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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HAZARD EVALUATION AND TECHNICAL ASSISTANCE REPORT NO. TA 77-70

Redfield Company
Denver, Colorado

February 1978

Study Requested By:
Personnel Manager
Redfield Company
Denver, Colorado

Report Prepared By:
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Study Dates: September 26-27, 1977

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

I. SUMMARY

On September 26 and 27, 1977, a survey team from the National Institute for Occupational Safety and Health(NIOSH) provided technical assistance in evaluating workroom air contaminant levels at the request of the employer at Redfield Company, Denver, Colorado. The conclusions and recommendations presented in this report are based on environmental measurements, observation of the work-place and work practices, medical questionnaires and a review of current literature.

Airborne concentrations of contaminants - total and respirable particulate and respirable free silica - were obtained in the workers' breathing zone and in the general work area. All personal samples for total and respirable particulate were below the criteria established for this survey. All samples for respirable free silica were below the limits of detection for the analytical method used; however, high volume total particulate and respirable dust samples indicated the presence of free silica.

Information from medical questionnaires indicated that six of the thirteen employees interviewed complained of symptoms characteristic of workers in dusty trades - congestion and difficulty breathing. One worker complained of folliculitis on his forearms.

The potential for overexposure of employees to contaminants exists in this buffing/polishing operation. Recommendations are presented for the alleviation of this potential hazard.

II. EVALUATION

A. Process Description

Redfield Company is engaged in the production of telescopic sights for rifles. Aluminum metal tubes of various outer and inner diameters are received, cut, formed, buffed, polished, anodized and assembled into rifle scopes. There are approximately 250 production employees and approximately 70 administrative personnel overall. The area of evaluation has approximately 16 workers and one supervisor. It is an area approximately 30 feet by 15 feet and for the purposes of this report, will be divided into three rooms designated Room 1, Room 2 and the Harper Room (which includes the control room). See Figure I.

1. Room 1 and Room 2

Room 1 and Room 2 contain buffing and polishing wheels and belt sanders. There is one man assigned to each machine; assignments vary from day to day. Racks of rifle parts are brought in by the lead man and placed before each machine. The buffer takes each piece and places it on a rod so that it will rotate freely when placed against the air pocket type cloth buffing wheel.

The buffer applies the Learok® bar buffing compound (See Table I) to the rotating wheel and then buffs the part. This process is known as cut and color buffing. After cut and color buffing, the buffer uses a sewn type cloth wheel and a bar color or polish (also known as jewelers rouge) compound applied in the same manner. This provides a mirror finish to the part and is known as color buffing.

The belt sanders are used to smooth the rough striations and edges caused by the machining of the part. No compound is added to these sanding belts. The degree of sanding desired is attained by the use of belts of varying coarseness.

There is local exhaust ventilation provided by means of a hood for each buffing wheel and each sanding belt. Each hood has sides that can be opened to change wheels and an adjustable tongue at the top to prevent particles from flying in the face of the worker.

Each worker is allowed 15 minutes at the end of his shift to clean out his exhaust hoods and duct work which connects to the main duct. Long handled probes are provided for this purpose. Every 1 to 1.5 months, the main duct work is cleaned. The lead man is charged with the responsibility of cleaning any duct work that becomes clogged during the shift.

2. Harper Room

The Harper Room consists of an enclosed area containing the Harper automatic buffing machine and an adjacent control room. See Figure I. One employee operates the Harper from the control room, where he is able to place and remove the parts to be buffed on a rotating, oblong assembly and adjust the speed of the rotating assembly, the speed of the 4 revolving buffing wheels and the rate of application of Liquabrade® liquid buffing compound (See Table I). The Liquabrade® is added automatically by a nozzle which moves back and forth across the revolving buffing wheels. There is an adjustable glass window covering the opening separating the operator from the buffing wheels which he may raise or lower. Ventilation is provided in the Harper Room by means of one exhaust fan located in the ceiling.

The operator cleans the Harper room each day by hosing the machine and rafters down with high pressure air and then sweeping the floor.

The company provides single-use throw-away type dust respirators for employee use. The Harper Room operator is the only employee who routinely uses this respirator. Use of this respirator is not a company requirement.

B. Evaluation Design Methods and Criteria

In this particular buffing operation, there is potential for exposure of employees to particulates generated by the operation. The categories in which the hazards to employee health may lie are total nuisance particulate exposure, respirable particulate exposure and exposure to one or more forms of silica. The following paragraphs in this section explain how samples to assess employee exposure to the above hazards were obtained and why they were taken in that manner. Also presented is the recommended criteria used to evaluate these health hazards and the rationale for such a criteria.

