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Maurice S. Reizen, M.D., Director

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Worker wearing a personal air sampler for measuring the work environment dust exposure.

PERSONAL AIR SAMPLING

Russel G. Scovill, District Engineer, Saginaw

The Division of Occupational Health today is employing a relatively new technique for evaluating employee exposure to dust in the work environment. The technique utilizes a battery operated air pump which is small enough to be worn by the individual worker to capture a sample of the contaminant in a micropore filter placed adjacent to his breathing zone. The sampler is worn by the employee for a period of from one to several hours while performing his regular work.

Those who are familiar with the use of film badges and dosimeters for radiation monitoring will recognize a parallel in this method. As opposed to the instantaneous dose rate obtained by direct reading instruments, film badges and dosimeters measure total radiation dosage over a longer period of time. This makes them invaluable in determining the hazards of variable or intermittent exposures.

The personal air sampling method embodies several prime advantages: the equipment is convenient to use. The longer sampling period produces a result more representative of the worker's actual exposure in a typical work situation. For certain intermittent, variable or mobile jobs (such as payloader operators), the personal air sampler permits the kind of exposure assessment which was previously most difficult when not impossible.

EQUIPMENT AND USE

The personal air sampling pump is attached directly to the worker, usually on his belt. The sample collection device is attached near his shirt collar or lapel with a suction hose leading to the air pump. The cover photo shows a typical placement of the pump on a worker; its position can be shifted to accommodate the nature of the work. The hose routing may also be varied to accommodate extreme limits of arm and shoulder movement.

This equipment contrasts sharply with its predecessors—the electrostatic precipitator and the long-standard Greenberg-Smith impinger sampling method with a 20-30 pound line-powered pump and liquid impingment collection flask. While this method was modified by the development of the more portable midget impinger which could be operated by a hand cranked pump, sufficiently representative sampling was tiring to the investigator. Of necessity, breathing zone impinger samples are limited to 10-20 minutes each—repeated as often as might be desirable throughout the work cycle or work day to obtain an accurate measure of the overall exposure.

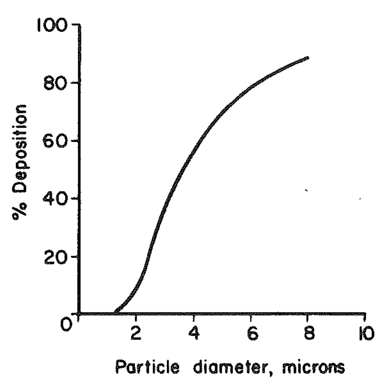
The personal air sampling technique is especially valuable to assess many irregular or mobile work exposures that are difficult or impossible to measure by traditional methods. Examples are numerous: the process operator who must inspect an enclosed conveyor or unjam an overfilled screen; the foundry truck driver who must empty hoppers and travel into unventilated corners of the plant; the maintenance man who may be called upon to work in an area while adjacent production operations continue; and the "clean-up gangs" whose jobs vary throughout the work shift and who at times cannot be protected by the process ventilation.

