the worker's belt and fasten the field monitor to the lapel or shirt front (as close to the breathing zone as is practical). Remove the top cover of the plastic monitor, then invert the monitor making certain the exposed filter is facing downward. Turn the pump on and adjust to the calibrated flow rate (1.0 to 2.5 lpm). Record the following information in a logbook.
1. Filter number
2. Pump start time and date
3. Flow rate
4. Subject's name and job title
5. Type of operation or process
6. Ventilation controls and is the worker wearing a respirator approved for asbestos?
The pump should be checked periodically during the sampling period for proper operation and flow rate.

8.1.3 Optimum Sampling Times
The requirement for the minimum count of 100 fibers or 20 fields in 8.3.9 was determined to be the best compromise to achieve adequate precision for the airborne fiber estimate and reasonable counting times. An optimum fiber density of about 1 to 5 fibers per microscope count field is recommended. To estimate appropriate sampling times for feasible counting and optimal counting, one must consider the following constraints:
1. microscope count field area (generally 0.003 to 0.006 mm²)
2. pump flow rate (typically 2.5 lpm maximum)
3. average airborne fiber concentrations
4. counting rule range of 20 to 100 fields
5. adequate fiber density to obtain a minimum count of 10 fibers in 100 fields, which is the least total fiber count that yields an acceptable count precision
6. background airborne particulate levels that can reduce the count precision due to an obscuring of fibers on the filter surface
The preceding constraints were considered in drawing Figures 1 and 2. These figures were developed from the following relationship:

$$\text{sampling time} = \frac{(FB/FL) (ECA/MFA)}{(FR) (AC) (1000)} \text{ minutes}$$

where:

- $FB/FL = 1$ to 5 fibers/field
- $ECA =$ effective collecting area of filters (855 mm$^2$ for 37-mm filter with effective diameter of 33 mm)
- $MFA =$ microscope field area (generally 0.003 to 0.006 mm$^2$)
- $FR =$ Pump flow rate (generally 1.0 to 2.5 lpm)
- $AC =$ Air concentration of fibers in fibers/cm$^3$.

Figure 1 (microscope field area = 0.003 mm$^2$) and Figure 2 (microscope field area = 0.006 mm$^2$) show optimum and feasible sampling times for a pump flow rate of 1.7 lpm. Each individual responsible for sampling asbestos should prepare a similar chart for his particular pump flow rate and microscope field area before sampling is performed to aid in estimating proper sampling times. On Figures 1 and 2, the areas with solid shading lines are generally the optimum conditions for counting. The broken shading lines are for conditions very close to optimal. However, feasible counting conditions may extend down to about 0.1 fiber/field and and above 5 fibers/field. Recommended sampling times are most strongly influenced by background airborne particulate levels, once all the other constraints have been estimated. For heavy particulate levels, it may be necessary to limit each filter to about 60 to 180 minutes sampling duration. Each individual responsible for sampling should work closely with the microscopist to attain as high as possible filter surface fiber densities (up to about 5 fibers/field), while avoiding filter surface background particulate levels that create very difficult or impossible counting conditions. If one has very little idea of airborne fiber and particulate levels, the best procedure is to take several long samples (as one 8-hour or two consecutive 4-hour samples) in conjunction with several short samples (as four consecutive 2-hour or eight consecutive 1-hour samples). If the longer samples prove very difficult to count, the microscopist will have the shorter samples to fall back on.

From Figures 1 and 2, it can be seen that there are certain sampling times which will yield optimum fiber densities on the filter for almost all airborne fiber concentrations from 1 to 10 fibers/cm$^3$. These optimum times have been calculated and are presented in Figure 4. Note that the optimum times given by Figure 4 are approximate and can be varied by as much as $\pm$ 25%. The nomogram is intended as a guide to be used where no prior knowledge of the air concentration is available.

8.1.4 End of Sampling Period

Remove the field monitor, replace the plastic top cover and the small end caps, and store the monitor. Always shut off the pump when changing monitors to avoid contaminating or damaging the pump. Record the pump shutoff time and flow rate in the logbook.

8.1.5 Blanks

With each batch (25 to 50 filters) of samples sent for analysis, submit two unopened field monitors which have been subjected to the same treatment as the samples except that they were not exposed to the sampling environment. Label these as blanks. If the blanks yield fiber counts greater than 5 fibers/100 fields, then the entire sampling procedure should be examined carefully for the cause of contamination. The
mounting solution of Section 8.2.1 should also be examined for contamination and/or crystal growth.

8.1.6 Shipping
The field monitors in which the samples are collected should be shipped in a rigid container with sufficient packing material to prevent crushing.

8.1.7 Numbers of Samples
When sampling for the Federal ceiling standard of 10 fibers (>5 μm)/cm², [29 CFR 1910.1001(b)(3), effective July 7, 1972], only one sample (15 minutes maximum duration) is necessary, theoretically. However, several samples should be taken during expected periods of peak air concentrations to allow for detection of gross sampling or counting errors.

When sampling for determination of noncompliance with the Federal 8-hour TWA standard of 2 fibers (>5 μm)/cm², [29 CFR 1910.1001(b)(2)], one should continuously sample as large a portion of the work day as is feasible for airborne concentrations of about 2 to 10 fibers/cm². However, for a lower airborne concentration such as 0.5 fiber/cm², one sample might require 4 to 8 hours sampling time in order to get the proper filter fiber density (Section 8.1.3). For this situation, the 8-hour TWA exposure would be determined from one 8-hour or two 4-hour samples as appropriate.

8.2 Sample Preparation

8.2.1 Preparation of Mounting Solution
A very important part of the sample evaluation is the mounting process. This process involves a special mounting medium of prescribed viscosity. The proper viscosity is important in order to expedite filter dissolving and still minimize particle migration. After the sample has been mounted, an elapsed time of approximately sixty minutes is needed before the sample is ready for evaluation.

Combine the dimethyl phthalate and diethyl oxalate in a one to one ratio by volume and pour into a Wheaton balsam bottle. Add approximately 0.05 (= 0.005) grams of new membrane filter per milliliter of solution to reach the necessary viscosity. The mixture must be stirred periodically until the filters have dissolved and a homogeneous mixture is formed. The normal shelf life of the mounting solution is about three months. Twenty milliliters of mounting solution will prepare approximately 300 samples.

8.2.2 Sample Mounting
Cleanliness is important! A dirty working area may result in sample contamination and erroneous counts. The following steps should be followed when mounting a sample.

1. Clean the slides and cover slips with lens tissue. Lay each slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.

2. Wipe all the mounting tools clean with lens tissue and place them on a clean surface (such as lens tissue). All tools should be wiped clean prior to mounting each sample.

3. Using the glass rod supplied with the Wheaton balsam bottle, apply a drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of solution so that after the cover slip has been placed on top, the solution extends only slightly beyond the filter boundary. If the quantity is greater than this, particle migration may occur.
4. Using another glass rod, spread the mounting media into a triangular shape. The size of this triangle should coincide with the dimension of the filter wedge.

5. Separate the middle and bottom sections of the field monitor case to expose the filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface. The filter can be very carefully removed from the cassette for cutting, but this should only be done with great care.

6. Grasp the filter wedge with the tweezers on the perimeter of the filter which was clamped between the monitor case sections. Do not touch the filter with your fingers. Place the wedge, sample side up, upon the mounting medium.

7. Pick up a clean cover slip with tweezers and carefully place it on the filter wedge. Once this contact has been made, do not reposition the cover slip.

8. Label the slide with the sample number and current date before proceeding to the next filter. On the bottom (backside) of the slide, trace the perimeter of the filter wedge with a felt tip marking pen. This will enable the counter, after the filter has become transparent, to stay within the filter perimeter when counting.

9. The sample should become transparent within fifteen minutes. If the filter appears cloudy, it may be necessary to press very lightly on the cover slip. This is rarely necessary; however, counting should not be started until an hour after the mounting. This allows the microscopic texture of the filter to become invisible to microscope viewing.

10. Discard the sample mount after two days if it has not been counted. Crystals appearing similar to asbestos fibers may begin to grow at the mounting media/air interfaces. They seldom present any problems if the slide is examined before two days. In any case, stay away from the filter's edges when counting and sizing.

8.3 Counting of Fibers

8.3.1 Place the slide on the mechanical stage of the microscope and position the center of the wedge under the objective lens and focus upon the sample. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from perimeter to wedge tip). Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.

8.3.2 It is essential to continually scan over a range of focal planes (generally the upper 10 to 15 micrometers of the filter surface) with the fine focus control during each field count. This is especially necessary for asbestos fibers due to their impaction into the filter matrix.

8.3.3 On most airborne samples, asbestos fibers will generally have fiber diameters less than one micrometer. Therefore, it is necessary to look carefully for faint fiber images.

8.3.4 Regularly check phase ring alignment.

8.3.5 When an agglomerate (mass of material) covers a significant portion of the field of view (approx 1/6 or greater) reject the field and select another. (Do not include it in the number of fields counted.) However, report the fact as it may have meaning on other data collection.

8.3.6 Bundles of fibers are counted as one fiber unless both ends of the fiber can be clearly resolved.

8.3.7 Count only fibers with a length to width ratio greater than or equal to 3:1.

8.3.8 Count only fibers greater than 5 micrometers in length. (Be as accurate as possible in accepting fibers near this length.) Measure curved fibers along the curve to estimate the total length.
8.3.9 Count as many fields as necessary to yield a total count of at least 100 fibers. Exceptions: a) count at least 20 fields even if you count more than 100 fibers, and b) stop at 100 fields even if you haven't reached 100 fibers.

8.3.10 For fibers that cross either one or two sides of the counting field, the following procedure is used to obtain a representative count. COUNT any fiber greater than 5 micrometers in length, that lies entirely within the counting area. COUNT as “½ fiber” any fiber with only one end lying within the counting area. DO NOT COUNT any fiber crossing any two sides. Reject and do not count all other fibers. Refer to Figures 5 through 10. Note that the fibers in Figures 5 through 10 are not representative of the appearance of most asbestos fibers. Most fibers have a very faint image.

9. Calibration and Standards

9.1 Sampling Train Calibration
The accurate calibration of the sampling pump is essential to the correct calculation of the air volume sampled. The frequency of calibration is dependent on the use, care, and handling to which the pump is subjected. Pumps must be recalibrated if they have just been repaired, misused, or received from the manufacturer. If the pump receives hard usage, more frequent calibration may be necessary. Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples.

The accuracy of calibration is dependent upon the type of instrument used as a reference. The choice of a calibration instrument will depend largely on where the calibration is performed. For laboratory testing, a 1-liter buret used as a soap bubble flow meter or wet-test meter is recommended. Other standard calibrating instruments, such as a spirometer, Mariotti's bottle, or dry gas meter can be used. The calibration should be of sufficient precision that the 95% confidence limits on the flow rate are ± 10% (95% of the flow rates will fall within ± 10% of the calibrated value).

Instructions for calibration with the soap bubble flow meter follow. The sampling train used (pump, hose, filter cassette) in the pump calibration should be the same as the one used in the field.

9.1.1 Check the voltage of the pump battery with a voltmeter both with the pump off and while it is operating to assure adequate voltage for calibration. If necessary, charge the battery to manufacturer's specifications.

9.1.2 Fill a beaker with 10 ml of soap solution.

9.1.3 Connect the filter cassette inlet to the top of the buret with a length of hose.

9.1.4 Turn the pump on and moisten the inside of the soap bubble meter by immersing the open end of the buret into the soap solution and drawing bubbles up the inside of the buret. Perform this task until the bubbles are able to travel the entire length of the buret without breaking.

9.1.5 Adjust the pump rotameter to provide a flow between 1.5 to 2.5 lpm.

9.1.6 With a water manometer, check that the pressure drop across the filter is less than 13 inches of water (about 1 inch of mercury).

9.1.7 Start a soap bubble up the buret and measure the time it takes for the bubble to travel a minimum volume of 1 liter.

9.1.8 Repeat the procedure in 9.1.7 at least three times, average the results, and calculate the calibrated flow rate by dividing the volume traveled by the soap bubble by the elapsed time. If the range between the highest and lowest of the three flow rates is greater than about 0.33 lpm, then the calibration should be repeated since it is likely that the precision is not adequate.

239-11
9.1.9 Data required for the calibration include the volume measured, elapsed time, pressure drop, air temperature, atmospheric pressure (or elevation), pump serial number, date, and name of person performing the calibration.

9.1.10 Corrections to the flow rate for pumps with rotameters may be necessary if the pressure (elevation) or temperature where the samples are collected (actual flow rate) differs significantly from that where the calibration was performed (indicated flow rate). Actual flow rates at time of sampling may be calculated for a linear scale rotameter by using the following correction formula:

\[
Q_{\text{actual}} = Q_{\text{indicated}} \sqrt{\frac{P_{\text{actual}}}{P_{\text{indicated}}} \cdot \frac{T_{\text{actual}}}{T_{\text{indicated}}}}
\]

where both pressure (P) and temperature (T) are in absolute units such as:

\[
\text{psia} = \text{psig} + 14.7
\]

\[
\text{deg Rankin} = \text{deg Fahrenheit} + 460
\]

\[
\text{deg Kelvin} = \text{deg Celsius} + 273
\]

9.2 Microscope Setup

9.2.1 Porton Reticle and the Counting Field

The asbestos fiber count procedure consists of comparing fiber length to the diameters of calibrated circles of a Porton reticle, and counting all fibers greater than 5 micrometers in length lying within a given counting field area. The Porton reticle is a glass plate inscribed with a series of circles and rectangles. The left half of the reticle is divided into six rectangles constituting the counting field. The counting field is illustrated in Figures 5 through 10.

9.2.2 Placement in Eyepiece

The Porton reticle is placed inside the Huygenian eyepiece where it rests on the field-limiting diaphragm. If other types of eyepieces are used, it may be necessary to insert a counting collar for retaining the reticle. The reticle should always be kept clean, since dirt on the reticle is in focus and could complicate the counting and sizing process.

9.2.3 Stage Micrometer

The Porton reticle cannot be used for counting until it has been properly calibrated with a stage micrometer. Most stage micrometer scales are approximately two millimeters long and are divided into units of one-hundredth of a millimeter (ten micrometers).

9.2.4 Microscope Adjustment

When adjusting the microscope, follow the manufacturer's instructions while observing the following guidelines.

1. The light source image must be in focus and centered on the condenser iris or annular diaphragm.

2. The particulate material to be examined must be in focus.

3. The illuminator field iris must be in focus, centered on the sample, and opened only to the point where the field of view is illuminated.

4. The phase rings (annular diaphragm and phase-shifting elements) must be concentric.

9.2.5 Porton Reticle Calibration Procedure

Each eyepiece-objective-reticle combination on the microscope must be calibrated. Should any of the three be changed (disassembly, replacement, zoom adjustment, etc.), the combination must be recalibrated. Calibration may change if interpupillary dis-
Lance is changed. For proper calibration, the following procedure should be followed closely.

With a 10X objective in place, place the stage micrometer on the mechanical stage, focus the millimeter scale, and center the image. Change to the 40-45X objective and adjust the first millimeter scale division to coincide with the left boundary of the Porton rectangle. Measure the distance between the left and extreme right boundaries of the Porton rectangle, estimating any portion of the final division. This measurement represents 200 L units. The rectangle is 100 L units on the short vertical dimension. The calculated "L" is inserted into the formula $D = L(2^N)^{1/2}$ where "N" is the circle number (indicated on the reticle) and "D" is the circle diameter. Since the circle diameters vary logarithmically, every other circle doubles in diameter. For example, circle number three is twice the diameter of number one; number four is twice the diameter of number two. When the circle sizes have been determined, the counting field area which consists of the left six smaller rectangles can be calculated from the relation 10,000 $L^2$. This completes the reticle calibration for this specific objective-eyepiece-reticle combination.

Example for Porton Reticle

The following calibration was obtained for a pair of 10X Huygenian eyepieces and a 43X objective:

$200 \text{ } L = 0.148 \text{ } \text{mm} = 148 \text{ } \text{micrometers}$
$100 \text{ } L = 0.074 \text{ } \text{mm} = 74 \text{ } \text{micrometers}$

One L-unit = 0.74 micrometers

Thus Circle #1 has a diameter $D = L(2^1)^{1/2} = 0.74(2)^{1/2} = 0.74 \times (1.414) = 1.05$ micrometers.

