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Research & Development Center
May 22, 1973

BRAKE AND CLUTCH EMISSIONS GENERATED DURING VEHICLE OPERATION
Michael G. Jacko, Bendix; Robert T. DuCharme, Bendix; and Joseph H. Somers, EPA (Presented at the 1973 SAE National Automobile Engineering Meeting, Detroit, May 16, 1973).

SUMMARY
by J. W. Axelson

Emission collectors were installed on the right front disc brake and the right rear drum brake and on the dry clutch assembly. The left brakes were left in their normal configuration and were used to monitor the operation of the shrouded brakes.

Three types of samples were collected and analyzed for asbestos. These were the airborne collected on 8.0 u and 0.2 u filters; the sump material; and the debris on the brake surfaces. Optical microscopy with phase contrast at 400X and transmission electron microscopy at 22,000X were used to identify and measure the amounts of asbestos.

The overall average of asbestos content in brake emission was 0.23 per cent from all three sources in three different tests. Some fibers were longer than 20 u. Only 3.7 per cent of the asbestos emission was airborne for the test vehicle and only 2.9 per cent is estimated for trucks.

It was estimated that 51,500 tons of asbestos are used in friction materials annually and about 37,000 tons are actually worn away.

Knowing the asbestos emission in ugms per mile it is possible to calculate the total annual asbestos emission per year. This comes to a total of 158,200 pounds (79.1 tons) but only 3.2 per cent or 5060 pounds (2.53 tons) is airborne. Over 99.7 per cent of the total asbestos wear is converted to olivine or forsterite.

Note

Extrapolating the Ford data of only 0.0023 per cent of lining wear appearing as asbestos fiber, the total friction wear estimated by Bendix of 61,800 tons would give an asbestos emission of 1.42 tons (2840 pounds) which is a little more than one half of the Bendix value. This is not bad agreement considering the wide differences in test procedures and type of calculations.

Distribution on Reverse Side

64058

Research and
Engineering Center
December 30, 1966

H. G. Koch

Brake Decomposition Products
Public Health Service

During a recent meeting on asbestos and health at the Public Health Service, I learned that the Public Health Service had performed brake wear studies utilizing dynamometer equipment at the American Brake Shoe Company in Mahwah, New Jersey. These data were reported on April 8, 1966, to the Assistant to the Chief for Epidemiology and Field Studies, Department of Health by Jeremiah Lynch, Senior Sanitary Engineer, Engineering Section, Research and Technical Services Branch. Briefly, the results showed practically no fiber in the decomposition product at test temperatures up to approximately 400-500F. Sample evaluation was by electron micrograph.

When the test temperature approximated 700F in so-called panic stops, the overload condition apparently deteriorated the resin bond permitting fiber to be ripped out of the brake instead of being worn off. Approximately 15 per cent of the fiber was visible in this decomposition material. The results are summarized below.

Type of Brake	Test Condition	Per Cent Fiber
Disc brake	normal city driving	Less than 5%
Bus brake	normal city driving	0
Auto brake	100-200F	[illegible] (Few Fibers)
Auto brake	300-500F	Less than 1%
Auto brake	600-700F	[illegible]
Auto clutch	normal city driving	0
Bus brake	450-550F	0
Auto brake	400-600F	[illegible]0 (Few Fibers)
Auto brake	100-300F	0
Bus brake	450-550F	0

Mr. Lynch believes that the results clearly indicate that wear of brake linings is not a significant factor in contributing fiber to the atmosphere. He intends to publish his data as a brief note very shortly. I have invited him to visit the Research Center to review our results with you and have indicated that we would give him permission to quote our figures.

I believe that publication under the auspices of a government laboratory would be far more beneficial than by Johns-Manville. I shall notify you as soon as a firm date has been established for this visit.

J. [illegible]

[illegible]/mse

cc: F. L. Pundsack
W. C. Streib
Dr. K. Smith, [illegible]
J. P. Leineweber
Attn: G. [illegible]

44108

General Headquarters
April 21, 1967

F. L. Pundsack - Finderne

Brake Lining Wear Dust
Your Letter of 3/14 to F. J. Solon
Your File 259

Confirming our phone conversation of this morning, I approve your recommendation that we collaborate with the U. S. Public Health Service through the release of information from this study.

The publication of our data under their auspices will certainly carry considerable weight.

It was certainly of considerable interest, in a recent discussion with Dr. L. J. Cralley, to learn that their findings parallel ours very closely.

The photographs which you requested be returned are attached.

H. M. Jackson

enc

cc: F. J. Solon

66035

Research & Engineering Center
March 27, 1968

J. Solon - DH
H. M. Jackson - DH
K. V. Lindell - Asb
F. L. Pundsack
H. G. Koch
J. Leineweber

Brake Lining Decomposition

I thought you would like to have a copy of Jerry Lynch's draft of a paper on brake lining decomposition which is to be submitted for publication in the Journal of Air Pollution Control Association.

S. Speil

SS/rs

April 8, 1960

Mr. J. R. Lynch, Assistant Chief
Environmental Activities, Field Studies
Department of Health, Education & Welfare
Occupational Health Program
[illegible] Broadway
Cincinnati, Ohio [illegible]

Dear Jerry:

Thank you very much for sending me a draft of your paper on brake lining decomposition which is scheduled for publication in the Journal of Air Pollution Control Association.

You asked if I had any comments. My one major comment is that the paper represents an honest, straightforward presentation of the facts. I wish that there were more such factual exposition in the literature.

The one point I would raise in the very last sentence of the paper. Thus, although urban air contains a few free fibers as a result of brake lining wear, they represent a very small proportion of the total asbestos used in the manufacture of brakes, and an apparently inconsequential amount plays in urban air pollution when compared with other sources of free fibers.

In the context of the reference to Crulley, et al, 'Sources and Identification of Respirable Fibers', I would ass me that the last five words "other sources of free fibers" refers to the presence of many types of fibers other than asbestos in the atmosphere. However, in the paper you have used, somewhat interchangeably, the words 'asbestos' and 'fiber'. Therefore, to the occasional reader, and especially one interested in 'bad press', one might get the impression that these last five words refer to the presence of considerable asbestos fiber in the air from other sources. I do not believe that you intended to infer this.

I was unable to reach you by phone today, but did speak to Howard Ayer. He suggested the possibility that you might want to delete the last eight words. However, since you probably do want to reference Dr. Cralley's presentation, I might suggest that you use some slight modification, such as, "when compared with sources of free fibers, other than asbestos" or, less desirably, and I do not think what you mean, "when compared with other sources of free fibers, in addition to asbestos".

I hope that you will be able to modify this last sentence, especially in view of your department's efforts to prevent any possible misuse of your words.

Very truly yours,

Dr. Sidney Spell, Director
Corporate Research & Development

SS/rs

cc: Mr. Howard Ayer - HEW, Cincinnati
Dr. Lewis Cralley - HEW, Cincinnati

bcc: H. M. Jackson - DH
J. Solon - DH
K. V. Lindell - Acb
W. P. Raines - DH
F. L. Pundsack
H. G. Koch
W. C. Streib
E. M. Fenner

4410D

COPY

Research and Engineering Center
November 27, 1963

File: 456-G

Dr. K. W. Smith - GH

Brake Lining Wear Dust

I am enclosing three envelopes containing dust removed from the brakes of the following cars:

Car	Lining	Mileage
Comet	PC-2008/PC-3049	1266 miles
Newport	PC-594/DM-1613	340 miles
Chevrolet	Inlite equipment	9900 miles

You will find that the dust consists partly of ferrous particles, presumably abrasion products from the cast iron brake drums. The remainder should be predominantly abrasion products from the brake lining themselves. We can supply information on the composition of the brake linings used in the first two cars. The third car was equipped with competitive linings, a composition not known to us, but undoubtedly containing asbestos fiber.

W. C. Nash

ek/CK

cc: W. E. Streib
C. L. Meserve

000897

Johns-Manville

Research & Engineering Center

P O Box 159
Manville, N J 08835
(201) 722-9000

September 6, 1972

Dr. M. G. Jacko
Materials and Processes Department
Bendix Research Laboratories
Southfield, MI 48075

Dear Dr. Jacko:

We have finally completed the analysis of the brake lining wear debris you sent to us. These samples were described as follows in your letter to Dr. Speil of July 5, 1972.

Sample No. 1 - Vehicle Test 1
J-M No. 4123-58-1 Detroit Traffic Schedule
Right Front Brake
Surfaces Sample

Sample No. 2 - Vehicle Test 1
J-M No. 4123-58-2 Detroit Traffic Schedule
Right Rear Brake
Surfaces Sample

Sample No. 3 - Vehicle Test 1
J-M No. 4123-58-3 Detroit Traffic Schedule
Right Rear Brake
Airborne Sample

The fiber content of the samples and the weight loss on ignition are given below. The fiber content was determined by the rub-out procedure which I believe we explained to you at the time of your visit to our laboratory.

