REPORT ON

THE NATURE OF THE PARTICULATE MATTER PRESENT IN THE ATMOSPHERE IN A NUMBER OF AREAS WHERE CERAMIC BRAKE LININGS ARE PRODUCED

This report describes the results of a general hygiene survey, and of an environmental investigation undertaken to determine the extent of the pollution of the atmosphere in certain parts of the plant of the Bendix Products Division, Bendix Aviation Corporation, South Bend, Indiana, with dust produced in the manufacture of ceramic brake linings. The samples were collected in four areas of the plant, namely, the ceramic laboratory, the blending and the production areas of Department 176, and in another building at a grinder used to size the buttons to specification, on January 20 and 21, 1955.

Description of the Process

The manufacture of ceramic linings begins with the weighing of metallic powders and compounds into a batch of 400 pounds. The various powders which form a blend are transferred manually to the weighing buckets from individual drums or bags, which are stored in the blending room. The weighed powders are then introduced into a blender in which they are tumbled and mixed intimately for several hours. The blended powder is next compressed by a "slugging" machine into cylinders approximately 1/2 inch in diameter and 1/2 inch in length. These slugs are first granulated and put through a coarse screen and then reground so as to pass through a fine screen, after which the powder is ready for use in the production area.

In the production area, the fine powder is pressed into discs of varied diameter in a Stokes press in a step called "preforming." The operator of the press also places the pressed discs within shallow metal cups. The cups and "preformed" discs then go to either of two Toledo presses where higher pressure is applied to fasten the disc to the metal cup. Following this operation, which is called "compacting" or "coining", the buttons are sintered by subjecting them to high temperature for a definite period of time. After removal from the sintering oven, the buttons are "coined" again at a higher pressure than that applied in the initial "coining" step. After being ground to specification on a Blanchard Grinder, the buttons are ready for assembling into brakes.

In addition to the production operations, the department operates a ceramic laboratory, where test blends of powders are prepared, and certain control tests are conducted.

The various areas and the locations of the different pieces of equipment within them are shown schematically in Figure 1.

The Problem

The powders used originally to produce the ceramic brake linings include: zinc, iron, copper, tin, molybdenum, aluminum, silicates, silica, and graphite. The use of lead oxide in one type, and of antimony in another, has been found to improve the performance of the braking action of the linings. On this account, the production of brake linings containing lead oxide was started in October, 1954, but was suspended after a brief period when the potential hazard to health due to exposure to lead dusts was

recognized. Concern as to the extent of the potential hazard to health associated with the exposure of workmen to other metallic and mineral dusts which may be used in the future has caused management to appraise the situation and to consider certain measures for the control of the dust, so that improved types of brake linings can be made safely. A little over 30 persons are involved in the various operations of the department. Of this number, 9 men work in the ceramic laboratory on a variety of development and testing problems and have been exposed intermittently to dusts containing lead and antimony. The remainder of the men are engaged in the production of the linings and have been exposed for three years to the various materials used originally; some of them incurred some previous exposure to lead during a six month period of its use which ended in October, 1954, but are expected to be exposed to lead again beginning in February, 1955. This analytical survey undertook first to determine the nature of the suspended matter in the air during the processing of the original mixture of powders, and then, by means of a special run, to determine the contamination of the atmosphere with lead when a batch of powder to which lead oxide had been added was being prepared in the blending area.

Results

The analytical results are listed in Table 1. These are arranged in relation to the four areas in which work with ceramic linings is now being done. Table 2 lists the concentrations of a number of the materials which were found on analyzing three samples of settled dust removed from ledges or equipment in the laboratory, and in the blending and production areas.

Discussion

The threshold limits of the concentrations of a number of these materials in the atmosphere of the working area have been agreed upon more or less generally, and are listed below:

Antimony	0.5 mg/M^3
Iron oxide fume	15.0 mg/M^3
Lead oxide as dust	0.15 mg/M^3
Zinc oxide fume	15.0 mg/M^3
Silica	
(above 50% free)	5 million particles per cu. ft.
(5-50% free)	20 million particles per cu. ft.
(below 5% free)	50 million particles per cu. ft.
Dust (nuisance, no free silica)	50 million particles per cu. ft.