Then our circle diameter calibration table looks like:

Diameter of Circle #1 = 1.05 micrometers
#2 = 1.48
#3 = 2.09
#4 = 2.96
#5 = 4.19
#6 = 5.92

Field area = $(10,000) (L^2) = (100 \text{ } L) (100 \text{ } L) = (0.074) (0.074) = 0.0055 \text{ } \text{mm}^2$

Thus fibers with a length greater than a distance halfway between the diameters of the #5 and #6 circles would be counted.

If a Patterson Globe and Circle reticle is used, a different calculation procedure is required. The circle diameters are related as follows. The #25 circle diameter is $(0.1)$ (reticle length).

The circle diameters are proportional to the ratio of their numbers. Thus the #20 circle diameter is $(20/25)$ or 0.8 times the #25 circle diameter.

10. Calculations

10.1 The average airborne asbestos fiber concentration estimated by the filter sample may be calculated from the following formula:

$$AC = \frac{(FB/FL) - (BFB/BFL)(ECA)}{(1000)(FR)(T)(MFA)}$$
where:

\[
\begin{align*}
AC & = \text{Airborne fiber concentration in (fibers > 5 \mu m)/cm}^2. \\
BFB & = \text{Total number of fibers counted in the BFL fields of the blank or control filters in fibers > 5 \mu m.} \\
BFL & = \text{Total number of fields counted on the blank or control filters.} \\
ECA & = \text{Effective collecting area of filter (855 mm}^2 \text{ for a 37-mm filter with effective diameter of 33 mm).} \\
FR & = \text{Pump flow rate in liters/min (lpm).} \\
FB & = \text{Total number of fibers counted in the FL fields in fibers > 5 \mu m.} \\
FL & = \text{Total number of fields counted on the filter.} \\
MFA & = \text{Microscope count field area in mm}^2 \text{ (generally 0.003 to 0.006).} \\
T & = \text{Sample collection time in minutes.}
\end{align*}
\]

10.2 Recount criteria. It is very desirable for a counter to conduct a “blind recount” for about 1 in every 10 filter wedges (slides) counted. Alternatively, a second counter could perform the blind recount. In training sessions for novice counters, the trainee should conduct a blind recount for filter wedges counted by an experienced, proficient counter. In all cases, we will observe differences between the first and second counts of the same filter wedge. Most of these differences will be due to chance alone, that is, due to the random variability (precision) of the count method. Statistical recount criteria enable us to decide whether observed differences can reasonably be explained due to chance alone or are probably due to systematic differences between counters or microscopes or due to some other biasing factor.

The following recount criterion is for a pair of counts that estimate some airborne fiber concentration (AC) in fibers/cm². The criterion is given at the type-I error level. That is, there is a 5% maximum risk that we will reject a pair of counts for the reason that one might be biased, when the large observed difference is really due to chance.

Reject a pair of counts because one might be biased if:

\[
(AC_2 - AC_1) > 2.77(AC)(CV^2_{FM})
\]

where:

\[
\begin{align*}
AC_1 & = \text{lower estimated airborne fiber concentration} \\
AC_2 & = \text{higher estimated airborne fiber concentration} \\
\overline{AC} & = \text{average of the two airborne concentration estimates} \\
CV_{FM} & = \text{average CV for the two concentration estimates which are a function of the total fiber count (FB) in each case. Use the relation in Section 4 or Figure 3.}
\end{align*}
\]

For a pair of counts on the same filter, reject the pair because one might be biased if:

\[
(FB_2 - FB_1) > 2.77(FB)(CV_{FM})
\]

where:

\[
\begin{align*}
FB_1 & = \text{lower fiber count on the filter (total fibers)} \\
FB_2 & = \text{higher fiber count on the filter (total fibers)} \\
\overline{FB} & = \text{average of the two total fiber counts} \\
CV_{FM} & = CV_T \text{ for the value } FB. \text{ Use the relation in Section 4 or Figure 3.}
\end{align*}
\]

11. References


11.2 Weidner, R. B. and H. E. Ayer, “Dust Exposure in Asbestos Processing”, Transactions of the


11.10 Comments of the Johns-Manville Corporation with Respect to the Notice of Proposed Rule-making: Occupational Exposure to Asbestos, Federal Register, October 9, 1975. Submitted to the public record at the U. S. Department of Labor, Occupational Safety and Health Administration, April 1976.


FIGURE 1. Optimum Sampling Times for airborne asbestos where microscopic field area = 0.003 mm²
FIGURE 2. Optimum sampling times for airborne asbestos where microscopic field area = 0.006 mm$^2$
FIGURE 3. Total coefficient of variation as a function of total fiber count.
FIGURE 4. Nomogram of optimum sampling times for airborne asbestos fibers in concentrations of 1 to 10 fibers/cm$^3$
LIST OF FIGURES
(S through 10)

FIGURE 5. DO NOT COUNT. Fiber crosses top and bottom sides.

FIGURE 6. COUNT. One fiber.

FIGURE 7. COUNT. One-half fiber. Fiber crosses left side and one end lies within count area.

FIGURE 8. COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.

FIGURE 9. DO NOT COUNT. Fiber crosses two sides.

FIGURE 10. DO NOT COUNT. Fiber crosses two sides (bottom left corner).
COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.
COUNT. One fiber (top right corner).
INTRODUCTION

The Georgia Tech Research Institute performed industrial hygiene sampling during the removal of existing acoustical ceiling material in Russell Hall, Brumby Hall, Hill Hall and Creswell Hall. In addition samples were taken during the removal of material from a boiler room in Bolton Hall. Air sampling was performed by Mr. Brent Bailey and other Georgia Tech EES staff members, during the period of June 17 - August 23, 1983 at the request of Mr. J. Wayne Simpson of Gemco Construction Company on June 3, 1983. All analyses were performed by Georgia Tech's Environmental Laboratory within 12 hours of sampling and the results reported to Mr. W. C. Willis of Gemco Construction Company. The following report summarizes the results of sampling and analyses including conclusions and discussion of findings. The results of air sampling are included in Appendix A. A copy of the analytical method employed is attached as Appendix B. Appendix C contains copies of the Occupational Safety and Health Administration (OSHA) asbestos standard and the Environmental Protection Agency (EPA) asbestos standard.

CONCLUSIONS AND RESULTS

1. Work area samples taken during the removal of asbestos-containing acoustical ceiling material indicated fiber concentrations that were not in excess of OSHA asbestos standard of 2 fibers*/cc, but did exceed the NIOSH recommended standard of 0.1 fibers*/cc. Ninety-nine work area samples were taken during the eight week period. Ninety-three samples had a concentration of 0.1 fibers*/cc. Six (6) samples had a concentration of 0.1 fibers*/cc with the high sample having a concentration of 0.52 fibers*/cc.

2. The results of the area samples taken outside the work area but inside the building ranged from less than 0.01 to 0.02 fibers*/cc. The results of the area samples taken outside the building were 0.01 fibers*/cc and under with the exception of one sample with a count of 0.05 fibers*/cc.

3. Air sampling conducted, after all removal and clean-up activities were completed in each work area, indicated fiber concentrations below the OSHA asbestos standard and the NIOSH recommended standard.

4. The OSHA asbestos standard contains a requirement for full-shift personal monitoring to determine the 8-hour, time-weighted average airborne fibers greater than 5 micrometers in length.
concentrations and ceiling concentrations of asbestos fibers*. On future asbestos abatement projects, it is recommended that full-shift personal monitoring be conducted.

5. The NIOSH method P & CAM No. 239 was used to analyze the fiber* concentrations listed in this report. This method does not determine a fiber concentration of fibers shorter than 5 micrometers in length or thinner than 0.3 micrometers. Strong evidence exists that these short or thin fibers present the greatest threat to those people exposed. To determine the concentration of fibers such as these, analysis must be conducted using an electron microscope. While the cost of this analysis ($300 - $400 per sample) is prohibitive for analyzing all samples, it is suggested that, on future asbestos abatement projects, the University have samples taken before and after removal and analyzed by electron microscopy, to determine the fiber count of fibers less than 5 micrometers in length or thinner than 0.3 micrometers in addition to those fibers greater than 5 micrometers.

DESCRIPTION OF FACILITY

Russell, Brumby, Creswell, and Hill Halls are dormitories located on the campus of the University of Georgia in Athens, Georgia. Typical plans at each dorm are included in figures 1-16. Figures 1-7 are plans of Creswell Hall, Figures 8-12 are plans of Russell Hall, Figures 13-14 are plans of Hill Hall, and Figures 15-16 are plans of Brumby Hall.

Acoustical ceiling material was to be removed from floors 2-9 of Russell Hall, floors 2-9 of Brumby Hall, plus a rotunda, floors 1, 5, 6, 7 and 8 of Creswell Hall, and all four floors of Hill Hall. The work area was located on these floors with material and personnel transport provided by an elevator with access to the ground floor. All of these areas were considered "contaminated" areas.

DISCUSSION OF FINDINGS

A survey of protocol was designed to meet the requirements of the asbestos removal contract between Gemco Construction Company and the University of Georgia. Air sampling was conducted during and after removal activities to determine airborne filter concentrations. All air samples were collected and analyzed as described in the National Institute for Occupational Safety and Health (NIOSH) method P & CAM No. 239. To provide prompt results, samples were analyzed within 12 hours at Georgia Tech's Engineering Experiment Station in Atlanta, Georgia.

During removal activities, 102 work area samples were taken, generally two per floor on each day of sampling. Fifty-one samples were taken outside the building while removal was in progress. Fifty samples were taken inside the building but outside the work area to determine if a significant number of fibers were being emitted from the work area.

*Fibers greater than 5 micrometers in length
After removal and clean-up, 63 samples were taken to determine the post-work fiber* count. The level of less than 0.05 fibers*/cc had been established by the University as acceptable for re-entry and occupancy. One (1) of the 63 sample results exceeded this count and the area was cleaned a second time. Repeat samples, afterwards, indicated fiber* counts had been reduced below 0.05 fibers*/cc.

This report prepared by:  
Kenneth E. Johnson, CSP  
Leader, Safety Group

This report reviewed by:  
James L. Burson, CIH, CSP  
Chief, Environmental Health and Safety Division

*Fibers greater than 5 micrometers in length.
APPENDIX A

RESULTS OF AIR SAMPLING
GEORGIA INSTITUTE OF TECHNOLOGY  
Engineering Experiment Station  
Safety & Health Services  
INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant: University of Georgia  
Materials: Fibers greater than 5 microns in length

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/17/83</td>
<td>AA-436</td>
<td>Outside Building - River St.</td>
<td>08:51</td>
<td>345.4</td>
<td>199</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S. of Dorm Adj. trailer</td>
<td></td>
<td></td>
<td></td>
<td>2.001</td>
</tr>
<tr>
<td>11</td>
<td>AA-439*</td>
<td>Inside Work Area - Hall water</td>
<td>09:15</td>
<td>136.6</td>
<td>69</td>
<td>VOID*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fountain - 10th floor</td>
<td></td>
<td></td>
<td></td>
<td>VOID*</td>
</tr>
<tr>
<td>11</td>
<td>AA-444*</td>
<td>Inside Work Area - 10th floor</td>
<td>09:03</td>
<td>140.7</td>
<td>10</td>
<td>&lt;2800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ON Counter</td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>11</td>
<td>AA-434</td>
<td>Inside Building - Outside Work</td>
<td>09:03</td>
<td>406.0</td>
<td>202</td>
<td>&lt;2800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area - Fire Ext. 9th floor</td>
<td></td>
<td></td>
<td></td>
<td>&lt;2800</td>
</tr>
<tr>
<td>11</td>
<td>AA-435</td>
<td>Blank</td>
<td></td>
<td></td>
<td></td>
<td>&lt;2800</td>
</tr>
</tbody>
</table>

* Equipment malfunction - filter would not clear.

** - Filters 439 and 444 were placed in the scraping area by construction workers.
**INDUSTRIAL HYGIENE SAMPLING SUMMARY**

**Plant**: University of Georgia  
**Materials**: Fibers greater than 5 microns in length  
**Location**: Russell Dormitory

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>% Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/18/83</td>
<td>AA-445</td>
<td>Outside Building - on Post Support - West side of Post St</td>
<td>10:35 - 14:15</td>
<td>6.766.6</td>
<td>340</td>
<td>&lt;2800 &lt;0.01</td>
</tr>
<tr>
<td>6/18/83</td>
<td>AA-437</td>
<td>Inside Building - Outside Work Area</td>
<td>10:40 - 13:00</td>
<td>29.20</td>
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<tr>
<td>6/18/83</td>
<td>AA-438</td>
<td>Inside Work Area - Room behind Elevators on 10th floor</td>
<td>10:32 - 12:58</td>
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<td>Inside Work Area - Rm 1025</td>
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*NOTE* - Pump # 1919 was found on the floor when the pumps were turned off.
### Industrial Hygiene Sampling Summary

**Plant:** University of Georgia  
**Materials:** Fibers greater than 5 microns in length  

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>11/19/83</td>
<td>AA-503</td>
<td>Outside Building - Basketball</td>
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<td>Post BBing + Tractor</td>
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<td>11/16</td>
<td>AA-512</td>
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<td>Inside Work Area - 10th Floor</td>
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<td>On Water Fountain in Hall</td>
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<td>11/24</td>
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<td>Inside Work Area - 9th Floor</td>
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<td>On Counter of Room 914</td>
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### INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant:** Russell Dorm  
**Materials:** Fibers less than 5 microns in length

<table>
<thead>
<tr>
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<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>6/20/83</td>
<td>AA-501</td>
<td>Outside Building - Tongue of trailer</td>
<td>0858 1402</td>
<td>604.9</td>
<td>304</td>
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<tr>
<td>11</td>
<td>AA-492</td>
<td>Inside Work Area - 9th floor on counter of Rm 943</td>
<td>1105 1310</td>
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<td>125</td>
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<td>AA-494</td>
<td>Inside Building- outside work area - on counter of Rm 880</td>
<td>1107 1305</td>
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<td>11</td>
<td>AA-509</td>
<td>Inside Work Area - 9th floor on counter of Dolphin Lounge</td>
<td>1104 1311</td>
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### INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant:** University of Georgia

**Materials:** Fibers greater than 5 microns in length

<table>
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<tr>
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<th>Description</th>
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<th>Sample Time (Min.)</th>
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<tbody>
<tr>
<td>6/21/83</td>
<td>AA-501</td>
<td>Outside Building - on Window ledge, on Baxter St. side of Dam</td>
<td>08:48 - 14:01</td>
<td>624</td>
<td>313</td>
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<td>7/1</td>
<td>AA-491</td>
<td>Inside Work Area - Rm 801 on the counter</td>
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<td>7/1</td>
<td>AA-496</td>
<td>Inside Work Area - 8th floor on Top of Closet door in hallway</td>
<td>11:58 - 13:00</td>
<td>236</td>
<td>18</td>
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<tr>
<td>7/1</td>
<td>AA-508</td>
<td>Inside Building - Outside Work Area, 7th floor on closet door</td>
<td>11:09 - 13:01</td>
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* Pump #5053 was not running when filters were checked at approx. 1:30PM.
Plant: University of Georgia  

Materials: Fibers greater than 5 microns in length

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<tr>
<td>6/29/63</td>
<td>AA-141</td>
<td>Outside Building - Window ledge on South side of room</td>
<td>0903-1411</td>
<td>6.6</td>
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<td>AA-142</td>
<td>Inside Work Area - Rm 825 on counter</td>
<td>1118-1344</td>
<td>2.8</td>
<td>144</td>
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<td>AA-143</td>
<td>Inside Work Area - 8th floor elevator lobby on fountain</td>
<td>1126-1346</td>
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<td>AA-144</td>
<td>Inside Building - Outside Work Area - 6th floor elevator lobby</td>
<td>1132-1349</td>
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<td>135</td>
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<td>Description</td>
<td>Sampling Period</td>
<td>Sample Volume (Liters)</td>
<td>Sample Time (Min.)</td>
<td>Concentration</td>
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<tr>
<td>6/23/73</td>
<td>AA-646</td>
<td>Outside Building - Window ledge</td>
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<td>632</td>
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<td>floor lobby on water fountain</td>
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## Industrial Hygiene Sampling Summary