Before beginning the discussion, some background on the sources of criteria is in order. There are three criteria used to evaluate the toxic air contaminants in an industrial setting: (1) NIOSH criteria documents for Recommended Occupational Health Standards, (2) Proposed and Recommended Threshold Limit Values (TLVs) of the American Conference of Governmental Industrial Hygienists (ACGIH), and (3) Occupational and Safety Health Administration Standards. These values are based on the current state of knowledge concerning the toxicity of the specific substances. These levels are values to which it is believed that nearly all workers may be exposed for an 8-10 hour day, 40 hour workweek, over a working lifetime. However, because of a wide variation in individual susceptibility, a small percentage of workers may experience discomfort from some substances at concentrations at or below the recommended level; a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational disease. As stated previously, Table II presents the criteria recommended for the specific substances of concern. The source is also indicated. The levels chosen are the most current of the three sources and the respective OSHA Standard is also listed. These levels, with the exception of the OSHA Standards, are not to be used as relative indices of hazard nor are they to be used as fine lines between safe and unsafe conditions. Legally, the OSHA Standards do represent fine lines between safe and unsafe conditions, for they are enforceable.

Inspection of Table II will indicate that the formulae (total and respirable) set forth by the ACGIH and OSHA for various forms of quartz reduce to the respective levels for nuisance total and respirable particulate; i.e., 10 and 5 mg/M^3 and 15 and 5 mg/M^3, respectively, if zero is substituted for percent quartz. This relationship exists because the most important factor in determining relevant exposure levels is the percent silica found in the total and respirable measurements. NIOSH's recommended criteria for respirable free silica is 0.05 mg/M^3 regardless of crystalline form.[4] NIOSH considers the respirable fraction to be the preponderant factor in silica exposure and accordingly recommends a level that is sufficiently low to preclude the use of different levels for different crystalline forms.

1. Total Nuisance Particulate

The ACGIH (1) recommends a level of 10 mg/M^3 of total particulate if the quartz content is less than one percent. This level is not based on toxic effect on the lungs or the production of organic disease. Nuisance dust in excessive concentrations can reduce visibility in the workplace, cause unpleasant deposits on skin and clothing, and may directly cause injury to the skin by clogging pores (folliculitis) or indirectly by the hard cleansing procedures necessary for their removal. Unlike silica dust, which causes scar tissue (collagen) in the lungs when inhaled, nuisance dusts do not cause destruction of the air spaces in the lungs, do not cause scar tissue to be formed to a significant extent and the tissue reaction it does cause is usually reversible or nonprogressive if the employee is removed from exposure.

Samples for total nuisance particulate were obtained with a MSA model G portable personal sampling pump which operated at a flow rate of 1.7 liters per minute (lpm). Air in the worker's breathing zone was drawn through a tared (pre-weighed) polyvinyl chloride (PVC) filter contained in a 3-piece plastic filter cassette. Contaminants in the sampled air were removed by the filter. The filter was returned to the laboratory for post weighing on a Perkin Elmer AD-2 balance. Differences in the pre- and post-weights indicated the amount of contaminant filtered out of the known volume of air sampled. The time an employee wears the sampling device should approximate as closely as possible the full shift; consequently, the sampling apparatus was kept on the employee as long as possible during his shift.

2. Respirable Nuisance Particulate

A distinction is made between total particulate and respirable particulate based on particle size. Studies have shown that particles of a size 5 micrometers and smaller will not be filtered out by the mucous linings of the nasal passages, throat, and bronchi and will be deposited in the lungs[2]. These small particles have greater potential for causing damage than particles larger than 5 micrometers. Therefore, the ACGIH recommends a level of 5 mg/M^3 for exposure to respirable sized particles. The sampling apparatus for total particulate was also used for respirable particulate. However, a cyclone assembly was attached to the filter. The purpose of the cyclone is to aerodynamically separate, from the sampled air before it reaches the filter, particles greater than 5 micrometers in diameter. Analysis was also done gravametrically.