Iron dusts are not considered dangerous to health, although the lungs of workers who have been exposed to dusts of the oxides are discolored characteristically (siderosis). Sufficiently high concentrations of certain metal fumes, including those of zinc oxide, produce a most disagreeable but transient disturbance known best as metal fume fever. Since fume is not produced (except in the sintering operation), the use of zinc powder is not likely to produce any difficulties. Industrial poisoning by molybdenum has not been reported in spite of the considerable use of molybdenum compounds in industry.

Elementary selenium is relatively inert, and industrial poisoning from selenium is rare. Soluble selenium compounds, however are highly toxic.

As is shown by the data in Table 1, the threshold limit for lead is exceeded in a number of the operations. In the laboratory, the screening of blend 790, results in the production of concentrations of lead in the air which are 15 times the threshold limit.

This operation is intermittent in character, and exposure to the concentrations found occurs approximately 4 times per shift during periods of 10 minutes at a time. During the operations under investigation at this time, the operator wore a dust respirator, and thus his exposure was of much lower intensity, presumably, than that indicated by the analyses. The test, however, does show that appreciable quantities of lead-bearing dust is dispersed into the atmosphere.

The grinding of "buttons" fashioned from #1270 powder contaminated the air with antimony dust to an extent well in excess of the threshold limit. The grinder was provided with an exhaust apparatus, which however, failed to collect the dust so created, to a satisfactory extent.

All of the operations in the blending area are potentially hazardous, but the extent of the actual hazard will vary with the toxicity of the materials handled, some being essentially harmless and others dangerous. The processing of a batch of metal powder (#790) containing lead oxide showed that certain operations are extremely dusty and that high concentrations of toxic materials can be dispersed into the atmosphere. The present method used to transfer metallic material from the various drums and containers from the storage area for weighing and mixing before blending yields heavy contamination of the atmosphere. When the powder contains lead oxide, as in powder #790, the amount of lead in the atmosphere at all operating sites exceeded the threshold limit for industrial safety. All machinery in the blending area, therefore, must be provided with

dust collecting equipment. Some of the most severe types of exposure are of short duration (filling and unloading the blender, filling the slugger and granulating), while others, like "slugging", are more continuous. However, when production expands to the point where several batches of blend #790 are worked up per shift, personnel will be exposed to high concentrations of lead for an appreciable portion of the work day.

Dust counts were generally below 5 million particles per cu. ft. of air, so that the hazard to health due to exposure to free crystalline silica is insignificant. However, in one count, made while the powders were being weighed in the blending area, 25 million particles per cu. ft. of air were found. This exceeds the threshold limit for dusts which contain free silica in the range between 5% and 50%. It is possible, therefore, that under conditions of expanded production, some degree of hazard might arise, unless control measures are taken.

Since blends of powder containing lead oxide were not being processed in the production area on the days when this survey was made, it was not possible to determine directly the extent of the atmospheric contamination with lead in this area. However, it is possible to estimate the likely extent of this contamination at each of the operations from the total amount of suspended matter found in the atmosphere, on the assumption that, in accordance with the composition of the formula, about 10 per cent of the suspended material in the air will be lead. On this basis, the highest concentrations of lead would occur when the hoppers of the Stokes presses are being filled, but the concentrations of lead at all of the other

locations in the production area would also be above the threshold limit. The calculated concentrations are shown in parentheses in Table 1. The hoppers are filled 5 to 6 times per shift, each filling requiring about 3 to 5 minutes.

In the case of the grinding operation, a small amount of dust escapes the dust collector. On the basis of the amount of particulate matter found here, the lead dust generated by this operation would also be above the threshold limit.

Examination of operations in the various areas revealed that the need for dust collection had been recognized and is provided for in some of the equipment. The grinder in the laboratory, and the blender, as well as the slugging and granulating machines in the blending area, are so equipped. The blender is provided with two exhaust openings which can be so adjusted as to collect dust at its loading and discharge ends. The sluggers are provided with the usual exhaust openings, as supplied for use of tableting machines in the pharmaceutical industry, however, an increase in the face velocity at the suction opening will probably be required in order to capture the heavier dust which is being handled. The granulator is also supplied with an exhaust opening which can be adjusted to capture the dust at either the loading or discharge ends of the machine.

The ducts in the blending area connect to a wet cyclone to remove the dust which has been collected. The air is then discharged directly into the production area. Make-up air to the blending section is taken from the production section.