	No. 1	No. 2	No. 3
Initial Sample Weight (mg)	50.78	46.50	45.70
Weight of Ash After Ignition @ 400C (mg)	43.50	31.10	30.20
Weight Loss on Ignition	14.4%	33.1%	33.9%
Total Fiber in Sample (micrograms)	2.54	0.98	2.73
Percent Fiber in Original Sample	0.005	0.002	0.006

We were unable to determine the element distribution because our emission spectrograph has been disassembled for our move to Denver.

If you have any questions regarding these samples or procedures you can contact Dr. Speil. He will be available through the month of September. After that time you can contact me in Denver. Our mailing address and telephone number in Denver will be:

Johns-Manville Corporation
P. O. Box 5108
Denver, Colorado 80217

Phone: (303) 770-1000

Very truly yours,

J. P. Leineweber

mp

cc: Dr. S. Speil

Research & Engineering Center
September 30, 1966

K. V. Lindell, Asbestos

Hazardous Dust

Upon our return from Asbestos, S. Speil and myself met with Dr. Ken Smith, H. G. Koch, Research Manager of Packings and Friction Materials, and other members of the Basic Research group to discuss the status of the program on brake lining dusts. Since this was a subject we discussed briefly with you, I thought you might be interested in a few of the essential details and conclusions reached at this meeting.

The brake lining dust sample was collected by wearing a brake against a brake drum with the whole assembly enclosed in a boxlike apparatus. As the brake was worn, 150 cfm of filtered air was drawn through the system and the airborne dust was collected on a Millipore filter. Dust remaining in the brake drum was also collected. The airborne dust was illustrated in the electron micrographs which we left with you the other day. X-ray analysis showed this material to be amorphous with no crystalline structure, although by spectrographic analysis there was sufficient MgO and SiO_2 in the proper ratios to account for the original chrysotile in the brake lining composition. Rubbing out the agglomerate mass and examining this under an electron microscope showed evidence of some small fibers reduced to their ultimate fibril diameter. The amount of such fibers is difficult to ascertain, but tests are under way to get the best guesstimate. Gas analyses of the fumes given off during these tests have not been successful, and we have not been able to determine as yet whether any heavy organic gases were present in the effluent air.

You probably know that Dr. Ken Smith had previously submitted samples of brake dust collected from the drums of other pilot plant tests. This material had been sent to the Industrial Hygiene Foundation in Pittsburgh for intratracheal animal tests under the direction of Dr. Paul Gross. The results of these original tests should be completed by November to see if "asbestos bodies" are evident.

Dr. Smith planned to submit samples of this new airborne material to the same location for additional tests. Dr. Smith advised me that he had discussed this matter with Dr. George W. Wright, Director of Medical Research, St. Luke's Hospital, Cleveland, and as I understood from you, a member of your scientific committee on occupational health. Dr. Smith said that Dr. Wright was in agreement and approved of the Pittsburgh location as the best place to conduct these tests. Speil and I passed along to Dr. Smith your instructions that the Scientific Council should be used to determine the best location for such studies, and apparently this has been done with the proposed program.

It was agreed at this meeting that the technique used to collect the brake dust sample should be described and illustrated to members of the Hygiene Foundation and any others you feel should be included from the QAMA Occupational Health Institute or Scientific Council. In this way, the technique of sampling as well as the medical results would be understood and approved by an outside agency. A similar approach would be taken on new methods of identification which might be developed.

Samples of air dust collected in Detroit under the direction of Dr. A. J. Vorwald (Wayne State University) will be sent to Research for examination to determine if asbestos fibers are present in particulate matter collected from the atmosphere, and if it is, how much is present.

You probably are familiar with most or all of the above, but I am taking no chances of a breakdown in communications in this important matter.

W. C. Streib

ch
cc: S. Speil
File

COPY FORM	INITIALS	DATE
	PC	

BOX NUMBER	SEGMENT NO.	REQUESTING PARTY
1159		

NOTES

BRAKE WEAR DUST, 1963-64

Research & Engineering Center
December 13, 1963

D. Bailey

Brake Lining Wear Dust

You will recall that during his recent visit to the Research Center, Dr. K. W. Smith mentioned a recent theory that asbestos fibers freed in the wearing of brake linings might have some pathological effects. Mr. Koch has obtained wear dusts from three cars and I would appreciate your examining these microscopically to see if you can identify asbestos fibers in this material. I am attaching a work request (FD #345) to cover this work.

I am also attaching the pertinent correspondence and would like to call your attention to Dr. Smith's request for the material remaining after your tests.

Would you please let me know when you have completed your examination, at which time we can again get together with Dr. Smith to determine if any additional work is required.

W. C. Streib

WCS/jep

cc: K. W. Smith, GE
A. C. Smith
L. B. Blair
F. L. Pundsack
H. G. Koch
File

PRODUCED
JM - 83

COPY

GHQ
December 2, 1963

W. C. Streib, Research

Brake Lining Wear Dust

You have received a copy of H. G. Koch's letter to me of November 27, 1963, on this subject. I am forwarding the three envelopes containing the dust to you for analysis. As discussed on my recent visit, I wonder if you could have this dust analyzed to see if there are any free and recognizable asbestos fibers in it? If there is any dust left over, could you please retain it for I might like to have it used by our research pathologist at the Industrial Hygiene Foundation in Pittsburgh?

I shall be very pleased to visit you again at the Center to discuss the results of your tests when obtained.

Kenneth W. Smith, M.D.

cc: H. G. Koch, Research

Research and Engineering Center
November 27, 1963

File: 456-G

Dr. K. W. Smith - GH

Brake Lining Wear Dust

I am enclosing three envelopes containing dust removed from the brakes of the following cars:

Car	Lining	Mileage
Comet	PC-2308/PC-3049	1266 miles
Newport	PC-594/DM-1618	540 miles
Chevrolet	Inlite equipment	9900 miles

You will find that the dust consists partly of ferrous particles, presumably abrasion products from the cast iron brake drums. The remainder should be predominantly abrasion products from the brake lining themselves. We can supply information on the composition of the brake linings used in the first two cars. The third car was equipped with competitive lining, a composition not known to us, but undoubtedly containing asbestos fiber.

H. G. Koch

ek/GK

cc: W. C. Streib
C. L. Meserve

Title: PETROGRAPHIC AND X-RAY DIFFRACTION ANALYSES OF BRAKE LINING WEAR DUSTS

Requested by: W. C. Streib - Request No. FD-345

SUMMARY

Three samples of brake lining wear dust were examined petrographically to determine whether chrysotile fiber can be distinguished in this type of material. Two of the samples were also examined by X-ray diffraction for confirmation. The samples were from the following brake linings:

(1) 1963 Comet
(2) 1963 Pontiac
(3) Chevrolet 6, Inlite Lining

Petrographic examination showed the following:

The dust from the Comet lining contained an organic binder, plus small percentages of quartz, magnetite, carbonates, talc, and (rarely) a few chrysotile fibers. Chrysotile in sizes recognizable under the microscope constituted less than one per cent of the total.

The dust from the Pontiac lining appeared similar to the one from the Comet lining, showing the same components in comparable amounts. Only an occasional bundle of chrysotile fiber could be detected after prolonged examination of several slides.

The Chevrolet brake lining dust differs somewhat from the others, in that it contains possibly 10 per cent quartz. Talc appears to be absent. A small amount of graphite appears to be present, but was not positively identified. An occasional small bundle of chrysotile fiber was noted, as in Samples 1 and 2.

X-ray diffraction results:

Dust from Comet Lining	quartz	weak pattern
	chrysotile	trace
	talc	trace
	magnetite	trace
Dust from Inlite Lining of Chevrolet	iron	major
	quartz	minor
	magnetite	trace

The "trace" of chrysotile detected by X-ray diffraction in the Comet lining dust could possibly amount to as much as 5 per cent of the total. This would indicate that in addition to the occasional fibers seen microscopically, there may be some

Notebook No. 2910, p 52; 2864, p 88

File 456

finely divided and possibly coated fibrils not recognized under the light microscope. Failure of X-ray diffraction to detect any chrysotile in the Chevrolet lining dust sets the chrysotile content of this sample as well below 5 per cent. The Pontiac lining sample was not examined by X-ray diffraction, but the incidence of microscopically recognizable chrysotile in this sample is of the same order as in the Comet sample.

Contents: Summary only.

Approved by F. L. Pundsack Reported by D. Bailey

X-ray Diffraction by J. P. McGourty

eh
cc: K. W. Smith, GH

C. F. Rassweiler, GH
A. C. Smith (3)
F. L. Pundsack
W. C. Streib
H. G. Koch
D. Bailey
J. P. McGourty
Library (2)

S-

1310

BRAKE LINING & WEAR DUST 1966

Research & Development Department (R & D)

JOHNS-MANVILLE RESEARCH AND ENGINEERING CENTER

Report No. 456-2506

Date December 19, 1966

Title: STUDY OF WEAR DUST FROM BRAKE LINING
Project 2550

SUMMARY

Brake lining wear dust was collected on a membrane filter mounted in a box which surrounded a brake run on an inertia dynamometer. In addition to this airborne fraction, the dust that settled to the floor of the box and that which remained within the brake was also collected. A total of 6-1/2 grams of dust was collected from 2150 stops during a total time of about 110 hours. The airborne portion was 2.7 grams. Most of the stops were made from 35 miles per hour at 10 ft/sec^2 deceleration, interspersed with stops from 50 mph (about 10 per cent).