### Plant
University of Georgia
Russell Dorm

### Materials
Fibers greater than 5 microns in length

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<th>Date</th>
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<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
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<th>Concentration Fibers/Filter</th>
<th>Concentration Fibers/cc</th>
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<tbody>
<tr>
<td>6/24/83</td>
<td>AA-683</td>
<td>Outside Building - On Post (Baxter st side of Dorm)</td>
<td>09:01 - 14:02</td>
<td>66.2</td>
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<td>AA-684</td>
<td>Inside Work Area - 6th floor on top of hall closet door</td>
<td>10:46 - 13:20</td>
<td>308.5</td>
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<td>AA-686</td>
<td>Inside Building Outside Work Area - 5th floor water fountain</td>
<td>10:44 - 13:19</td>
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<td>Inside Work Area - 2nd floor on top of closet door</td>
<td>10:53 - 13:24</td>
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<td>6/25/83</td>
<td>AA-666</td>
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<td>AA-612</td>
<td>Inside Work Area - 10th, floor on top of counter in</td>
<td>12:2 to 13:30</td>
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<td>Inside Building Outside Work Area</td>
<td>11:51 to 13:56</td>
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<td>AA-668</td>
<td>Inside Work Area - 5th, Floor Rm 521 on counter</td>
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<td>Sample Volume (Liters)</td>
<td>Sample Time (Min.)</td>
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<td>6/24/83</td>
<td>AA-1671</td>
<td>Outside Building - on top of ledge on East side of dorm</td>
<td>0905 - 1415</td>
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<td>1100 - 1300</td>
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<td>130</td>
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<td>1122 - 1331</td>
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## INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant**: University of Georgia  
**Materials**: Fibers greater than 5 microns in length

<table>
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<th>Date</th>
<th>Sample Number</th>
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<th>Concentration</th>
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<tbody>
<tr>
<td>4/27/83</td>
<td>AA-681</td>
<td>Outside Building - on window</td>
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<td>0849 - 1145</td>
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<td>On top of counter in Good lounge</td>
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<td>AA-686</td>
<td>Inside Building - Outside Work</td>
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### Industrial Hygiene Sampling Summary

**Plant:** University of Georgia  
**Materials:** Fibers greater than 5 microns in length

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<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<td>Post next to trailer</td>
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* Pump stopped running
** Tear in filter
## INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant**: University of Georgia  
**Materials**: Fibers greater than 5 fibers in length

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<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
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<td>AA-1662</td>
<td>Outside building - on window</td>
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### Plant
University of Georgia
Russell Hall

### Materials
Fibers, greater than 5 microns in length

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<td>Inside Work Area - 8th floor Room 843 on counter</td>
<td>1004-1149</td>
<td>210</td>
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<td>Inside Building - outside work Area - 2nd office on right in housing office</td>
<td>1000-1407</td>
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**INDUSTRIAL HYGIENE SAMPLING SUMMARY**

**Plant:** University of Georgia  
**Materials:** Fibers greater than 5 microns in length

<table>
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<th>Date</th>
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<td>Inside Work Area - Stairwell of 4th floor</td>
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<td>11</td>
<td>AA-768</td>
<td>Inside Work Area - 4th floor on water fountain in lobby</td>
<td>0841</td>
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* Sample #780 was torn by a worker
* * Sample #768 was voided because of paint contamination
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Materials: Fibers greater than 5 microns in length
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<td>Description</td>
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<td>Sample Time (Min.)</td>
<td>Concentration</td>
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<tr>
<td>7/2/83</td>
<td>AA-772</td>
<td>Clean Air Test - 9th Floor In</td>
<td>1355-1405</td>
<td>2890</td>
<td>1445</td>
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<tr>
<td></td>
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<td>T. V. Lounge on A.C. Unit</td>
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<td>Clean Air Test - 10th Floor</td>
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<td>1408-1410</td>
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<td>1355-1405</td>
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<td>Rm 931 on Counter</td>
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<td>&lt;2800</td>
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* NOTE: Sample AA-776 was voided because it was too dusty to read.
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<th>Date</th>
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<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>7/13/83</td>
<td>AA-779</td>
<td>Outside Building - on top of ledge by dumpster</td>
<td>0924 1420</td>
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<td>11</td>
<td>AA-781</td>
<td>Inside Building - outside work on 2nd floor</td>
<td>0929 1419</td>
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### Industrial Hygiene Sampling Summary

#### Plant
- University of Georgia
- Brumby Hall

#### Materials
- Fibers greater than 5 microns in length

<table>
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<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>7/14/83</td>
<td>AA-1094</td>
<td>Inside Work Area - 9th Floor Room 953 on Counter</td>
<td>1041-1304</td>
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<td>143</td>
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<td>11</td>
<td>AA-1093</td>
<td>Outside Building - On Vergean Post on Boxer St. side of building</td>
<td>934-1431</td>
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<td>AA-964</td>
<td>Inside Building - Outside Work Area - 8th floor hallway</td>
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### Industrial Hygiene Sampling Summary

**Plant**: University of Georgia  
**Materials**: Fibers greater than 5 microns in length

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<td>AA-965</td>
<td>Outside Building - on Dumpster</td>
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<td>AA-1085</td>
<td>Inside Work Area - Room 9-1 on counter</td>
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<td>242</td>
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<td>AA-941</td>
<td>Inside Work Area - on door to Sea Breeze Wing 8th floor</td>
<td>1036</td>
<td>482</td>
<td>241</td>
<td>3000</td>
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<td>AA-970</td>
<td>Inside Work Area - on door to Darling and Co. wing</td>
<td>1035</td>
<td>488</td>
<td>244</td>
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<td>Description</td>
<td>Sampling Period</td>
<td>Sample Volume (Liters)</td>
<td>Sample Time (Min.)</td>
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<td>7/16/83</td>
<td>AA-962</td>
<td>Outside Building on Dumpster</td>
<td>0730 - 1345</td>
<td>790</td>
<td>385</td>
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<td>AA-1092</td>
<td>Inside Work Area - 9th floor</td>
<td>0815 - 1345</td>
<td>602</td>
<td>301</td>
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<td>11</td>
<td>AA-936</td>
<td>Inside Work Area - 8th floor - on Door</td>
<td>0819 - 1345</td>
<td>678</td>
<td>339</td>
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<td>11</td>
<td>AA-867</td>
<td>Inside Building - outside work area</td>
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<td>11</td>
<td>AA-928</td>
<td>Clean Air Test 9th floor Brumby</td>
<td>0924 - 1045</td>
<td>3042</td>
<td>1521</td>
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<td>AA-949</td>
<td>Clean Air Test - 9th Floor Brumby</td>
<td>0926 - 1045</td>
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## Industrial Hygiene Sampling Summary

### Plant
University of Georgia

Brumby Hall

### Materials
Fibers greater than 5 microns in length

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>1/1/93</td>
<td>AA-939</td>
<td>Outside Building - Baxter</td>
<td>0930 - 1400</td>
<td>526.6</td>
<td>262</td>
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<td></td>
<td></td>
<td>St. Side of Brumby</td>
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<td>11</td>
<td>AA-1691</td>
<td>Inside Building - Outside Work</td>
<td>1025 - 1325</td>
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<td></td>
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<td>Area - 7th floor Resident Asst. Apt.</td>
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<td>AA-942</td>
<td>Inside Work Area - 8th floor</td>
<td>1013 - 1328</td>
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*Note: The table provides details on the sampling locations, dates, and concentrations of fibers.*
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<th>Concentration</th>
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<td>AA - 950</td>
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<td>1305</td>
<td>1304</td>
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<tr>
<td></td>
<td></td>
<td>Room 759 on counter</td>
<td>(sun)</td>
<td>(mon)</td>
<td></td>
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<tr>
<td>11</td>
<td>AA - 863</td>
<td>Clean Air Test - 7th floor</td>
<td>1306</td>
<td>1255</td>
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<td>In lounge on A.C. unit</td>
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<td>Description</td>
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<td>Sample Volume (Liters)</td>
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<td>Concentration</td>
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<td>7/18/33</td>
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<td>AA-928</td>
<td>Inside Work Area on counter</td>
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<td>AA-930</td>
<td>Inside building - outside</td>
<td>1005-1335</td>
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<td></td>
<td></td>
<td>work area</td>
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<td></td>
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<td>4th floor, 6th floor, lounge</td>
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<td>AA-1070</td>
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<td>Bank</td>
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<td>Sample Time (Min.)</td>
<td>Concentration</td>
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<td>7/19/83</td>
<td>AA-926</td>
<td>Outside Building - in finished product</td>
<td>6:05-13:46</td>
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<td>591</td>
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<td>On Backside of Brumby</td>
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<td>7/11</td>
<td>AA-848</td>
<td>Inside Work Area - 6th floor Rm 601 on counter</td>
<td>10/6-13:23</td>
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<td>AA-847</td>
<td>Inside Building - outside work area Rm 415 on counter</td>
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</table>
# Industrial Hygiene Sampling Summary

**Plant:** University of Georgia  
**Materials:** Fibers greater than 5 microns in length

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>1/19/88</td>
<td>AA-1096</td>
<td>Clean Air Test - 6th floor in Lounge on A.C. Unit</td>
<td>1149-1325</td>
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<td>&lt;2800</td>
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<td>AA-1069</td>
<td>Clean Air Test - 5th floor in Rm 517 on counter</td>
<td>1144-1328</td>
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<td>1539</td>
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<td>AA-911</td>
<td>Clean Air Test - 6th floor in Rm 623 on counter</td>
<td>1151-1328</td>
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<td>22800</td>
</tr>
<tr>
<td>1/11</td>
<td>AA-937</td>
<td>Clean Air Test - 5th floor in T.V. Lounge on A.C. Unit</td>
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<td>Sample Volume (Liters)</td>
<td>Sample Time (Min.)</td>
<td>Concentration</td>
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<td>7/20/83</td>
<td>AA-934</td>
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<td>Inside Work Area - 5th floor Room 512 on Counter</td>
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<td>Description</td>
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<td>Sample Volume (Liters)</td>
<td>Sample Time (Min.)</td>
<td>Concentration</td>
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<td>Inside Work Area - on Counter</td>
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Plant: University of Georgia

Materials: Fibers greater than 5 microns in length
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<td>0741 1051</td>
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# INDUSTRIAL HYGIENE SAMPLING SUMMARY

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**Plant:** University of Georgia

**Materials:** Fibers greater than 5 microns in length
### Plant

**University of Georgia**

**Brumby Hall**

### Materials

Fibers greater than 5 microns in length

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**Plant**: University of Georgia  
**Materials**: Fibers greater than 5 microns in length

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<tr>
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<td>7/26/83</td>
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## Industrial Hygiene Sampling Summary

**Plant:** University of Georgia  
**Materials:** Fibers greater than 5 microns in length

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<th>Date</th>
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<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
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<tbody>
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### Industrial Hygiene Sampling Summary

**Plant**: University of Georgia  
**Materials**: Fibers greater than 5 microns in length

<table>
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<tbody>
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<td>(Fri.)</td>
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<td>1/28/83</td>
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### Plant

**University of Georgia**

**Russell Hall**

### Materials

Fibers greater than 5 microns in length

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# Industrial Hygiene Sampling Summary

**Plant:** University of Georgia  
**Materials:** Fibers, Greater than 5 microns in length

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<tbody>
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**Report No.:** 45
# Industrial Hygiene Sampling Summary

**Plant:** University of Georgia - Creswell Hall  
**Materials:** Fibers, greater than 5 microns in length

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<td>AA-1156</td>
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*Note: Sample 1163 was voided because of exposure to rain.*
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<tbody>
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<td>8/2/83</td>
<td>AA-1167</td>
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<td>1005-1231</td>
<td>330.3</td>
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<td>8/3/88</td>
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<td>Canv Air Test - 40Funda</td>
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<td>(Thur)</td>
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**Materials:** Fibers greater than 5 microns in length

**Plant:** University of Georgia Brumby Hall
## Industrial Hygiene Sampling Summary

**Plant:** University of Georgia  
**Materials:** Fibers greater than 5 microns in length

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<thead>
<tr>
<th>Date</th>
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<td>8/3</td>
<td>AA-1147</td>
<td>Clean Air Test - Rotunda</td>
<td>13:19 (Wed)</td>
<td>2992</td>
<td>14:46</td>
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<td>AA-1146</td>
<td>Clean Air Test - Rotunda</td>
<td>13:21 (Wed)</td>
<td>2990</td>
<td>14:45</td>
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<td>0920 1349</td>
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<td>11</td>
<td>AA-1195</td>
<td>Outside Building - On Loading dock by tunnel</td>
<td>0849 1409</td>
<td>640</td>
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<td>AA-1174</td>
<td>Inside Work Area</td>
<td>0914 1345</td>
<td>542</td>
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<td>AA-1220</td>
<td>Inside Building - Outside Work Area - 4th floor in Lobby</td>
<td>0859 1405</td>
<td>612</td>
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## Industrial Hygiene Sampling Summary

**Plant:** University of Georgia

**Materials:** Fibers greater than 5 microns in length

<table>
<thead>
<tr>
<th>Date</th>
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<th>Sample Time (Min.)</th>
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<tr>
<td>3/5/83</td>
<td>PE-314-13</td>
<td>Inside Building - Outside</td>
<td>10:05 - 11:55</td>
<td>220</td>
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<td>Work Area - First Floor</td>
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<td></td>
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<td>Outside Elevator</td>
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<tr>
<td>11</td>
<td>PVC-214-19</td>
<td>Inside Work Area - 5th Floor</td>
<td>10:10 - 11:40</td>
<td>180</td>
<td>90</td>
<td>14,000</td>
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<td>PVC-214-14</td>
<td>Block</td>
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<td>&lt; 2800</td>
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### Plant: University of Georgia  
### Materials: Fibers greater than 5 microns in length

<table>
<thead>
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<th>Description</th>
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<th>Sample Time (Min.)</th>
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<tbody>
<tr>
<td>8/5/83</td>
<td>PVC-214-07</td>
<td>Clean Air Test - 6th Floor</td>
<td>12:30 - 12:44</td>
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<td>1454</td>
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<td>Rm 609</td>
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<td>(Fr.) (Sat)</td>
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<td>PVC-214-15</td>
<td>Clean Air Test - 6th Floor</td>
<td>12:35 - 12:41</td>
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<td>Room 629</td>
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Plant: University of Georgia  
Creswell Hall  

Materials: Fibers greater than 5 microns in length  

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<th>Sample Time</th>
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<tbody>
<tr>
<td>8/10/83</td>
<td>P1C-24-06</td>
<td>Inside work area - first floor</td>
<td>11:10 - 13:59</td>
<td>338 (Liters)</td>
<td>169 (Min.)</td>
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<td>P1C-314-10</td>
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**INDUSTRIAL HYGIENE SAMPLING SUMMARY**

**Plant**: University of Georgia

**Materials**: Fibers greater than 5 microns in length

<table>
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<th>Date</th>
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<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>8/1/83</td>
<td>AA-1542</td>
<td>Outside Building - On A.C. Unit</td>
<td>0930 1331</td>
<td>486.8</td>
<td>241</td>
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<tr>
<td>11</td>
<td>AA-1544</td>
<td>Inside Building - Outside Work Area - 1st floor Stairwell</td>
<td>1028 1329</td>
<td>363</td>
<td>181</td>
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<td>AA-1208</td>
<td>Inside Work Area - Large Arched Ceiling Lobby on Bath</td>
<td>1001 1243</td>
<td>325.6</td>
<td>162</td>
<td>3.000</td>
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<td>AA-1234</td>
<td>Inside Work Area - Large Arched Ceiling Lobby - on scaffolding</td>
<td>1000 1242</td>
<td>322.4</td>
<td>162</td>
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* Sample # AA-1234 would not clear because the filter got wet.*
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<td>8/1/83</td>
<td>AA-1543</td>
<td>Clean Air Test - 5th Floor Room</td>
<td>13:07 - 13:58</td>
<td>29.82</td>
<td>1481</td>
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<td>(Sun) (Mon)</td>
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<td>AA-1546</td>
<td>Clean Air Test - 5th Floor In Kitchen - lower</td>
<td>13:11 - 13:59</td>
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<td>on counter</td>
<td>(Sun) (Mon)</td>
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### INDUSTRIAL HYGIENE SAMPLING SUMMARY