It was noted that the batch weighing operation in the blending step produced the greatest amount of dust, and that clothing

of the operator became heavily coated with the various powders and dusts. Upon completing the weighing of the powders, the operator applied a stream of compressed air to his clothing to dislodge the dust. This practice, which is reprehensible, regardless of the nature of the dust, was seen to disperse clouds of dust into the atmosphere.

Dust covered the equipment and collected on the floor near various pieces of equipment, particularly in the case of the slugging machines. It was also noted that the operators eat lunch in their respective work areas and that washing facilities are not readily available.

It is evident that the present operating procedures and practices are not in keeping with good industrial practice, from the hygiene viewpoint, and that when they involve the use of compounds of lead and antimony, or other potentially dangerous materials, they are unduly fraught with hazard.

Recommendations

The observations and the results of the analytical survey suggest the application of the following procedures for the control of potential hazards:

1. The substitution of non-toxic materials for the toxic substances like lead oxide and antimony, if possible, thereby reducing the over all hazard. If this is impossible or undesirable for technical and economic reasons, the exposure must be brought under rigid control and so maintained.

2. Equipment for the control of dust should be supplied in the following ways and at the following locations in the blending area.

a. Provide closed and mechanically exhausted hoppers for storing the various metallic and mineral powders used in the process. A mobile batch-weighing tank provided with a dust collector system should be provided for weighing the powders that are needed. The types of equipment required to store and handle powders and to collect the dust have been worked out tentatively by the engineering department, and should be installed as soon as possible.

b. Provide exhaust hoods which enclose the blender, and the slugging and granulating machines, satisfactorily. These hoods can be provided with hinged sides or tops for easy ingress for repairs or for introduction of the powders.

3. Dust collecting equipment should be supplied in the production area at the following points:

a. In the hoppers of the Stokes machines.

b. Behind each compactor. A baffled slot opening should be used to capture the dust now distributed into the air by the compressed air blasts which are used to remove the buttons from the press.

4. Exhaust equipment of the following types should be supplied in the ceramic laboratory.

a. Exhaust hoods for all testing equipment. The equipment generally is small enough to set on tables enclosed in hoods such as are used to collect chemical fumes.

b. An exhaust canopy over the sintering oven.

c. The grinder should be properly hooded. This might be accomplished by supplying a baffled slot the length of the table.

5. All duct work for the above exhaust hoods should be connected to an efficient dust collector, the effluent stream of which should be essentially clean and should discharge to the outside.

6. Make-up air should be taken from the outside and tempered sufficiently for comfort in cold weather.

7. A vigorous and effective housekeeping program should be instituted and maintained, whereby machinery, floors and other surfaces are cleaned frequently by vacuum, so as to prevent the redispersion of accumulated dust into the air through vibration or other means.

8. The eating of lunch in the blending and production areas should be forbidden and prevented by supervision if necessary.

9. Suitable and conveniently located sanitary facilities (for washing) and a clean lunch room should be provided. In addition, adequate locker rooms and bathing facilities are required. Men who work with particulate lead compounds must change from street clothing into work clothing daily, and conversely bathe and change clothing at the end of their work. This necessitates a double locker system, and time (at the expense of the employer) for changing and bathing.

10. The collection of dust used at the Blanchard Grinder should be improved by providing a large baffled opening at the back of the machine to capture dust dispersed by the air blast which is used to clean the table on which the buttons are placed. The cover now provided on the right-hand side of the machine should be extended at least a foot to the left, and the suction opening should be placed in the top of this baffle, rather than at the edge as at present.

11. Exhaust canopy hoods should be provided for each of the ovens being used for the sintering of ceramic brake linings.

12. A regimen of medical control, with suitable examinations and laboratory tests properly spaced in relation to the needs of the situation, should be instituted. Full advice on the nature of the procedures may best be given after conference with medical personnel.

13. A regimen of atmospheric sampling and analysis should be instituted and maintained at such intervals as to follow changes in process and production from the aspect of their effects upon atmospheric contaminations.

By achieving suitable operating conditions in accordance with the foregoing recommendations, and by maintaining the two types of check on such conditions, it will be possible to control the potential hazards of these operations so as to eliminate any and all cases of poisoning, as well as all apprehension that may be associated with the potential hazards.

