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Research & Engineering Center
September 8, 1970

MEMO FOR FILE:

VISIT TO INLAND DIVISION OF GENERAL MOTORS - AUGUST 31, 1970
Brake Lining Decomposition Products

Dr. Merle Gibson, Medical Director of the Inland Division of General Motors, commented during the J-M Research Center session of the Asbestosis Course held June 15 through 18, 1970, at Mt. Sinai Hospital, that results of work at Inland did not agree with the data presented by Jerry Lynch on the decomposition of brake lining materials. He agreed to set up a meeting with Dr. George Rappaport, head of the Chemical Laboratory at Inland's Dayton laboratory, to review both Inland and J-M research on this project.

After several brush-offs, I was able to arrange a meeting with Dr. Gibson and Dr. Rappaport on August 31. Also present during part of the meeting were Mr. G. W. Beck, Chief Engineer for Inland, and Mr. J. (Joe) H. Overwein, Assistant Chief Engineer.

Summary

Dr. Rappaport doubted the validity of the general data presented by Jerry Lynch on the breakdown of brake linings. After reviewing J-M's data and discussing peripheral information, he is convinced of the validity of our data showing less than 1 per cent chrysotile content. He suggested, as a final test, that the biological effect of the brake lining decomposition products be determined by animal tests. These may be sponsored by General Motors with Dr. Selikoff. Dr. Gibson still believes asbestos to be the main cause of lung cancer, and objects to any additional input to the atmosphere no matter how slight. I doubt if he can be convinced otherwise.

Discussion

Dr. Rappaport was quite frank in his discussion, especially when Dr. Gibson was not present. Inland has done no significant work on capturing and analyzing reaction products from brake wear. They were planning to begin a project in the near future.

Dr. Rappaport had been asked to comment on the validity of Jerry Lynch's results. He reacted unfavorably to the paper and did not accept any conclusions because the paper:

1. presented only approximate fiber concentrations;

2. gave no detailed experimental techniques;

3. did not define the technique for "quantification" of fiber content; and,

4. did not define the effectiveness of collecting all decomposition products.

He was also concerned about whether the decomposition products, whatever they might be, were in themselves carcinogenic.

The following J-M reference material was used as a basis for discussing our work and answering Dr. Rappaport's questions.

1. Research Report 456-2506 (December 19, 1966) - STUDY OF WEAR DUST FROM BRAKE LINING, written by D. Sinclair.

2. Research Report 456-T-94 (June 13, 1968) - WEAR PRODUCTS FROM BRAKE LINING, written by S. W. Wegrzyn.

3. Research Memo M456-386 (November 8, 1967) - COLLECTION OF WEAR DUST FROM AUTOMOTIVE BRAKE ASSEMBLY DURING INERTIA DYNAMOMETER TEST, written by W. R. Randolph.

4. Research Report 404-67 (August 3, 1970) - METHOD FOR THE QUANTITATIVE DETERMINATION OF CHRYSOTILE FIBER IN SAMPLES FROM VARIOUS SOURCES, written by A. F. Burns, K. L. Jaunarajs, and G. P. Reimschussel.

The discussion included:

1. A re[illegible]of test apparatus and techniques, with special refe[illegible]to the millipore system of collecting samples, and [illegible]own efficiency in collecting all particulate decom[illegible]tion products.

2. The techniques for quantifying fiber, including the previous point count method and the more recent radioactive tracer method.

3. The quantitative test data showing that 50 to 80 per cent of the wear products were collected as either airborne or "in the box" samples.

4. Analytical data on both the airborne material and the composite material illustrating the collection of all residual products from decomposition of asbestos (equal MgO and SiO_2 contents).

5. Pictures of airborne and total composite samples.

6. Discussion of amorphous material vs fosterite in the decomposition products, with different severity of wear as evidenced by average drum temperatures of 175, 330 and 550F, respectively.

7. Actual detailed "chrysotile" contents in the various samples and their relationship to the chrysotile content in the original product.

We also discussed certain subjects which Dr. Rappaport indicated he was particularly interested in. These included:

1. "Asbestos" bodies vs ferruginous bodies.

2. Factors influencing respirability of fibers, including Timbrell's work and recent Battelle work on retention of extremely fine particulate matter.

3. The proposed programs on the effect of fiber diameter, fiber length, and aspect ratio, including J-M programs, Webster's work, and others. Dr. Rappaport was particularly concerned with the effect of particle size and fiber diameter of the decomposition products, and its relation to respirability.

4. Extraction of minerals from lung tissue, including low temperature ashing, and hydroxide of Hyamine treatment.

After a full morning's discussion, Dr. Rappaport indicated to Messrs. Beck, Overwein, and Dr. Gibson that he was satisfied the decomposition products, in fact, contained only very small quantities of chrysotile. He suggested the desirability of conducting tests to show that these decomposition products were not biologically harmful and calculating the actual "net input" of chrysotile to the ambient air from the decomposition of brake linings based on our data and known brake lining statistics.

(We have already recognized the complexity of such an undertaking in our calculations on the fiber contributed by decomposition of asphalt asbestos paving. For example, how much fiber is removed per day from the atmosphere by fall-out, rain, wind, migration, etc., as compared to the input from any source of contamination.)

General Motors, through Dr. Gibson, is seriously considering funding work at Mt. Sinai, but no specific program has apparently been defined. Inland personnel were invited to visit us at the Research Center at any time to discuss the problem and any of their suggested programs. I will send Dr. Rappaport those portions of the above-mentioned Research reports which can be released without disclosing proprietary information.

Dr. Gibson is still a firm believer that asbestos is the major, positive cause for lung cancer. I think he is overpowered by the Selikoff mystic and that it is worthless to try to convince him otherwise then by direct statements from Dr. Selikoff. However, the others present at the meeting could probably be convinced that no problem exists by a few animal experiments with calcined asbestos, calcined serpentine, and brake lining wear material.

S. Speil

SS/rs

cc:
J. R. M. Hutcheson, Asbestos Plant
H. M. Jackson, DH
F. L. Pundsack
L. R. Blair
Att: J. Dec
E. M. Fenner
H. G. Donovan
J. P. Leineweber
W. C. Streib

Research and Engineering Center
March 6, 1967

File: 259-1

F. L. Pundsack

Study of Wear Dust from Brake Lining
(Excerpted from Dr. David Sinclair's Report
456-2506)

We request permission to send the attached excerpts from this report to Mr. J. R. Lynch, Public Health Service Laboratories, 1014 Broadway, Cincinnati, Ohio.

Mr. Lynch has carried out a study of brake lining wear dust using specimens collected under a variety of test conditions at the laboratories of the American Brake Shoe Corporation at Mahwah, New Jersey. His results are in general accord with those of David Sinclair. Mr. Lynch observed very little if any residual chrysotile fiber except in the case of "panic" stops which deteriorated the resin and allowed the release of a few fiber clumps.

During S. Speil's visit to the Public Health Service Laboratories, Cincinnati, Ohio on December 7 and 8, 1966, Mr. Lynch indicated that he intended to publish his data as soon as possible. He welcomed the opportunity to include any substantiating data which Johns-Manville might be able to furnish.

We believe that the publication of information pertaining to the breakdown of chrysotile fiber during the wear of brake linings would be more convincing and would receive more publicity if presented by an unbiased source such as a government laboratory than by Johns-Manville.

May we have your permission to send this excerpt to Mr. Lynch.

S. Speil

H. G. Koch

SS:mef

Enclosures

Since 1945 :-

Principal Ingredients In Many J-M Automotive Friction Materials:

85
173

Phenolic resins (phenol, cresol and some xylol used)
Cashew nut shell polymers (long chain phenolics)
Butadiene-styrene type polymers (synthetic rubber)
Sulphur
Rubber accelerators

Asbestos fiber
Microcel

Barytes
Zinc oxide
Lead oxide (litharge)
Carbon black
Graphite
Anthracite coal

Brass
Zinc
Lead
Copper

Coal tar products in asb tape impregnation before 1945 in automotive linings & industrial — now used only in industrial.

11/4/64

9/14/66

Bill. Koch - [illegible]; Brake lining dust

Designed enclosure to go around complete brake - very fine filter both side. Collected 12 grms dust: -

(a) outlet filter - [illegible] 2.7 gm.

(b) in drum ([illegible]) = on [illegible]

(c) Disassembled brake & dust

No asbestos (fibrous material) in samples -

= no chrysotile [illegible]

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

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 (ID #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, GH
A. C. Smith
L. R. Blair
F. L. Pundsack
H. G. Koch
File

Research and Engineering Center
March 14, 1967

File 259

F. J. Solon - GHQ

Brake Lining Wear Dust

Attached is some self-explanatory correspondence from Bill Koch and Sid Speil requesting permission to release certain information on the study of wear dust from brake lining to Mr. J. R. Lynch of the Public Health Service Laboratories. A copy of the information which they propose to release is attached, too.

I would like to have your opinion on whether or not this information should be released.

F. L. Pundsack

F. L. Pundsack

ae
Enc.

P.S. Would you please return the two photographs attached to the report. These are the only copies we have at present.

FLP

4/20 FJS - Advised that he enthusiastically approved collaboration w USPHS on this project. Publication under their auspices will carry considerable weight.

4/2 Advised FLP of approval.

Research & Engineering Center
September 30, 1970

C. Sheckler, DH

BIOLOGIC EFFECT OF BRAKE DRUM WEAR DUST

On page 10 of your recently distributed history of J-M health research you state "Also, in July, 1968, the Industrial Hygiene Foundation completed work on another research project for Johns-Manville -- a study of the effect of automobile brake-drum dust on the lungs of laboratory animals. This research showed that brake-drum dust is biologically inert, producing minor, reversible lesions of the lung when injected into the trachea of rats and hamsters".

Drs. Gibson and Rappaport of the Inland Division of General Motors are very much concerned whether brake drum dust produces any biologic effect. Dr. Rappaport indicated to me that he was satisfied that brake wear was not a significant contributor of chrysotile to the atmosphere based on our well-documented work at the Research Center. (For your information, I am attaching a copy of my memo on my recent visit to Inland.)

Inland was considering establishing a program with Selikoff to study the effect of brake lining wear dust. If the results of Dr. Gross' work were made available to them, I believe they would be satisfied. If this information has been reported by Dr. Gross, I would appreciate receiving a copy of it, with your permission to forward it to Inland Division of General Motors.

S. Speil

SS/rs

Attachment

11/5

GHQ
November 4, 1970

S. Speil - Research

BIOLOGIC EFFECT OF BRAKE DRUM WEAR DUST
YOUR LETTER OF 9/30/70

I have reviewed the files in relation to the work reported in the History of Johns-Manville Health Research.

The report referred to was a Preliminary Study of Brake-Drum Dust: Comparative Pathogenicity, by Dr. Paul Gross, dated February 14, 1967. I am enclosing a copy of this report for your file and distribution to Drs. Gibson and Rappaport of the Inland Division of General Motors, if you consider it to be useful.

C. L. Sheckler

CLS:mw
Attach.

NOV 9 1970

Research & Engineering Center
November 5, 1970

C. L. Sheckler

BIOLOGIC EFFECT OF BRAKE DRUM WEAR DUST
YOUR LETTER OF NOVEMBER 4, 1970

Thank you very much for sending me Paul Gross' report on the "Preliminary Study of Brake-Drum Dust: Comparative Pathogenicity".