3. Silica

Silica or silicon dioxide, is probably the most ubiquitous mineral on earth. When inhaled in its crystalline form, silica can cause a lung disease known as silicosis. Silicosis is a nodular pulmonary (lung) fibrosis which is progressive and dehabilitating. Also known as grinder's asthma, grinder's rot, grinder's consumption, dust consumption and others, the symptoms in the initial stages of silicosis are gradual and not pronounced. Symptoms include cough, shortness of breath, wheezes and repeated nonspecific chest illnesses. As the size and number of fibrous nodules in the lungs increases, shortness of breath, rapid breathing and impairment of the oxygen exhange capabilities of the lungs becomes more apparent. Tuberculosis is a common complication. It is believed that exposed persons who smoke are more likely to develop silicosis than those who do not.[3] Crystalline structure has an important influence on tissue reaction. Of the three forms of crystalline silica of interest here, cristobalite is more fibrogenic than either quartz or tripoli. Tripoli, a microcrystalline form of silica, will be considered as quartz for the purposes of this discussion. (The greater toxicity of cristobalite is the reason for reducing the recommended exposure level by a factor of 2; see Table II.) Again particle size plays an important part in the deposition of particles in the lungs. The primary site of infection is the alveolar spaces in the lungs. In experimental animals, silicosis has been produced with particles as large as 8-10 micrometers; however, it is considered that particles below 1 micrometer are the most dangerous since that is the optimum size for alveolar passages.

The rationale for assessing a worker's total and respirable particulate exposure is tha same as for nuisance dusts. That is, particle size influences toxicity and the criteria to be used. However, with silica, it is important because percentage distribution of silica particles is variable between the respirable fraction and the total dust measurement. General area samples were obtained in order to determine the percentage composition of silica for the total and respirable matter. These samples were obtained by using a high-volume vacuum pump to pull a large volume of air (5-6X the personal pump volume) in order to obtain enough sample to analyze. Note the average of 23% determined in the total measurement and 16% in the respirable fraction (Table III).

Personal samples for silica were taken on the same identical filters and with the same sampling apparatus as the nuisance dust measurements. After gravimeteric analysis for weight gain, the filters were examined by X-ray diffraction, a method which is specific for the various forms of silica.

III. RESULTS AND DISCUSSION

Table III contains the results for the general area samples for total and respirable particulate, quartz, and cristobalite. Table IV contains the results of the personal samples taken for total and respirable particulate, quartz and cristobalite.

Inspection of Table IV reveals that no worker's exposure exceeded the ACGIH or OSHA criteria for either total or respirable particulate and all exposures to quartz and cristobalite were below the limits of detection for the analytical method used. While the personal samples did not reveal the presence of free silica, the high volume samples did indicate free silica - 23% of the total dust measurement and 16% of the respirable dust measurement. This evidence suggests free silica exposure; however, this author believes this is not the case, for the following reasons. If you assume that the high volume area samples from which the percent respirable silica was determined are truly representative of the personal respirable samples, then the percentage (16%) can be applied to the personal sample data. This would result in 11 of 17 personal samples exceeding the NIOSH criteria for respirable silica. (The eleven samples would be those greater than 0.31 mg/M^3 respirable particulate. For example, 16% of 0.32 mg/M^3 is 0.051 mg/M^3 which is greater than NIOSH criteria.) However, this assumption is not valid because the methods used to obtain the high volume and personal samples were not identical-the flow rates, cyclones and location of sampling apparati were different. In addition, if this 16% figure were applied, 11 of 17 samples would be above the 0.03 mg limit of detection and should have been indicated on the personal samples; however, the personal samples did not detect any free silica (See Table IV). While the preceding discussion dealt only with the particular situation at the time the survey was performed, the potential for employee exposure exists in this operation. If subsequent sampling revealed the presence of respirable free silica in personal breathing zone samples, then the criteria for total and respirable dust would be reduced in relation to the percent silica in the high volume sample. For example, assuming that another high volume sample showed 23% total and 16% respirable free silica, then the ACGIH and OSHA levels for total and respirable particulate would become 1.58 and 0.56 mg/M^3, and 1.67 and 0.56 mg/M^3, respectively. These new criteria are obtained by substituting 23% and 16% in the respective formulae in Table II. An increase in the number of buffers/polishers (thereby an increase in particulates generated) or an increase in the workday (time exposed) may allow detectable concentrations to be found on personal samples.

Six of the twelve employees interviewed indicated symptoms that they associated with the environmental conditions in the workplace; namely, running nose, sinus trouble, difficulty breathing, tightness in chest, a funny taste in the mouth. These six workers had worked for Redfield or other companies in similar operations from 3 to 7 years with an average of 4.75 years. Five workers had smoking histories from 3 to 20 years. One employee complained of folliculites on his forearms. This is probably due to his practice of rolling up his sleeves when he works.