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<td>8/8/83</td>
<td>AA-1149</td>
<td>Inside Work Area - On</td>
<td>0940 1335</td>
<td>456</td>
<td>238</td>
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<td>Railing in Tunnel</td>
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<td>PVC-214-11</td>
<td>Outside Building - On, loading</td>
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<td>Date</td>
<td>Sample Number</td>
<td>Description</td>
<td>Sampling Period</td>
<td>Sample Volume (Liters)</td>
<td>Sample Time (Min.)</td>
<td>Concentration</td>
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<td>AF-1550</td>
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<td>1309 - 1337</td>
<td>2921</td>
<td>1468</td>
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<td>1311 - 1340</td>
<td>2938</td>
<td>1469</td>
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Materials: Fibers greater than 5 microns in length.
## INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant**: University of Georgia  
**Material**: Fibers greater than 5 microns in length

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Number</th>
<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
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<td>8/10/83</td>
<td>AA-1556</td>
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<td>Outside Building - on A.C. Unit on Humphkin St. Side</td>
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<td>591</td>
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<td>Inside Work Area - 4th Floor, Room 419 on Lav.</td>
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<tr>
<td>Date</td>
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<td>8/12/83</td>
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<td>Inside Building - outside work - area reception area, ledge</td>
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<td>Sample Time (Min.)</td>
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<td>8/12/83</td>
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<td>1253 - 1331 (Fri.) (Sat.)</td>
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Plant: University of Georgia
Materials: Fibers greater than 5 microns in length
**INDUSTRIAL HYGIENE SAMPLING SUMMARY**

**Plant**: University of Georgia  
**Materials**: Fibers greater than 5 microns in length

<table>
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<tr>
<th>Date</th>
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<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
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<td>8/13/83</td>
<td>AA-1482</td>
<td>Inside Work Area - Right</td>
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GEORGIA INSTITUTE OF TECHNOLOGY  
Engineering Experiment Station  
Safety & Health Services

INDUSTRIAL HYGIENE SAMPLING SUMMARY

Plant: University of Georgia  
Creswell Hall

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<tr>
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<td>1420 - 1240</td>
<td>2691</td>
<td>1339</td>
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<td>Date</td>
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<td>8/14/83</td>
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<td>Clean Air Test - Brumby Hall</td>
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<td>&lt;2,800</td>
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### Industrial Hygiene Sampling Summary

**Plant:** University of Georgia  
**Creswell Hall**  
**Materials:** Fibers greater than 5 microns in length

<table>
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<tr>
<th>Date</th>
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<th>Description</th>
<th>Sampling Period</th>
<th>Sample Volume (Liters)</th>
<th>Sample Time (Min.)</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>8/11/83</td>
<td>AA-1603</td>
<td>Clean Air Test - 1st floor</td>
<td>Start: 1129 Stop: 1020</td>
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<td>Main lobby</td>
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<td>AA-1607</td>
<td>Clean Air Test - 1st floor</td>
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### Plant
University of Georgia

- Bolton Hall Boiler room, Crosswell Hall

### Materials
Fibers greater than 5 microns in length

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<td>8/18/83</td>
<td>AA-1598</td>
<td>Outside Work-Area on Railing in Stairwell</td>
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<td>Inside Building - Outside Work Area - In Dirty Room</td>
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<td>Inside Work Area - Room 742</td>
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**Industrial Hygiene Sampling Summary**

**Plant:** University of Georgia  
**Materials:** Fibers greater than 5 microns in length

<table>
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<tbody>
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<td>8/18/83</td>
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<td>AA-1605</td>
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<td>9/20/83</td>
<td>AA-1476</td>
<td>Clean Air Test - Creswell Hall</td>
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* NOTE - Pumps # 9224 and 9245 were found unplugged so sample time and volume was impossible to determine.
### INDUSTRIAL HYGIENE SAMPLING SUMMARY

**Plant:** University of Georgia  
**Creswell Hall**

**Materials:** Fibers greater than 5 microns in length

<table>
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*NOTE - Sample # 1618 was voided because the filter cassette was found on the floor separated from the pump. Also the pump had been moved.*
Plant: University of Georgia
Creswell Hall and Bolton Hall

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# Industrial Hygiene Sampling Summary

**Plant:** University of Georgia  
**Materials:** Fibers greater than 5 microns in length

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* NOTE - Voided because filter would not clear
APPENDIX B

NIOSH METHOD P & CAM 239
PROCEDURES FOR FIBER COUNTING BY MICROSCOPY

SAMPLE PREPARATION

Preparation of the Mounting Solution

Combine in a one-to-one ratio (by volume) dimethyl phthalate and diethyl oxalate and pour into a Wheaton balsam bottle. The viscosity of the solution must then be adjusted; if the mixture is too "thin" the solution will cause the movement of the fibers on the filter; if it is too "thick" the filters will not dissolve completely. The viscosity is adjusted by adding blank filters to the solution. The number of filters to add is based on the amount of solution prepared; approximately 0.05 ± 0.005 grams of new membrane filter per milliliter of solution. Use 10 ml each reagent, 1.2 g of MCEF membranes. The resulting solution should appear about as viscous as molasses. The normal shelf life of the solution is about three months. Twenty ml of mounting solution will prepare approximately 300 samples.

Sample Mounting

1. Clean the slides and cover slips with lens tissue. Lay each slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.

2. Wipe all the mounting tools clean with lens tissue and place them on a clean surface (such as lens tissue). All tools should be wiped clean prior to mounting each sample.

3. Using the glass rod supplied with the Wheaton balsam bottle, apply a drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of the solution so that after the cover slip has been placed on top, the solution extends only slightly beyond the filter boundary. If the quantity is greater than this particle migration may occur.

4. Using another glass rod, spread the mounting media into a triangular shape. The size of the triangle should coincide with the dimension of the filter wedge.

5. Separate the middle and bottom sections of the cassette to expose the filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface. The filter should not be removed from the cassette for cutting.

6. Grasp the filter wedge with the tweezers on the perimeter of the filter which was clamped between the cassette sections. DO NOT TOUCH THE FILTER WITH YOUR FINGERS. Place the wedge, SAMPLE SIDE UP, upon the mounting solution.

7. Pick up a clean cover slip with tweezers and carefully place it on the filter wedge. Once contact has been made, DO NOT REPOSITION THE COVER SLIP.
8. Label the slide with the sample number before proceeding to the next filter. On the bottom (backside) of the slide, trace the perimeter of the filter wedge with a felt tip marking pen. This will enable the counter, after the filter has become transparent, to stay within the filter perimeter when counting.

9. The sample should become transparent within about 15 minutes. If the filter appears cloudy, it may be necessary to press VERY LIGHTLY, on the cover slip. This is rarely necessary; however, counting should not be started until an hour after the mounting.

10. Samples should be counted within two days of mounting. Crystals appearing similar to asbestos fibers may begin to grow at the mounting media/air interfaces.

COUNTING OF FIBERS

1. Place the slide on the mechanical stage of the microscope and position the center of the wedge under the objective lens and focus upon the sample. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from perimeter to filter tip). Stay away from the filter's edges when counting and sizing. Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.

2. It is essential to continually scan over a range of focal planes (generally the upper 10 to 15 micrometers of the filter surface) with the fine focus control during each field count. This is especially necessary for asbestos fibers due to their impaction into the filter matrix.

3. On most airborne samples, asbestos fibers will generally have fiber diameters less than one micrometer. Therefore, it is necessary to look carefully for faint fiber images.

4. Regularly check the phase ring alignment.

5. When a mass of material covers a significant portion of the field of view (about one-sixth or greater) reject the field and select another. (Do not include in the number of fields counted.) However, report the fact as it may have meaning on other data collection.

6. Bundles of fibers are counted as one fiber unless both ends of the fiber can be clearly resolved.

7. Count only fibers with a length to width ration greater than or equal to 3:1.

8. Count only fibers greater than 5 micrometers in length. Measure curved fibers along the curve to estimate the total length.

9. Count as many fields as necessary to yield a total count of a least 100 fibers. EXCEPTIONS: a). count at least 20 fields even if you count more than 100 fibers, and b). stop at 100 fields even if you haven't reached 100 fibers.
10. Rules for selecting fibers to be counted: a). COUNT any fiber greater than 5 micrometers in length, that lies entirely within the counting area, b). COUNT as "½ fiber" any fiber with only one end lying within the counting area, and c). DO NOT COUNT any fiber crossing any two sides of the counting area.

**CALCULATIONS AND RECORDKEEPING**

1. The following data must be recorded in the microscopy data book: a). name of client, b). date of analysis, c). sample number, d). initials of person performing the analysis, e). total number of fibers counted, f). total number of fields counted, g). air volume (if supplied), h). fibers per filter, and i). fibers per cubic centimeter of air (if applicable). Additionally, any comments or notes should be recorded. Also a notation should be made if any deviations from the standard procedure were made.

2. To calculate total fibers per filter:

   \[
   \text{fiber/filter} = \left( \frac{\# \text{ of fibers counted}}{\# \text{ of fields}} \right) \times \left( \text{fields/filter} \right)
   \]

3. To calculate fibers per cubic centimeter of air:

   \[
   \text{fibers/cc} = \left( \frac{\# \text{ of fibers per filter}}{\left( \text{liters of air sampled} \right) \times 1000} \right)
   \]

**QUALITY CONTROL**

1. Approximately one blank should be submitted for every 20 samples.

2. Approximately one filter out of every ten should be selected for recounting. For a pair of counts on the same filter, reject both values because one might be biased if:

   \[
   (\text{FB}_2 - \text{FB}_1) > 2.77 \left( \frac{\text{FB}}{\text{CV}_{\text{FB}}} \right)
   \]

   Where:
   - \text{FB}_1 = lower fiber count (total fibers)
   - \text{FB}_2 = higher fiber count (total fibers)
   - \text{FB} = average of the two total fiber counts
   - \text{CV}_{\text{FB}} = \text{CV}_T \text{ for the value FB. Use the relation in figure 1.}
Total coefficient of variation as a function of total fiber count

Figure 1.
ASBESTOS FIBERS IN AIR
National Institute for Occupational Safety and Health
Analytical Method

<table>
<thead>
<tr>
<th>Analyzer:</th>
<th>Asbestos fibers</th>
<th>Method No.:</th>
<th>P&amp;CAM 239</th>
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<td>Air</td>
<td>Range:</td>
<td>0.1-60 fibers/cm³</td>
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<td>Filter collection,</td>
<td>Precision (CV₉):</td>
<td>0.24 to 0.38</td>
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<td>Date Issued:</td>
<td>3/30/77</td>
<td>Classification:</td>
<td>D (Operational)</td>
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1. Principle of the Method

1.1 This method describes the equipment and procedures for collecting, mounting, and counting asbestos fibers on cellulose ester membrane filters in the evaluation of personal samples of airborne asbestos fibers. The purpose of the method is to determine an employee’s index of exposure to airborne asbestos fibers. The method is primarily a personal monitoring technique, but can be used for area monitoring.

1.2 The sample is collected by drawing air through a membrane filter by means of a battery powered personal sampling pump. The filter is transformed from an opaque solid membrane to a transparent optically homogeneous gel. The fibers are sized and counted using a phase-contrast microscope at 400-450X magnification.

1.3 Definitions. Asbestos fiber, for counting purposes, means a particulate which has a physical dimension longer than 5 micrometers and with a length to diameter ratio of 3 to 1 or greater. Asbestos includes chrysotile, cummingtonite-grunerite (amosite), crocidolite, fibrous tremolite, fibrous anthophyllite, and fibrous actinolite.

1.4 Any laboratory attempting to use this procedure should have at least one counter attend a training course conducted by an experienced, proficient laboratory. Novice, untutored counters, using only published instructions, can easily obtain counts of half those performed by experienced, proficient counters. Large differences between laboratories can be caused by: 1) differences in technique and observing ability among counters and 2) small, but significant, differences between microscopes meeting the basic specifications of Section 6.2. The following procedures are recommended:

1.4.1 All microscopists who perform asbestos counting should meet together for an “asbestos counting workshop” at least quarterly. This is best accomplished with counters from several laboratories using their own microscopes.

1.4.2 Each microscopist should count the same series of slides and with the results being compared.

1.4.3 Differences between counters should be resolved with side-by-side counting of the fields by the different counters.

1.4.4 Individuals who are found to be persistent outliers over several sessions should be encouraged to seek other tasks in their respective laboratories.
2. Range and Sensitivity

2.1 The usable range is primarily a function of sample volume, microscope count field area, and background airborne particulates. The influence of these variables is discussed in 8.1.3. For a microscope count field area of 0.003 mm² (see Figure 1) and a pump flow rate of 1.7 lpm, the optimal fiber densities would be produced over the range of 0.4 fiber/cm² (8-hour sample) to about 60 fibers/cm² (15-minute sample). For a field area of 0.006 mm² (see Figure 2) and a pump flow rate of 1.7 lpm, the optimal range is 0.2 fiber/cm² (8-hour sample) to about 30 fibers/cm² (15-minute sample). In each case, the optimal detection limits are inversely proportional to pump flow rate.

The upper detection limit can be extended by using sample times less than 15 minutes or using lower flow rates. The lower detection limit can be extended by increasing the flow rate up to about 2.5 lpm. Filter surface fiber densities less than optimal (less than about 0.5 to 1.0 fiber per count field) are still adequate, but will lead to decreased precision for the method (increased coefficient of variation, see Section 4). The minimum total fiber count in 100 fields considered adequate for reliable quantitation is 10 fibers. Thus, the lower limit of reliable quantitation is 0.1 fiber/cm² (100,000 fibers/m²). For this level, a flow rate of about 2.5 lpm is recommended. For a field area of 0.003 mm², the minimum sample time would be about 2 hours. For a field area of 0.006 mm², the minimum sample time would be about 1 hour.

2.2 This method considers only fibers with a length to diameter ratio of 3 to 1 or greater and a length greater than 5 micrometers.

3. Interferences

In an atmosphere known to contain asbestos, all particulates with a length to diameter ratio of 3 to 1 or greater, and a length greater than 5 micrometers should, in the absence of other information, be considered to be asbestos fibers and counted as such.

4. Precision and Accuracy

4.1 In the past decade, there have appeared a number of articles examining sources of variation in the asbestos sampling and counting procedure. These include: Lynch et al. (11.1), Weidner and Ayer (11.2), Conway and Holland (11.3), Leidel and Busch (11.4), Beckett and Attfield (11.5), and Rajhans and Bragg (11.6). The sources of variation will be discussed by stages in the membrane filter evaluation procedure.

4.2 Sources of Variation in the Sampling Process. These include variations in pump flow rate, proximity of the filter to the employee's body, and filter location (left to right) in the employee's breathing zone.

4.2.1 Section 9.1 requires that the personal sampling pump be calibrated with sufficient accuracy such that the 95% confidence limits on the flow rate are ± 10%. This is equivalent to a coefficient of variation (CV) of about 5%. However, this CV makes a negligible contribution to the total CV for the method due to the relatively large CV of the counting procedure.

4.2.2 Conway and Holland (11.3) concluded that positioning of the filter cassette on the wearer (regarding the angular portions of the filter and their proximity to the wearer) is not a significant factor in determining the fiber distribution on filters.

4.2.3 Weidner and Ayer (11.2) concluded that there is no appreciable difference between samples collected on either the right or left sides of a breathing zone or between samples collected side-by-side, especially for samples with concentrations less than 2.5 fibers/cm².
4.3 Sources of Variation In the Counting Procedure

4.3.1 Random variations exist in the fiber distribution on a filter wedge (intra-wedge variability). The industrial hygiene literature has seen considerable debate in the last 20 years concerning whether or not the distribution of mineral dust or asbestos fibers on a filter surface is adequately described by a Poisson distribution probability density function. Leidel and Busch (11.4) found excellent agreement between empirical error variance and theoretical variance calculated from the assumption of Poisson distributed true counts. They concluded that there was not excessive variation among count fields for a filter wedge and that clumping of fibers (non-random coalescence) did not occur.