The airborne dust was examined by light microscope, electron microscope, X-rays and other means. Asbestos fiber could be detected only by the electron microscope which gave a maximum of 1.4 per cent fiber by weight in the wear dust, although the lining contains 70 per cent chrysotile fiber.

This result is accounted for by the high surface temperature and severe abrasion during even the mild braking of these tests when the average temperature did not exceed 200°F. Calculations show that the surface temperature at the true area of contact (1 per cent of the apparent area) can reach 2000°C or more. It is concluded that most of the fiber is converted to an amorphous mineral by intense heat and fine grinding.

It is recommended that samples of the particulate matter in the atmosphere be collected at suitable distances from highways and the sample examined in the electron microscope for asbestos.

Contents: Summary, Introduction, Experimental Method, Results, Appendix I (calculations), Appendix II (Tables 1 and 2), Appendix III (Figures 1-4), and Appendix IV (References).

Reported by: David Sinclair

David Sinclair
Basic Physics Section

ae

cc: F. J. Solon, GH
K. W. Smith, MD -GH
A. C. Smith (2+S)
F. L. Pundsack
Att: S. Speil
J. Dec
H. G. Koch
W. C. Streib
H. W. Gilbert
H. F. Remde
D. Sinclair
Library (2)

INTRODUCTION

Laboratory measurements were made to determine what type of particulate matter and gases are given off when a brake lining is worn during operation. The wear of the drum, usually cast iron, is necessarily included. Of special interest is the airborne dust expelled into the atmosphere from the moving brake. Previously, some observations had been made at Johns-Manville Research and Engineering Center on dust removed by hand from a laboratory brake,[1] but this is the first time, to our knowledge, that any observations have been made on the airborne fraction.

A search of the literature revealed no measurements on brake lining wear dust, although the rate of wear is sometimes given.[2,3] Recently, numerous articles[4,5] have appeared calling attention to the widespread use of asbestos in materials such as brake linings, floor tile, roofing, asbestos-cement products, etc. It is usually assumed that as these materials wear, much of the asbestos fiber is dispersed into the atmosphere, thereby contributing to air pollution and creating a health hazard. This is understandable, since the asbestos content of these materials is often high, 70 per cent in the brake linings used in these tests, and asbestos is commonly considered to be indestructible.[4] However, we know of no measurements made to test this assumption or to observe the amount of asbestos in urban atmospheres.

The present tests show that during the wear of brake linings very little asbestos fiber is dispersed into the atmosphere. Examination of the airborne dust by light microscope, electron microscope, and X-ray diffraction showed very little of the original chrysotile fiber. Nearly all the fiber appears to have been converted to an amorphous mineral by the severe abrasion and intense heat generated during brake operation. A point-count made on eight electron micrographs gave an upper limit of 1.4 per cent fiber in the airborne dust.

This is not surprising when one calculates the amount of energy dissipated while operating a passenger car brake. It is shown in the appendix that the heat generated raises the temperature of the surface of contact between brake lining and drum to about 2400°C. This high temperature occurs on the surface of the lining at the regions of actual contact with the drum, much less than the apparent area of contact.[6] These regions of contact are worn away during rubbing, so that the actual contact continually shifts to new regions. As a result, the wear particles of asbestos, resin, etc., are heated to a very high temperature for a very short time. Bowden and Tabor[6] observed many incandescent hot spots during the rubbing of metals on glass.

EXPERIMENTAL METHOD

A wooden box, approximately a 1-1/2-ft cube with a Lucite top, was constructed to fit around a 1961 Ford brake mounted on the C inertia machine in the Friction Materials Research Section pilot plant. Figure 1 is a photograph of the box mounted on the brake. The left rear side has a conical air inlet which carries a 1-ft-square Flanders fiber glass filter on the entrance, and tapers to a 4-in.-square opening at the outlet into the box. The right front side of the box carries two 8 x 10-in. filter holders for Gelman membrane filters. These holders are connected through flexible hoses to a 7-1/2-hp industrial vacuum cleaner (not shown). When the vacuum cleaner was run, about 150 cfm of dust-free air was drawn through the Flanders filter, over the brake and out through the membrane filters to collect the airborne wear dust.

The pressure drop across the membrane filters was about 15-cm Hg, measured with the mercury manometer shown standing on the box at the right, connected to a petcock on the exit side of the filters. The pressure drop across the Flanders filter was about 3/4-in. H_2O, measured with the water manometer shown on the left, connected to a tube through the side of the box.

Since the interior of the box was under a negative pressure of 3/4-in. H_2O, it was necessary to seal the joints and screw holes against entrance of dusty ambient air. This was done on the outside with DUXSEAL and on the inside with contact adhesive. The interior of the box and the parts of the brake and mounting within the box were painted white to show up any wear particles that settled out. The stationary hubs at each end of the brake drive-shaft were sealed to the ends of the box with 1/16-in. rubber sheet and rubber cement.

Figure 2 shows the auxiliary equipment used to measure the relative rate of evolution of wear dust during and after braking. At the left rear is seen a Sinclair-Phoenix aerosol photometer connected to the side of the box through a petcock. In the left foreground is a logarithmic amplifier connected to a Varian recorder on the right. Dusty air was drawn continuously from within the box and through the photometer at a rate of about 1 cfm by means of a 1/6-hp Gast pump. Since this rate of air removal is about 0.7 per cent of the total air flow, its reduction of the amount of dust collected on the membrane filters is negligible.

Figure 3 shows the type of record obtained during stops from 35 and 50 miles per hour at 10 to 12 ft/sec^2 deceleration at intervals of 2-1/2 minutes. Two of the stops were from 50 mph as indicated and the others from 35 mph. Usually a more or less regular pattern occurred in which the dust concentration fell to near zero between each of several stops and then remained at an intermediate level for a couple of stops.

The marks numbered 2, 3, and 4 are calibration points for the logarithmic amplifier. They are obtained by interposing neutral optical filters of known light transmission into the photometer light beam.

Figure 4 is the resultant calibration curve which shows the approximate logarithmic relationship between chart reading and dust concentration, the latter proportional to scattered light intensity. For example, a chart reading of 50 corresponds to a dust concentration about 100 times that for a reading of 5.

Dust was collected during 2150 stops, most of it on two membrane filters. The average temperature of the brake lining was kept at 175-200°F and was measured with a thermocouple set in a hole in the lining about 1/16 in. below the surface. The temperature was kept low, in order to simulate average braking, by increasing the time between stops to 3 to 4 minutes when overheating commenced. As indicated earlier, this temperature is far below the instantaneous surface temperature (see Appendix I).

RESULTS

Three fractions of wear dust were collected:

1. Airborne dust collected on membrane filters: 2.71 gm;
2. Dust removed from within brake after completion of test: 3.54 gm;
3. Dust collected from within box after completion of test: 0.214 gm.

These fractions all include some cast iron worn from the drum, about 1 gm total. The samples were analyzed for ignition loss, by light and electron microscope, X-ray spectrometer, emission spectrograph, infra-red spectrograph, and Coulter particle size analyzer. In addition, air samples were withdrawn from the box during braking and analyzed by the Gollob Analytical Service. Table 1 shows the results obtained.

Table 2 shows the composition of linings used. It is seen that the finished lining is about 70 per cent chrysotile fiber after the water and other volatiles are driven off.

The total weight of sample collected, 6.46 gm, is much less than the measured weight loss of the brake shoes and drum: primary, 4.0 ±1 gm; secondary, 7.0 ±1; and 2 ±1 gm. However, the accuracy of these weights is questionable because of the heaviness of the shoes and the drum. We feel certain that negligible loss of dust occurred during the tests, so that we cannot account for the discrepancy.

APPENDIX I

Calculation of surface temperature of lining.

These tests simulate a front wheel brake of a 1961 Ford, designed to decelerate 30.5 per cent of the car mass, or 1270 pounds. At a velocity of 50 mph = 73.5 ft/sec the kinetic energy of this mass is 106,000 ft-lb or 136 Btu. At a deceleration of 10 ft/sec^2 this heat is generated during a stop of 7.35 seconds' duration. During the first second, the average rate of heat generation is 34.6 Btu per second = 8.72×10^3 cal/sec. This heat is generated over a total lining area of 52.5 sq in. (21 x 2-1/2) rubbing against cast iron.

Bowden and Tabor[6] give a method which allows a calculation of the true area of contact. Their experiments on metals showed that the actual area of contact is directly proportional to the load. As the load was increased, the points of contact* flowed plastically until the area of contact was sufficient to support the load. In the case of less ductile materials such as brake linings, the points of contact would be crushed until the load-bearing area was large enough so that the crushing strength was no longer exceeded.