I do not intend to send this to Drs. Gibson or Rappaport since the conclusions arrived at in this report cannot in any way be related to the problem of carcinogenesis. They refer, instead, only to the effect of the material on the connective tissue, that is, the fibrotic effect.

Thank you again for sending me this information.

S. SPEIL

SS/rs

Research and Engineering Center
June 2, 1967

S. Speil

Asbestos in Brake Linings Research

Details of the investigation to which you refer are included in SAE paper 670511 "Chemical Changes at Brake Wear Surfaces" by R. L. Gatrell and T. P. Schreiber.

A group of interesting papers were presented at the same meeting, most of them by General Motors Technical Center people. Although copies of several of these papers are in circulation, they are of such interest to so many of our men that I am asking Miss Kinder to order as many of them as are presently available. They can be routed to you first, and I would appreciate a chance to read them after you have looked them over. A list of the papers follow:

670501 Conditions Upsetting Brake Lining and Drum Compatibility - R. W. Kiekel, Carlisle Corp.

670502 Brake Linings as Related to Brake Performance - R. E. Nelson, Abex

670509 The Story of the "Beta" Group - An Unusual Organization Working on Brake Lining Problems - R. E. Antheil, Inland Mfg. Div., GMC

670510 Laboratory Evaluation of Brake Lining Materials - A. J. Burkman and F. H. Highley, Engrg. Staff, GMC

670511 Chemical Changes at Brake Wear Surfaces - R. L. Gatrell and T. P. Schreiber, Res. Labs., GMC

670512 New Devices to Assist in Friction Material Development - Richard Musschuk, Inland Mfg. Div., GMC

670513 Development of a Slip-Stick Measuring Device for Laboratory Noise Evaluation of Brake Linings - John Wiley, GMC

670514 Application of Infrared Spectroscopic and Gas Chromatographic Techniques to Brake Lining Development George Rappaport and Gerald Goldfinger, Inland Mfg. Div., GMC

Continued....

I agree that it would be well to discuss in detail with Messrs. Gatrell and Schreiber the work which they reported in No. 670511. I know that you are particularly interested in the techniques for examination of char film, as well as the effects of thermal degradation on asbestos.

I would be particularly interested in getting their views on a basic research which I would like to carry out at this location into the mechanism of friction fade and recovery. We believe that these are related to the formation of the char film.

I understand that you would be available for a vist to the General Motors Laboratories in Detroit on any of the following days: July 20, 21, 25, 26 and 27. I would also be available on these days and would like to accompany you. Since I will be away for the next three weeks, I am asking Hank Gilbert by copy of this letter to try to set up a date with General Motors through our Detroit office.

H. G. Koch

HGK:mfd

cc: H. M. Jackson - DM
F. L. Pundsack
K. L. Kinder
J. Dee
H. W. Gilbert
File
C

Another idea came from New York state comptroller Arthur Levitt. He asked that the laws be changed so the Government could set price ceilings on drugs essential to human life. This would permit drug developers to recover costs and get a reasonable return on invested capital and outlaw what he considers excessive profits.

Witnesses at next week's hearings will probably be several physicians and Dr. Richard Burack of Harvard. He is the author of a new book, "Handbook of Prescription Drugs," which purports to describe how the drug industry is gouging the public.

Sweat components, skin lipids are mosquito repellents

Lactic acid, a normal constituent of human sweat, and skin lipids act as mosquito repellents. The acid is one of three sweat components that repel the insects when tested in an olfactometer, Dr. W. A. Skinner, executive director of life sciences research at Stanford Research Institute, Palo Alto, Calif., told the ACS Santa Clara Valley Section. Identity of the other two is being investigated.

Dr. Skinner heads a four-man team at SRI that is seeking to pinpoint naturally occurring mosquito repellents and attractants in man. He is working in conjunction with a group at the University of California's medical center in San Francisco under Dr. Howard Maibach. That group is spearheading the entomological and dermatological aspects of the problem.

Development of improved methods that will safeguard man from mosquito bites is the goal of the study.

Collecting sample
Tie-in between sweat and skin lipids

The U.S. Army Medical Research and Development Command is sponsoring the project. It is part of a broader study aimed toward control of mosquito-propagated diseases.

"It's now clear that some people are more attractive to mosquitoes than others," Dr. Skinner says. Components of sweat and skin lipids may be the key to this phenomenon, he notes.

The UC group devised some novel monitoring techniques. One of these consists of noting the number of seconds that elapse before three out of six mosquitoes (enclosed in a screen cage) probe when the screen is exactly 1 cm. above the forearm of the person being tested. The reading is the PT—probe time—50 for the individual.

The medical center team has been running PT 50 measurements on a large sampling of people. Values range from 10 to 40 seconds for most. A small percentage of those tested show a PT 50 reading below 10 seconds (they are very attractive to the mosquitoes), while some rate higher than 40 seconds (they are less attractive).

Another device used is a small cage olfactometer which consists of a screened cage with two inlet ports through which a stream of air passes. The air going through one of the ports first sweeps over a sample of sweat or skin lipid. Mosquitoes in the cage veer toward or away from the latter stream depending on whether they are attracted or repelled by it.

Factors that both attract and repel mosquitoes occur in human sweat. The balance of the two types of components probably varies in different individuals, which would account for the different degree of attraction to the pests. Dr. Skinner hopes that gas chromatographic analyses, now under way, will reveal the identity of the agents.

There is an interesting tie-in between the lipid repellency and the sweat attraction factors, Dr. Skinner says. For example, the SRI workers find that a person with a sweat composition that attracts mosquitoes usually has a lower concentration of repellent in his skin lipids.

In addition to the identification of lactic acid, the study points up a number of other clues to the structure of naturally occurring repellents. Examples include:

- Liquid-liquid extraction with diethyl ether of sweat at pH1 yields a highly repellent fraction containing a mixture of hydroxy fatty acids besides lactic acid.
- Triglyceride and unsaturated hydrocarbon fractions in skin lipids show evidence of repellency.
- Skin lipid fatty acids in the C_8 to C_{11} range are repellents; the higher-molecular-weight fatty acids are not.

"Identity of the attractants and repellents will be a major step toward devising better methods of preventing mosquito bites," Dr. Skinner says. "A topical or a systemic repellent may evolve from this knowledge. Or we may be able to devise a diet, or develop a drug, that will influence preferential biosynthesis of the natural repellent materials."

Break-in period improves performance of brake linings

An analytical chemist and a physicist at General Motors' research laboratories have found, with the aid of electron microprobe analysis and infrared spectrophotometry, why auto brake linings work better after a break-in period than before. The improved performance is due to a calcined asbestos layer that forms on lining surfaces after a little wear. The GM work also shows that experimental preconditioned linings containing added calcined asbestos work better than regular linings, chemist R. L. Gatrell told a Chicago meeting of the Society of Automotive Engineers.

The research is part of a company-wide effort to develop improved frictional materials, particularly for organic disk brake linings. GM and other brake engineers have long known that brake linings develop a thin, dark layer, sometimes called a char layer, during the break-in period, Mr. Gatrell explains. But they have not known what this layer is.

In explaining the choice of the electron microprobe technique, Mr. Gatrell says that the method is uniquely suited to studying very thin films. In addition to giving a view of the surface, like an electron microscope does, it also chemically analyzes the surface. Also, it probes only 1 to 2 microns into a surface.

Using this method, physicist T. P. Schreiber examined cross sections of samples of worn lining. He found a surface layer with a higher electrical conductivity than the substrate in areas where asbestos constitutes the lining surface. This layer is about 8 microns thick.

The GM workers also observed that when the electron beam was focused for 30 seconds or more on a substrate area containing asbestos, the area's conductivity increased until it resembled that of the surface layer. As no chemical change could be detected, they assumed that heat generated by the electron beam had decomposed the asbestos. Asbestos, when heated to 1470° F., decomposes into four [illegible] forsterite, and [illegible]

The GM workers then turned to IR analysis to examine worn material from a brake lining to see if it did indeed contain calcined asbestos. They compared the IR spectra of the debris with that of commercial asbestos and calcined asbestos. They found that the debris spectrum has a band at 870 cm⁻¹ characteristic of the calcined material.

Following up this finding, experimental linings were made containing 5, 20 and 30% of calcined asbestos added to a regular lining formulation. Laboratory friction tests showed that the base lining faded—started to lose frictional properties—at 600° F. The 20 and 30% test samples showed improved performance before they were broken in. For instance, the 20% sample showed a distinct recovery in its coefficient of friction at 650° F. during its first test run. When fully broken in, all three test samples showed better frictional properties over a wider range of temperatures than did the base material.

Mr. Gatrell explains that further and more prolonged laboratory tests eventually proved the sample with 20% asbestos to have the best and most consistent properties. He says these tests were so encouraging that this lining has been tested in field runs. It has performed satisfactorily in both level country and in the mountains.

Selenium-containing inorganics in paper may play cancer role

Selenium in inorganic compounds is one of the most toxic substances known and may be an important cause of lung cancer and emphysema, says Dr. Philip W. West of Louisiana State University. Selenium is found in relatively large quantities—about 10 p.p.m.—in cigarette paper and to a significant degree in most other kinds of paper. Smoking thus may be the immediate danger to some people, but burning of trash containing a large amount of paper could affect nonsmokers too, he told a joint meeting of the Baton Rouge sections of the American Chemical Society and American Institute of Chemical Engineers. He received the annual Charles E. Coates Memorial Award at the meeting.

Dr. West says his conclusions are based on preliminary studies of selenium in tobacco and papers. Numerous further studies are needed, he adds. These should include development of additional analytical methods, [illegible] selenium and [illegible] compounds [illegible] levels of selenium [illegible]

Coates award winner West
6.5 p.p.m. selenium in C&EN

nal combustion engines, and ways for ultimate disposal of any captured selenium compounds.

At present, other work is under way, Dr. West notes. One study, by Dr. James P. Lodge, Jr., of the National Center for Atmospheric Research, Boulder, Colo., involves aerosol production of some of the various forms of selenium. The aim of this work is to find the proper particle size range for use in animal exposure studies. Another area involves study of how effective cigarette filters are in removing selenium.

So far, some 70 different kinds of paper have been investigated at LSU and found to contain selenium. The selenium content varies widely with the type of paper. Typical newsprint has 4 p.p.m. selenium; mimeograph paper, 0.7 p.p.m.; rice paper, 5.6 p.p.m.; paper towels, 1.2 p.p.m.; a bond paper, 1.4 p.p.m., and stock that C&EN is printed on, 6.5 p.p.m.

Tobacco in U.S.-made cigarettes has between 2 and 4 p.p.m. selenium, much less than does the paper. Two kinds of cigarettes made in the U.S.S.R. had 6.8 and 6.4 p.p.m. of selenium in the papers and 0.8 and 1.4 p.p.m. of selenium in the tobaccos. "Paper" used to wrap some U.S. cigars contains more than 10 p.p.m. selenium.

"Selenium probably comes into lungs as the di- or trioxide," Dr. West says. "Then, in the presence of water, it becomes selenous or selenic acid. No data are available on the cumulative effects of selenium compounds on tissues."