4.3.2 Variations exist in the fiber distribution on the total filter surface (inter-wedge variability) due to the random or non-random distribution of fibers across the total surface of the filter. This type of variation is easily confused with intra-wedge variations. The count procedure does not require counting of multiple sectors of the filter. There may be significant differences between average counts for different wedges, or the fiber distribution variations for the total filter surface may be greater than the variations of the Poisson distribution. If either of these occur experimentally, one must use the experimental variations to estimate the minimum precision of the count procedure. The minimum precision is governed by the variations of the fiber distribution on the total surface of the filter.

Conway and Holland (11.3) concluded the distribution of fibers on filters is not uniform and the distribution of fiber counts is more disperse than Poisson. For their filters which had significant variations in fiber concentrations between sectors (as much as 50-60% of the total filter mean), they described the following relation for the standard deviation of the total number of fibers counted on a wedge (N)

\[ \text{empirical } s(N) = 1.6 \sqrt{N} \]

where \( N \) is about 100. The Poisson standard deviation would be:

\[ \text{Poisson } \sigma(N) = \sqrt{N} \]

Rajhans and Bragg (11.6) in Series I of their study found significant variation between filter segments and rejected the Poisson distribution for the total filter surface. However, in Series II of their study, utilizing various experimental modifications, they found no significant variation between filter segments and no reason to reject the assumption of Poisson distributed fiber counts.

4.3.3 Systematic variations due to differences between microscopes were studied by Leidel and Busch (11.4). In their study using five different brands of microscopes, they found no significant differences among four, but the fifth gave counts approximately 45% higher on the average than the other four.

4.3.4 Variations due to differences between counters should be examined at three levels: experienced counters occasionally counting, experienced counters routinely counting, and inexperienced (new or untutored) counters. Leidel and Busch (11.4) studied five experienced counters, with one counting only occasionally. There were no significant differences among three of the counters, but a fourth was 16% lower than the first three. The fifth, who occasionally counted, averaged 27% higher than the first three. Conway and Holland (11.3) studied three experienced counters and three inexperienced counters. They found statistically significant differences between the means of both the experienced and inexperienced counters that typically were in the range plus or minus 5 to 15%. They concluded that experience as a fiber counter is not a significant parameter affecting intercounter variations.
Rajhans and Bragg (11.6) found no significant differences among means of five experienced counters in Series I of their study. But in their carefully controlled Series II, an analysis of variance showed significant variations between counters that were plus or minus 1 to 15%.

4.3.5 Variations between laboratories are most likely due to systematic biases and are not a significant additional source of random variations. Any additional variations are most likely due to differences in counting technique. Beckett and Attfield (11.5) observed that standard counters improved greatly after personal instruction; also new counters, after instruction, tended to overcompensate and get exceedingly high counts. Additionally, they found that counts from an experienced laboratory that had not had contact with other laboratories performing the same analysis were as far from the standard values as were the counts by new counters.

4.4 Sources of variations between samples taken at different times on one employee eluting one work shift can affect the exposure estimate for that employee. These are primarily due to a) differences in exposure concentrations during the day, b) differences in location of the employee within the plant, and c) differences in work operation performed by the employee during the day. These sources of variation can be controlled by proper choice of sampling strategy. Refer to Leidel and Busch (11.7) and Leidel, Busch, and Lynch (11.8) for an extended discussion of sampling strategies. Interday temporal variations can affect the exposure estimates obtained on different days. Refer to Leidel, Busch, and Crouse (11.9) for a discussion of this type of variation.

4.5 Until recently, the total coefficient of variation (CV_T) for the sampling and counting procedure was best estimated from the work of Conway and Holland (11.3). The conclusions of their study included:

4.5.1 The precision of their procedure for filters not containing an abundance of fine fibers can be estimated by a coefficient of variation of 16.2%. This value includes variation among counters and observed interaction effects.

4.5.2 The accuracy of the procedure for similar filters may be estimated for a 100-fiber count by a coefficient of variation of 21.4%. This assumes that the contribution of the overall variance from the nonuniform fiber distribution is additive.

4.5.3 A high percentage of very fine fibers on the filter can significantly affect the standard deviation and confidence limits for counts by different counters. After combining variations in fiber concentrations over the entire filter with those for different counters, it was concluded:

a. For filters with a low concentration of fine fibers, the coefficient of variation is estimated at 21% and the 95% confidence interval is ±43%.

b. For filters with a high concentration of fine fibers, the coefficient of variation is estimated at 25% and the 95% confidence interval is ±50%.

Lynch, Kronoveter, and Leidel (11.1) have also reported on variations of the method. Their intralaboratory study utilized the data from a large number of dust counts made by different methods by experienced counters over a period of years in an epidemiologic study of the asbestos products industry. They concluded that the standard deviation of counts of fibers longer than 5 micrometers on membrane filters could be estimated from the relation \( \sigma = (N)^{1/2} \). Thus for counts of about 100 fibers, the coefficient of variation could be estimated at about 15.2% and the 95% confidence limits at ±30.4%. These values are lower than the values reported by Conway and Holland (11.3).

Recently, the Johns-Manville Corporation conducted an in-house investigation of the asbestos count method (11.10). The study data contained total fiber counts for over
100 filters with each filter counted by two to five counters. From the Johns-Manville data, NIOSH calculated over 100 estimates of the count CV for the method (11.11). The NIOSH CV estimates included random intrafilter variations and intercounter variations, but did not include random pump flow rate variations. It was found that the count coefficient of variation (all random variations except for pump variations) was a function of the total fiber count. NIOSH then included a CV of 0.05 for random pump variations (see Section 9.1) in the CV-estimator equation to obtain a CVT-estimator. The CVT-estimator line is plotted on Figure 3 for total fiber counts in the range 10 to 100 fibers. Or the following equation can be used:

$$CV_T = \frac{1}{\text{antilog}_{10}(-0.215 - 0.203 \log_{10}(FB)) + 0.0025)}$$

where FB is total fiber count as discussed in Section 10.

Figure 3 demonstrates that for a total fiber count of 100, the best CVT is attainable with the appropriate sampling times given in 8.1.3 and the count rules in 8.3.9. When making decisions regarding compliance with the OSHA asbestos exposure standards in 29 CFR 1910.1001, the statistical procedures given in Leidel et al. (11.11) should be followed. The procedures are based on statistical theory and assumptions given in References 11.12, 11.13.

Because of the possibility of systematic biases due to differences between microscopes, counters, and laboratories as discussed above, it is strongly recommended that any laboratory counting asbestos should participate in an interlaboratory quality control program that includes the counting of standard reference filters. These standard filters are available from NIOSH through the Proficiency Analytical Testing (PAT) Program. The PAT Program is used by the American Industrial Hygiene Association (AIHA) as part of its Laboratory Accreditation Program. Each laboratory’s quality control program must include protocols for routinely adjusting and calibrating sampling and counting equipment plus training and evaluation programs for counters.

5. Advantages and Disadvantages of the Method

5.1 The method is intended to give an index of employee exposure to airborne asbestos fibers of specified dimensional characteristics.

5.2 It is not meant to count all asbestos fibers in all size ranges or to differentiate asbestos from other fibrous particulates.

6. Apparatus

6.1 Sampling Equipment

The personal sampling equipment train consists of 1) personal sampling pump, 2) tubing, 3) clothing spring clip, 4) tubing-to-field monitor metal adaptor, and 5) field monitor (filter and holder).

6.1.1 Personal Sampling Pump. The pump must be capable of sampling at 1.0 to 2.5 liters per minute (lpm) against a flow resistance of 7.5 inches of water (1.4 cm Hg) for 8 continuous hours on a fully charged battery.

6.1.2 Tubing. Laboratory tubing such as rubber or plastic with 6-mm bore and about 100 cm length.

6.1.3 Clothing Spring Clip. The clip attaches the rubber tubing to the lapel or shirt of the individual being monitored.

6.1.4 Tubing-to-field Monitor Adaptor. A short metal adaptor with ridges on one end to grip the inside of the tubing. The other end is designed for a pressure fit into the field monitor.

6.1.5 Field Monitor (Filter and Holder). The only field monitor currently considered acceptable by NIOSH is manufactured by the Millipore Corporation. The unit con-
sists of 1) a three section styrene plastic case designated Millipore Aerosol Monitor Case, 2) a 37-mm diameter plain white cellulose ester membrane filter designated Millipore AA (pore size of 0.8 micrometer), 3) a support pad, and 4) two plastic sealing caps. If a large number of samples are to be taken, it may be less expensive to reuse the plastic cases. Great care must be taken in the cleaning and reassembly process. The outside mating surfaces of the field monitors may be covered with a "shrink-fit" band to provide proper sealing and a writing surface for filter identification.

6.2 Optical Equipment and Microscope Features

6.2.1 Microscope body with binocular head.
6.2.2 10X Huygenian eyepieces are recommended. Other eyepieces can be substituted if necessary. Wide field eyepieces can be used; however, wide field eyepieces may yield a count field area less than 0.003 mm² with the Porton reticle. This is not always desirable from the standpoint of obtaining optimum sampling times (see Section 8.1.3). If wide field eyepieces are used, it is preferable to use the Patterson Globe and Circle reticle to obtain a larger count field area.
6.2.3 Koehler illumination (preferably built-in with provisions for adjusting light intensity).
6.2.4 A Porton reticle is recommended. Others such as the Patterson Globe and Circle can be substituted.
6.2.5 Mechanical stage.
6.2.6 Phase-Contrast condenser with a numerical aperture (N.A.) equal to or greater than the N.A. of the objective.
6.2.7 40-45X phase contrast achromatic objective (N.A. 0.65 to 0.75).
6.2.8 Phase-ring centering telescope or Bertrand lens.
6.2.9 Green or blue filter, if recommended by microscope manufacturer.
6.2.10 Stage micrometer with 0.01 mm subdivisions.
6.2.11 For general guidance on phase contrast microscopy, consult Needham (11.12), Clark (11.15) and McCrone (11.14).

6.3 Filter Mounting Equipment. Experience has shown that certain equipment is useful for efficient sample mounting. The following items are recommended for extracting and mounting a portion of the filter for counting.

6.3.1 Microscope slides. 2.5 by 7.5 cm glass slides are most commonly used. Sample number, data, initials, etc., can be conveniently written on a frosted end slide.
6.3.2 Cover Slips. Cover slips are a necessary part of the slide mount and optical system. The shape should be appropriate for the size of the filter wedge. The appropriate cover slip depends upon the objective to be used. Ordinarily, objectives are optically corrected for a #1½ (0.17 millimeter) thickness cover slip. Improper cover glass thickness will detract from the final image quality.
6.3.3 Scalpel. A scalpel is needed to cut out a portion of the filter to be examined. A number-ten curved blade scalpel is recommended.
6.3.4 Tweezers. A pair of fine-tipped tweezers is used to remove the membrane filter slice from the field monitor and place it upon the slide.
6.3.5 Lens Tissue. To insure cleanliness, a lint-free tissue is recommended. This tissue should also be used for wiping mounting tools and for cleaning slides and cover slips.
6.3.6 Glass Rod. A fire-polished glass rod may be used to spread the mounting solution on the slide.
6.3.7 Wheaton Balsam Bottle. This special glass container has a glass top which prevents contamination of the mounting solution. A glass rod is included for dispensing the solution.

7. Reagents
Chemicals should be reagent grade, free from particles and color, conforming to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

7.1 Dimethyl phthalate
7.2 Diethyl oxalate

Avoid getting the mounting solution on the skin. Wash skin promptly with soap and water if skin contact occurs.

3. Procedure

8.1 Sampling

8.1.1 General Information
Guidelines for the monitoring of employee exposures to industrial atmospheres are given in Reference 11.8. The Federal requirements for monitoring employee exposure to airborne asbestos are found in 29 CFR 1910.1001.

8.1.2 Mounting the Sampling Pump on the Worker
Fasten the sampling pump to the worker's belt and fasten the field monitor to the lapel or shirt front (as close to the breathing zone as is practical). Remove the top cover of the plastic monitor, then invert the monitor making certain the exposed filter is facing downward. Turn the pump on and adjust to the calibrated flow rate (1.0 to 2.5 lpm). Record the following information in a logbook.

1. Filter number
2. Pump start time and date
3. Flow rate
4. Subject's name and job title
5. Type of operation or process
6. Ventilation controls and is the worker wearing a respirator approved for asbestos?

The pump should be checked periodically during the sampling period for proper operation and flow rate.

8.1.3 Optimum Sampling Times

The requirement for the minimum count of 100 fibers or 20 fields in 8.3.9 was determined to be the best compromise to achieve adequate precision for the airborne fiber estimate and reasonable counting times. An optimum fiber density of about 1 to 5 fibers per microscope count field is recommended. To estimate appropriate sampling times for feasible counting and optimal counting, one must consider the following constraints:

1. microscope count field area (generally 0.003 to 0.006 mm²)
2. pump flow rate (typically 2.5 lpm maximum)
3. average airborne fiber concentrations
4. counting rule range of 20 to 100 fields
5. adequate fiber density to obtain a minimum count of 10 fibers in 100 fields, which is the least total fiber count that yields an acceptable count precision
6. background airborne particulate levels that can reduce the count precision due to an obscuring of fibers on the filter surface

239-7
The preceding constraints were considered in drawing Figures 1 and 2. These figures were developed from the following relationship:

\[
\text{sampling time} = \frac{(FB/FL)(ECA/MFA)}{(FR)(AC)(1000)} \text{ minutes}
\]

where:
- \(FB/FL = 1\) to 5 fibers/field
- \(ECA\) = effective collecting area of filters (855 mm\(^2\) for 37-mm filter with effective diameter of 33 mm)
- \(MFA\) = microscope field area (generally 0.003 to 0.006 mm\(^2\))
- \(FR\) = Pump flow rate (generally 1.0 to 2.5 lpm)
- \(AC\) = Air concentration of fibers in fibers/cm\(^3\).

Figure 1 (microscope field area = 0.003 mm\(^2\)) and Figure 2 (microscope field area = 0.006 mm\(^2\)) show optimum and feasible sampling times for a pump flow rate of 1.7 lpm. Each individual responsible for sampling asbestos should prepare a similar chart for his particular pump flow rate and microscope field area before sampling is performed to aid in estimating proper sampling times. On Figures 1 and 2, the areas with solid shading lines are generally the optimum conditions for counting. The broken shading lines are for conditions very close to optimal. However, feasible counting conditions may extend down to about 0.1 fiber/field and above 5 fibers/field. Recommended sampling times are most strongly influenced by background airborne particulate levels, once all the other constraints have been estimated. For heavy particulate levels, it may be necessary to limit each filter to about 60 to 180 minutes sampling duration. Each individual responsible for sampling should work closely with the microscopist to attain as high as possible filter surface fiber densities (up to about 5 fibers/field), while avoiding filter surface background particulate levels that create very difficult or impossible counting conditions. If one has very little idea of airborne fiber and particulate levels, the best procedure is to take several long samples (as one 8-hour or two consecutive 4-hour samples) in conjunction with several short samples (as four consecutive 2-hour or eight consecutive 1-hour samples). If the longer samples prove very difficult to count, the microscopist will have the shorter samples to fall back on.

From Figures 1 and 2, it can be seen that there are certain sampling times which will yield optimum fiber densities on the filter for almost all airborne fiber concentrations from 1 to 10 fibers/cm\(^3\). These optimum times have been calculated and are presented in Figure 4. Note that the optimum times given by Figure 4 are approximate and can be varied by as much as ± 25%. The nomogram is intended as a guide to be used where no prior knowledge of the air concentration is available.

8.1.4 End of Sampling Period
Remove the field monitor, replace the plastic top cover and the small end caps, and store the monitor. Always shut off the pump when changing monitors to avoid contaminating or damaging the pump. Record the pump shutoff time and flow rate in the logbook.

8.1.5 Blanks
With each batch (25 to 50 filters) of samples sent for analysis, submit two unopened field monitors which have been subjected to the same treatment as the samples except that they were not exposed to the sampling environment. Label these as blanks. If the blanks yield fiber counts greater than 5 fibers/100 fields, then the entire sampling procedure should be examined carefully for the cause of contamination. The
mounting solution of Section 8.2.1 should also be examined for contamination and/or crystal growth.