For metals, Bowden and Tabor found that the yield pressure is three times the tensile strength. We make the same assumption for brake linings. Johns-Manville Research report 56-T-44, received from A. J. Taylor, gives a tensile strength of 1590 psi for a lining similar to that used in these tests. The yield pressure is then p_m = 4770 psi = 6.87×10^5 lb/sq ft.

According to the definition of the yield pressure, $p_m = L/a$, where L is the load and a is the real area of contact. The load on the lining may be calculated by equating the torques about the axle of the simulated car.

The torque on the tires is

$$mdR = 1270 \times 10 \times 1.09/32.2$$

Here, m = mass decelerated = 30.5 per cent of total mass of car = 1270-lb mass.

d = deceleration = 10 ft/sec^2 = (10/32.2)g

R = rolling radius = 1.09 ft

The torque on the brake lining is

$$\mu Lr = 0.4 \times L \times 0.463$$

Here, μ = coefficient of friction = 0.4

L = load

r = drum radius = 0.463 ft

Equating these two torques gives the load, L = 2320-lb force.

*The roughness of even the smoothest brake lining (10-microinch average) is about 2500 times molecular dimensions.

The real area of contact is given by the ratio of the load to the yield pressure

$$a = L/p_m = 2320/4770 = 0.487 \text{ sq in.}$$

Since the apparent area of contact, A = 52.3 sq in., the per cent real contact is 0.93 per cent. The per cent real contact is alternatively given by the ratio of the applied pressure to the yield pressure.

The equation used to calculate the temperature is given by Carslaw and Jaeger.[10] The maximum temperature of a strip* (the lining) sliding over a semi-infinite medium (the drum) is given by

$$T_{max} = q\frac{2\sqrt{21}}{\sqrt{\pi v Kcd}}$$

$q = 2.78 \times 10^3$ cal/sec. cm^2 = rate of heat generation per sq cm of real contact area

$l = 26.8$ cm = 1/2 length of lining

$K = 0.111$ cal/cm·sec.^oC = thermal conductivity of drum

$c = 0.1189$ cal/gm^oC = specific heat of drum

$d = 7.5$ gm/cm^3 = density of drum

$v = 888$ cm/sec = average rubbing velocity of lining over drum during first second.

These values give $T_{max} = 2440^oC$ near the beginning of a stop from 50 miles per hour at 10 ft/sec^2 decleration.

For a stop from 35 mph, the maximum temperature would be about 2000^oC.

*The equation is derived for a moving heat source. Since the conductivity of the lining is 1/84th that of the drum, the lining may be treated as a heat source.

republication.

	Fraction collected (sample condition)	Ignition loss 800F	Light microscope Ashed 800F	Electron microscope[7] Ashed	spe[illegible]	Coulter counter Blended**	Gas analysis [illegible] Pure Air
1	Airborne 2.71 gm	13.5%	no fiber glassy or brown agglomerates	few fibers *** see photos[7] ~~attached~~	no [illegible] ide[illegible] I[illegible]	median diams. Number 2.75 microns- Mass 4.75 microns	
2	Within brake 3.54 gm	19.5%	no fiber glassy or brown agglomerates	(analysis incomplete)	no [illegible] ide[illegible]	--------	
3	Within box 0.214 gm	31.0%	no fiber glassy or brown agglomerates contaminated*	(analysis incomplete)	no [illegible] ide[illegible]	--------	
	Observer - S. Wegrzyn		D. Bailey	D. Bailey	[illegible]	A. Burns	Coll[illegible] Analytical Service

*This very small fraction was contaminated with paint, [illegible] 1.4 per cent by weight.

**Dilute suspension in water beaten in Waring blender for [illegible]

TABLE 2. BRAKE LINING COMPOSITION

	Primary shoe PC 3504 %	Secondary shoe PC 3442 %
SC-1 solvent	2.06	1.5
Gas	4.12	5.0
Polyrez 2231 cashew resin	4.74	5.2
3M Company NC 320 cashew resin	7.62	8.4
Water	3.09	2.5
Hexa	0.62	0.6
Carbon Black	--	0.8
Coal	5.16	11.0
Whiting	3.51	3.5
Iron Oxide, Red	--	0.5
Hycar 1411	1.03	1.0
Mapico	0.82	-
Barytes	2.78	-
Luminite Cement	0.52	-
7M06 Fiber	63.93	60.0
	100.00%	100.00%