IV. RECOMMENDATIONS

The following recommendations are made in order to improve working conditions in the buffing area and to reduce the potential for exposure of employees to contaminants.

1. Since the potential for exposure to silica exists for the buffers/polishers in this operation, it is recommended that a medical and environmental monitoring program be developed and implemented.

All workers in the buffing operation should be appraised of the hazard and relevant symptoms of silica exposure and the increased risk of impaired health due to the combination of smoking and free silica exposure. Medical examinations, including as a minimum - a medical and occupational history to elicit data on worker exposure to free silica and signs and symptoms of respiratory disease, a chest x-ray and pulmonary function tests - should be available to each worker, prior to employment and at least once each three years thereafter.

The working environment should be evaluated every six months and after each process change to determine if hazardous levels of contaminants are being generated. Sampling should be by personal monitoring conducted in a manner similar to that used in this study.

Details of the medical and environmental programs are presented in the NIOSH criteria document on Crystalline Silica.[4]

2. While it is not required by the Federal Occupational Safety and Health Administration that an employer have a written respirator program if he supplies respirators to his employees if exposures cannot be documented above the TLV; in the case of Colorado's State Occupational Safety and Health Program, it is a requirement. The providing of respirators - even single-use, throw-away types - without an accompanying written respirator program, is grounds for a citation. (In the case of disparate requirements between State and Federal programs, the most stringent requirement takes precedence.)

NIOSH's position is consistent with the State in this case. The supply of respirators without the attendant instructions regarding care, use and limitations may lead to employee apathy regarding his respiratory protection. The consequences of the use of an incorrect respirator in an emminently hazardous area are obvious. Therefore, it is recommended that a respirator program be established according to the Occupational Safety and Health Standards Respiratory Protection - (29 CFR 1910.134, revised January 1976). Establishment of this program will eliminate at least one problem noted in this survey-the single use respirators employed were not stored in a "convenient, clean and sanitary location"{(1910.134)(b)(6)} but were stored in area contaminated by the buffing operation.

3. The local ventilation hoods for the buffing and polishing machines are generally those that are recommended by the ACGIH in their Industrial Ventilation Manual;[5] however, they are in obvious need of repair. Broken hoods and inadequately repaired ductwork will not allow the system to operate properly. Figures II and III are Xerox® copies of design criteria for buffing and polishing wheels and belt sanders found in the Industrial Ventilation Manual. Modification of the present system to fit these design criteria should be sufficient to capture the generated contaminants. Two important points are the adjustable tongue at the top and the underhanging lip at the bottom. The workers do not adjust the tongue as the wheel gets smaller and the tongue is probably not long enough to block contaminants as the wheel reduces to the one-inch radius replacement point. It is recommended that this tongue be kept as close to the wheel as possible to reduce the amount of particles thrown back out of the hood by the motion of the wheel. Extending the underhanging lip of the hood out farther would eliminate the waste accumulating on the floor at the feet of the worker. Housekeeping, or the lack of,affects significantly the amount of contaminants to which a worker is exposed. Resuspension of toxic materials is a major source of exposure to workers.

The general appearance of the hoods in Rooms 1 and 2 are probably indicative of the entire system. Therefore, it is recommended that Redfield evaluate its ventilation system needs, repair and modify the present system and determine if it will service those needs. It may be that the system will perform to everyone's satisfaction if it is repaired and maintained properly.

The difficulty of using the hoods as designed and still maintaining high quality finished material is appreciated. The company may wish to consider customizing certain hoods for specific jobs in order to maximize the enclosure without sacrificing accessability. Since the buffing operation only finishes 3-4 differently shaped parts this may be feasible.

4. The air velocity into the Harper room should be increased to prevent contaminant contact with the operator. Also, the operator should lower the access window as far as possible in order to reduce his exposure. Reducing the size of this opening will also increase the inward air velocity at the opening.

5. Employees complained of the irritating smoke generated by the buffing operation. This smoke is probably due to the organic compounds - stearic acid, beef tallow - in the buffing compounds and the oil that is on the incoming pieces. The degree of smoke generated is a function of a) the size of the buffing wheel and the amount of buffing compound used, b) the size and shape of the part to be buffed, and c) the pressure exerted by the buffer as he applies the piece to the wheel. Greater volumes of smoke are created by smaller wheels, more buffing compound, smaller pieces and greater pressure. The individual buffer can generate as much smoke as he wants by applying greater pressure to the buffing wheel. It is recommended that the buffers not try to generate as much smoke as possible; if the proper quality work can be obtained with less pressure then the job should be done in that manner. If more buffing compound and more pressure is required as the wheel gets smaller, the company may wish to consider changing wheels before they reach the present replacement criteria of one inch radius. Also, the pieces should be cleaned to remove the machining oil before buffing. If a solvent is used, then good health and safety practices should be followed relative to the type of solvent used.