CONTAMINANT STANDARDS

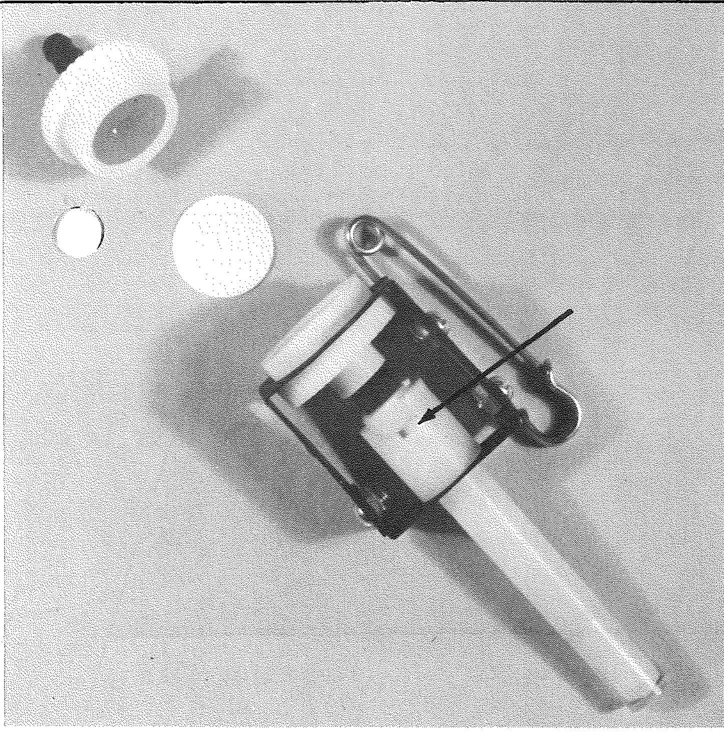
The most commonly used guidelines for permissible occupational exposures are called Threshold Limit Values (referring to the *threshold of effect,* whether it be irritation, narcosis, reversible or irreversible physiological damage) or Maximum Allowable Concentrations as in Michigan's Occupational Health Rules. Within specified fluctuation ranges, these are usually time weighted average values for an 8-hour work day. Thus, satisfactory air sampling with "standard" methods involves not only the sampling equipment itself, but requires careful observation of the process and work task variables plus a (rudimentary) study of the exposure times involved. The personal air sampler meets all of these needs by virtue of its longer measuring time, and is potentially more accurate and more representative of the actual exposure.

In the case of most dusts and some metal fumes, short term concentrations can exceed the daily average TLV many times without harmful consequence, providing the daily total dose does not exceed the 8-hour exposure at the TLV. For such exposures, personal air sampling is well suited. Lead, cobalt, beryllium and

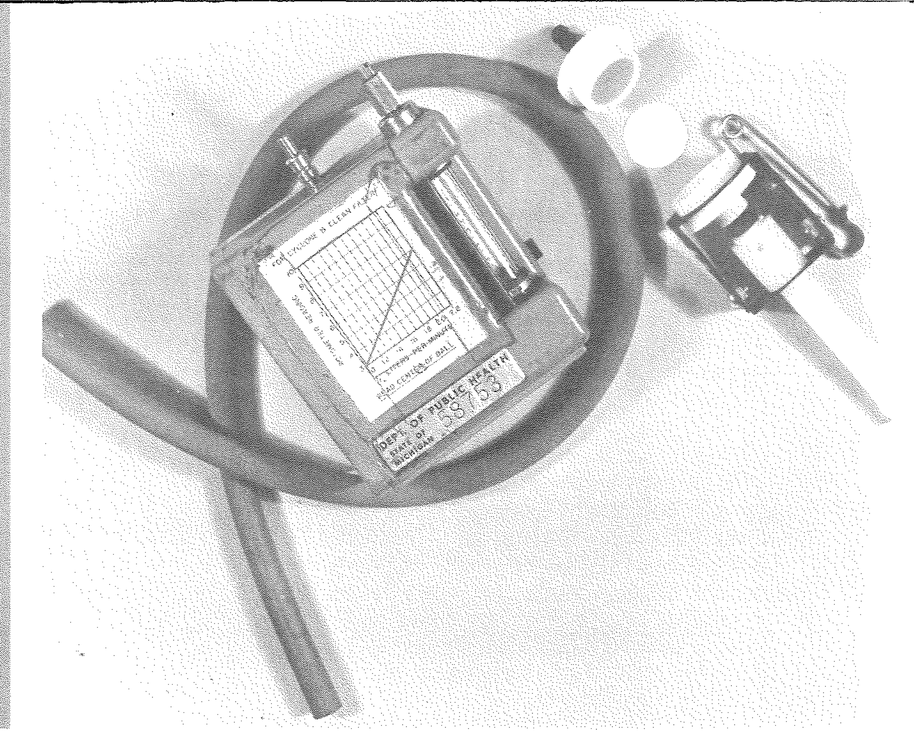
FIGURE 1



Deposition of particles in upper respiratory tract



(FIGURE 2) Exploded view of miniature cyclone. Arrow indicates orifice through which dust is collected.



(FIGURE 3) Entire system: cyclone, filter, suction hose, battery pump and flow meter case.

their compounds have relatively low threshold limit values. The high degree of accuracy and convenience in field use make personal air sampling a logical choice for evaluating many exposures to these materials.