The method which Dr. West and his coworkers use to determine selenium is the ring oven technique. A heated, cylindrical metal block is used [illegible]

in filter papers. Color and its intensity identifies the selenium and indicates quantities present.

Selenium has long been known to be very toxic. Hydrogen selenide, for example, is about 200 times more toxic than hydrogen cyanide, Dr. West says. Selenium oxychloride is such a vesicant that it reacts violently with human skin and forms a "burn" or open lesion. In the U.S., the maximum allowable concentration of selenium in potable water has been set at 50 p.p.b.

Selenium is found in significant quantities in soils in the Rocky Mountain states and western plains states. Vegetation growing in soils of relatively high selenium content may concentrate selenium in them. Cigarette papers are made from flax straw which is grown west of the Mississippi River, where soil selenium is relatively high. This can account for the high amounts of selenium found in cigarette papers.

Some plants require selenium for growth; these are called selenium indicator plants. They may concentrate selenium in their tissues 100 times or more above that of the soil in which they grow.

Selenium's effects on animals has long been noticed, although the effects have been only recently attributed to selenium. "Blind staggers," "alkali disease," or "praying disease" in cattle have been noted as far back as the 13th century, when some of Marco Polo's animals suffered from alkali disease in western China after eating seleniferous vegetation that is now known to grow in that part of the world.

Scientists are also investigating selenium in the atmosphere. Dr. Yoshi- [illegible] b

Research & Engineering Center
May 29, 1967

File: 456

H. G. Koch

F

Asbestos in Brake Linings

You may already have seen the attached brief summary from C&EN, May 29, 1967 issue. Insofar as the possibility of improving brake lining by incorporating calcined chrysotile is concerned, this is a matter for your research people. However, I was particularly intrigued by the reference to the use of electron microprobe and infrared analysis to study the think, dark char layer on the worn brake lining.

R. L. Gatrell and T. P. Schreiber, of the General Motors Research Laboratory, have come to the same conclusion that we have; namely, that the debris from the brake lining was similar to that of calcined asbestos. The article states, "they found that the debris spectrum has a band (infrared) at 870 cm.-1, charatteristic of the calcined material". Although they state that "asbestos when heated to 1470F decomposes into four materials: quartz(?), enstatite, forsterite, and water", they do not specifically state that they were able to identify any one of these compounds individually in the product.

If you have good contacts with the GM Research Center, you may want to set up a meeting to discuss their work and their results from a scientific standpoint. If so, I would like to participate. If you do not have good contacts, I would be glad to pursue this myself and discuss with the GM Research people their results as part of our general program of studying decomposition products. Your comments and those of others receiving this letter would be appreciated before I proceed further.

S. Speil

SS/rs

cc: H. Jackson, DH
F. L. Pundsack
E. M. Fenner
J. P. Leineweber

Division Headquarters
November 4, 1964

KWS	
CLS	11/6

Dr. K. W. Smith - 2nd Floor

As per our discussion, herewith is a list of the ingredients generally found in J-M automotive friction materials.

R. T. HALSTEAD

JOHNS-MANVILLE RESEARCH AND ENGINEERING CENTER

Report No. 456-T-86

Date January 20, 1964

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 — F. L. Pundsack

Reported by D. Bailey — D. Bailey

X-ray Diffraction by J. P. McGourty — 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)

F

D/J

File 9/12

Subject: Brake Lining Dust — Microscopical Examination

K – Lawrence
make file
Stickers project

Dr. K.W. Smith

Complying with your request in our phone conversation of May 6th, I have searched through the technical notebooks covering microscopy for 1964 and 1965. I regret that no record covering your informal request for examination of brake lining dust was made. However, I do recall examining the dust via the optical microscope at magnifications up to 500x, and I was unable ~~to detect~~ by the method used to detect anything that could be shown to be fibrous.

Don Bailey

[redacted]

Since 1945:-

Principal Ingredients In Many J-M Automotive Friction Materials:

58
123

Phenolic resins (phenol, cresol and some xylol used)
Cashew nut shell polymers (long chain phenolics)
Butadiene-styrene type polymers (synthetic rubber)
Sulphur
Rubber accelerators

Asbestos fiber
Microcel

Barytes
Zinc oxide
Lead oxide (litharge)
Carbon black
Graphite
Anthracite coal

Brass
Zinc
Lead
Copper

Coal tar products in asb. tape impregnation before 1945 in automotive linings & industrial - now used only in industrial

11/4/64

General Headquarters
August 2, 1967

S. Speil - Finderne

Asbestos Health Meeting - July 6
File 259

As you requested, I have attempted to identify the origin of the brake lining dust samples which were forwarded to Dr. Paul Gross, of the Industrial Hygiene Foundation.

I have been unable to find a specific reference to the shipping of the dust to Dr. Gross, but the copies of correspondence attached may give a clue as to what was ultimately forwarded.

H. M. Jackson

enc-2

cc: F. L. Pundsack, Finderne
W. [illegible], Finderne

December 2, [illegible]

J. G. Streib, Research

Brake Lining Wear Dust

You have received a copy of H. G. Koch's letter to me of November 27, 1952, 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

KWS	12/23
CLS	

Research & Engineering Center
December 13, 1963

D. Bailey

Brake Lining Wear Dust

You will recall that during his recent visit to the Research Center, Mr. 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 (FP #345) to cover this work.

I am also attaching the pertinent correspondence and would like to call your attention to Mr. 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 Mr. Smith to determine if any additional work is required.

W. G. Streib

WGS/jmp

cc: K. W. Smith, GM
A. C. [illegible]
L. H. [illegible]
F. L. Pundsack
H. G. Koch
File

SEP 1 1971

August 27, 1971

Dr. Joseph H. Sommers
National Air Pollution Control Association
Division of Motor Vehicle R&D
5 Research Drive
Ann Arbor, Michigan 48108

Dear Dr. Sommers:

Dr. Michael Jacko of Bendix Corporation visited the Research and Engineering Center on August 17 to discuss our previous work on wear of brake linings and to review in general terms only his proposed research protocol for his contract with your group. We were much impressed with Dr. Jacko's thoroughness and the fact that he had become so well grounded in the problems connected with this project since the awarding of the contract in May.

During his visit we reviewed several reports based on brake test work at the Johns-Manville Research & Engineering Center. The thrust of this work was essentially to prove to our own satisfaction, and to the satisfaction of Public Health Service personnel, that most of the asbestos in drum brake linings is destroyed during normal usage. The resultant inorganic product is chemically the same, but physically and crystallographically it is entirely different and, insofar as we know, is not biologically active.

A careful review of the data presented in these reports indicate recoveries of material on an inorganic basis of 50 to 80 per cent, which was entirely satisfactory insofar as the basic requirements of our effort. I am sure that more sophisticated analyses and more careful sampling by Dr. Jacko will yield better material balances, but I believe his conclusions concerning the destruction of chrysotile will resemble our own.

I am enclosing copies of the following reports which served as the basis for our discussion:

1. Report 456-2506 - Study of Wear Dust from Brake Lining

Dr. Joseph Sommers
NAPCA, Ann Arbor, Michigan

2.	Report 456-T-94	-	Wear Products from Brake Lining - Nature of the Material
3.	Memorandum M456-386	-	Collection of Wear Dust from Automotive Brake Assembly During Inertia Dynamometer Test
4.	Report 404-67	-	Method for the Quantitative Determination of Chrysotile Fiber in Samples from Various Sources

These can be used by your organization or any personnel associated with this specific contract. I would prefer that they not be divulged to others without our permission. On this basis, you are free to send them to Dr. Jacko for his use.

As I expressed to you during our phone conversation in the past, I would very much like the opportunity to visit Dr. Jacko's laboratory and, if possible, discuss his work with him in more specific detail as soon as actual progress warrants such a meeting.

Sincerely,

Dr. Sidney Speil, Director
Corporate, Mining & Pipe Divisions

SS/rs

Attachments (4)

bcc:
C. Sheckler, DH
F. L. Pundsack
E. M. Fenner
J. H. Zettel
J. Dec
J. P. Leineweber

SANTA BARBARA, CALIF.
NEWS-PRESS
D. 35,000 S. 36,500

MAR 28 1968

Applying Brakes Might Also Be Releasing Cancer Agent

SAN DIEGO (AP) — Every time you hit your brakes, you may be polluting the air with a substance suspected of causing cancer, a pathologist says.

The substance is asbestos, widely used in brake lining. It also is found in roofing, insulation and many other industrial materials.

Dr. W. A. D. Anderson of the University of Miami School of Medicine has found tiny asbestos fibers in the lungs of 31 per cent of the men and 20 per cent of the women in a group of 500 persons studied at random in Miami.

"Surveys in other cities have shown asbestos in the lungs of up to 50 per cent of cross sections of the population," Dr. Anderson said in a report given to a symposium for science writers sponsored by the American Cancer Society.

"An increased incidence of lung cancer among asbestos workers has been noted for years," he said. "The magnitude of asbestos exposure in general urban populations has only been recently documented."

Dr. Anderson said lung cancer, which he called "the major cancer problem in this country," may be caused by many substances. In addition to asbestos, he cited cigaret smoke and automobile exhaust.

"The evidence that cigaret smoke contains a lung cancer-producing factor is overwhelming," he said, "but success so far in changing this exposure factor in the general population cannot be described as overwhelming or even good."

TUCSON, ARIZ.
D. 41,000

MAR 28 1968

Every Time You Hit Your Brakes—Pollution!

SAN DIEGO (AP) — Every time you hit your brakes, you may be polluting the air with a substance suspected of causing cancer, a pathologist says.

The substance is asbestos, widely used in brake lining. It also is found in roofing, insulation and many other industrial materials.

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"The evidence that cigarette smoke contains a lung cancer-producing factor is overwhelming," he said, "but success so far in changing this exposure factor in the general population cannot be described as overwhelming or even good."

Dr. Anderson says his laboratory has been able to produce lung cancers in rats and mice similar to those which occur in man by long exposure to air containing one or two parts per million of a nitro-olefin substance. This substance, he said, has been found in engine exhaust.

CULVER CITY, CALIF.
STAR-NEWS
D. 6,000

MAR 27 1968

Car brakes linked to cancer, air pollution in urban areas

SAN DIEGO (AP) — Every time you hit your brakes, you may be polluting the air with a substance suspected of causing cancer, a pathologist says.

The substance is asbestos, widely used in brake lining. It also is found in roofing, insulation and many other industrial materials.

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"An increased incidence of lung cancer among asbestos workers has been noted for years," he said. "The magnitude of asbestos exposure in general urban populations has only been recently documented."

Dr. Anderson said lung cancer, which he called "the major cancer problem in this country," may be caused by many substances. In addition to asbestos he cited cigarette smoke and automobile exhaust.

"The evidence that cigarette smoke contains a lung cancer-producing factor is overwhelming," he said, "but success so far in changing this exposure factor in the general population cannot be described as overwhelming or even good."

Dr. Anderson said his laboratory has been able to produce lung cancers in rats and mice similar to those which occur in man by long exposure to air containing one or two parts per million of a nitro-olefin substance. This substance, he said, has been found in engine exhaust.

"None of our present methods of diagnosis and treatment have made any real dent in the mortality from lung cancer. Unless something new, not presently even on the horizon, is discovered in diagnosis or therapy, the answer to the problem of lung cancer must lie in studies directed to causation and prevention."