6. To prevent folliculitis on the forearms, it is suggested that employees roll their sleeves down to prevent skin contact with dermatitis causing substances. If this is unsuccessful, then the use of barrier creams - lotions which provide a protective covering on the skin and can be washed off after work - is recommended. Table V lists some examples of barrier creams available. Mention of brand names in this report does not constitute an endorsement by NIOSH.

7. The floor clean-up procedure in the Buffing Area uses high pressure air hose and sweeping. Both these methods are unsatisfactory good work practices since both cause more contaminants to become airborne. A more satisfactory substitution would be wet vacuuming.

ACKNOWLEDGEMENTS

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V. REFERENCES

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2. The Industrial Environment - its Evaluation and Control, HEW (1973) pg. 496.

3. Occupational Diseases, A Guide to their Recognition. Gafafer, W.M., Ed. HEW (1964) Public Health Service Publication No. 1097.

4. Criteria for a Recommended Standard . . .Occupational Exposure to Crystalline Silica. (1974). NIOSH Publication No. 75-120.

5. Industrial Ventilation, A Manual of Recommended Practice. American Conference of Governmental Industrial Hygienists. 14th Ed. (1976).

OTHER REFERENCES

a. Documentation of Threshold Values. American Conference of Governmental Industrial Hygienists, 3rd Ed. Cincinnati, Ohio 1971.

b. "NIOSH Manual of Sampling Data Sheets." (March 1977). NIOSH Publication No. 77-159.

c. "Ventilation Requirements for Grinding, Buffing and Polishing Operations." (September 1974). NIOSH Publication No. 75-107.

d. "A Guide to Industrial Respiratory Protection." (June 1976). NIOSH Publication No. 76-189.

Table I

CONSTITUENTS OF MATERIALS USED IN BUFFING OPERATIONS
Redfield Company
Denver, Colorado

September 26-27, 1977

Material	Constituents	
Barrel of Rifle Scope	Aluminum	100%
LEArok® - bar buffing compound	Stearic Acid	16.73%
	Beef tallow	8.36%
	Tripoli	49.94%
	Free silica	24.97%
Liquabrade® - liquid buffing compound	Dowicide "G"	1/10 of 1%
	Triethanolamine	2%
	Tripoli	42%
	Petrolatum	6.5%
	Stearic Acid	11.5%
	Water	~38%
CR Chrome Rouge	Silica	~22%
	Aluminum oxide	~63%
	Petrolatum	4%
	Stearic Acid	15%

TABLE II

EVALUATION CRITERIA

Redfield Company
Denver, Colorado

Substance	Most Current recommended level	Source	OSHA Standard
Total nuisance particulate (<1% quartz)	10 mg/M^3	ACGIH, 1977	15 mg/M^3
Respirable nuisance particulate (<1% quartz)	5 mg/M^3	ACGIH, 1977	5 mg/M^3
Silica - quartz Respirable	$\frac{10\ mg/M^3}{\%\ Resp.\ quartz\ +2}$	ACGIH, 1977	$\frac{10\ mg/M^3}{\%\ Resp.\ quartz\ +2}$
Total	$\frac{30\ mg/M^3}{\%\ quartz\ +\ 3}$	ACGIH, 1977	$\frac{30\ mg/M^3}{\%\ quartz\ +\ 2}$
Silica - cristobalite	$\frac{1}{2}\left[\frac{30\ mg/M^3}{\%\ quartz\ +\ 3}\right]$	ACGIH, 1977	$\frac{1}{2}\left[\frac{30\ mg/M^3}{\%\ quartz\ +\ 2}\right]$
Silica - respirable (all forms)	0.05 mg/M^3	NIOSH, 1974	

TABLE III

HIGH VOLUME GENERAL WORKAREA SAMPLES FOR
TOTAL AND RESPIRABLE WEIGHT AND CRYSTALLINE FORM

REDFIELD COMPANY
DENVER, COLORADO

September 26-27, 1977

Location	Sampling Time (minutes)	Sample Volume (M^3)	Total Weight (mg/M^3)	Quartz (mg/M^3)	Cristobalite
Room 1	465[a]	4.2	.78	.18	ND[b]
	465[c]	4.2	.35	.07	ND
Room 2	465[a]	4.2	.79	.17	ND
	465[c]	4.2	.32	.04	ND