mac
11/4/66

APPENDIX III

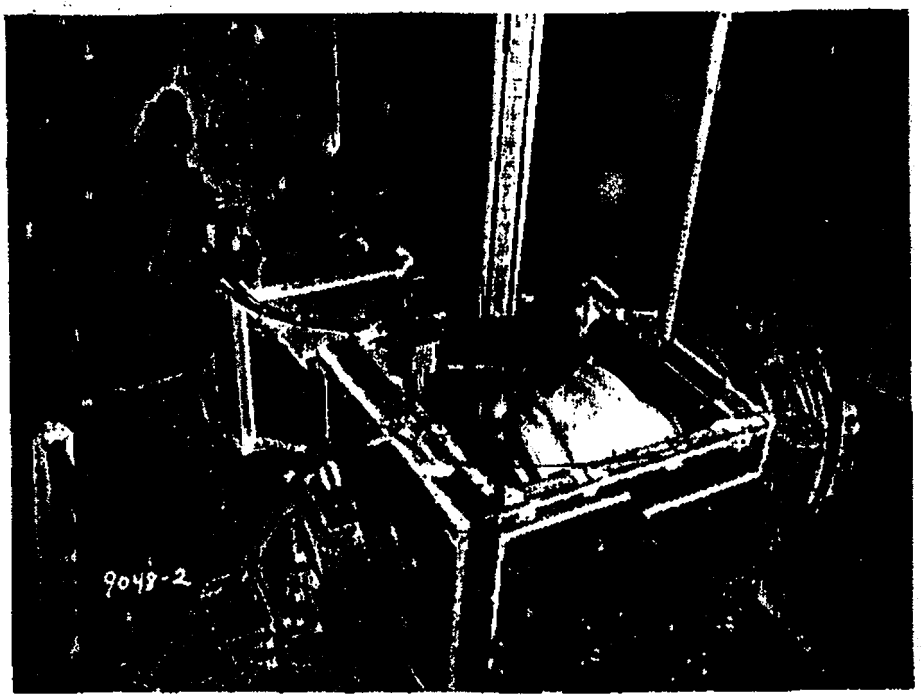


Figure 1

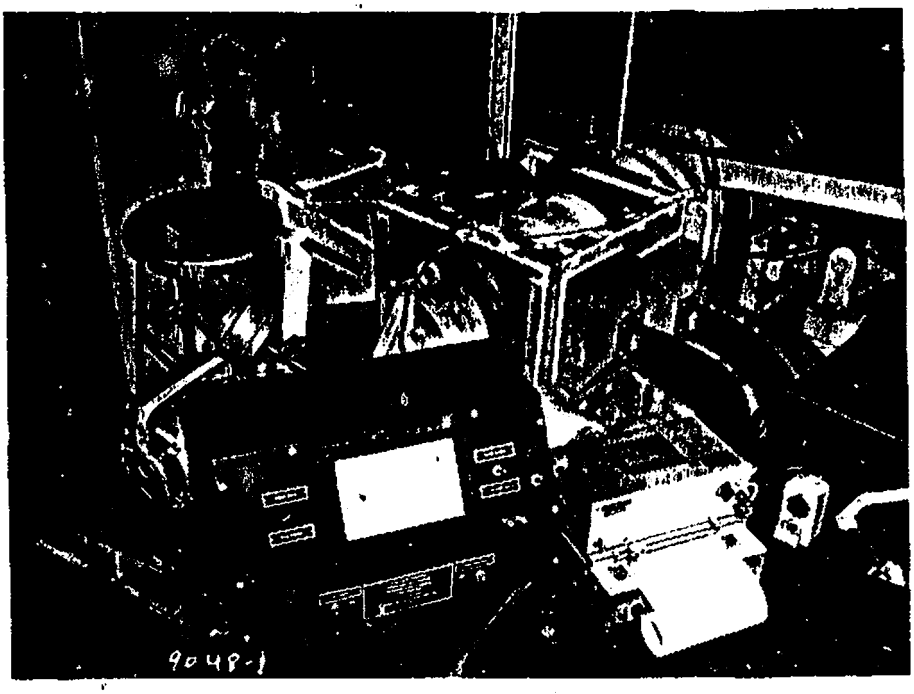
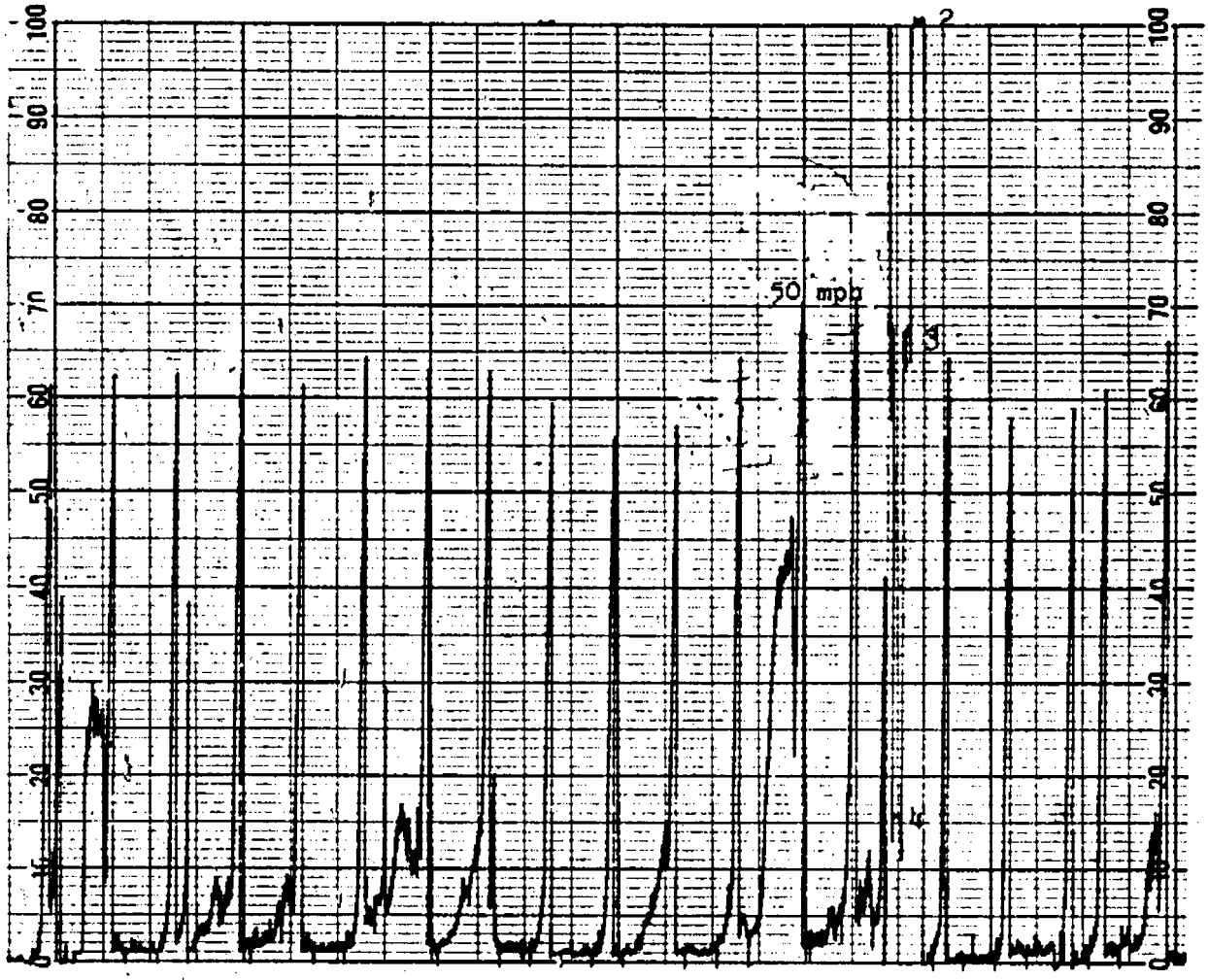
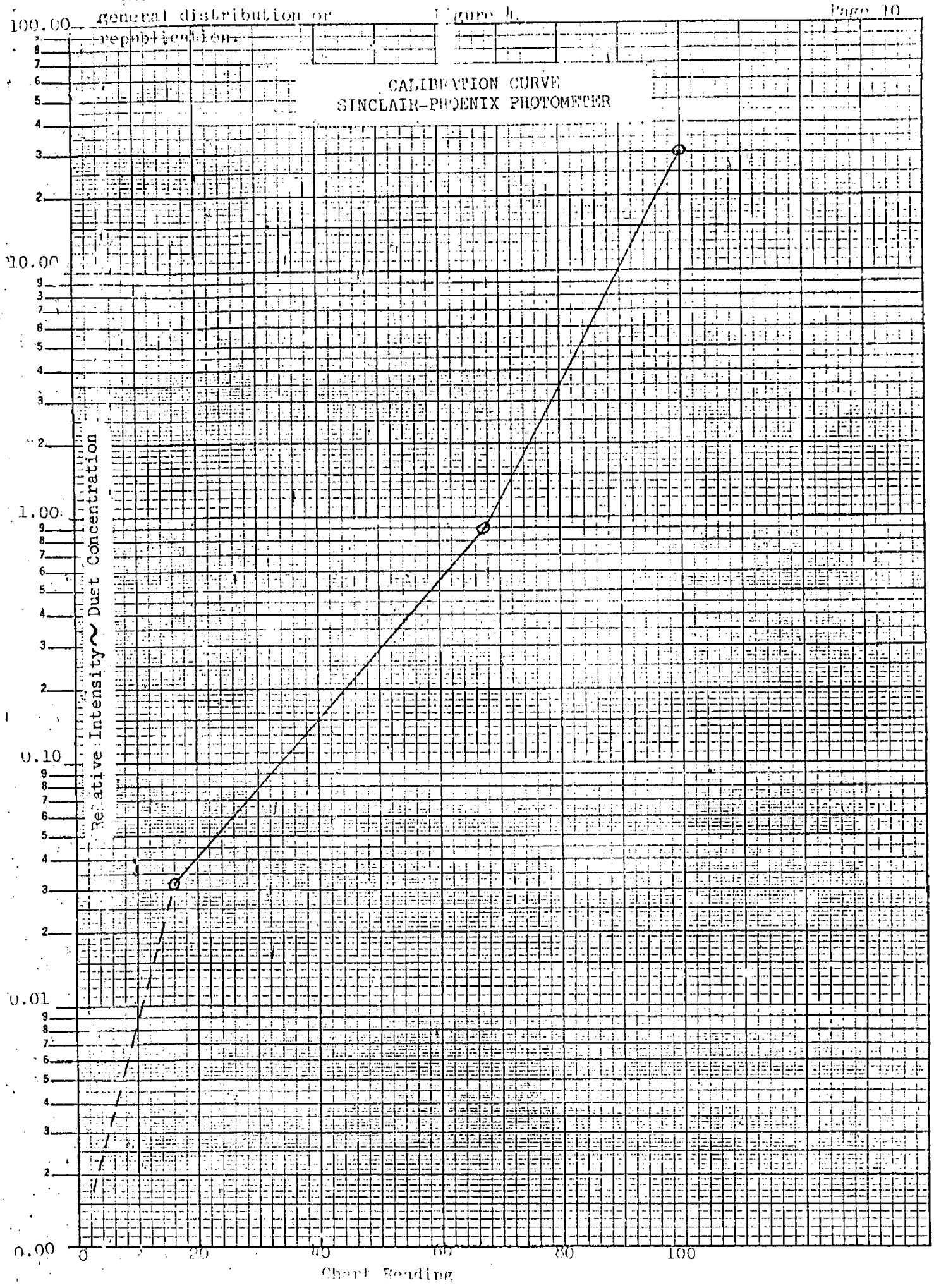


Figure 2

APPENDIX III

Figure 3




CALIBRATION CURVE
SINCLAIR-PHOENIX PHOTOMETER
Relative Intensity ~ Dust Concentration
100.00
10.00
1.00
0.10
0.01
0.00
0
20
40
60
80
100
Chart Reading

APPENDIX IV

References

1. Research report 456-T-86, January 20, 1964, "Petrographic and X-ray Diffraction Analyses of Brake Lining Wear Dusts", D. Bailey, J. P. McGourty.

2. Mechanical Design and Systems Handbook, Chap. 28, p 43, D. Sinclair, McGraw-Hill, 1964.

3 "The Fundamentals of Asbestos Friction Materials", R. T. Halstead, Paper Trade J., 118, p 30-33, March 2, 1944.

4. Biological Effects of Asbestos, p 196, J. G. Thomson, N.Y. Academy of Sciences, December 31, 1965.

5. Chem. Week, September 10, 1966.

6. The Friction and Lubrication of Solids, Vol 1, F. P. Bowden and D. Tabor, Oxford, Clarendon Press, 1950.

7. Report 456-Int-607, December 8, 1966, "Brake Lining Wear Dust - Evaluation by Light and Electron Microscopy", D. Bailey.

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JOHNS-MANVILLE RESEARCH
AND ENGINEERING CENTER

6/17

Report No. 456T-94

Date June 13, 1968

Title: WEAR PRODUCTS FROM BRAKE LINING - Nature of the Material

Requested by: H. G. Koch (F-381)

SUMMARY

Airborne brake lining wear dust was collected on a Gelman filter membrane mounted in an air tight enclosure (box). The enclosure contained a brake assembly which was connected to an inertia dynamometer. Wear dust was collected at three different temperatures (phases). The average temperature of Phase I was 175F; Phase II, 330F; and Phase III, 550F; simulating various traffic conditions. In addition, wear dust was collected from the brake assembly and the inner surfaces of the sealed box.

In Phase I a series of sets of stops were made. The airborne dust was collected at the end of each set of stops. Only one set of stops was made in Phases II and III.