Toxic substances soluble in body fluids, such as lead and mercury compounds, may be absorbed wherever they are deposited and the total weight suspended in the air is of hygienic significance. To sample for such materials a filter may be all that is required at the sample collector. When sampling for certain mineral dusts, however, not all of the suspended particulate matter in the workroom air may be harmful so different collecting equipment is required.

RESPIRABLE DUST SAMPLING

The human body is wondrously equipped to protect itself against many life stresses, including dust, and is able to filter out (by depositing in the upper respiratory and lung passages) practically all dust particles larger than 10 microns in diameter and most of those between 5 and 10 microns (Figure 1). Only smaller particles can reach fine passages and innermost areas of the lungs, the bronchioles and the alveoli. The deposits in the upper lung passages are removed from the body by ciliary action and upward flow of mucous.

The dust disease (pneumoconiosis) silicosis receiving attention in Michigan and elsewhere at the present time is caused by excessive exposure and subsequent lung deposition of fine particles of the insoluable mineral quartz. In this disease, fibrotic or scar tissue is formed on the inner working surfaces of the lungs by the action of inhaled quartz dust particles, decreasing the area available for gas transfer.

When we speak of "respirable dust" we are consequently referring only to particles capable of penetrating into the lungs — particles considerably smaller than 10 microns. Since typical airborne dust includes many particles larger than 5 to 10 microns, to achieve results truly representative of dust exposures affecting the lungs, the sampling device must be selective. A total airborne dust sample for pneumoconiosis-producing dust could be very misleading. To prevent this, the sampling apparatus must be able to discriminate between the large and small particles of dust in the air.

The development of "respirable" dust sampling devices has occurred through efforts of researchers and industrial hygienists both in the United States and abroad. Presently, a two-stage sample collector is employed. The first stage is a miniature cyclone air cleaner which duplicates the "dust collection" performance of the human upper respiratory tract—it is very effective on the largest of the airborne particles but is able to remove from the air stream progressively fewer of those smaller than approximately 7 microns. The particles which are of "respirable size" (and would reach the lungs) pass to a second stage filter placed at the outlet of the cyclone. Table 1 specifies minimum cyclone performance necessary to match the "collection efficiency" of the upper respiratory tract. Figure 2 is an exploded view of the miniature cyclone presently in use by the Michigan Department of Public Health. Figure 3 shows the cyclone, the filter holder, the suction hose connecting to the battery pump and the flow meter case.

TABLE 1

Percent of Particles of Specific Size Range to Equal Respirable Fraction

Aerodynamic Diameter (Unit density sphere) micra	Minimal % Collected
2.0	90
2.5	75
3.5	50
5.0	25
10.0	0

The collector shown is a development of our instrument laboratory and incorporates a 25 mm diameter vinyl metricel filter with a pore size of 0.8 micron. Each filter is pre-weighed under controlled conditions and mounted in clean, serially numbered plastic holders in our analytical laboratory. After collection of the sample, the filter is reweighed and the amount of dust captured is reported in terms of *milligrams of respirable dust per cubic meter of air.*

RESPIRABLE DUST STANDARDS

At present, we evaluate the dust exposure by use of the *proposed threshold limit value* for respirable mass sampling. The purpose of this proposed standard is to encourage collection of comparison data and to foster further development of sampling equipment that will hasten the day when the personal air sampling method will be in common use. In order to use this standard, we need to know also the percentage of quartz in the respirable dust fraction. One current method for obtaining a sufficiently large sample of the respirable dust for quartz analysis is to use a high volume electrostatic precipitator preceded by a cyclone which is larger than the one on the personal air sampler but which matches it in collection performance. Quartz content of the high-volume sample is determined by our analytical laboratory using the x-ray diffraction instrument. Further, refinement of laboratory techniques now permits direct analysis for quartz from the individual filter samples, thus eliminating another sampling step and providing a more direct evaluation of the worker's environment.