Average quartz in total particulate samples = 23%
Average quartz in respirable particulate samples = 16%

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a - total particulate samples
b - non detectable
c - respirable particulate samples

TABLE IV

PERSONAL SAMPLES FOR RESPIRABLE PARTICULATE AND CRYSTALLINE FORM

REDFIELD COMPANY
DENVER, COLORADO

September 26-27, 1977

Job Description	Sampling time (minutes)	Sampling volume (M^3)	Total particulate (mg/M^3)	Respirable particulate (mg/M^3)	Quartz (mg/M^3)	Cristobalite (mg/M^3)
Lead man	420	.71	.94	.25	ND	ND
Polisher/Buffer	417	.71	2.28	.65	"	"
" "	413	.70	1.53	.20	"	"
" "	411	.70	8.24	1.51	"	"
" "	410	.70	2.84	1.74	"	"
" "	300	.51	1.63	.35	"	"
" "	471	.80	5.90	.54	"	"
" "	503	.86	1.69	.48	"	"
" "	497	.85	1.60	.42	"	"
" "	495	.84	3.51	.06	"	"
" "	525	.83	3.07	.47	"	"
" "	490	.77	2.45	.36	"	"
" "	515	.81	1.31	.15	"	"
" "	490	.77	1.04	.10	"	"
" "	369	.63	.94	.21	"	"
" "	434	.74	1.93	.46	"	"
" "	403	.69	1.41	.61	"	"
" "	395	.67	1.60	-	-	-
Recommended level			10	5	.05	total
Limits of detection			0.01 mg	0.01 mg	0.03 mg	0.04 mg

Table V

Protective Creams

West Protective Cream # 211 or #311
West Chemical Products Company
42-16 West Street
Long Island City, New York 10017

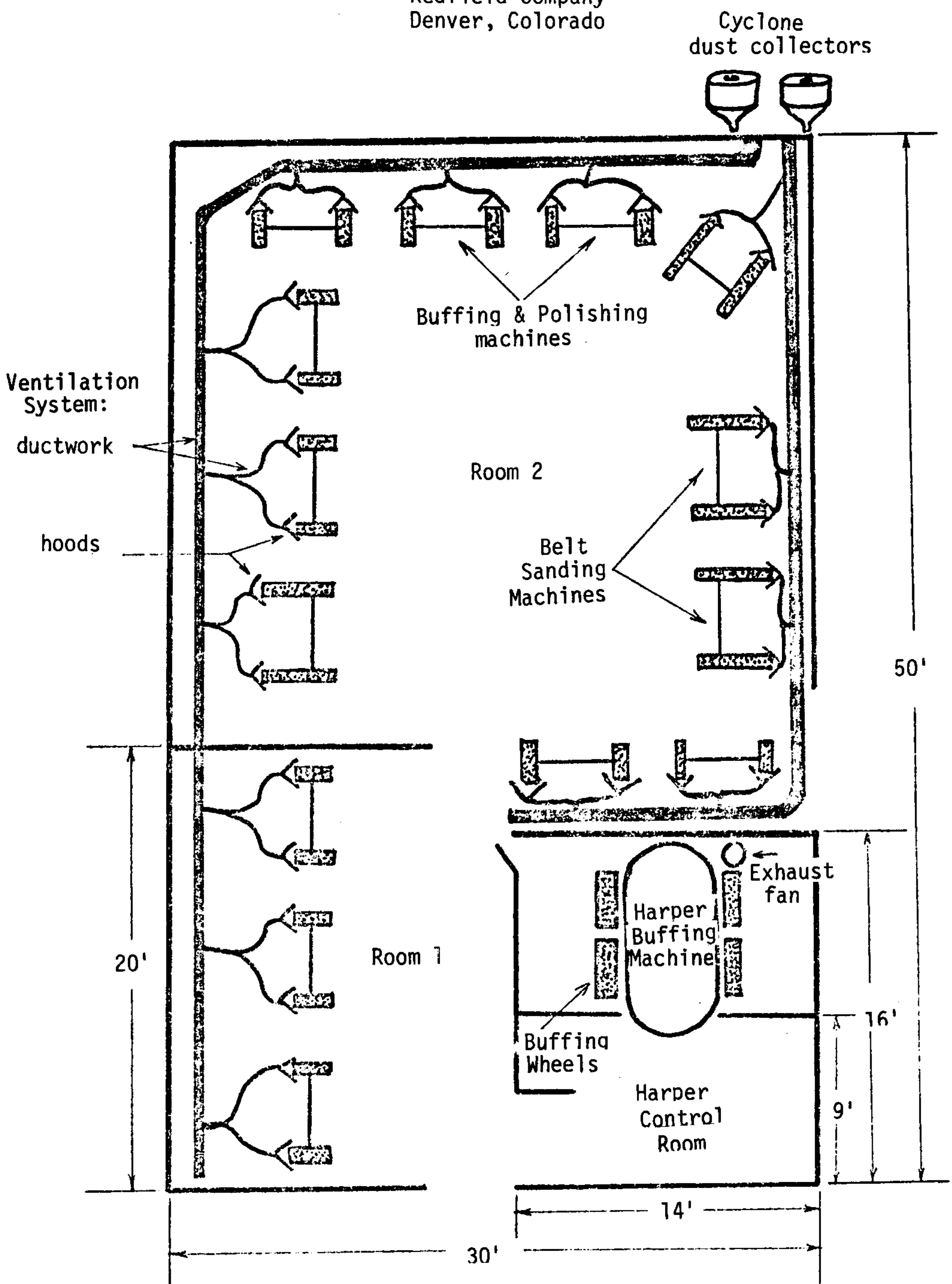
Ply #9
Milburn Company
3246 E. Woodbridge
Detroit, Michigan 48207