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TABLE 1

THE LEVELS OF CONCENTRATION OF CERTAIN METALS IN THE ATMOSPHERE OF DEP
(CERAMIC BRAKE LINING MANUFACTURE)

Analysis Number	Section	Operation	Date and Hour	Minutes Sampled	PM* Mg/M^3	Average size in microns
55A-499	Laboratory mixing room	General atmosphere of room. Near button testing and while sintering 530-9 powder	2:22 pm 1-20-55	10	1.65	1-2
55A-500	Laboratory mixing room	While grinding buttons of #1270 powder	2:40 pm 1-20-55	5	6.35	2-3
55A-501	Laboratory mixing room	While screening powder blend #790 (4 x/shift, 10 min. each)	3:30 pm 1-20-55	5	2.3	3-5
55A-502	Blending area	Center of area No activity	3:58 pm 1-20-55	20	1.0	2-3
55A-505	Blending area	While mixing Cu, Al, Silicate, Graphite, SiO_2, and Tin of blend #790	9:31 am 1-21-55	17	115.0	3-5
55A-506	Blending area	While adding Fe, Zn, Mo and Pb_3O_4	9:38 am 1-21-55	6	61.5	2-3

* PM - Particulate Matter

Table 1 (continued)

Analysis Number	Section	Operation
55A-507	Blending area	While filling large blender with powder #790
55A-512	Blending area	While unloading #790 from blender with large powder container
55A-513	Blending area	While placing containers of #790 on slugger
55A-514	Blending area	While slugging #790
55A-517	Blending area	Coarse screening of #790 in granulator (part of batch)
55A-518	Blending area	Fine screening of #790 in granulator
55A-503	Production area	Compacting #530-9 on #2 Press
55A-504	Production area	Behind #2 Press
55A-508	Production area	Preforming on #5 Press (530-9)

* PM - Particulate Matter

Date and Hour	Minutes Sampled	PM* Mg/M^3	Average size in microns	Mg/M^3 Pb	Sb	Zr
10:03 am 1-21-55	2.5	20.0	2-3	2.2		
12:20 pm 1-21-55	7	44.5	2-3	11.4		1.4
2:10 pm 1-21-55	2	145	3-5	19.0		2.4
2:15 pm 1-21-55	15	10.5	2-3	1.2		<0.1
3:10 pm 1-21-55	2.5	2.5	3-4	0.03		<0.1
3:18 pm 1-21-55	3.0	5.6	2-3	0.24		<0.1
4:23 pm 1-20-55	10	1.0	2-3	0.009		
4:37 pm 1-20-55	15	6.4	2-3	0.01		0.1
10:13 am 1-21-55	21	1.4	2-3	0.025 (0.14)		<0.1

Table 1 (continued)

Analysis Number	Section	Operation	Date and Hour
55A-509	Production area	In aisle behind #5 Press	10:40 am 1-21-55
55A-510	Production area	Compacting #625 powder on large Stokes Press #6	11:42 am 1-21-55
55A-511	Production area	While filling hopper of #5 Press	12:05 pm 1-21-55
55A-515	Production area	Compacting #530-9 on #1 Press	2:32 pm 1-21-55
55A-516	Production area	Behind Press #1	2:47 pm 1-21-55
55A-519	Blanchard Grinder	Grinding 530-9	4:20 pm 1-21-55
55A-520	Blanchard Grinder	Grinding 530-9	4:25 pm 1-21-55

* PM - Particulate Matter

Minutes Sampled	PM * Mg/M³	Average size in microns	Mg/M³ Pb	Sb	Zn
9	2.3	2-3	0.003 (0.23)		<0.10
20	3.5	3-5	0.003 (0.35)		<0.10
3.5	39.3	3-5	0.009 (3.9)		0.20
13	2.3	3-4	0.04 (0.23)		<0.10
14	6.2	3-4	0.02 (0.62)		0.11
4	7.0		(0.7)		0.39
5	2.0		(0.20)		0.10

TABLE 2

ANALYSIS OF SETTLED DUST REMOVED FROM EQUIPMENT IN DEPARTMENT 176

Percentage of Components Found in Dusts from Various Sources

Components	Laboratory	Blending Area	Production Area
Lead	0.29	0.24	0.45
Antimony	0.49	-	-
Zinc	1.6	2.33	2.68
Free crystalline silica	7.5	8.7	14.0

Distribution of Particles According to Size
(Percentage)