VALIDATION AND EXPERIENCE

Several of the references from which we have validated this method of air sampling and workroom evaluation are listed at the end of this article. The transition from a dust count to a weight basis has long been advocated by many industrial hygienists in this country; in fact, weight limits were used before adoption of the present dust count limits. In 1959, the Johannesburg Pneumoconiosis Conference recommended a weight limit for coal dust. In recent years, the wisdom of a weight basis for evaluating dusts that can cause pneumoconiosis has been apparent to many investigators. This view emerged not only because of the inherent limitations and relative tediousness of the impinger sampling and microscopic counting method, but because of the advantages of the longer-term air sample.

As with any new method, questions arise as to how it compares with existing methods and standards. Table 2 lists data from some of our recent studies that have included personal sampling for respirable mass concentrations.

Those with statistical interests may feel that there is some inconsistency in the ratios between the results of the two methods. Based upon our experience in impinger sampling and microscopic counting, we find acceptable—even if approximate—the agreement between the methods. In fact, we believe that the correlation found to date is a testimony to the validity of the respirable mass sampling method, especially when considering that these samples were collected from a wide variety of processes and involved dusts of different composition.

TABLE 2

Plant Type	Work Location and Remarks	Dust Counting MPPCF		Respirable Mass Mg/M³		Sample Meas. Dust Ratio: TLV	
		TLV	Samples	TLV	Samples	Dust Count	Resp. Mass
1. Vitrified Tile	Mixing Bldg. Main Work Area Maint. & Insp. Areas		32,25 43,128	.4	1.9–0.1		4.7–.25
2. Limestone Mill		20	32,48 250	1.5	10.7–6.8	1.6,2.4, 12.5	4.5–7.3
3. Cement Plant	Old Dryer Bldg.	12.5	22,78	1.1	3.9– .7	.6,1.8	.6—3.5
4. Grey Iron Foundry	Basement, General Air	13	11	.7		.8	
	Laborer Truck Driver				1.8,1.9		2.6–2.7 1.0,1.6,2.1
	Trucker's Breathing zone at end of shake-out conveyor	7.3	14.1	.6	.6	2	1
	General air, sorting room	7.3	7.9,5.7				
	Breathing zone of 2 sorters	7.3	10.8,30.2	.6	.4,.8	1.5,4	.7,1.3
5. Foundry Molding	Sand Slinger	11	10	1.0	1.01	.9	1.0
6. ″	″ ″	11	10	1.0	1.00	.9	1.0
7. ″	″ ″	11	18	1.0	1.00	1.6	1.0
8. Sintering Plant		50	44	15	37	.9	2.5
9. Malleable Iron Foundry	Bobbing Operator 1-1	6.3	av. of 3=9	.43	av. of 2=.6	1.5	1.5
	Bobbing Operator 1-4	6.3	av. of 3=6	.43	.5	1.3	1
	Bobbing Operator 2-1	6.3	av. of 2=30	.43	2.0	4.7	4.5

NOTES ON THE SAMPLING AND ANALYTICAL PROCEDURE

We have found remarkably congenial cooperation from employees when they are asked to wear the personal air sampler for the first time. The workers appear to appreciate the interest shown in their environment and are not troubled by the minor inconvenience of wearing the equipment and the periodic checking of sample flow rate.

Sample flow rate is of great importance for two reasons: first, if it is allowed to vary from the established flow of 1.7 liters per minute, the cyclone performance will be adversely affected and its dust separation will no longer match that of the upper respiratory tract. Second, accurate flow rate (and time) are necessary to fix the total volume of air that has been sampled. To date, the pumps we use have given satisfactory service when the batteries are properly charged. Minimum time is required in adjusting flow rate as well as checking the position and tightness of the sampling assembly and hose.

Early model sample assemblies (cyclone and filter) were found to be cumbersome and prone to come apart in the field, sometimes voiding an irreplacable sample. Our present model, developed in our equipment and analytical labs, overcomes most of these disadvantages by being considerably lighter and more securely seated.

Filters are conditioned in a controlled atmosphere preweighed for 24 hours and are then mounted in the holder by laboratory personnel. The sampling assembly is used as a unit in the field and is returned to the laboratory for processing. Filters are removed and again conditioned for 24 hours before weighing on a micro balance. Presently, collected material in the cyclone is discarded unless special analysis is requested.