Kerodex #51
Ayerst Labs
685 - 3rd Avenue
New York, New York 10017

FIGURE I

BUFFING AREA

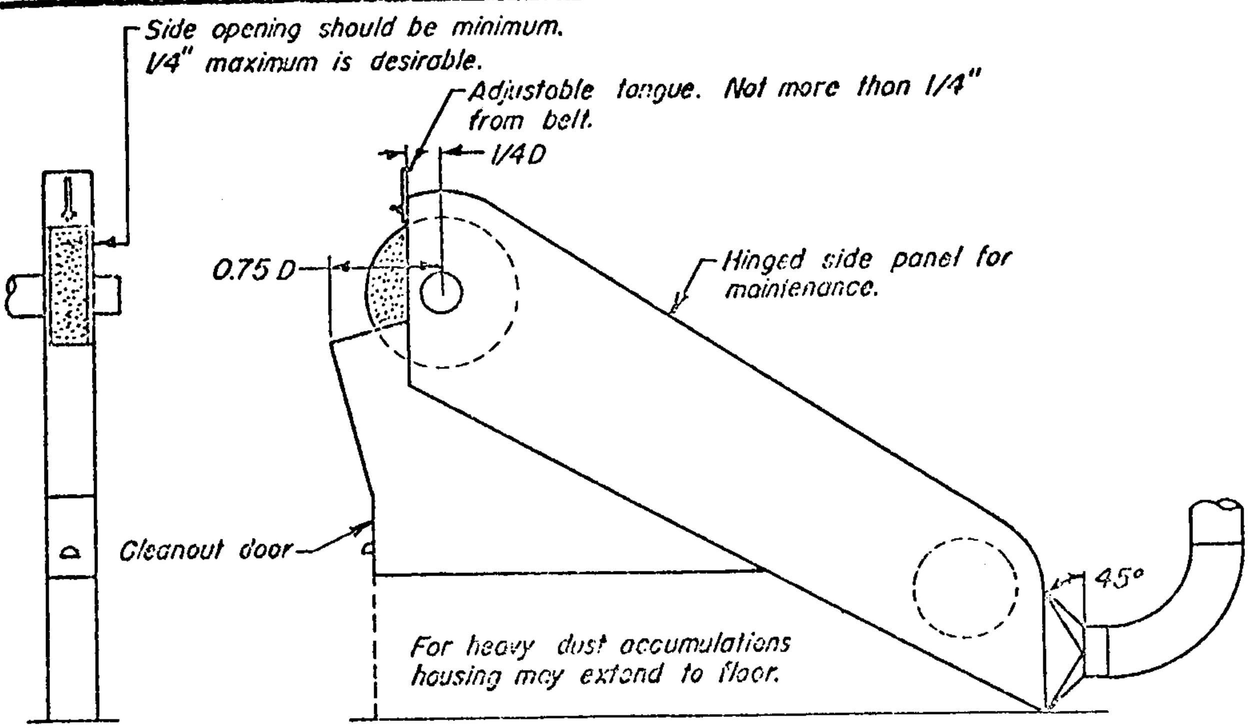
Redfield Company
Denver, Colorado



SCALE: 1" = 7'

Figure II

Reproduced from best available copy.