8.1.6 Shipping
The field monitors in which the samples are collected should be shipped in a rigid container with sufficient packing material to prevent crushing.

8.1.7 Numbers of Samples
When sampling for the Federal ceiling standard of 10 fibers (>5μm)/cm³, [29 CFR 1910.1001(b) (3), effective July 7, 1972] only one sample (15 minutes maximum duration) is necessary, theoretically. However, several samples should be taken during expected periods of peak air concentrations to allow for detection of gross sampling or counting errors.

When sampling for determination of noncompliance with the Federal 8-hour TWA standard of 2 fibers (>5μm)/cm³, [29 CFR 1910.1001(b) (2)], one should continuously sample as large a portion of the work day as is feasible for airborne concentrations of about 2 to 10 fibers/cm³. However, for a lower airborne concentration such as 0.5 fiber/cm³, one sample might require 4 to 8 hours sampling time in order to get the proper filter fiber density (Section 8.1.3). For this situation, the 8-hour TWA exposure would be determined from one 8-hour or two 4-hour samples as appropriate.

8.2 Sample Preparation

8.2.1 Preparation of Mounting Solution
A very important part of the sample evaluation is the mounting process. This process involves a special mounting medium of prescribed viscosity. The proper viscosity is important in order to expedite filter dissolving and still minimize particle migration. After the sample has been mounted, an elapsed time of approximately sixty minutes is needed before the sample is ready for evaluation.

Combine the dimethyl phthalate and diethyl oxalate in a one to one ratio by volume and pour into a Wheaton balsam bottle. Add approximately 0.05 (± 0.005) grams of new membrane filter per milliliter of solution to reach the necessary viscosity. The mixture must be stirred periodically until the filters have dissolved and a homogeneous mixture is formed. The normal shelf life of the mounting solution is about three months. Twenty milliliters of mounting solution will prepare approximately 300 samples.

8.2.2 Sample Mounting
Cleanliness is important! A dirty working area may result in sample contamination and erroneous counts. The following steps should be followed when mounting a sample.

1. Clean the slides and cover slips with lens tissue. Lay each slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.

2. Wipe all the mounting tools clean with lens tissue and place them on a clean surface (such as lens tissue). All tools should be wiped clean prior to mounting each sample.

3. Using the glass rod supplied with the Wheaton balsam bottle, apply a drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of solution so that after the cover slip has been placed on top, the solution extends only slightly beyond the filter boundary. If the quantity is greater than this, particle migration may occur.
4. Using another glass rod, spread the mounting media into a triangular shape. The size of this triangle should coincide with the dimension of the filter wedge.

5. Separate the middle and bottom sections of the field monitor case to expose the filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface. The filter can be very carefully removed from the cassette for cutting, but this should only be done with great care.

6. Grasp the filter wedge with the tweezers on the perimeter of the filter which was clamped between the monitor case sections. Do not touch the filter with your fingers. Place the wedge, sample side up, upon the mounting medium.

7. Pick up a clean cover slip with tweezers and carefully place it on the filter wedge. Once this contact has been made, do not reposition the cover slip.

8. Label the slide with the sample number and current date before proceeding to the next filter. On the bottom (backsie) of the slide, trace the perimeter of the filter wedge with a felt tip marking pen. This will enable the counter, after the filter has become transparent, to stay within the filter perimeter when counting.

9. The sample should become transparent within fifteen minutes. If the filter appears cloudy, it may be necessary to press very lightly on the cover slip. This is rarely necessary; however, counting should not be started until an hour after the mounting. This allows the microscopic texture of the filter to become invisible to microscope viewing.

10. Discard the sample mount after two days if it has not been counted. Crystals appearing similar to asbestos fibers may begin to grow at the mounting media/air interfaces. They seldom present any problems if the slide is examined before two days. In any case, stay away from the filter's edges when counting and sizing.

8.3 Counting of Fibers

8.3.1 Place the slide on the mechanical stage of the microscope and position the center of the wedge under the objective lens and focus upon the sample. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from perimeter to wedge tip). Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.

8.3.2 It is essential to continually scan over a range of focal planes (generally the upper 10 to 15 micrometers of the filter surface) with the fine focus control during each field count. This is especially necessary for asbestos fibers due to their impaction into the filter matrix.

8.3.3 On most airborne samples, asbestos fibers will generally have fiber diameters less than one micrometer. Therefore, it is necessary to look carefully for faint fiber images.

8.3.4 Regularly check phase ring alignment.

8.3.5 When an agglomerate (mass of material) covers a significant portion of the field of view (approx 1/6 or greater) reject the field and select another. (Do not include it in the number of fields counted.) However, report the fact as it may have meaning on other data collection.

8.3.6 Bundles of fibers are counted as one fiber unless both ends of the fiber can be clearly resolved.

8.3.7 Count only fibers with a length to width ratio greater than or equal to 3:1.

8.3.8 Count only fibers greater than 5 micrometers in length. (Be as accurate as possible in accepting fibers near this length.) Measure curved fibers along the curve to estimate the total length.
8.3.9 Count as many fields as necessary to yield a total count of at least 100 fibers. Exceptions: a) count at least 20 fields even if you count more than 100 fibers, and b) stop at 100 fields even if you haven't reached 100 fibers.

8.3.10 For fibers that cross either one or two sides of the counting field, the following procedure is used to obtain a representative count.

COUNT any fiber greater than 5 micrometers in length, that lies entirely within the counting area. COUNT as "1/2 fiber" any fiber with only one end lying within the counting area. DO NOT COUNT any fiber crossing any two sides.

Reject and do not count all other fibers. Refer to Figures 5 through 10. Note that the fibers in Figures 5 through 10 are not representative of the appearance of most asbestos fibers. Most fibers have a very faint image.

9. Calibration and Standards

9.1 Sampling Train Calibration

The accurate calibration of the sampling pump is essential to the correct calculation of the air volume sampled. The frequency of calibration is dependent on the use, care, and handling to which the pump is subjected. Pumps must be recalibrated if they have just been repaired, misused, or received from the manufacturer. If the pump receives hard usage, more frequent calibration may be necessary. Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples.

The accuracy of calibration is dependent upon the type of instrument used as a reference. The choice of a calibration instrument will depend largely on where the calibration is performed. For laboratory testing, a 1-liter buret used as a soap bubble flow meter or wet-test meter is recommended. Other standard calibrating instruments, such as a spirometer, Marriott's bottle, or dry gas meter can be used. The calibration should be of sufficient precision that the 95% confidence limits on the flow rate are ± 10%. (95% of the flow rates will fall within ± 10% of the calibrated value).

Instructions for calibration with the soap bubble flow meter follow. The sampling train used (pump, hose, filter cassette) in the pump calibration should be the same as the one used in the field.

9.1.1 Check the voltage of the pump battery with a voltmeter both with the pump off and while it is operating to assure adequate voltage for calibration. If necessary, charge the battery to manufacturer's specifications.

9.1.2 Fill a beaker with 10 ml of soap solution.

9.1.3 Connect the filter cassette inlet to the top of the buret with a length of hose.

9.1.4 Turn the pump on and moisten the inside of the soap bubble meter by immersing the open end of the buret into the soap solution and drawing bubbles up the inside of the buret. Perform this task until the bubbles are able to travel the entire length of the buret without breaking.

9.1.5 Adjust the pump rotameter to provide a flow between 1.5 to 2.5 lpm.

9.1.6 With a water manometer, check that the pressure drop across the filter is less than 13 inches of water (about 1 inch of mercury).

9.1.7 Start a soap bubble up the buret and measure the time it takes for the bubble to travel a minimum volume of 1 liter.

9.1.8 Repeat the procedure in 9.1.7 at least three times, average the results, and calculate the calibrated flow rate by dividing the volume traveled by the soap bubble by the elapsed time. If the range between the highest and lowest of the three flow rates is greater than about 0.33 lpm, then the calibration should be repeated since it is likely that the precision is not adequate.
9.1.9 Data required for the calibration include the volume measured, elapsed time, pressure drop, air temperature, atmospheric pressure (or elevation), pump serial number, date, and name of person performing the calibration.

9.1.10 Corrections to the flow rate for pumps with rotameters may be necessary if the pressure (elevation) or temperature where the samples are collected (actual flow rate) differs significantly from that where the calibration was performed (indicated flow rate). Actual flow rates at time of sampling may be calculated for a linear scale rotameter by using the following correction formula:

\[ Q_{\text{actual}} = Q_{\text{indicated}} \frac{P_{\text{cal}}}{P_{\text{actual}}} \cdot \frac{T_{\text{cal}}}{T_{\text{actual}}} \]

where both pressure (P) and temperature (T) are in absolute units such as:

- psia = psig + 14.7
- deg Rankin = deg Fahrenheit + 460
- deg Kelvin = deg Celsius + 273

9.2 Microscope Setup

9.2.1 Porton Reticle and the Counting Field
The asbestos fiber count procedure consists of comparing fiber length to the diameters of calibrated circles of a Porton reticle, and counting all fibers greater than 5 micrometers in length lying within a given counting field area. The Porton reticle is a glass plate inscribed with a series of circles and rectangles. The left half of the reticle is divided into six rectangles constituting the counting field. The counting field is illustrated in Figures 5 through 10.

9.2.2 Placement in Eyepiece
The Porton reticle is placed inside the Huygenian eyepiece where it rests on the field-limiting diaphragm. If other types of eyepieces are used, it may be necessary to insert a counting collar for retaining the reticle. The reticle should always be kept clean, since dirt on the reticle is in focus and could complicate the counting and sizing process.

9.2.3 Stage Micrometer
The Porton reticle cannot be used for counting until it has been properly calibrated with a stage micrometer. Most stage micrometer scales are approximately two millimeters long and are divided into units of one-hundredth of a millimeter (ten micrometers).

9.2.4 Microscope Adjustment
When adjusting the microscope, follow the manufacturer’s instructions while observing the following guidelines.

1. The light source image must be in focus and centered on the condenser iris or annular diaphragm.
2. The particulate material to be examined must be in focus.
3. The illuminator field iris must be in focus, centered on the sample, and opened only to the point where the field of view is illuminated.
4. The phase rings (annular diaphragm and phase-shifting elements) must be concentric.

9.2.5 Porton Reticle Calibration Procedure
Each eyepiece-objective-reticle combination on the microscope must be calibrated. Should any of the three be changed (disassembly, replacement, zoom adjustment, etc.), the combination must be recalibrated. Calibration may change if interpupillary dis-
distance is changed. For proper calibration, the following procedure should be followed closely.

With a 10X objective in place, place the stage micrometer on the mechanical stage, focus the millimeter scale, and center the image. Change to the 40-45X objective and adjust the first millimeter scale division to coincide with the left boundary of the Porton rectangle. Measure the distance between the left and extreme right boundaries of the Porton rectangle, estimating any portion of the final division. This measurement represents 200 L units. The rectangle is 100 L units on the short vertical dimension. The calculated \(L\) is inserted into the formula \(D = L(2^N)^{1/2}\) where \(N\) is the circle number (indicated on the reticle) and \(D\) is the circle diameter. Since the circle diameters vary logarithmically, every other circle doubles in diameter. For example, circle number three is twice the diameter of number one; number four is twice the diameter of number two. When the circle sizes have been determined, the counting field area which consists of the left six smaller rectangles can be calculated from the relation \(10,000 \, L^2\). This completes the reticle calibration for this specific objective-eyepiece-reticle combination.

Example for Porton Reticle

The following calibration was obtained for a pair of 10X Huygenian eyepieces and a 43X objective:

\[
\begin{align*}
200 \, L & = 0.148 \, \text{mm} = 148 \, \text{micrometers} \\
100 \, L & = 0.074 \, \text{mm} = 74 \, \text{micrometers} \\
\text{One L-unit} & = 0.74 \, \text{micrometers}
\end{align*}
\]

Thus Circle #1 has a diameter \(D = L(2^N)^{1/2} = 0.74(2^1)^{1/2} = 0.74 \times 1.414 = 1.05\) micrometers.

Then our circle diameter calibration table looks like:

- Diameter of Circle #1 = 1.05 micrometers
- \#2 = 1.48
- \#3 = 2.09
- \#4 = 2.96
- \#5 = 4.19
- \#6 = 5.92

Field area = \((10,000) \, (L^2) = (100 \, L) \times (100 \, L) = (0.074) \times (0.074) = 0.0055\) mm²

Thus fibers with a length greater than a distance halfway between the diameters of the #5 and #6 circles would be counted.

If a Patterson Globe and Circle reticle is used, a different calculation procedure is required. The circle diameters are related as follows. The #25 circle diameter is \((0.1)\) (reticle length).

The circle diameters are proportional to the ratio of their numbers. Thus the #20 circle diameter is \((20/25)\) or 0.8 times the #25 circle diameter.

10. Calculations

10.1 The average airborne asbestos fiber concentration estimated by the filter sample may be calculated from the following formula:

\[
AC = \frac{(FB/FL) - (BFB/BFL)}{(1000) \times FR \times TI \times MFA}
\]

239-13
where:

\( AC = \) Airborne fiber concentration in \((\text{fibers} > 5 \, \mu\text{m})/\text{cm}^2\).

\( \text{BFB} = \) Total number of fibers counted in the BFL fields of the blank or control filters in fibers > 5 \, \mu\text{m}.

\( \text{BFL} = \) Total number of fields counted on the blank or control filters.

\( \text{ECA} = \) Effective collecting area of filter \((855 \, \text{mm}^2 \text{ for a 37-mm filter with effective diameter of 33 mm})\).

\( \text{FR} = \) Pump flow rate in liters/min (lpm).

\( \text{FB} = \) Total number of fibers counted in the FL fields in fibers > 5 \, \mu\text{m}.

\( \text{FL} = \) Total number of fields counted on the filter.

\( \text{MFA} = \) Microscope count field area in \(\text{mm}^2\) \((\text{generally} \, 0.003 \text{ to } 0.006)\).

\( T = \) Sample collection time in minutes.

10.2 Recount criteria. It is very desirable for a counter to conduct a “blind recount” for about 1 in every 10 filter wedges (slides) counted. Alternatively, a second counter could perform the blind recount. In training sessions for novice counters, the trainee should conduct a blind recount for filter wedges counted by an experienced, proficient counter. In all cases, we will observe differences between the first and second counts of the same filter wedge. Most of these differences will be due to chance alone, that is, due to the random variability (precision) of the count method. Statistical recount criteria enable us to decide whether observed differences can reasonably be explained due to chance alone or are probably due to systematic differences between counters or microscopes or due to some other biasing factor. The following recount criterion is for a pair of counts that estimate some airborne fiber concentration \((AC)\) in \(\text{fibers/cm}^2\). The criterion is given at the type-I error level. That is, there is a 5% maximum risk that we will reject a pair of counts for the reason that one might be biased, when the large observed difference is really due to chance. Reject a pair of counts because one might be biased if:

\[
(AC_2 - AC_1) \text{ exceeds } 2.77(\overline{AC})(CV_{FB})
\]

where:

\( AC_1 = \) lower estimated airborne fiber concentration

\( AC_2 = \) higher estimated airborne fiber concentration

\( \overline{AC} = \) average of the two airborne concentration estimates

\( CV_{FR} = \) average CV for the two concentration estimates which are a function of the total fiber count \((FB)\) in each case. Use the relation in Section 4 or Figure 3.

For a pair of counts on the same filter, reject the pair because one might be biased if:

\[
(FB_2 - FB_1) \text{ exceeds } 2.77(\overline{FB})(CV_{FB})
\]

where:

\( FB_1 = \) lower fiber count on the filter (total fibers)

\( FB_2 = \) higher fiber count on the filter (total fibers)

\( \overline{FB} = \) average of the two total fiber counts

\( CV_{FB} = CV_T \) for the value \(FB\). Use the relation in Section 4 or Figure 3.

11. References


11.2 Weidner, R. B. and H. E. Ayer, "Dust Exposure in Asbestos Processing", Transactions of the
American Conference of Governmental Industrial Hygienists, May 1972, pp. 103-121, San Francisco, California.