SANTA MONICA, CALIF.
OUTLOOK
D. 30,000

MAR 27 1968

Brakes, Exhaust Blamed

Cancer Tied To Traffic Products

SAN DIEGO (AP) — Every time you hit your brakes, you may be polluting the air with a substance suspected of causing cancer, a pathologist says.

The substance is asbestos, widely used in brake lining. It also is found in roofing, insulation and many other industrial materials.

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"Surveys in other cities have shown asbestos in the lungs of up to 50 per cent of cross sections of the population," Dr. Anderson said in a report released today at a symposium for science writers sponsored by the American Cancer Society.

Asbestos Factor

"An increased incidence of lung cancer among asbestos workers has been noted for years," he said. "The magnitude of asbestos exposure in general urban populations has only been recently documented."

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"The evidence that cigarette smoke contains a lung cancer-producing factor is overwhelming," he said, "but success so far in changing this exposure factor in the general population cannot be described as overwhelming or even good."

Auto Exhaust Tests

Dr. Anderson said his laboratory has been able to produce lung cancers in rats and mice similar to those which occur in man by long exposure to air containing one or two parts per million of a nitro-olefin substance. This substance, he said, has been found in engine exhaust.

"None of our present methods of diagnosis and treatment have made any real dent in the mortality from lung cancer. Unless something new, not presently even on the horizon, is discovered in diagnosis or therapy, the answer to the problem of lung cancer must lie in studies directed to causation and prevention."

The best hope for prevention, he said, is in identifying and changing those things in our environment which cause cancer.

JOHNS-MANVILLE
RESEARCH & ENGINEERING CENTER
P.O. BOX 159 • MANVILLE, NEW JERSEY • TELEPHONE: (201) RANDOLPH 2-9000

JM

March 6, 1967

Mr. J. R. Lynch
Public Health Service Laboratories
1014 Broadway
Cincinnati, Ohio

Dear Mr. Lynch:

During your recent visit to this laboratory I reviewed with you Dr. David Sinclair's report on the study of wear dust from brake lining. You asked whether you might have a copy of this report and I promised to try to get you one.

On checking I learned that it is contrary to our present policy to release complete copies of our official laboratory reports to outside organizations, but I have obtained permission to send you the attached excerpts. I think that you will find that they contain all of the essential data and information which you require.

I hope that you will let us know whether we can help you further in providing additional details for use in the paper which you are preparing, and that you will keep us in touch with your plans regarding when and where you intend to present the report.

Very truly yours,

H. G. Koch

HGK:mef
Enc.
cc: F. L. Pundsack -Enc.
S. Speil -Enc.
J. Dec -Enc.

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

12/2

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. Kaah

ek/[redacted]

cc: [redacted]
C. E. Meserve

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

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:

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H. G. Koch

ek/GK

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

C O P Y

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

JOHNS-MANVILLE RESEARCH AND ENGINEERING CENTER

Report No. 456-T-86

Date January 20, 1964

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
F. L. Pundsack

Reported by D. Bailey
D. Bailey

X-ray Diffraction by J P McGourty
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)

APPENDIX I

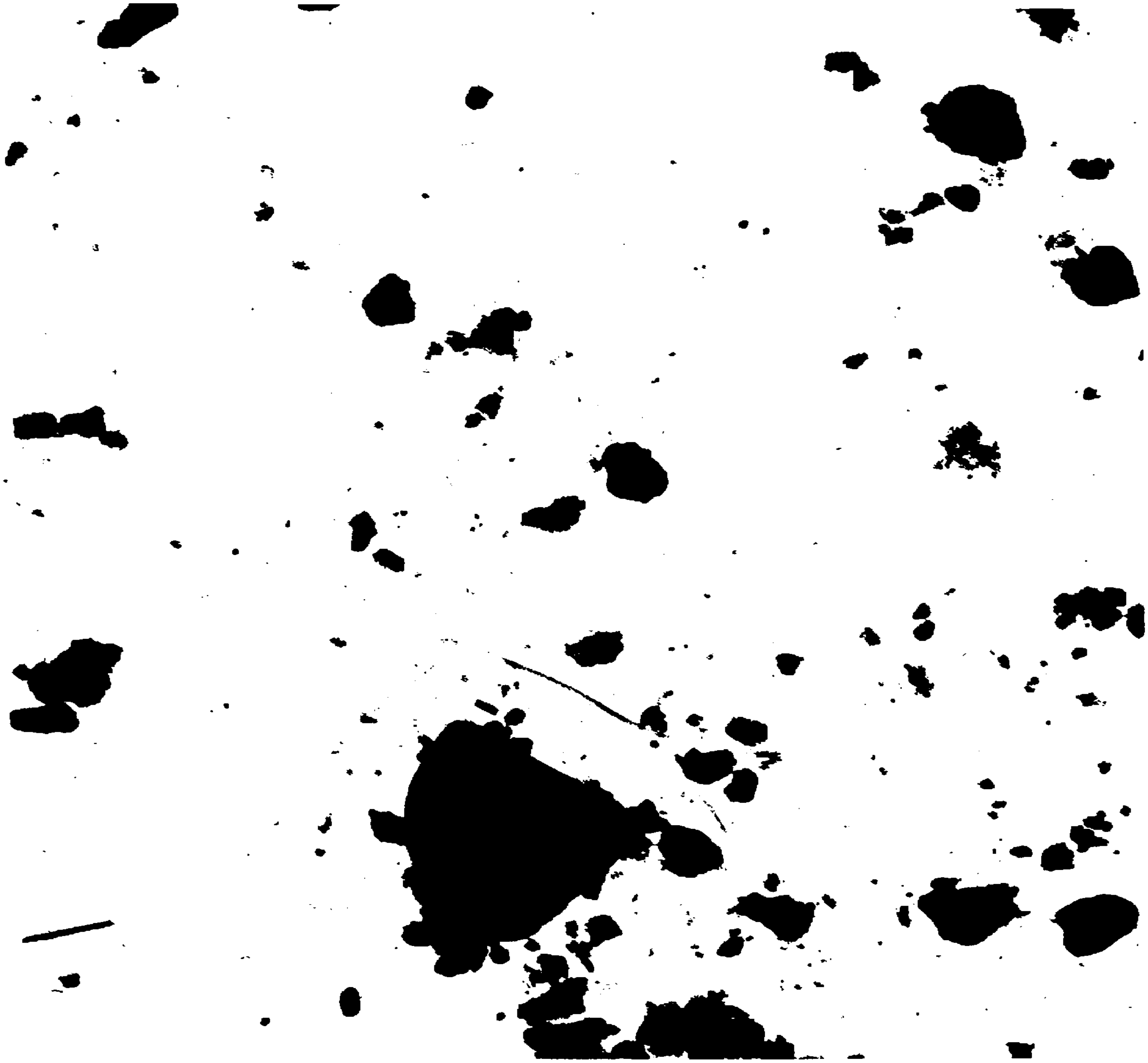
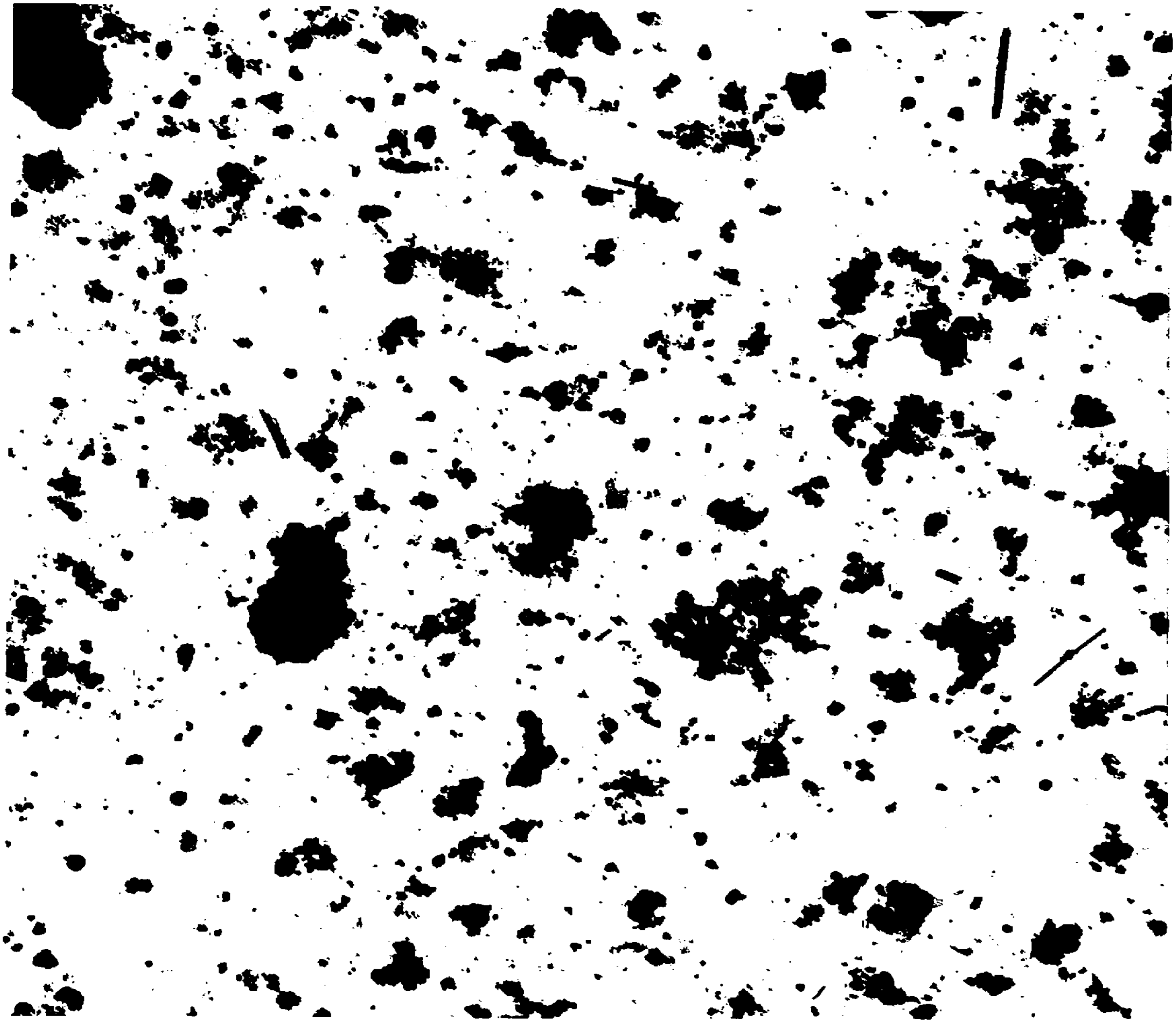


Figure 5. Electron Micrograph of Brake Lining Wear Dust
Phase II, Box and Drum Composite
Mag. 30,000X