SUMMARY

To date, we have found the personal air sampling method to be practical and accurate for measurement of dust exposure and acceptable to the workers. Best applications appear at this time to be for intermittent or variable work tasks or for the long-term measurement of highly toxic contaminants with extremely low TLV's. We intend to continue use of this technique as a valuable tool in assessing worker dust exposures.

REFERENCES:

1. "Subcommittee on Chemical Methods in Air Analysis, American Public Health Association: Sampling and Sampling Devices," *Supp. to Am. Journ. Pub. Health, Vol. 30, No. 2,* 1940.

2. Hyatt, E. C., *et al.* "A Study of Two-Stage Air Samples Designed to Simulate the Upper and Lower Respiratory Tract," *Proc. 13th International Congress on Occupational Health,* 1960.

3. Hamilton, R. J., and W. H. Walton. *The Selective Sampling of Respirable Dust, Inhaled Part and Vapors.* Oxford: Pergamon Press, 1961.

4. Lippmann, M., and W. B. Harris. "Size-Selective Samples for Estimating Respirable Dust Concentrations," *Health Physics, Vol. 8,* 1962.

5. Hatch, T. F., and P. Gross. *Pulmonary Deposition and Retention of Inhaled Aerosois.* New York: Academic Press, 1964.

6. Morrow, P. E. "Evaluation of Inhalation Hazards Based Upon the Respirable Dust Concept and the Philosophy and Application of Selective Sampling," *A.I.H.A. Journ., Vol. 25, No. 3,* May-June, 1964.

7. Roach, S.A., *et al.* "Testing Compliances with Threshhold Limit Values for Respirable Dust," *A.I.H.A. Journ., Vol. 28,* Nov.-Dec., 1967.

8. Ayer, H. E., G. W. Sutton, and I. H. Davis. "Report on Size-Selective Gravimetric Sampling in Foundries," U. S. Public Health Service. *Occupational Health Program, TR 39.* Cinncinnati: April, 1967.

9. Ayer, H.E. "The Proposed A.C.G.-I.H. Respirable Mass Limit for Quartz: Review and Evaluation," *Annual Meeting Transactions A.C.H.I.H.,* May, 1968.

10. Higgins, R. I., and P. Dewell. "A Gravimetric Size-Selecting Personal Dust Sampler," *British Cast Iron Research Assn.,* Alvechurch, Birmingham, England, May, 1968.

11. "Personal Respirable Dust Sampler," U. S. Bureau of Mines. *Mineral Industry Health Program, TPR 17.* Pittsburgh: Fall, 1969.

12. "Respirable Mass Sampling," A.I.-H.A. Aerosol Technology Committee, H. J. Ettinger, Chairman, *1970 Unpublished Report.*

BENTONITE

Alvin L. VanderKolk, Chief
Standards and Analysis Section

Bentonite is a type of clay containing appreciable amounts of the mineral montmorillonite. Bentonite normally has the ability to swell greatly by absorption of water. It is composed principally of aluminum and silicates, usually with some magnesium and iron. The general terms given to bentonite are Southern and Western, denoting the areas of origin in the United States. Southern Bentonite is found mainly in Mississippi; Western Bentonite is found in Arizona, Wyoming, and South Dakota.

Bentonite is used as a molding and sand additive in the foundry industry. Our main concern is that workers may breathe dust particles which contain crystalline silica. Excessive exposure to silica-bearing dust is known to cause silicosis. In order to establish dust exposure limits for the workers' protection, we perform x-ray diffraction analyses routinely on samples of airborne dust and parent materials. Commonly, we analyze for quartz, the most common crystalline form encountered in foundry dusts. During these analyses, cristobalite, another crystalline form of silica, showed up in some of the bentonite samples. Because of this we have begun to analyze bentonites from various sources for both quartz and cristobalite. Comparing our results with other laboratories, we learned that the Pennsylvania Department of Health reported similar findings.