11.10 Comments of the Johns-Manville Corporation with Respect to the Notice of Proposed Rulemaking: Occupational Exposure to Asbestos, Federal Register, October 9, 1975. Submitted to the public record at the U. S. Department of Labor, Occupational Safety and Health Administration, April 1976.


FIGURE 1. Optimum Sampling Times for airborne asbestos where microscopic field area = 0.003 mm².
FIGURE 2. Optimum sampling times for airborne asbestos where microscopic field area = 0.006 mm$^2$
FIGURE 3. Total coefficient of variation as a function of total fiber count.
FIGURE 4. Nomogram of optimum sampling times for airborne asbestos fibers in concentrations of 1 to 10 fibers/cm$^3$. 

EXAMPLE = 1.7 1pm
A = 0.00302 mm$^2$
READ: OPTIMUM TIME = 120 min
(± 25%)
LIST OF FIGURES
(5 through 10)

FIGURE 5. DO NOT COUNT. Fiber crosses top and bottom sides.

FIGURE 6. COUNT. One fiber.

FIGURE 7. COUNT. One-half fiber. Fiber crosses left side and one end lies within count area.

FIGURE 8. COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.

FIGURE 9. DO NOT COUNT. Fiber crosses two sides.

FIGURE 10. DO NOT COUNT. Fiber crosses two sides (bottom left corner).
   COUNT. One-half fiber. Fiber crosses bottom side and one end lies within count area.
   COUNT. One fiber (top right corner).
APPENDIX C

OSHA AND EPA ASBESTOS STANDARDS
OSHA

1910.1001 - ASBESTOS

(a) Definitions

For the purpose of this section.

(I) "Asbestos" includes chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite.

(2) "Asbestos fibers" means asbestos fibers longer than 5 micrometers.

(b) PERMISSIBLE EXPOSURE TO AIRBORNE CONCENTRATIONS OF ASBESTOS FIBERS

(1) Standard effective July 7, 1972. The 8-hour, time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed five fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(2) Standard effective July 1, 1976. The 8-hour, time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed two fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(3) Ceiling concentration. No employee shall be exposed at any time to airborne concentration of asbestos fibers in excess of 10 fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(c) METHODS OF COMPLIANCE

(1) ENGINEERING METHODS

(i) Engineering controls. Engineering controls, such as but not limited to, isolation, enclosure, exhaust ventilation, and dust collection, shall be used to meet the exposure limits prescribed in paragraph (b) of this section.

(ii) LOCAL EXHAUST VENTILATION

(a) Local exhaust ventilation and dust collection systems shall be designed, constructed, installed, and maintained in accordance with the American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971, which is incorporated by reference herein.
(b) See Section 1910.6 concerning the availability of ANSI-A9.2-1971, and the maintenance of a historic file in connection therewith. The address of the American National Standards Institute is given in Section 1910.100.

(iii) PARTICULAR TOOLS

All hand-operated and power-operated tools which may produce or release asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, such as, but not limited to, saws, scorers, abrasive wheels, and drills, shall be provided with local exhaust ventilation systems in accordance with subdivision (ii) of this subparagraph.

(2) WORK PRACTICES

(i) Wet methods. Insofar as practicable, asbestos shall be handled, mixed, applied, removed, cut, scored, or otherwise worked in a wet state sufficient to prevent the emission of airborne fibers in excess of the exposure limits prescribed in paragraph (b) of this section, unless the usefulness of the product would be diminished thereby.

(ii) Particular products and operations. No asbestos cement, mortar, coating, grout, plaster, or similar material containing asbestos shall be removed from bags, cartons, or other containers in which they are shipped, without being either wetted, or enclosed, or ventilated so as to prevent effectively the release of airborne asbestos fibers in excess of the limits prescribed in paragraph (b) of this section.

(iii) Spraying, demolition, or removal. Employees engaged in the spraying of asbestos, the removal, or demolition of pipes, structures, or equipment covered or insulated with asbestos, and in the removal or demolition of asbestos insulation or coverings shall be provided with respiratory equipment in accordance with paragraph (d) (2) (iii) of this section and with special clothing in accordance with paragraph (d) (3) of this section.

(d) PERSONAL PROTECTIVE EQUIPMENT

(1) Compliance with the exposure limits prescribed by paragraph (b) of this section may not be achieved by the use of respirators or shift rotation of employees, except:

(i) During the time period necessary to install the engineering controls and to institute the work practices required by paragraph (c) of this section;

(ii) In work situations in which the methods prescribed in paragraph (c) of this section are either technically not feasible or feasible to an extent insufficient to reduce the airborne concentrations of asbestos fibers below the limits prescribed by paragraph (b) of this section; or
(iii) In emergencies.

(iv) Where both respirators and personnel rotation are allowed by subdivision (i) and (ii), or (iii) of this subparagraph, and both are practicable, personnel rotation shall be preferred and used.

(2) Where a respirator is permitted by subparagraph (1) of this paragraph, it shall be selected from among those approved by the Bureau of Mines, Department of the Interior, or the National Institute for Occupational Safety and Health Department, of Health, Education, and Welfare, under the provisions of 30 CFR Part 11 (37 P.R. 6244, March 25, 1972), and shall be used in accordance with subdivisions (i), (ii), (iii), and (iv) of this subparagraph.

(i) Air purifying respirators. A reusable or single use air purifying respirator, or a respirator described in subdivision (ii) or (iii) of this subparagraph, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour, time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed no more than 10 times those limits.

(ii) Powered air purifying respirators. A full facepiece powered air purifying respirator, or a powered air purifying respirator, or a respirator described in subdivision (iii) of this subparagraph, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour, time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed 10 times, but not 100 times, those limits.

(iii) Type "C" supplied-air respirators, continuous flow or pressure-demand class. A type "C" continuous flow or pressure-demand, supplied air respirator shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour, time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed 100 times those limits.

(iv) ESTABLISHMENT OF A RESPIRATOR PROGRAM

(a) The employer shall establish a respirator program in accordance with the requirements of the American National Standard Practices for respiratory Protection, ANSI Z88.2-1969, which is incorporated by reference herein.

(b) See Section 1910.6 concerning the availability of ANSI Z88.2-1969 and the maintenance of an historic file in connection therewith. The address of the American National Standards Institute is given in Section 1910.100.
(c) No employee shall be assigned to tasks requiring the use of respirators if, based upon his most recent examination, an examining physician determines that the employee will be unable to function normally wearing a respirator, or that the safety or health of the employee or other employees will be impaired by his use of the respirator. Such employee shall be rotated to another job or given the opportunity to transfer to a different position whose duties he is able to perform with the same employer, in the same geographical area and with the same seniority, status, and rate of pay he had just prior to such transfer, if such a different position is available.

(3) Special Clothing: The employer shall provide, and require the use of, special clothing, such as coveralls or similar whole body clothing, head coverings, gloves, and foot coverings for any employee exposed to airborne concentrations of asbestos fibers, which exceed the ceiling level prescribed in paragraph (b) of this section.

(4) Change rooms:

(i) At any fixed place of employment exposed to airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, the employer shall provide change rooms for employees working regularly at the place.

(ii) Clothes lockers: The employer shall provide two separate lockers or containers for each employee, so separated or isolated as to prevent contamination of the employee's street clothes from his work clothes.

(iii) Laundering:

(a) Laundering of asbestos-contaminated clothing shall be done so as to prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(b) Any employer who gives asbestos-contaminated clothing to another person for laundering shall inform such person of the requirement in (a) of this subdivision to effectively prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(c) Contaminated clothing shall be transported in sealed impermeable bags, or other closed, impermeable bags, or other closed, impermeable containers, and labeled in accordance with paragraph (g) of this section.

(e) METHOD OF MEASUREMENT

All determinations of airborne concentrations of asbestos fibers shall be made by the membrane filter method at 400-450 x (magnification) (4 millimeter objective) with phase contrast illumination.
(f) MONITORING

(1) Initial determinations. Within 6 months of the publication of this section, every employer shall cause every place of employment where asbestos fibers are released to be monitored in such a way as to determine whether every employee's exposure to asbestos fibers is below the limits prescribed in paragraph (b) of this section. If the limits are exceeded, the employer shall immediately undertake a compliance program in accordance with paragraph (c) of this section.

(2) Personal Monitoring

(i) Samples shall be collected from within the breathing zone of the employees, on membrane filters of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour, time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(ii) Sampling frequency and patterns. After the initial determinations required by subparagraph (I) of this paragraph, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of employees. In no case shall the sampling be done at intervals greater than 6 months for employees whose exposure to asbestos may reasonably be foreseen to exceed the limits prescribed by paragraph (b) of this section.

(3) Environmental monitoring

(i) Samples shall be collected from areas of a work environment which are representative of the airborne concentrations of asbestos fibers which may reach the breathing zone of employees. Samples shall be collected on a membrane filter of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour, time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(ii) Sampling frequency and patterns. After the initial determinations required by subparagraph (I) of this paragraph, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of the employees. In no case shall sampling be at intervals greater than 6 months for employees whose exposures to asbestos may reasonably be foreseen to exceed the exposure limits prescribed in paragraph (b) of this section.

(4) Employee observation of monitoring. Affected employees, or their representatives, shall be given a reasonable opportunity to observe any monitoring required by this paragraph and shall have access to the records thereof.
(g) CAUTION SIGNS AND LABELS

(1) Caution Signs

(i) Posting. Caution signs shall be provided and displayed at each location where airborne concentrations of asbestos fibers may be in excess of the exposure limits prescribed in paragraph (b) of this section. Signs shall be posted at such a distance from such a location so that an employee may read the signs and take necessary protective steps before entering the area marked by the signs. Signs shall be posted at all approaches to areas containing excessive concentrations of airborne asbestos fibers.

(ii) Sign specifications. The warning signs required by subdivision (i) of this subparagraph shall conform to the requirements of 20" x 14" vertical format signs specified in Section 1910.145(d)(4), and to this subdivision. The signs shall display the following legend in the lower panel, with letter sizes and styles of a visibility at least equal to that specified in this subdivision.

LEGEND

<table>
<thead>
<tr>
<th>NOTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos</td>
</tr>
<tr>
<td>Dust Hazard</td>
</tr>
<tr>
<td>Avoid Breathing Dust</td>
</tr>
<tr>
<td>Wear Assigned Protective Equipment</td>
</tr>
<tr>
<td>Do Not Remain in Area Unless Your Work Requires It</td>
</tr>
<tr>
<td>Breathing Asbestos Dust May be Hazardous to Your Health</td>
</tr>
</tbody>
</table>

Spacing between lines shall be at least equal to the height of the upper of any two lines.

(2) Caution Labels

(i) Labeling. Caution labels shall be affixed to all raw materials, mixtures, scrap, waste, debris, and other products containing asbestos fibers, or to their containers, except that no label is required where asbestos fibers have been modified by a bonding agent, coating, binder, or other material so that during any reasonably foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section will be released.
(ii) Label specifications. The caution labels required by subdivision (i) of this subparagraph shall be printed in letters of sufficient size and contrast as to be readily visible and legible. The label shall state:

CAUTION
Contains Asbestos Fibers
Avoid creating Dust
Breathing Asbestos Dust May Cause
Serious Bodily Harm

(h) HOUSEKEEPING

(1) Cleaning. All external surfaces in any place of employment shall be maintained free of accumulations of asbestos fibers if, with their dispersion, there would be an excessive concentration.

(2) Waste disposal. Asbestos waste, scrap, debris, bags, containers, equipment, and asbestos-contaminated clothing, consigned for disposal, which may produce in any reasonably foreseeable use, handling, storage, processing, disposal or transportation airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section shall be collected and disposed of in sealed impermeable bags, or other closed, impermeable containers.

(i) Recordkeeping

(1) Exposure records. Every employer shall maintain records of any personal or environmental monitoring required by this section. Records shall be maintained for a period of at least 20 years and shall be made available upon request to the Assistant Secretary of Labor for Occupational Safety and Health, the Director of the National Institute for Occupational Safety and Health, and to authorized representatives of either.

(2) Employee access. Every employee and former employee shall have reasonable access to any record required to be maintained by subparagraph (1) of this paragraph, which indicates the employee's own exposure to asbestos fibers.

(3) Employee notification. Any employee found to have been exposed at any time to airborne concentrations of asbestos fibers in excess of the limits prescribed in paragraph (b) of this section shall be notified in writing of the exposure as soon as practicable but not later than 5 days of the finding. The employee shall also be timely notified of the corrective action being taken.

(j) MEDICAL EXAMINATIONS

(1) General. The employer shall provide or make available at his cost, medical examinations relative to exposure to asbestos required by this paragraph.
(2) Preplacement. The employer shall provide or make available to each of his employees, within 30 calendar days following his first employment in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination, which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(3) Annual examinations. On or before January 31, 1973, and at least annually thereafter, every employer shall provide, or make available, comprehensive medical examinations to each of his employees engaged in occupations exposed to airborne concentrations of asbestos fibers. Such annual examination shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(4) Termination of employment. The employer shall provide, or make available, within 30 calendar days before or after the termination of employment of any employee engaged in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(5) Recent examinations. No medical examination is required of any employee, if adequate records show that the employee has been examined in accordance with this paragraph within the past 1-year period.

(6) Medical records.

(i) Maintenance. Employers of employees examined pursuant to this paragraph shall cause to be maintained complete and accurate records of all such medical examinations. Records shall be retained by employers for at least 20 years.

(ii) Access. Records of the medical examinations required by this paragraph shall be provided upon request to employees, designated representatives, and the Assistant Secretary in accordance with 29 CFR 1910.20(a)-(e) and (g)-(i). These records shall also be provided upon the request to the Director of NIOSH. Any physician who conducts a medical examination required by this paragraph shall furnish to the employer of the examined employee all the information specifically required by this paragraph, and any other medical information related to occupational exposure to asbestos fibers.
§ 61.20 Applicability.

The provisions of this subpart are applicable to those sources specified in §61.22.

§ 61.21 Definitions.

Terms used in this subpart are defined in this Act. In Subpart A of this part, or in this section as follows:

(a) "Asbestos" means actinolite, amosite, anthophyllite, chrysotile, crocidolite, tremolite.

(b) "Asbestos material" means asbestos or any material containing asbestos.

(c) "Particulate asbestos material" means finely divided particles of asbestos material.

(d) "Asbestos tailings" means any solid waste product of asbestos mining or milling operations which contains asbestos.

(e) "Outside air" means the air outside buildings and structures.

(f) "Visible emissions" means any emissions which are visually detectable without the aid of instruments and which contain particulate asbestos material.

(g) "Asbestos mill" means any facility engaged in the conversion of any asbestos ore deposits.

(h) "Commercial asbestos" means any variety of asbestos which is produced by extracting asbestos from asbestos ore.

(i) "Manufacturing" means the combining of commercial asbestos, or in the case of woven friction products the combining of textiles containing commercial asbestos, with any other materials, including commercial asbestos, and the processing of this combination into a product as specified in §61.22(c).

(j) "Demolition" means the wrecking or taking out of any load-supporting structural member, such as beams and load-supporting walls, or any non-load-supporting member, such as ceilings and non-load-supporting walls.

(k) "Roadways" means any material that contains asbestos and can be crumbled, pulverized, or reduced to powder, when dry, by hand pressure.

(l) "Control device asbestos waste" means any asbestos-containing waste material that is collected in a pollution control device.

(m) "Renovation" means the removing or stripping of friable asbestos material from any building, duct, boiler, tank, reactor, turbine, furnace, or structural member. Operations in which load-supporting structural members are removed or taken out are excluded.

(n) "Planned renovation" means a renovation operation, or a number of such operations, in which the amount of friable asbestos material that will be removed or stripped within a given period of time can be predicted. Operations that are individually nonscheduled are included, provided a number of such operations can be predicted to occur during a given period of time based on operating experience.

(o) "Emergency renovation" means a renovation operation that results from a sudden, unexpected event, and is not a planned renovation. Operations necessitated by non-routine failures of equipment are included.

(p) "Adequately wetted" means sufficiently mixed or coated with water or an aqueous solution to prevent dust emissions.

(q) "Removing" means taking out friable asbestos materials from any building, duct, boiler, tank, reactor, turbine, furnace, or structural member from any building, structure, facility, or installation.