EMS 620A

APPENDIX I

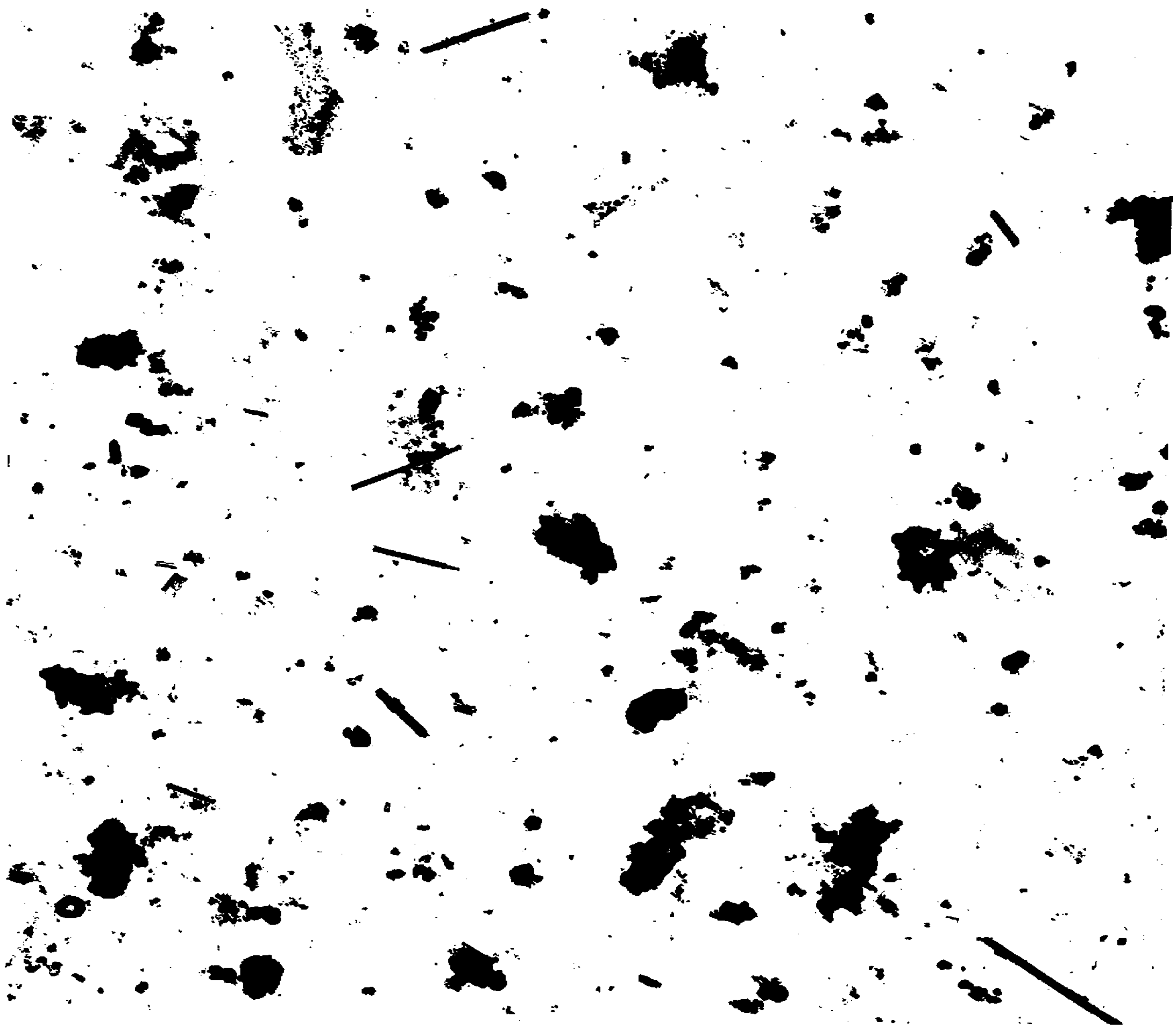


1 micron

Figure 7. Electron Micrograph, Brake Lining, Wear Dust
Phase III, Drum and Box Composite
Mag. 30,000X

EMS 622A

APPENDIX I



1 micron

Figure 6. Electron Micrograph, Brake Lining, Wear Dust
Phase III, Sample 1
Mag. 30,000X

EMS 621A

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)

Notebook 723, p 141.

File 456

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, Bowdem 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 456-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 declerated = 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

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

$q = 2.78 \times 10^3$ 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.°C = thermal conductivity of drum

c = 0.1189 cal/gm°C = 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°C 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°C.

*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.

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

Fraction collected Sample portion	Loss on ignition 900F	Light microscope Ashed 900F	Electron microscope Ashed	X-ray spectrometer Ashed	Emission spectrograph Ashed		Infra-red spectrograph As collected	Coulter counter Blended**	Gas analysis
1 Airborne 2.71 gm	13.5%	no fiber glassy or brown agglomerates	few fibers *** see photos ~~attached~~	no chrysotile identified Iron	MgO	31%	no chrysotile identified Phenolics?	median diams. Number 2.75 microns Mass 4.75 microns	Pure Air
					SiO_2	31%			
					Fe_2O_3	19%			
					CaO	4%			
					Al_2O_3	2%			
					Ba	Trace			
2 Within brake 3.54 gm	19.5%	no fiber glassy or brown agglomerates	(analysis incomplete)	no chrysotile identified Iron	MgO	31%	--------	--------	
					SiO_2	31%			
					Fe_2O_3	19%			
					CaO	4%			
					Al_2O_3	2%			
					Ba	Trace			
3 Within box 0.214 gm	31.0%	no fiber glassy or brown agglomerates contaminated*	(analysis incomplete)	no chrysotile identified Iron	MgO	31%	--------	--------	
					SiO_2	31%			
					Fe_2O_3	19%			
					CaO	4%			
					Al_2O_3	2%			
					Ba	Trace			
					Paint				
Observer - S. Wegrzyn		D. Bailey	D. Bailey	[illegible]	J. Sutherland		S. Wegrzyn	A. Burns	Coll[illegible] Analytical Service

*This very small fraction was contaminated with paint, wood, etc. from box.

***Not more than 1.4 per cent by weight.

**Dilute suspension in water beaten in Waring blender for 1 minute.

TABLE 1. ANALYSIS OF BRAKE LINING AND DRUM WEAR DUST

	Fraction collected	Ignition loss 800F	Light microscope[7]	Electron microscope[7]	X-ray spectrometer[7]	Emission spectrograph[7]		Infra-red spectrograph	Coulter counter	Gas analysis
	Sample condition-		Ashed 800F	Ashed	Ashed	Ashed		As collected	Blended**	Pure Air
1	Airborne	13.5%	no fiber	few fibers ***	no chrysotile	MgO	31%	no chrysotile	medien diems.	
	2.71 gm		glassy or	see photos[7]	identified	SiO_2	31%	identified	Number 2.75 microns	
			brown	~~attached~~	Iron	Fe_2O_3	19%	Phenolics?	Mass 4.75 microns	
			agglomerates			CaO	½%			
						Al_2O_3	2%			
						Ba	Trace			
2	Within	19.5%	no fiber	(analysis	no chrysotile	MgO	31%	---------	---------	
	brake		glassy or	incomplete)	identified	SiO_2	31%			
	3.54 gm		brown		Iron	Fe_2O_3	19%			
			agglomerates			CaO	½%			
						Al_2O_3	2%			
						Ba	Trace			
3	Within	31.0%	no fiber	(analysis	no chrysotile	MgO	31%	---------	---------	
	box		glassy or	incomplete)	identified	SiO_2	31%			
	0.214 gm		brown		Iron	Fe_2O_3	19%			
			agglomerates			CaO	½%			
			contaminated*			Al_2O_3	2%			
						Ba	Trace			
						Paint				
	Observer -	S. Wegrzyn	D. Bailey	D. Bailey	J. McCurty	A. Sutherland		S. Wegrzyn	A. Burns	Collcl Analytical Service

*This very small fraction was contaminated with paint, wood, etc. from box.