Belt width inches	Exhaust volume cfm	Exhaust volume cfm
	Good enclosure *	Poor enclosure
1 1/2	220	300
2	390	610
3	500	740
4	610	880
5	880	1200
6	1200	1570

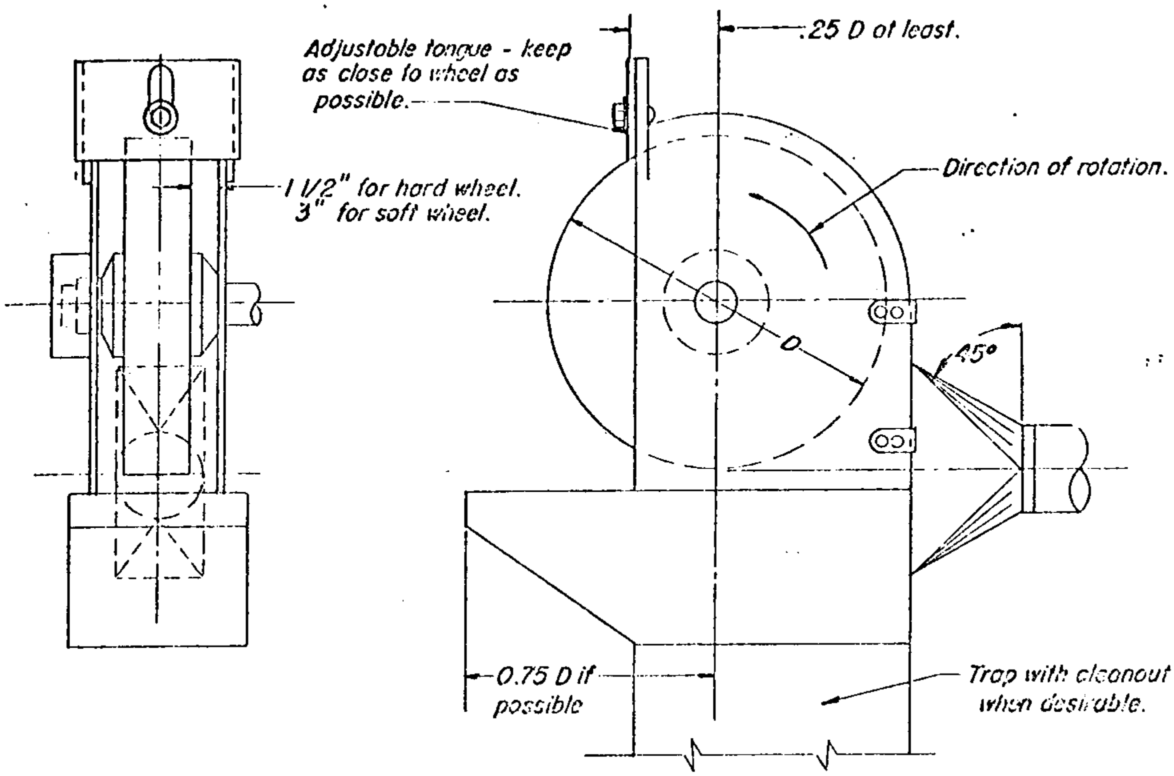
* Hood as shown. No more than 25% of wheel exposed.
Entry loss = 0.40 VP
Duct velocity = 3500 fpm minimum

Note:
For titanium and magnesium eliminate hopper and use 5000 fpm through hood cross section.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

BACKSTAND IDLER POLISHING MACHINE

DATE 1-7? | VS-40?



Minimum duct velocity : 4500 fpm branch.
3500 fpm main.

Entry loss : 0.65 VP for straight take-off.
0.40 VP for tapered take-off.

Wheel diam. inches	Wheel width * inches	Exhaust volume cfm	Exhaust volume cfm
		Good enclosure	Poor enclosure
to 9	2	300	400
over 9 to 16	3	500	610
over 16 to 19	4	610	740
over 19 to 24	5	740	1200
over 24 to 30	6	1040	1500
over 30 to 36	6	1200	1990

* In cases of extra wide wheels, use wheel width to determine exhaust volume.

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BUFFING AND POLISHING

DATE 1-71 VS-406