Range of Size of Particles (Microns)			
1-1.99	11.8	12.3	7.1
2-2.99	29.5	25.6	22.3
3-3.99	16.2	16.1	18.6
4-4.99	13.8	17.5	8.6
5-5.99	15.3	13.3	10.0
6-6.99	-	1.9	1.0
7-7.99		1.9	1.4
8-8.99	2.9	5.7	9.5
9-9.99			
10 and over	10.4	5.7	21.5
	100.0	100.0	
Mean Size	4.5	4.3	5.5

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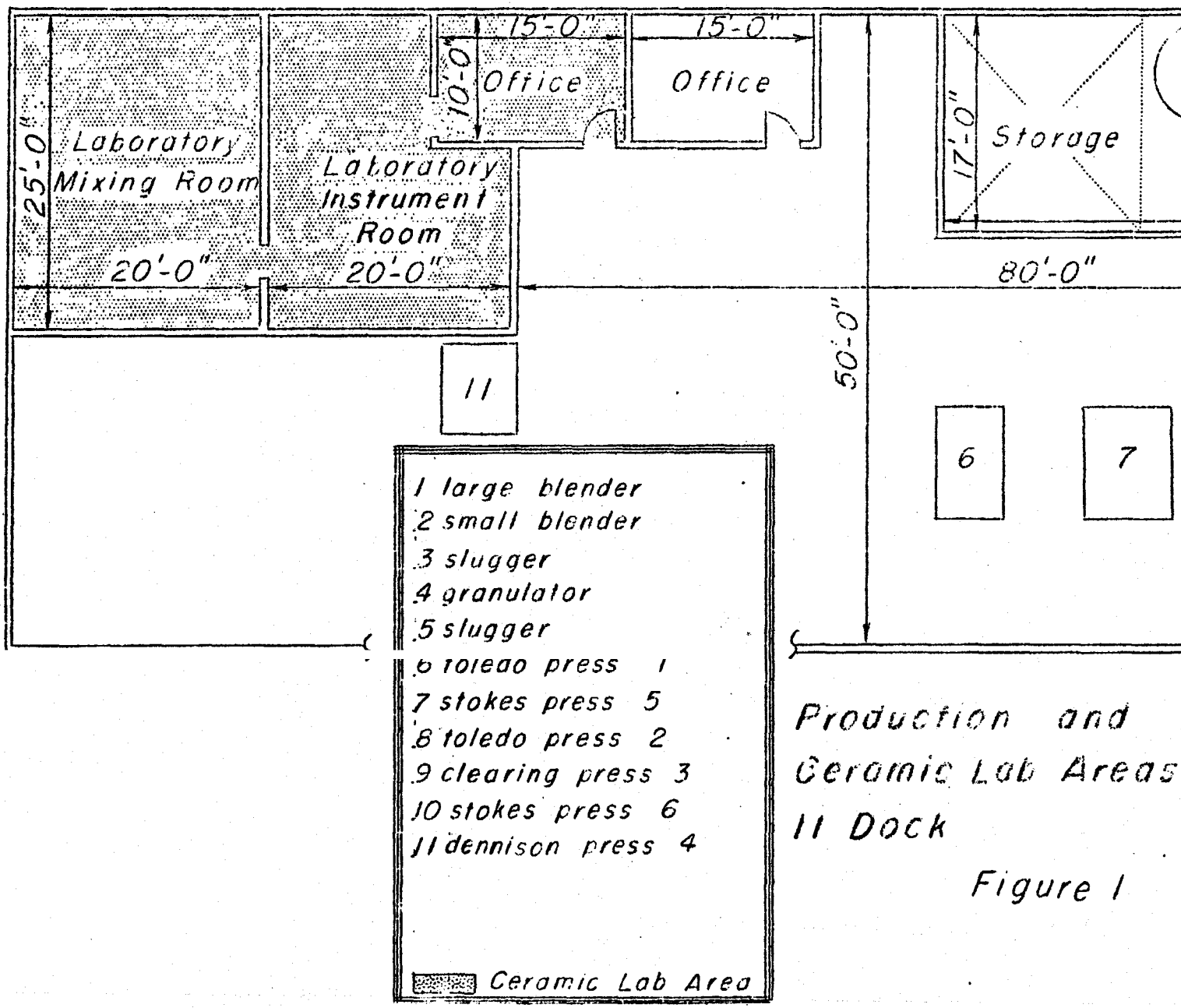

Production and Ceramic Lab Areas
11 Dock

Figure 1