***Not more than 1.4 per cent by weight.

**Dilute suspension in water beaten in Waring blender for 1 minute.

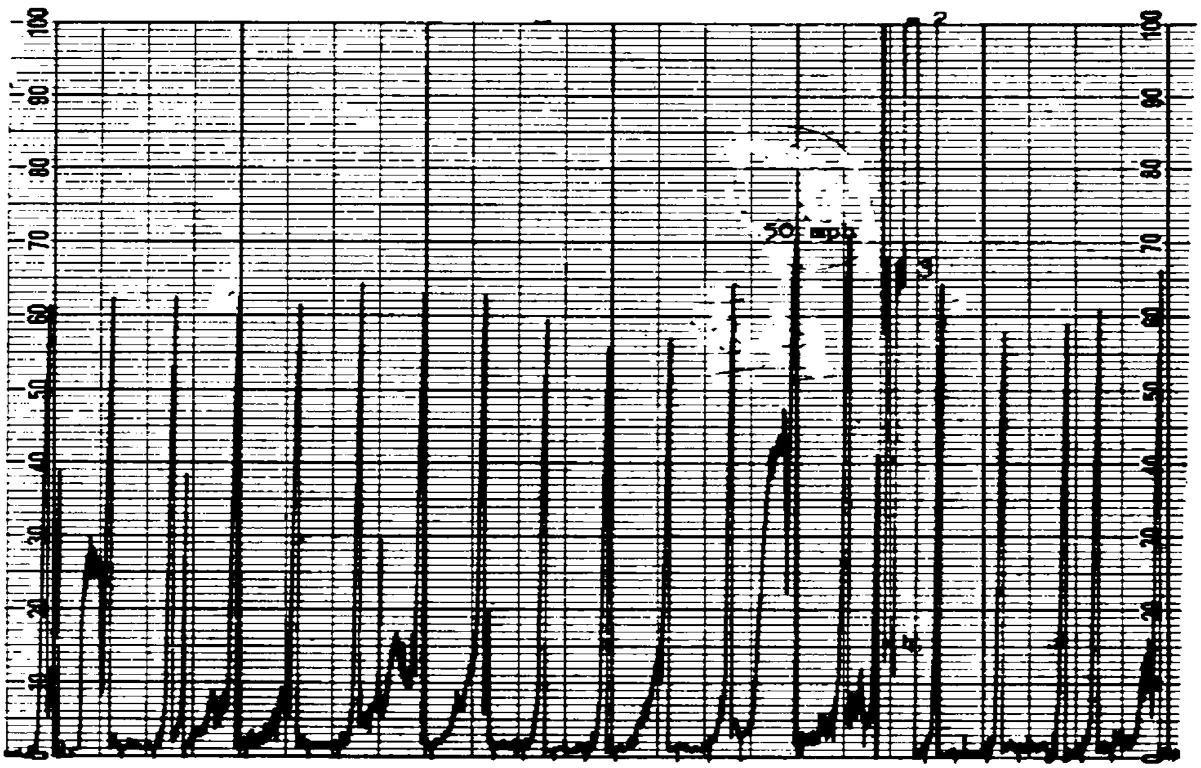
APPENDIX III

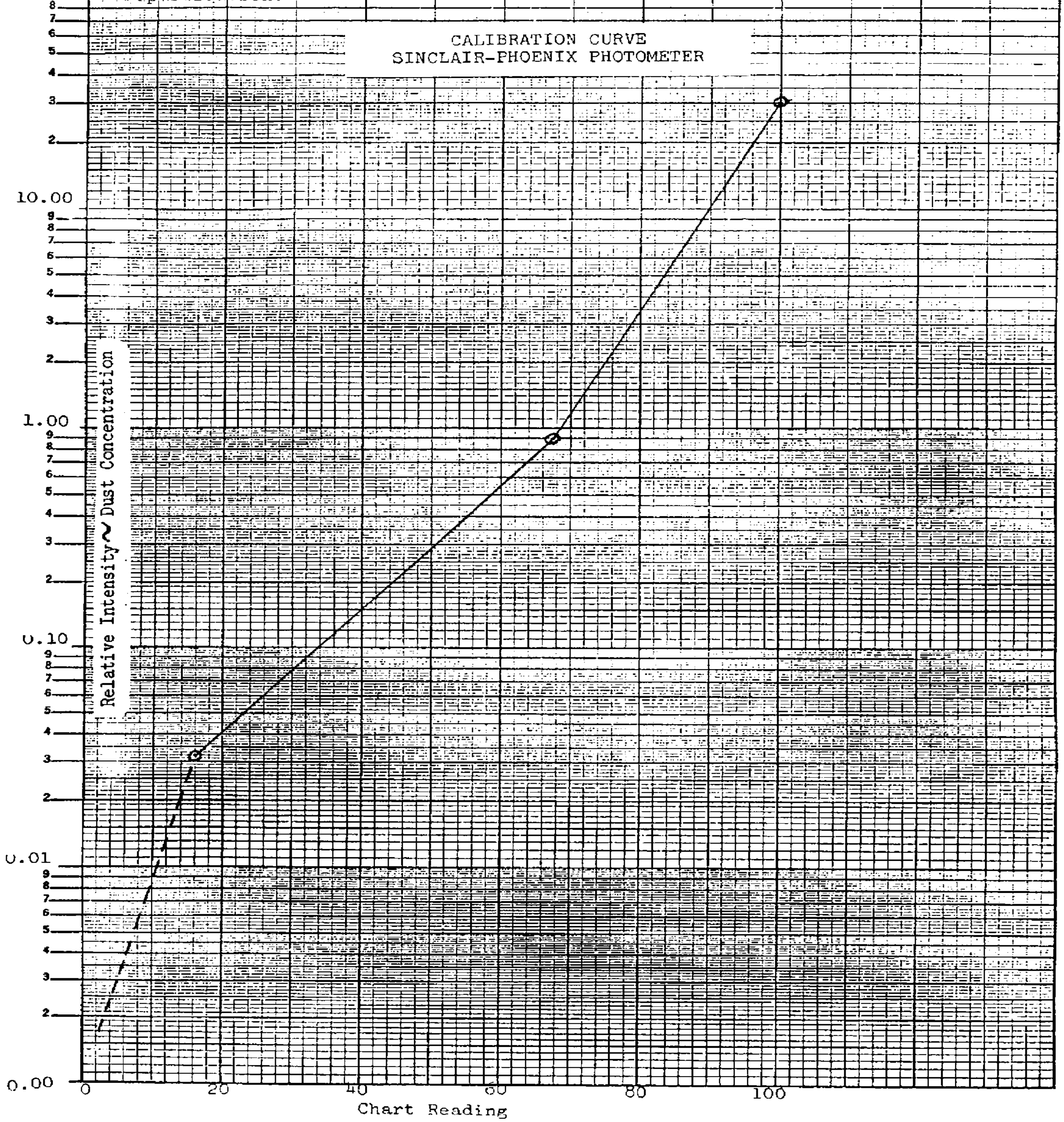
Figure 1

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.

8. Memorandum report No. 3-JM-5, December 9, 1966.

9. Memorandum report No. 3-AS-124, October 21, 1966.

10. Conduction of Heat in Solids, 2nd Ed., p. 269, H.S. Carslaw and J. C. Jaeger, Oxford, Clarendon Press, 1959.

Research & Engineering Center
March 1, 1967

STUDY OF WEAR DUST FROM BRAKE LINING
(Excerpted from Dr. David Sinclair's Report 456-2506)

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 2200 stops during a total time of about 110 hr. The airborne portion was 2.7 grams. Of the stops, 2150 were made from 35 mph at about 12 ft/sec^2 deceleration, interspersed with which were 50 stops from 50 mph.

The brake operating conditions were selected to give heavy wear of the linings without causing abnormally high temperatures, and would correspond roughly to that of heavy "stop and start" traffic on a highway with a 50 mph speed limit.

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 these tests, when the thermocouple temperatures before brake application were held to 200F maximum, and the peak temperatures indicated by the thermocouple in the lining probably never exceeded 300F. Calculations show that the surface temperature at the true area of contact (1 per cent of the apparent area) can reach 2000C or more. It is concluded that most of the fiber is converted to an amorphous mineral by intense heat and fine grinding.

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.

A search of the literature revealed no measurements on brake lining wear dust, although the rate of wear is sometimes given.[1, 2] Recently, numerous articles[3, 4] have appeared calling attention to the widespread use of asbestos in brake linings.

Although it has been assumed in some instances that much of the asbestos fiber is dispersed into the atmosphere, 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 fibrous material in the airborne dust. Most of this fibrous material cannot be positively identified as being either chrysotile or a degradation product thereof because of its fine size.

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 could theoretically raise the temperature of the surface of contact between brake lining and drum to about 2400C, assuming no melting. The high temperature typically occurs on the surface of the lining at the region of actual contact with the drum. This actual area of contact is much less than the apparent area of contact.[5] 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[5] 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 mph 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 aero 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 2200 stops, most of it on two membrane filters. The temperature of the brake lining surface was measured by a thermocouple set in a hole in the lining approximately 1/16-in. below the surface. The cooling interval between brake applications was adjusted so that this thermocouple indicated a temperature in the range between 175 to 200F just before brake application. This was done in order to simulate average braking. As indicated earlier, this temperature is far below the instantaneous surface temperature (see Appendix I).

Two typical electron micrographs are shown in the Appendix.

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.

The brake lining utilized in these experiments contained approximately 70 per cent chrysotile fiber with a cashew resin binder.

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 lb. 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/sec = 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[5] 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 456-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

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

Here = coefficient of friction = 0.4

L = load

r = drum radius = 0.463 ft

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

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

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[6]. The maximum temperature of a strip* (the lining) sliding over a semi-infinite medium (the drum) is given by

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

$q = 2.78 \times 10^3$ 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 °C = thermal conductivity of drum

c = 0.1189 cal/gm °C = 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} = 2440C near the beginning of a stop from 50 mph at 10 ft/sec^2 deceleration.

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

*The equation is derived from 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.

	Fraction collected	Ignition loss 300F	Light microscope[7]	Electron microscope[7]	X-ray spectrometer[8]	Emission spectrograph[9]		Infra-red spectrograph	Coulter counter	Gas analysis
	Sample condition-		Ashed 300F	Ashed	Ashed	Ashed		As collected	Blended**	
										Pure Air
1	Airborne	13.5%	no fiber	few fibers ***	no chrysotile	MgO	31%	no chrysotile	median diams.	
	2.71 gm		glassy or	see photos[7]	identified	SiO_2	31%	identified	Number 2.75 microns	
			brown	---	Iron	Fe_2O_3	19%		Mass 4.75 microns	
			agglomerates			CaO	1/2%			
						Al_2O_3	2%			
						Ba	Trace			
2	Within	19.5%	no fiber	(analysis	no chrysotile	MgO	31%	--------	--------	
	brake		glassy or	incomplete)	identified	SiO_2	31%			
	3.54 gm		brown		Iron	Fe_2O_3	19%			
			agglomerates			CaO	1/2%			
						Al_2O_3	2%			
						Ba	Trace			
3	Within	31.0%	no fiber	(analysis	no chrysotile	MgO	31%	--------	--------	
	box		glassy or	incomplete)	identified	SiO_2	31%			
	0.214 gm		brown		Iron	Fe_2O_3	19%			
			agglomerates			CaO	1/2%			
			contaminated*			Al_2O_3	2%			
						Ba	Trace			
						Paint				
	Observer -	S. Wegrzyn	D. Bailey	D. Bailey	J. McGourty	A. Sutherland		S. Wegrzyn	[illegible]. Burns	Collier Analytical Service

*This very small fraction was contaminated with paint, wood, etc. from box.