A material balance study was made between the weight loss of the brake shoes and drum, and the amount of dust collected from the three sources. The airborne portion was approximately 48 per cent of the total dust collected from a total of 2926 stops. This value is high because all dust samples were contaminated with iron and to a lesser degree with stencil ink used to spray the inner walls of the box. The source of the iron is from the brake drum and from areas on the brake backing plate where appreciable metal wear was noted. Analyses show that most of the contamination occurred during Phase I. The actual amount of dust collected was about 30 per cent higher than the weight loss of the brake shoes and drum because of the metal wear of the backing plate which is not weighed. The amount of dust collected from Phases II and III was about 45 per cent of the weight loss of the brake shoes and drum. This difference is partially attributed to the loss of water of crystallization of chrysotile and volatilization of organic material.

Chrysotile fiber was detected only by the electron microscope technique. The maximum concentration of fiber in the airborne dust was found in Phase III to be 0.55 per cent. On the drum and in the box composite the maximum fiber content was 0.65 per cent (Phase I).

Due to the severe abrasion and heat generated in the braking operation, the bulk of the fiber (70 per cent of the lining) was converted to an amorphous silicate. The amorphous silicate formed appreciable amounts of forsterite in Phase III, indicating that surface braking temperatures reached at least 600C.

The only organic constituent actually identified in the wear dust was cashew resin. Additional smaller components were detected but not identified. A phthalate plasticizer, a contaminant from stencil ink, was present in all samples examined.

This study is a continuation and expansion of the work begun by Dr. Sinclair. (See Report No. 456-2506.)

For details see "Results of Analysis" of this report and Memorandum M456-386.

Contents: Summary, Materials Submitted and Methods of Analysis, Results of Analysis and Photomicrographs (Appendix I).

Reported by S. W. Wegrzyn
Analytical Chemistry Section

X-Ray Work by J. P. McGourty
Analytical Chemistry Section

Spectrographic Work by A. J. Sutherland
Analytical Chemistry Section

Microscopic Work by D. A. Bailey
Basic Chemistry Research Section

Chromatographic Work by H. N. Smith
Analytical Chemistry Section

dl

cc: H. M. Jackson - DH
K. V. Lindell - Asb DH
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S. Speil
J. Dec
E. M. Fenner
H. G. Koch
H. F. Remde
C. N. Thompson
S. W. Wegrzyn
Library (2)

MATERIALS SUBMITTED AND METHODS OF ANALYSIS

Materials Submitted

Laboratory Index No.	Description
A97-44-1	Airborne dust Sample 2, Phase I
A97-44-2	Airborne dust Sample 6, Phase I
A97-44-3	Composite dust from drum and box, Phase I
A97-44-4	Airborne dust Sample 1, Phase II
A97-44-5	Composite dust from drum and box, Phase II
A97-44-6	Airborne dust Sample 1, Phase III
A97-44-7	Composite dust drum and box, Phase III

Only the above samples were analyzed and the drum and box samples were composited.

Methods of Analysis

The amount of airborne dust was determined by weighing filter membrane before and after collection. All other dust samples were collected by vacuum and weighed.

The samples were submitted for the following analyses or examination: spectrographic, X-ray, infrared, microscopic, and gas chromatographic.

The amount of chrysotile fiber was determined by the point count method that has been used for determining the amount of fiber in water samples.

RESULTS OF ANALYSIS

Materia' Balance

Only in Phase I were sets of dust collected at various stops to duplicate previous work. The remaining phases had only one set of stops. The data for Phase I is as follows:

Run No.	Net Stops	Grams of Airborne Dust Collected
1	6 (oil leak)	--
2	136	0.2520
3	167	0.3330
4	139	0.2460
5	439	1.5036
6	1259	3.6067
Total	2146	5.9413
Weight of dust from brake assembly		6.3930
Weight of dust in box		2.9630
Total dust collected in Phase I		15.2973 grams

The following table contains data from the three phases:

	Phase I	Phase II	Phase III
Temperature	175F	330F	550F
Number of stops	2146	720	60
Total dust collected (gms)	15.2973	1.7256	8.7435
Airborne dust collected (gms)	5.9413	1.3561	5.1218
Per cent airborne dust collected	38.8	78.6	58.6
Loss in weight of primary shoe (gms)	2.805	0.855	5.420
Loss in weight of secondary shoe (gms)	8.390	2.210	12.370
Loss in weight of drum shoe (gms)	0.605	0.880	0.976
Total loss in weight of brake assembly	11.800	3.945	18.766
$\frac{\text{total dust collected}}{\text{weight loss of assembly}} \times 100$	129.6	43.7	46.6

Totals

Airborne dust	12.4192
All dust	25.7664
Per cent airborne dust	48.2
Loss in weight of brake assembly	34.511
$\frac{\text{total dust collected}}{\text{weight loss of assembly}} \times 100$	74.6

It is obvious that Phase I is heavily contaminated. About 30 per cent more total dust was collected than the weight loss of the brake shoe and drum. The total dust collected in Phase II and III is 43.7 and 46.6 per cent respectively, of the weight loss of the brake shoes and drum. The reason for the lower values is, in part, due to the dehydration of the chrysotile and decomposition of organic components in the lining. Details of the contamination are found further in this report.

It is interesting to note that the secondary shoe wears from 2 to 3 times faster than the primary shoe. Discounting contamination, the amount of airborne dust collected per stop is 2.8, 2.4, and 85.3 milligrams per stop, respectively, for Phases I, II, and III. The rate of accumulation of airborne dust is about 30 times greater at 550F than for either of the lower temperatures.

Spectrographic Analysis (per cent in dry basis)

	Phase I			Phase II		Phase III	
Sample No.	2	6	Composite*	1	Composite*	1	Composite*
Ignition loss at 800F	30.8	11.4	20.2	19.0	15.7	16.9	15.8
MgO (approx.)	17	9	16	24	21	20	25
SiO_2 (approx.)	17	9	14	24	21	21	25
Fe_2O_3 (approx.) by diff.	25	67	46	31	36	39	28
Al_2O_3	0.70	0.40	0.40	0.60	0.63	0.67	0.76
B_2O_3	-	-	-	-	0.15	-	-
BaO	0.24	0.22	0.24	0.32	0.30	0.29	0.30
CaO	1.0	0.90	1.1	1.6	1.7	1.7	2.5
Cr_2O_3	2.8	0.44	0.40	0.16	0.42	0.21	0.42
PbO	1.7	0.31	0.40	0.12	0.30	0.40	0.42
CuO	0.03	0.07	0.30	0.02	0.06	0.016	0.06
Mn_2O_3	0.12	0.35	0.24	0.19	0.20	0.23	0.25
MoO_3	-	0.02	0.4	-	-	-	-
NiO	0.10	0.14	0.18	0.20	0.17	0.21	0.22
TiO_2	3.8	0.70	1.2	0.08	1.7	0.08	1.7
V_2O_5	<0.001	0.0014	0.0013	<0.001	<0.001	<0.001	<0.001
Loss on drying at 105C	2.7	2.0	2.1	0.7	0.6	0.4	Nil

*The composites are dust samples from the brake assembly and the box.

Analysis of Drum Filings (in per cent as received)

Iron - major
Cr - 0.058
Cu - 0.17
Mg - 0.0013
Mn - 0.33
Mo - 0.028
Ni - 0.10
Si - 2.5
Ti - 0.026
V - 0.013

Spectrographic analysis shows that each dust sample collected is contaminated with an appreciable amount of iron, particularly Sample 6 and composite of Phase I. The iron content of the brake linings is at most several per cent by inspection of the formulation. It is estimated that there is roughly a 25-35 per cent iron pickup from the drum and from the area of the brake backing plate. The iron pickup is abnormally high in Sample 6 and the composite of Phase I. The minor constituents found in the dust samples confirm the iron pickup based on analysis of the drum filings.

The chief source of the chromium, lead, and titanium contamination is from the stencil inks used to spray the inner walls of the box. X-ray analysis shows that $PbCrO_4$ and TiO_2 are components of the stencil ink.

The ratio of MgO/SiO_2 in each of the dust samples is essentially the same as the ratio for chrysotile. The amount of SiO_2 and the MgO is reduced proportionally, in most cases, based on increase of the Fe_2O_3 content from brake drum contamination.

X-Ray

The following X-ray powder diffractometer diagrams were obtained and identified:

Sample	Identification
Phase I, Sample 2	lead chromate ($PbCrO_4$)
Phase I, Sample 6	halos
Phase I, composite	halos
Phase II, Sample 1	halos
Phase II, composite	halos
Phase III, Sample 1	forsterite ($3\ MgO.SiO_2$) magnetite (Fe_2O_3) chrysotile - possible trace
Phase III, composite	forsterite
Stencil ink (white)	TiO_2 (major); talc (minor)
Stencil ink (yellow)	lead chromite ($PbCrO_4$)

The broad halos on diagrams of the four samples indicate a considerable amount of finely divided or amorphous material.

TiO_2 and $PbCrO_4$ are contaminants from stencil inks as confirmed by spectrographic analysis. This is shown by the high level of lead, chromium, and titanium.