(r) "Stripping" means taking off friable asbestos materials from any building, duct, boiler, tank, reactor, turbine, furnace, or structural member.

(s) "Fabricating" means any processing of a manufactured product containing commercial asbestos, with the exception of processing at temporary sites for the construction or restoration of buildings, structures, facilities, or installations.

(t) "Asbestos mill tailings" means any material that contains asbestos and that can be crumbled, pulverized, or reduced to powder, when dry, by hand pressure.

(u) "Active waste disposal site" means any disposal site other than an inactive site.

(v) "Asbestos-containing waste material" means any waste which contains commercial asbestos and is generated by a source subject to the provisions of this subpart, including asbestos mill tailings, control device asbestos waste, friable asbestos waste material, and bags or containers that previously held commercial asbestos.

(w) "Structural member" means any load-supporting member, such as beams and load-supporting walls, or any non-load-supporting member, such as ceilings and non-load-supporting walls.

(x) "Control device asbestos waste" means any material that contains asbestos and can be crumbled, pulverized, or reduced to powder, when dry, by hand pressure.
The demolition operation is exempted from cover or coat any duct, boiler, tank, re-
coated with friable asbestos materials to the demolition of any building, structure, facility, installation, or por-
tion thereof to be demolished is less than 160 square meters (ca. 160 square feet) used to in-
clude the information required by paragraph (d)(2) of this section, with the exception of the information re-
quired by paragraphs (d)(2)(iii), (d)(2)(v), (d)(2)(vii), (d)(2)(viii), and (d)(2)(ix), and shall state the
measured or estimated amount of friable asbestos materials which is present. Techniques of estimation shall be explained.

(2) Written notice of intention to demolish or renovate shall be provided to the Administrator by the owner or operator of the demolition or renovation operation. Such notice shall be postmarked or delivered to the Admin-
istrator at least 10 days prior to commencement of demolition, or as early as possible prior to commencement of emergency demolition subject to paragraph (d)(6) of this section, and as early as possible prior to commence-
ment of renovation. Such notice shall include the following information:

(i) Name of owner or operator.

(ii) Address of owner or operator.

(iii) Description of the building, structure, facility, or installation to be demolished or renovated, including the size, age, and prior use of the structure.

(iv) Schedule of planned demolition or renovation and method(s) to be employed.

(v) Procedures to be employed to meet the requirements of this paragraph and paragraph (i) of this section.

(vi) The name and address or location of the waste disposal site where the friable asbestos waste will be de-
posed.

(vii) Name, title, and authority of the State or local governmental repre-
sentative who has ordered a demolition or renovation which is subject to paragraph (d)(6) of this section.

(3) For purposes of determining whether a demolition or renovation operation constitutes a renovation within the meaning of this paragraph, the amount of friable asbestos materials that can be pre-
vented from released into the outside air. Such removal shall be carefully lowered and not thrown to the ground or a lower floor. Such materials that have not been removed or stripped shall be transported to the ground or a lower floor.

(4) The stripping of friable asbestos materials used on any pipe, duct, boiler, tank, reactor, furnace, or structural member that has been removed as a unit or in sections as provided in paragraph (d)(4)(iii) of this section shall be performed in accordance with paragraph (d)(4)(iv) of this section. It shall be performed in accordance with paragraph (d)(4)(iv) of this section. Rather than comply with the wetting requirement, a local exhaust ventilation and collection system may be used to prevent emissions to the outside air. Such local exhaust ventilation systems shall be designed and operated to capture the asbestos partic-
ulate matter produced by the stripping of friable asbestos materials. There shall be no visible emissions to the outside air from such local exhaust ventilation and collection systems except as provided in paragraph (f) of this section.

(v) The removing of friable asbestos materials that have been removed or stripped shall be adequately wetted to ensure that such materials remain wet during all remaining stages of demolition or renovation and related handling oper-
ations. Such materials shall not be dropped or thrown to the ground or a lower floor. Such materials that have been removed or stripped more than 50 feet above ground level, except those materials removed as units or in sections, shall be transported to the ground via dust-tight chutes or con-
tainers.

(vi) Except as specified below, the wetting requirements of this paragraph are suspended when the tem-
perature at the point of wetting is below 0°C (32°F). When friable asbestos materials are not wetted due to freezing temperatures, such materials shall be wetted as soon as possible.
spraying. There shall be no visible emissions to the outside air from the spray-on application of materials containing more than 1 percent asbestos, on a dry weight basis, used equipment and machinery, except as provided in paragraph (f) of this section. Materials sprayed on buildings, structures, and conduits shall contain less than 1 percent asbestos on a dry weight basis.

(1) Sources subject to this paragraph are exempt from the requirements of §§ 61.05(a), 61.07, and 61.09.

(2) Any owner or operator who intends to spray asbestos materials which contain more than 1 percent asbestos on a dry weight basis to insulate or fireproof equipment and machinery shall report such intention to the Administrator for at least 20 days prior to the commencement of the spraying operation. Such report shall include the following information:

(i) Name of owner or operator.
(ii) Address of owner or operator.
(iii) Location of spraying operation.
(iv) Procedures to be followed on the requirements of this paragraph.

(3) The spray-on application of materials in which the asbestos fibers are encapsulated within a luminous or resistant binder during spraying and which are not friable after drying is exempted from the requirements of paragraphs (e) and (e)(2) of this section.

(4) Rather than meet the no-visible-emission requirements as specified by paragraphs (a), (c), (d), (e), (h), (1), and (k) of this section, an owner or operator may elect to use the methods specified by § 61.23 to clean emissions containing particulate asbestos material before such emissions escape to or are vented to the outside air.

(5) Where the presence of uncombined water is the sole reason for failure to meet the no-visible-emission requirement of paragraphs (a), (c), (d), (e), (h), (l), and (k) of this section, such failure shall not be a violation of such emission requirements.

(6) Fabricating: There shall be no visible emissions to the outside air except as provided in paragraph (f) of this section, from any of the following operations if they use commercial asbestos or from any building or structure in which such operations are conducted:

(A) The fabrication of cement building products.
(B) The fabrication of friction products, except those operations that primarily involve the use of asbestos friction material.
(C) The fabrication of cement or silicate board for roofing and siding panels, laboratory furniture, bulkheads, partitions, and ceilings for marine construction, and flow control devices for the molten metal industry.
(D) Insulating: Molded insulating materials which are friable and wet-applied insulating materials which are friable after drying, installed after the effective date of these regulations, shall contain no commercial asbestos. The provisions of this paragraph do not apply to insulating materials which are spray applied; such materials are regulated under § 61.22(e).

(7) Waste disposal for manufacturing, fabricating, demolition, renovation and spraying operations: The owner or operator of any source covered under the provisions of paragraphs (a), (d), (e), or (h) of this section shall meet the following standards:

(A) There shall be no visible emissions to the outside air, except as provided in paragraph (j)(3) of this section, during the collection, processing, including, but not limited to, crushing, grinding, reconditioning, compaction, and transportation, or deposition of any asbestos-containing waste material which is generated by such source.

(B) All asbestos-containing waste material shall be formed into non-friable pellets or if not deposited at waste disposal sites which are operated in accordance with the provisions of § 61.22.

(8) Incineration: The provisions of paragraphs (a)(2), (d), (e), or (h) of this section shall apply to incineration of asbestos-containing waste material. Incineration shall meet the following requirements:

(A) The containers specified under paragraph (j)(3)(i)(B) of this section shall be labeled with a warning label stating:

**Caution**

Contains Asbestos

Avoid Opening or Breaking Container

Breathing Asbestos is Hazardous to Your Health

Alternatively, warning labels specified by Occupational Safety and Health Standards of the Department of Labor. Occupational Safety and Health Administration (OSHA) under 29 CFR 1910.93(a)(2)(ii) may be used.

(B) Processing of asbestos-containing waste material into non-friable forms:

(i) All asbestos-containing waste material shall be formed into non-friable pellets or if not deposited at waste disposal sites which are operated in accordance with the provisions of § 61.22.

(ii) All asbestos-containing waste material shall be deposited at waste disposal sites which are operated in accordance with the provisions of § 61.22.
sions to the outside air, except as provided in paragraph (k)(3) of this section, during the collection, processing, packaging, transporting or deposition of any asbestos-containing waste material which is generated by such source.

(2) All asbestos-containing waste material shall be deposited at waste disposal sites which have been approved in accordance with the provisions of this section.

(3) Rather than meet the requirements of paragraph (k)(1) of this section, an owner or operator may elect to meet the requirements in paragraphs (k)(2) and (i), or use an alternative disposal method which has received prior approval by the Administrator.

(i) There shall be no visible emissions to the outside air from the control device asbestos waste to the tailings conveyor, except as provided in paragraph (f) of this section. Such waste shall be subsequently processed either as specified in paragraph (k)(3)(ii) of this section or as specified in paragraph (k)(3)(iii) of this section.

(ii) All asbestos-containing waste material shall be adequately mixed, with a wetting agent recommended by the manufacturer, or as the agent to effectively wet dust and tailings and deposited at a waste disposal site. Such agent shall be used as recommended by the manufacturer of the agent. There shall be no discharge of visible emissions to the outside air from the wetting operation except as specified in paragraph (f) of this section.

(3) The perimeter of the site shall be fenced in a manner adequate to deter access by the general public, except as specified in paragraph (k)(4) of this section.

(4) Warning signs and fencing shall not be required where the requirements of paragraphs (k)(5)(i) or (ii) of this section are met, or where a natural barrier adequately deters access by the general public. Upon request and supply of appropriate information, the Administrator will determine whether

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**Legend**

ASBESTOS WASTE DISPOSAL SITE

BEARING ASBESTOS IS HAZARDOUS TO YOUR HEALTH

Notation

1. Sans Serif, Gothic or Block

2. Sans Serif, Gothic or Block

Print Gothic

Spacing between lines shall be at least equal to the height of the upper of the two lines.

(a) If air-cleaning is elected, as permitted by §§ 61.22(f) and 61.22(d)(4)(i)(v), the requirements of this section must be met.

(b) Fabric filter collection devices must be used, except as noted in paragraphs (b) and (c) of this section. Such devices shall be operated at a pressure drop of no more than 4 inches water gauge, as measured across the filter as it is being operated under the conditions of the test, and the fabric is not synthetic, indicate whether the filter is spun or not spun.

(c) If the fabric filter device utilizes a felted fabric, the density in oz./yd², the minimum thickness in inches, and the airflow permeability in ft/min/ft² for felted fabrics, except that 40 ft/min/ft² for woven fabrics or 35 ft/min/ft² for felted fabrics is allowed for filtering least one-sixteenth inch thick throughout. Synthetic fabrics must not exceed 35 ft/min/ft² for woven fabrics.
waste material.

(2) The average weight of asbestos-containing waste material disposed of, measured in kg/day.

(3) The concentration of asbestos in the air in the vicinity of the disposal site, measured in mg/m^3.

(4) The type of disposal site or incineration site used for ultimate disposal, the name of the site operator, and the name and location of the disposal site.

(5) For sources subject to § 61.22(i), a brief description of the site.

(6) The method or methods used to comply with the standard, or alternative procedures to be used.

(7) Such information shall accompany the information required by § 61.10.

The information described in this section shall be presented in the format of Appendix A of this part.

(a) There shall be no visible emissions to the outside air from any active waste disposal site where asbestos-containing waste material has been deposited, except as provided in paragraph (c) of this section.

(b) Warning signs shall be displayed at all entrances, and along the property lines and access roads, in a manner and location such that a person may easily read the legend. The warning signs required by this paragraph shall conform to the requirements of 20 FR 14 upright format signs specified in 20 U.S.C. 7414(d)(4) and this paragraph. The signs shall display the following legend in the lower panel, with letter sizes and styles of a visibility at 300 feet and more:

LEGEND

ASBESTOS WASTE DISPOSAL SITE
Do Not Create Dust
Breathing Asbestos is Hazardous to Your Health

Notation

1" Sans Serif, Gothic or Block
2" Sans Serif, Gothic or Block
14 Point Gothic

Spacing between lines shall be at least equal to the height of the upper of the two lines.

(c) The perimeter of the disposal site shall be fenced in order to adequately deter access to the general public except as specified in paragraph (d) of this section.

(d) Warning signs and fencing are not required where the requirements of paragraph (e)(1) of this section are met, or where a natural barrier adequately deters access to the general public. Upon request and supply of appropriate information, the Administrator will determine whether a fence or a natural barrier adequately deters access to the general public.

(e) Rather than meet the requirements of paragraph (a) of this section, an owner or operator may elect to meet the requirements of paragraphs (e)(1) or (e)(2) of this section, or may use an alternative control method for emissions from active waste disposal sites which has received prior approval by the Administrator.

1. At the end of each operating day, or at least once every 24-hour period while the site is in continuous operation, the asbestos-containing waste material which was deposited at the site during the operating day or previous 24-hour period shall be covered with at least 15 centimeters (ca. 6 inches) of compacted non-asbestos-containing material.

2. At the end of each operating day, or at least once every 24-hour period while the disposal site is in continuous operation, the asbestos-containing waste material which was deposited at the site during the operating day or previous 24-hour period shall be covered with a reservoir or petroleum.

Section 61.25 Waste disposal sites.

In order to be an acceptable site for disposal of asbestos-containing waste material under 42 U.S.C. 7414, the requirements of this section shall be met. The provisions of this subpart shall not apply to the following stationary sources:

(a) Extraction plans, ceramic plants, foundries, incinerators, and propellant plants which process beryllium ore, beryllium, beryllium oxide, beryllium alloys, or beryllium-containing waste.

(b) Machine shops which process beryllium, beryllium oxides, or any alloy containing such alloy contains more than 5 percent beryllium by weight.

(c) Chemical processing of beryllium.

Section 61.26 Applicability.

The provisions of this subpart are applicable to the following stationary sources:

(a) Extraction plans, ceramic plants, foundries, incinerators, and propellant plants which process beryllium ore, beryllium, beryllium oxide, beryllium alloys, or beryllium-containing waste.

(b) Machine shops which process beryllium, beryllium oxides, or any alloy containing such alloy contains more than 5 percent beryllium by weight.

(c) Chemical processing of beryllium.

Section 61.27 Emissions to the atmosphere.

(a) Emissions to the atmosphere shall be covered with at least 15 centimeters of compacted non-asbestos-containing material.

(b) Emissions to the atmosphere shall be covered with at least 15 centimeters of compacted non-asbestos-containing material.

(c) Emissions to the atmosphere shall be covered with at least 15 centimeters of compacted non-asbestos-containing material.

Section 61.30 Applicability.

The provisions of this subpart shall not apply to the following stationary sources:

(a) Extraction plans, ceramic plants, foundries, incinerators, and propellant plants which process beryllium ore, beryllium, beryllium oxide, beryllium alloys, or beryllium-containing waste.

(b) Machine shops which process beryllium, beryllium oxides, or any alloy containing such alloy contains more than 5 percent beryllium by weight.

Section 61.31 Definitions.

Terms used in this subpart are defined in the act, in subpart A of this part, or in this section as follows:

1. "Beryllium" means the element beryllium but not the beryllium oxides or alloys.

2. "Beryllium alloy" means any metal to which beryllium has been added in order to increase its beryllium content and which contains more than 0.1 percent beryllium by weight.

3. "Beryllium plant" means any facility engaged in the mixing, casting, or machining of propellant.

Section 61.32 Emission standard.

(a) Emissions to the atmosphere shall not exceed 10 grams of beryllium over a 24-hour period, except as provided in paragraph (b) of this section.

(b) Rather than meet the requirements of paragraph (a) of this section, an owner or operator may request approval from the Administrator to meet an ambient concentration limit on beryllium in the vicinity of the stationary source of 0.01 µg/m^3, averaged over a 30-day period.

(c) Approval of such requests may be granted by the Administrator provided:

1. At least 3 years of data is available which in the judgment of the Administrator demonstrates that the future ambient concentrations of beryllium in the vicinity of the stationary source will not exceed 0.01 µg/m^3, averaged over a 30-day period.

2. Such 3-year period shall be the 3 years ending the 30 days before the effective date of this standard.

3. The owner or operator submits a report to the Administrator within 30 days after the effective date of this standard.