**Dilute suspension in water beaten in Waring Blendor for 1 minute.

***Not more than 1.4 per cent by weight.

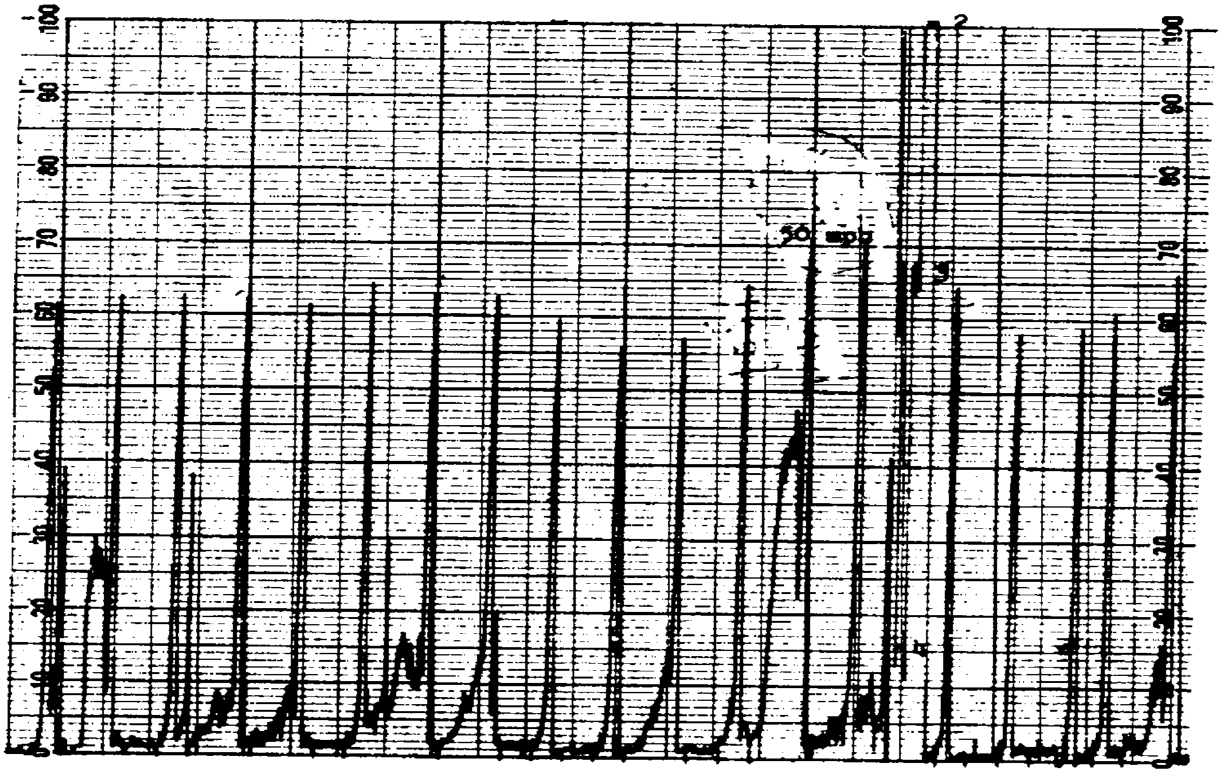
APPENDIX III

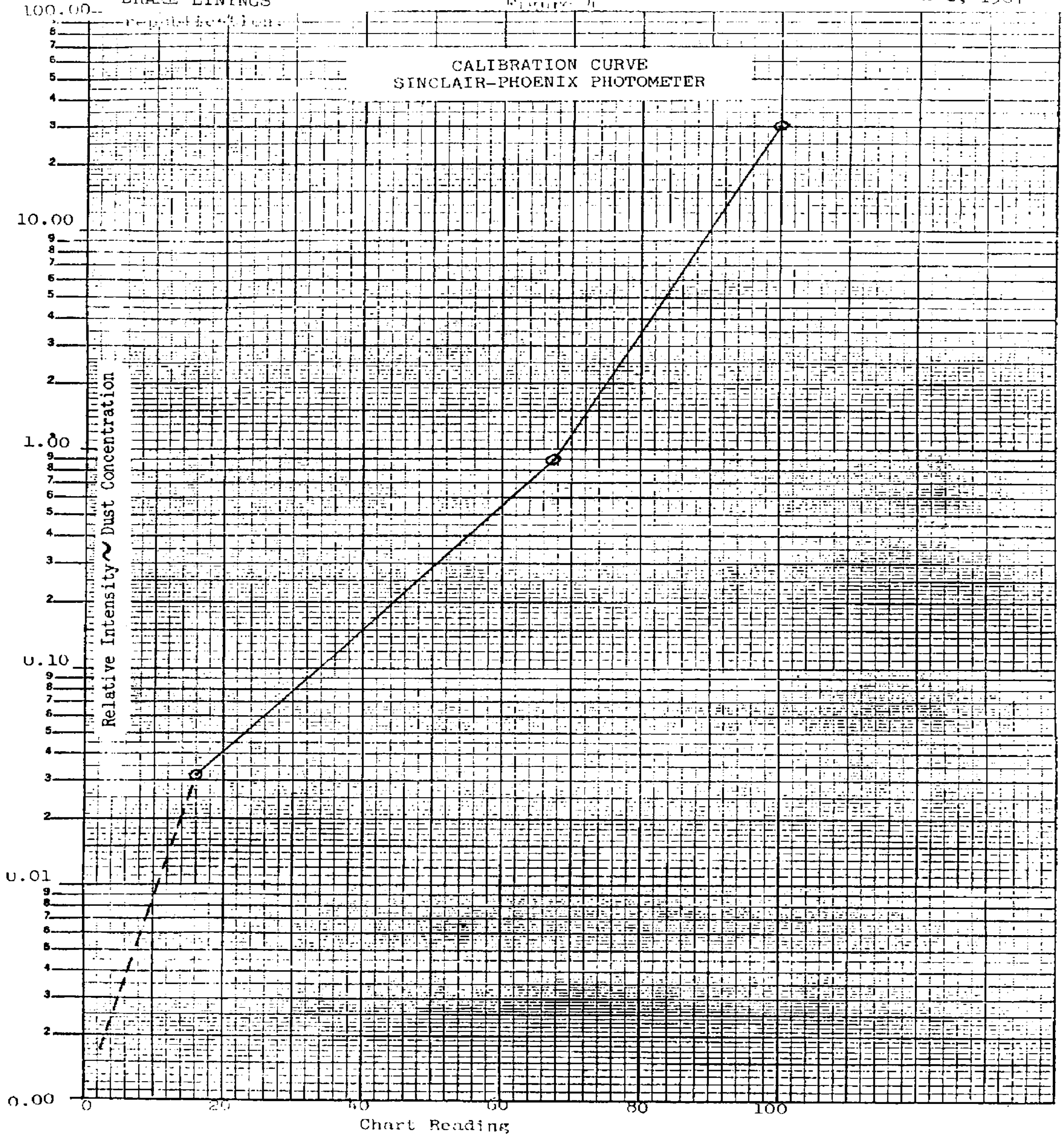
Figure 1

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 V

References

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

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

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

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

8. Memorandum report No. 3-JM-5, December 9, 1966.

9. Memorandum report No. 3-AS-124, October 21, 1966.

Fraction collected	Ignition loss 300F	Light microscope[7]	Electron microscope[7]	X-ray spectrometer[8]	Emission spectrograph[9]		Infra-red spectrograph	Coulter counter	Gas analysis
Sample condition-		Ashed 300F	Ashed	Ashed	Ashed		As collected	Blended**	
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		brown	---	Iron	Fe_2O_3	19%		Mass 4.75 microns	
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					Ba	Trace			
3 Within	31.0%	no fiber	(analysis	no chrysotile	MgO	31%	---------	--------	
box		glassy or	incomplete)	identified	SiO_2	31%			
0.214 gm		brown		Iron	Fe_2O_3	19%			
		agglomerates			CaO	½%			
		contaminated*			Al_2O_3	2%			
					Ba	Trace			
					Paint				
Observer - S. Wegrzyn		D. Bailey	D. Bailey	J. McGourty	A. Sutherland		S. Wegrzyn	A. Puras	Gollob Analytical Service

*This very small fraction was contaminated with paint, wood, etc. from box

***Not more than 1.4 per cent by weight.

**Dilute suspension in water beaten in Waring Blendor for 1 minute.

JOHNS-MANVILLE RESEARCH AND ENGINEERING CENTER

Report No. 456-T-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.

Notebook No. 3656, pp 27-31; 3613 pp 80-81; 3605, p 99; 3612, p 125; 3664, p 24

File 456 (211)

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
S. W. Wegrzyn
Analytical Chemistry Section

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

Spectrographic Work by A. J. Sutherland
A. J. Sutherland
Analytical Chemistry Section

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

Chromatographic Work by H N Smith
H. N. Smith
Analytical Chemistry Section

dl

cc: H. M. Jackson - DH
K. V. Lindell - Asb DH

F. L. Pundsack (2+S)
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

Material 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

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.

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

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

APPENDIX I

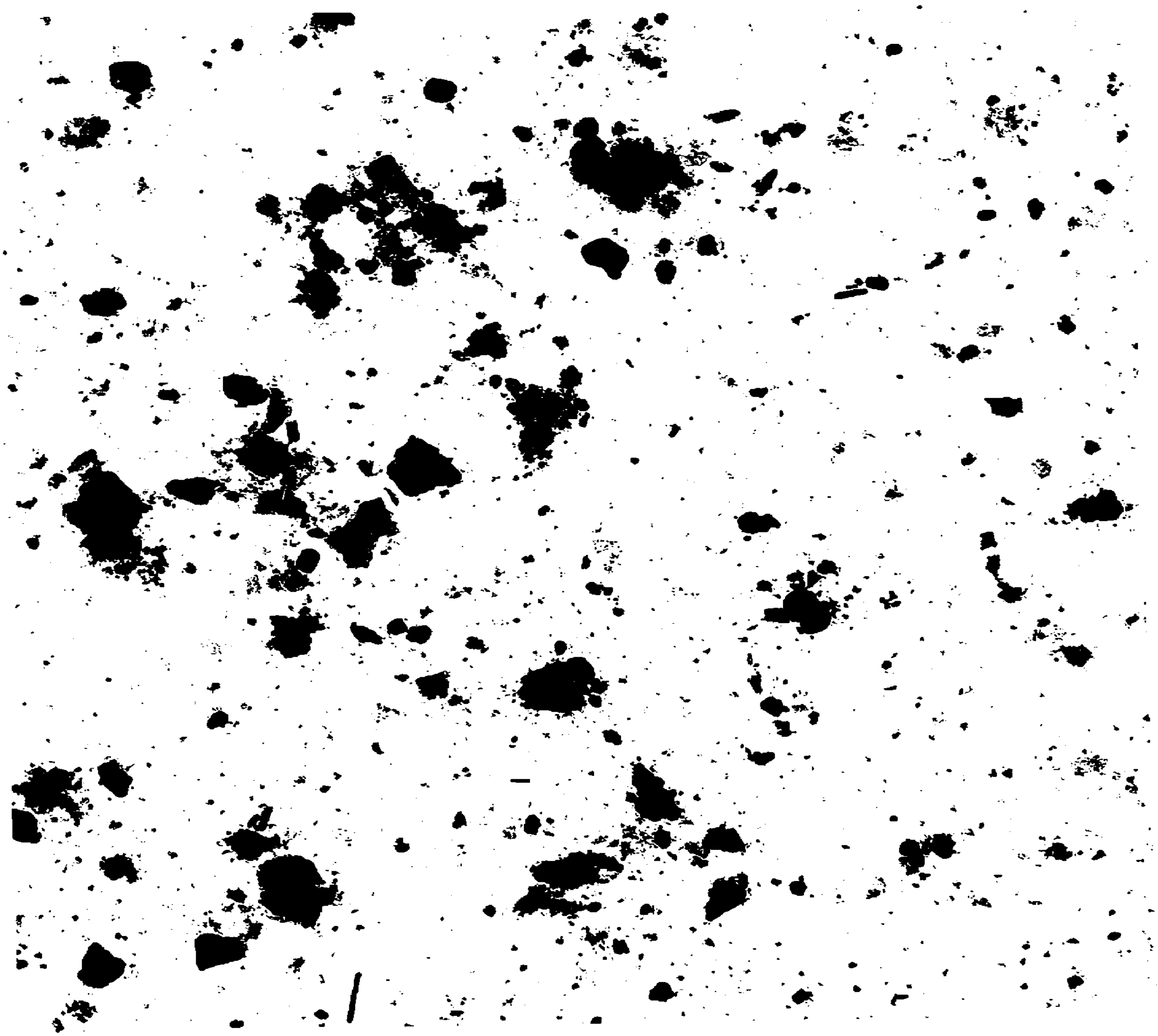


Figure 1. Electron Micrograph, Brake Lining Wear Dust
Phase I, Sample 2
Mag. 30,000X