Infrared

The following infrared spectra were obtained:

Chart No.	Sample	Identification
U-2581	Phase I, Sample 2	amorphous silica or silicate and trace of organics
U-2582	Phase I, Sample 6	amorphous silica or silicate and trace of organics
U-2583	Phase I, composite	amorphous silica or silicate and trace of organics

Infrared (cont'd)

Chart No.	Sample	Identification
U-2584	Phase II, Sample 1	amorphous silica or silicate and trace of organics
U-2585	Phase II, composite	amorphous silica or silicate and trace of organics
U-2586	Phase III, Sample 1	forsterite and trace of organics
U-2587	Phase III, composite	forsterite and trace of organics
U-2642	stencil ink (white)	acrylic resin and TiO_2
U-2643	stencil ink (yellow)	acrylic resin and a phthalate
U-2644	alcohol solubles of Phase I, Sample 3	phthalate plasticizer
U-2645	alcohol solubles of Phase I, Sample 6	phthalate plasticizer
U-2646	alcohol solubles of Phase I, Sample 4	phthalate plasticizer
U-2647	alcohol solubles of Phase II, Sample 1	phthalate plasticizer
U-2648	MEK solubles of Phase I, composite	phthalate plasticizer
U-2649	MEK solubles of Phase III, composite	phthalate plasticizer

The infrared spectra show that in the first two phases, amorphous silica or silicate and small amounts of organic material were detected in the dust samples. In Phase III (550F), forsterite was formed by the dehydration of the chrysotile and subsequent transformation to forsterite due to heat. The presence of forsterite indicates that the temperature of the brake system in Phase III was at least 600C.

In addition to contamination of the dust samples by inorganic components of the stencil inks, an organic component, a phthalate plasticizer of the ink, was also detected in most of the dust samples. Acrylic resin was not detected.

Pyrolysis Gas Chromatography (PGC)

All samples were pyrolyzed under identical conditions and the fragments were analyzed by gas chromatography. The chromatograms of the submitted samples were compared with the primary and secondary brake linings.

The original brake linings showed identical chromatograms. The only identifiable organic constituent in the pyrograms was cashew resin. Samples 2 and 6 of Phase I showed no evidence of cashew resin. The composite of Phase I showed the cashew resin plus a number of other smaller fragments probably aryl-type components.

In Phase II both samples showed the large cashew fragment; the composite contained more than Sample 1. In addition, the composite showed a significant amount of one other fragment of much lower molecular weight, not common to Phase I.

Both samples of Phase III showed almost identical chromatograms consisting mainly of the large cashew fragment.

Light Microscopy

The major constituent of all samples is a smoky brown to opaque material which appears to be essentially amorphous. They occur in flakes and masses ranging in size from less than one micron to over 200 microns. A trace of carbonate was noted in each sample. A trace of quartz was found in Phase I, Sample 1 and composite. Phase II composite showed a trace of glass fiber.

Electron Microscopy

Electron micrographs at a total magnification of 30,000 X are attached to this report. The samples were prepared by a rubbing out technique to break up loose agglomerates. The micrographs show aggregates made up of very fine material, a few solid particles and traces of chrysotile fiber. (See Figures 1 through 7)

The per cent of chrysotile fiber was determined by a modified point counting method used for determining amounts of fiber in water samples. The counts from the electron plates were made by the Packings and Friction Material Department.

The results are as follows:

Sample	Per Cent Chrysotile
Phase I, Sample 2	0.531
Phase I, Sample 6	0.065
Phase I, composite	0.65
Phase II, Sample 1	0.087
Phase II, composite	0.255
Phase III, Sample 1	0.551
Phase III, composite	0.390

COPY FORM	INITIALS	DATE
	~~8/15~~	8/15

BOX NUMBER	SEGMENT NO.	REQUESTING PARTY
4-1162		G Castle

NOTES

Oracle test 1966-67

Research and Engineering Center
December 13, 1966

A. C. Smith

Asbestos-environmental Problems
Status Report October-November 1966

1. Packings and Friction Materials Division

Study of wear products from friction materials (J. Dec)

During the period October 1 through November 30, 1966 the wear dust collected from the special dynamometer enclosure was analyzed in detail. The results were unexpected in that asbestos fiber could be detected only by the electron microscope which indicated a maximum of 1.4 per cent by weight fibrous debris. This is in contrast to about 70 per cent by weight chrysotile fiber in the original friction material.

David Sinclair has accounted for the difference in fiber content by suggesting that high surface temperatures and severe abrasion convert the asbestos fiber into an amorphous mineral. He further demonstrates mathematically that the very high temperatures (2000F) required to break down fiber to this extent could be generated at the contact surface of a friction material even during "mild" braking in which the apparent temperature does not exceed 200F. This derives from the fact that the true area of contact in the friction couple is about one per cent of the apparent area.

From this work it would appear that the fear of large quantities of asbestos fiber being introduced into the atmosphere as part of the wear dust of friction materials is unfounded. However, the tests to determine the biological effects of such dust, regardless of its fiber content, are not complete, and we are therefore not in a position to draw final conclusions.

2. Pipe Division

A. An inexpensive inner coating for TRANSITE pipe (J. H. Swensen)

A development program (Project P-22) is under way to develop an "Improved Soft Water Coating for Potable Water Pipe." The present coating, based on asphalt, has become more and more unacceptable due to taste and odor problems. Efforts are being directed toward a clear coating which will not affect water quality. Polyterpene-type coatings have looked promising although their UV resistance now appears to be less than satisfactory. A coating developed within this program will have to be inexpensive and may fill the needs for a general TRANSITE pipe coating. It is hoped that the improved soft water coating can be commercialized in the first quarter of 1967.

B. Effect of water flow through TRANSITE pipe

A layout of a system for studying the effects of flow and water composition on TRANSITE pipe has been prepared, and an assignment has been placed on the Engineering Department. Probably this system will not be operational until the second quarter of 1967.

3. Fiber Glass Insulations

Residue from flow of air through fiber glass ducts, etc.(G. J. Hannes)

Initial tests run by the Kettering Institute with Owens-Corning Fiberglas duct indicated no measurable release of fiber into the air stream. Much more extensive tests are under way now in the O-C laboratories under the supervision of the Kettering Institute. Johns-Manville duct liners and duct board are part of these tests, which will include a variety of air flow conditions. Complete data will not be available until about March 1, 1967.

4. Building Products Division

A. Degradation products of asbestos felt built-up roofs (J. Q. Trice)

The Instrument Development Company of Reston, Virginia, a division of Resources Research, Inc., is preparing a preliminary engineering drawing and specifications for equipment which they propose for the actual weathering and collection of materials. Briefly the environmental chamber will consist of four components: (a) the mechanical chamber, (b) the radiation system, (c) the air handling system, and (d) the liquid handling system. Detailed information will be available from the Instrument Development Company by December 15.

We now believe that the actual samples for weathering will have to be prepared outside the environmental chamber because of the high concentration of material thrown from the hot asphalt and from working with the roofing felts. After the samples have been prepared, one will be exposed in the environmental chamber and a second exposed on the roof of the Research laboratory so that at least visual observations can be made comparing the performance of the two samples.

Materials produced or released during the weathering process will fall into three categories:

(a) particulate - which will be collected on membrane filters
(b) water-soluble - which will be picked up by the wash water which must also be put through a membrane filter in order to collect solids which are removed by washing
(c) vaporized materials - which will be collected at the low temperature traps in the air circulating system.

B. Degradation products of asbestos-cement materials

A program for sampling and testing materials has been drawn up. The test program will include an examination of field-exposed material which has been in service for many years as well as laboratory exposure of products. In the case of field-exposed products, since shingles are partially exposed and partially covered in use, it is possible for us to obtain good reference samples and analyze the changes that have occurred to the exposed surface.

A preliminary examination of some vertically exposed normal-cured products after long exposure shows the following.

JM - 23

Source of Samples	Products	Exposure Period	Thickness decrease during exposure, inches
JM office building, Manville, New Jersey	Dry process shingles	1918-1964	0.003 to 0.020
JM plant, Nashua, New Hampshire	Dry process shingles	pre-1926-1966	0.001
JM plant, Nashua, New Hampshire	Flat TRANSITE	1921-1966	0.006
JM plant, Nashua, New Hampshire	Corrugated TRANSITE	1924-1966	0.012

The small amount of weathering exhibited by these products points up the need for very precise measurements in this test program.

5. Flooring Division

Wear products from flooring materials (J. Q. Trice)

Experimental work has not yet been started in this program.

6. General Company Research

Organic material in asbestos fibers (F. L. Pundsack)

Cape S Blue, packed in paper bags and in jute bags, was obtained from the Manville Pipe Plant, and the organic content extracted. The blue fiber packed in jute bags contained up to sixty (60) times as much organic material as did the fiber packed in paper bags. Jeffrey chrysotile packed in paper bags and in jute bags is being analyzed in the same way, and data will be available soon.

We are working with a company named Analtech to develop methods of identifying all the trace organic substances present in asbestos.