EMS 617A

APPENDIX I

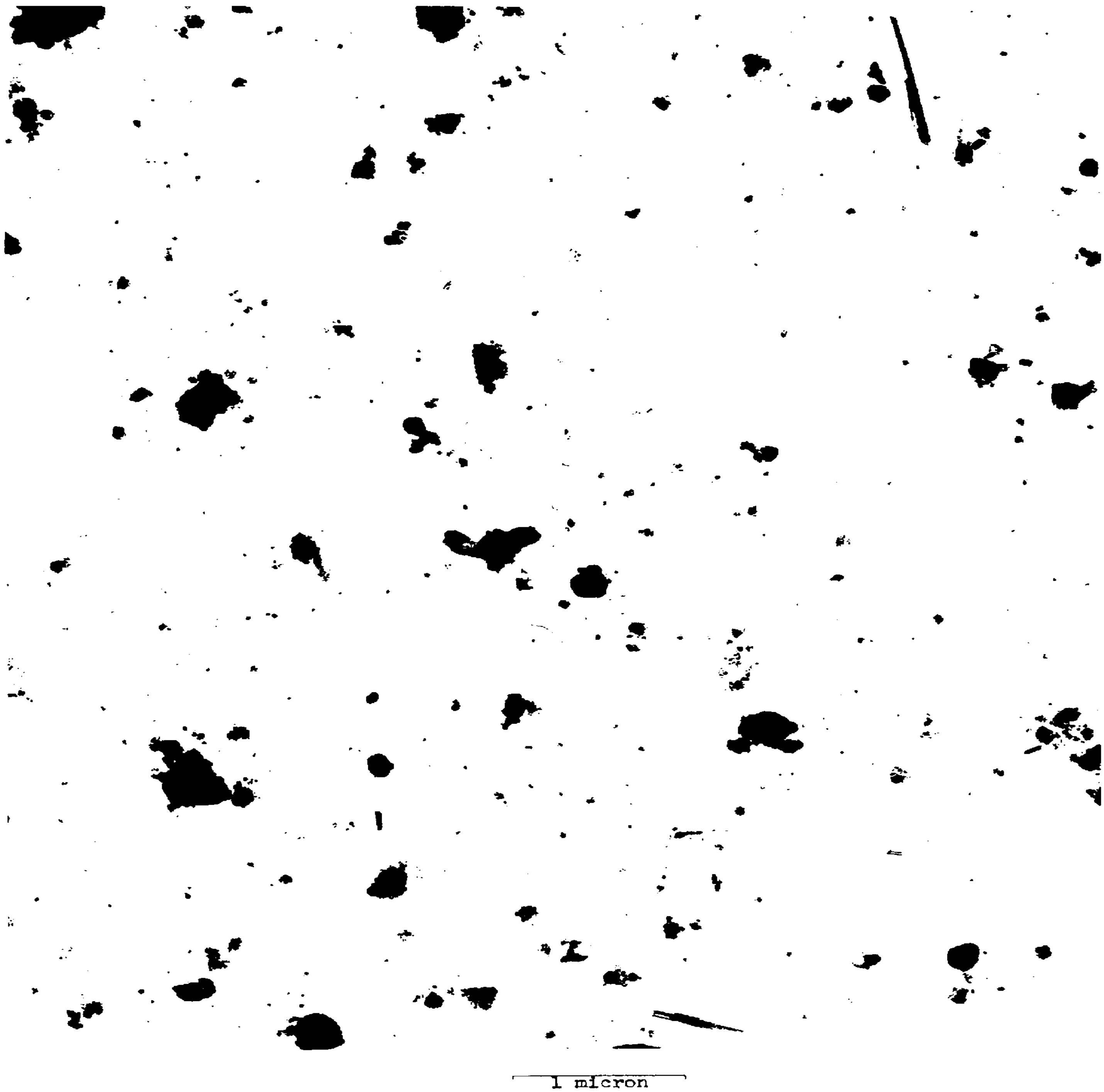
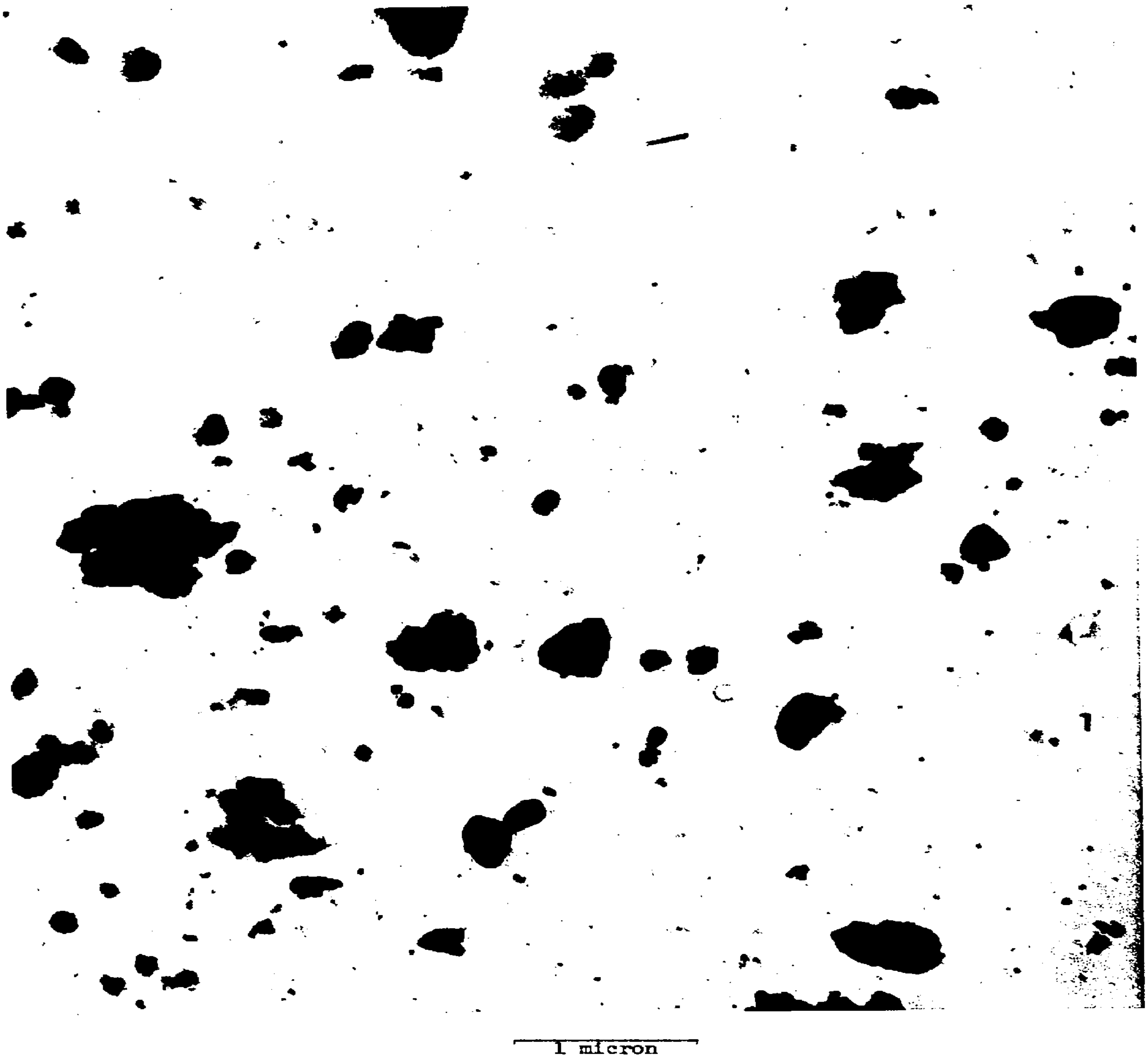


Figure 3. Electron Micrograph, Brake Lining, Wear Dust
Phase I, Drum, Shoe, and Box Composite
Mag. 30,000X

EMS 618A

APPENDIX I



1 micron

Figure 4. Electron Micrograph, Brake Lining, Wear Dust
Phase II, Sample 1
Mag. 30,000X

EMS 619C

INDUSTRIAL HYGIENE FOUNDATION OF AMERICA, INC.

MELLON INSTITUTE, 4400 FIFTH AVENUE

PITTSBURGH, PA. 15213

Report on

PRELIMINARY STUDY OF BRAKE-DRUM DUST: COMPARATIVE PATHOGENICITY

for

JOHNS-MANVILLE CORPORATION

by

Paul Gross, M.D.
Director of Research Laboratory

February 14, 1967

Robert T. P. deTreville, M.D.
Managing Director

Introduction

As an explanation for the occurrence of ferruginous ("asbestos") bodies in the lungs of 30 to 40% of the general population in large cities, Thomson[1] has indicated that urban populations are being exposed to asbestos dust and that a likely source of this dust was from the wearing down of automobile brakes.

Details of Preliminary Study

At the request of Dr. Kenneth W. Smith, Medical Director, Johns-Manville Corporation, a preliminary study of the pathogenicity of "brake-drum dust" was done. This dust, free of iron, was suspended in water and 1 ml containing 3.5 mg was injected intratracheally into rats and hamsters. Some of the rats were killed four days later. The lungs were examined microscopically and the changes compared with the four-day lesions seen in the lungs of rats injected intratracheally with the dusts of (a.) crystalline silica, (b.) chrysotile, and (c.) kaolin, respectively. The chrysotile had been similarly suspended in water and given in the same dosage.

Results

The results were as follows: crystalline silica and chrysotile caused a severe inflammation best described as an obliterative bronchiolitis that could not be differentiated one from the other. Whereas, the reactions caused by both, kaolin and brake-drum dust, were also similar to one another and were of the so-called "biologically inert" type. This reaction consisted essentially of the accumulation within scattered alveoli of scavenger cells filled with the respective dusts. There was no significant development of the connective tissue that, in the case of silica and chrysotile, tended to obliterate the air spaces and ducts.

Tentatively, therefore, the brake-drum dust tested should be categorized as "biologically inert."

Recommendations for Further Studies

A proposal for further investigation of the pathogenicity of brake-drum dust has been prepared at the request of Johns-Manville Corporation. Analytical laboratories at Johns-Manville Corporation have reportedly been unsuccessful in identifying asbestos fibers in brake-drum dust and the Industrial Hygiene Foundation's preliminary studies have shown that the dust behaves differently than chrysotile asbestos, with effects on lungs which closely resemble those produced by inert dusts, such as kaolin. If these findings should be borne out by further studies, their publication would help prove that Thomson's assumption was erroneous.

Essential to publication would be the development of data from inhalation of brake-drum dust by adequate numbers of several species of laboratory animals. Tentatively, it is suggested that of 40 animals in each of four species (guinea pigs, rats, hamsters and mice) 30 be exposed over most of their life span (two years in all except mice, which have a shorter life span and require only one year) to a concentration of about 100 mg/m^3, the other 10 serving as controls. This concentration would be produced in an 8' x 8' x 8' chamber by means of Wright dust-feed dispersion equipment. Frequent quantitation of the chamber atmosphere, close observation and care of the animals and extensive histopathological observations would be necessary over a three-year period of research. The cost would be $200,000: $50,000 the first two years and $100,000 the third. Histological sections will receive special staining and microscopic examination by research pathologists, who will take thousands of photomicrographs of their findings and use some of these to document their report, which will be suitable for publication.

As a means of developing additional information which cannot take the place of the inhalation study but will give earlier indication of lung changes, it is recommended that a similar study be done by intratracheal injection technique, giving 80 animals (20 of each species listed above) a single injection of near maximal dose tolerated without death. These animals would be pastured for one year, killed and examined by the same research pathological techniques. The two-year study would cost $75,000: $25,000 the first year and $50,000 the second (the second year including the histopathological studies and preparation of a report). Although not considered adequate for publication alone, the results by injection would be incorporated with the inhalation study findings and be a valuable supplement to it.

Costs of the combined studies will be $275,000: $75,000 the first year, and $100,000 on each of the two successive years.

References

1. Thomson, J.G., et al. Asbestos as Modern Urban Hazard. S. Afr. Med. J. 37:77-81, 1963.

Tentative Outline of Brake-Drum Dust Investigation

A. Intratracheal Injection ($75,000)

a. 20 Guinea Pigs
b. 20 Rats
c. 20 Hamsters
d. 20 Mice

Single injection of near-maximal dose tolerated without death.

Pastured for one year and killed.

B. Inhalation ($200,000)

a. 40 Guinea Pigs
b. 40 Rats
c. 40 Hamsters
d. 40 Mice

8' x 8' x 8' chamber Wright dust-feed dispersion (at least two needed).

Two-year exposure. Concentration ~ 100 mg/m^3.

One-year exposure for mice because of shorter life expectancy.

Two-year exposure for others.

Six-month holding period.

Six months for processing and writing report.

Total: Three-Year Study

Cost: $275,000

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