It may be of interest to note that in 1965 in the United States approximately five (5) times as much benz(a)pyrene was released in the form of cigarette smoke as was contained in all the asbestos used in this country for all purposes in the same year. Incidentally, more than one-half the benz(a)pyrene associated with asbestos was contained in the approximately 40,000 tons of imported blue fiber.

F. L. Pundsack

ae

cc: F. J. Solon - GHQ
K. W. Smith,MD -GHQ

Research & Engineering Center
January 25, 1967

A. C. Smith

ASBESTOS - ENVIRONMENTAL PROBLEMS
STATUS REPORT - JANUARY 24, 1967

1. PACKINGS AND FRICTION MATERIALS DIVISION

A. Study of Wear Products from Friction Materials (Dec)

As indicated in the report dated 12/13, only 1.4% of the wear dust collected was asbestos fiber. No information has yet been received regarding the dust samples submitted by Dr. K. W. Smith for biological testing. No additional sampling of wear dust is planned until information on biological effects is obtained.

2. PIPE DIVISION

A. An Inexpensive Inner Coating for TRANSITE Pipe (Swensen)

A polystyrene coating has been formulated which has shown more than the required resistance to ultra-violet and which meets the AWWA requirements for water-pipe coating. Long-term adhesion has been satisfactory to date (two months exposure). A Commercial Recommendation will be issued on or about February 15.

B. Effect of Water Flow through TRANSITE Pipe (Swensen)

Plant Engineering has estimated the costs of constructing a system to study the effects of flow and water composition on TRANSITE pipe to be approximately $280,000. In view of the high estimated cost, the proposed program and system are being revised.

3. FIBER GLASS INSULATIONS

A. Residue from Flow of Air through Fiber Glass Ducts, etc. (Hannes)

As mentioned in the December 13 report, the extensive test program is continuing. Data will be available about March 1.

4. BUILDING PRODUCTS DIVISION

A. Degradation Products of Asbestos Felt Built-Up Roofs (Trice)

Based on specifications and quotation from Instrument Development Co., Reston, Virginia, an appropriation request in the amount of $25,000 will be submitted by January 27 for an environmental chamber. This appropriation will be accompanied by a detailed program and an estimated total

cost. Delivery of the chamber is promised for 16 weeks after receipt of order.

B. Degradation Products of Asbestos-Cement Materials (Trice)

Samples of Steam Cured TRANSITE (COLORLITH) showed a decrease in thickness of less than 0.003-in. after at least 12 years vertical exposure on the REC test decks. (Normal Cured products showed a decrease in thickness of 0.001" - 0.020".)

The program of finding and examining exposed samples has been expanded to include wet and dry process as well as normal and steam cured samples.

5. FLOORING DIVISION

A. Wear Products from Flooring Materials (Trice)

A program is being prepared to utilize a modification of the type of environmental chamber being recommended for the asbestos-roofing program (Item 4A above).

6. CORPORATE RESEARCH

A. Organic Material in Asbestos Fibers (Speil)

Research Memorandum #M411-489 (12/29/66) presented a review of the literature concerning the occurrence and properties of benzopyrene in the atmosphere from smoking, exhaust fumes, overheated tar and asphalt, the general burning of rubbish, coffee roasting, etc. The outer layer of a "well done" charcoal-broiled steak was found to contain a substantial quantity of benzopyrene.

Samples of asbestos have been sent to Case Institute of Technology and Mount Sinai Hospital for experimental work they are conducting on their own.

Work has continued with Analteck Inc., on improving methods of identifying trace organic substances present in asbestos. Most recent information shows Jeffrey fiber from a paper bag to contain 19-31 mg organic material/100 gm of fiber, whereas samples from a jute bag showed 4 mg at the center and 16 mg adjacent to the surface of the bag -- the reverse of information obtained with Blue fiber. Additional tests are in progress.

We cooperated with the Veterans Administration Hospital, Hines, Illinois, who are studying the relationship between asbestosis and mesothelioma, where their work with mice showed heat-treated asbestos gave a more toxic reaction than unheated asbestos.

Hamster lung tissue samples submitted by the Health Service Institute, Fairleigh Dickinson University, examined by electron microscopy, showed the presence of both amosite and chrysotile asbestos.

W. M. MacAlpine

etr

cc-C. B. Burnett, GHQ
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COPY FORM	INITIALS	DATE

BOX NUMBER	SEGMENT NO.	REQUESTING PARTY
5 1310		BARRY CASTLEMAN

NOTES

JOHNS-MANVILLE RESEARCH AND ENGINEERING CENTER

Date: December 8, 1966

Title: BRAKE LINING WEAR DUST - Evaluation by Light and Electron Microscopy

Requested by: D. Sinclair

Reason for Request

To determine what proportion of the dust may still be of a fibrous nature.

Description of Sample

Air-borne sample of brake lining wear dust collected on Gelman membrane filter. Sample recovered by removal of Gelman filter by cold MEK. (Notebook 723, p 141)

Methods

The material was examined microscopically in bright field, dark field, and by phase contrast. A portion of the sample was rubbed out and placed on carbon-coated electron grids, as outlined in Research report 412-Int-1825. Two of the grids were then shadow-cast. The rub-out technique breaks up agglomerates, but rarely fractures solid material. It does to a certain extent reduce the length of chrysotile fiber, but does not split individual fibrils.

Eight electron micrographs of the shadow-cast material were taken and printed at a total magnification of 30,000X (EMS 479, A to H). Also, two electron micrographs of rubbed-out material that had not been shadow-cast and one electron micrograph of material that had not been rubbed out were taken for comparison. An electron diffraction pattern of a small fiber in the rubbed-out material (not shadow-cast) was obtained. Two electron micrographs of air-borne brake wear dust are attached to this report: Figures 1 and 2, Appendix.

By means of a transparent grid with quarter-inch openings placed over the micrographs of shadow-cast material, a point-count analysis was made in which the maximum fiber content was determined. Any elongated, rectangular particle three or more times its diameter, but not exceeding 600Å in diameter, was treated as a fiber. Particles and fibers were weighted according to the length of their shadows as follows: Particles and fibers were found to cast a shadow approximately equal to their diameters, one-quarter of an opening in the grid. Particles were classified as spherical, shadow equal to one-quarter of a grid opening, one-quarter to one-half, one-half to one, one to two, and two or greater; and the appropriate factor was applied. Over 2000 particles (including fibers) were counted.

Samples collected from the brake drum and from the box were examined by optical methods and by electron microscopy for comparison with the air-borne material.

Results

Light microscopy. The material as seen under the light microscope consists of finely divided, smoky-brown agglomerates about 5 to 30 microns in size. These are generally translucent, but include small amounts of opaque matter. Some fines, about one-half micron to three microns are also present. No fibers could be detected in this sample under the light microscope.

Electron microscopy. Most of the material seen in the electron micrographs of brake lining wear dust occurs as rounded particles, forming aggregates. A few small fibers 200-300Å in diameter are also present, occasionally exhibiting the "hollow-tube" structure noted in chrysotile.

File 456

Notebook 3474, pp 30,34,49,67.

Fiber content by point-count method. (The measurements were made by J. Lawler of Friction Materials and the work was supervised by D. Bailey.)

The percentage of fibers in a total of 2645 units counted, as calculated on a volume basis amounts to 1.4 per cent. Units counted as fiber ranged from about 200Å to about 600Å in diameter, and from 600Å to about 1.3 microns in length.

Electron diffraction. An electron diffraction pattern of a single fiber in the air-borne sample of brake wear dust was obtained. This pattern coincides with electron diffraction patterns which were obtained from single chrysotile fibers.

Discussion

The values obtained by the point-count method as outlined indicate that less than 2 per cent of the air-borne sample examined occurs as small fibers. These fibers are of the order of 200Å to 600Å in diameter and range from 600Å to 1.3 microns in length. Note also that somewhat longer fibers occur in brake wear dust that was not rubbed out. For example, a fiber 3 microns in length is shown in Figure 1, an electron micrograph of brake wear dust that was not rubbed out. Fibers of this length are of rare occurrence in the samples examined, and are usually attached to particulate material, as in Figure 1.

Samples obtained from the drum and the box were found to be comparable to the air-borne sample in general appearance and fiber content.

On the basis of an electron diffraction pattern obtained from a fiber in the air-borne sample of brake wear dust examined, and found to coincide with an electron diffraction pattern obtained from a known chrysotile fiber, it is apparent that some or all of the fibers in this sample of brake wear dust still retain the chrysotile structure. Thus, based on the methods used, the amount of chrysotile fiber that can be recognized as such in this sample does not exceed about 1.4 per cent on a volume basis.

Reported by: D. Bailey

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APPENDIX

1 micron

Figure 1. Brake Lining Wear Dust. Material ashed at 427°C, suspended in water and dried on formvar substrate. (Not rubbed out.)
Magnification 20,000X EMS 469A

APPENDIX

Figure 2. Electron Micrograph of Brake Lining Wear Dust (Rubbed out and shadow-cast).

EMS 479H

Magnification 30,000X