The following is a tabulation of analyses to date:

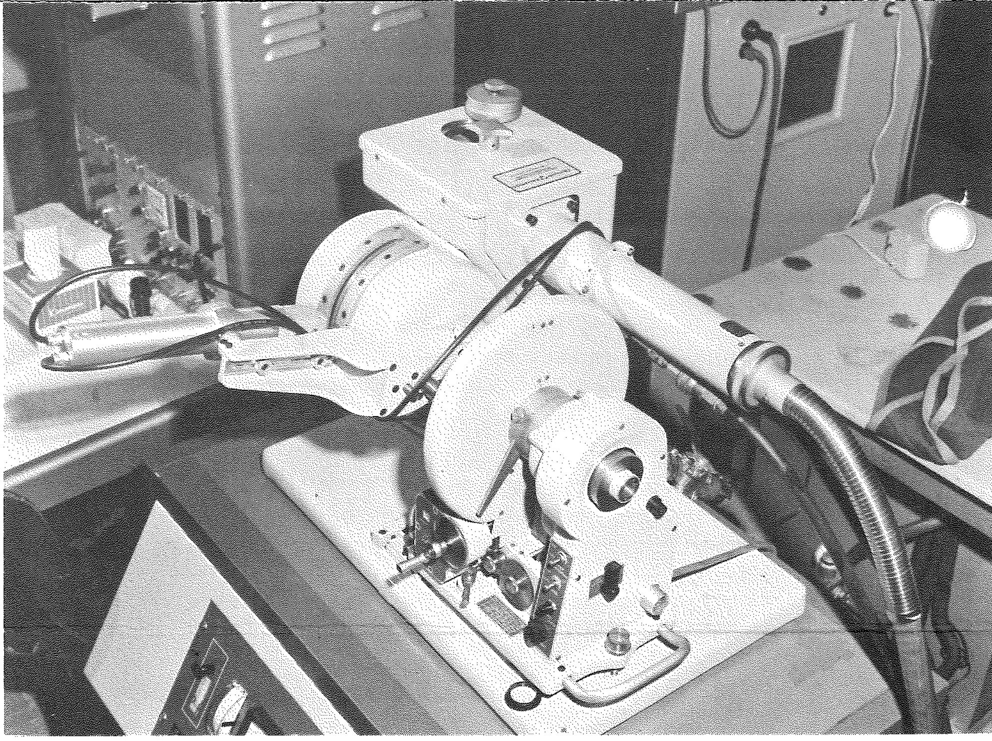
Source	*% Quartz*	*% Cristobalite*
Western Bentonite		
A	3	30
B*	1	11
C	6	0
D*	4	0
E	6	0
F*	4	0
G	5	0
H*	5	0
I	4	0
J	8	0
K*	11	0
L	0	9.5
M*	1	59
N*	3	0
O*	3	0

*Analyzed by Pennsylvania Department of Health

Southern Bentonite		
P	17	0
Q	0	0
R	13	Not checked

The results indicate that when Western Bentonites are encountered in industry, the presence of cristobalite as well as quartz is a real possibility.

X-ray fluorescence instrument with good radiation control. Operator cannot be exposed to unattenuated X-ray. Sample is moved into hole at top and rotated into position, a motion which also rotates shielding into position.



Hazards in X-RAY ANALYICAL WORK

Donald E. VanFarowe, Chief, Radiation Section

X-ray spectrographic diffraction and fluorescence machines used for research, development, and production control are involved in a high incidence of radiation overexposure and somatic damage. It has been estimated by B. Lindell of the National Institute of Radiation Protection, Stockholm, Sweden that about every 15th unit has been involved in an accident resulting in radiation injuries, and about every 13th unit has been involved in an accident resulting in clinical symptoms.

In the past 18 months, four injuries have been reported in Michigan as a result of the use of these instruments. (Forty-four industries and educational institutions in Michigan were registered in 1969 to use such instruments). The injuries ranged from erythema to severe lesions on fingers, hands, and chest. They resulted from the use of X-ray equipment without sufficient safety features and inadequate administrative control. Injuries occur most often during non-routine procedures such as maintenance and cleaning operations.

The Michigan Department of Public Health has adopted recommendations to owners and users with the basic safety prerequisite being a well designed instrument. Because of the many applications, the design criteria varies considerably from one use to another. Only a few years ago, most X-ray units were constructed individually and often each unit was different from the former.

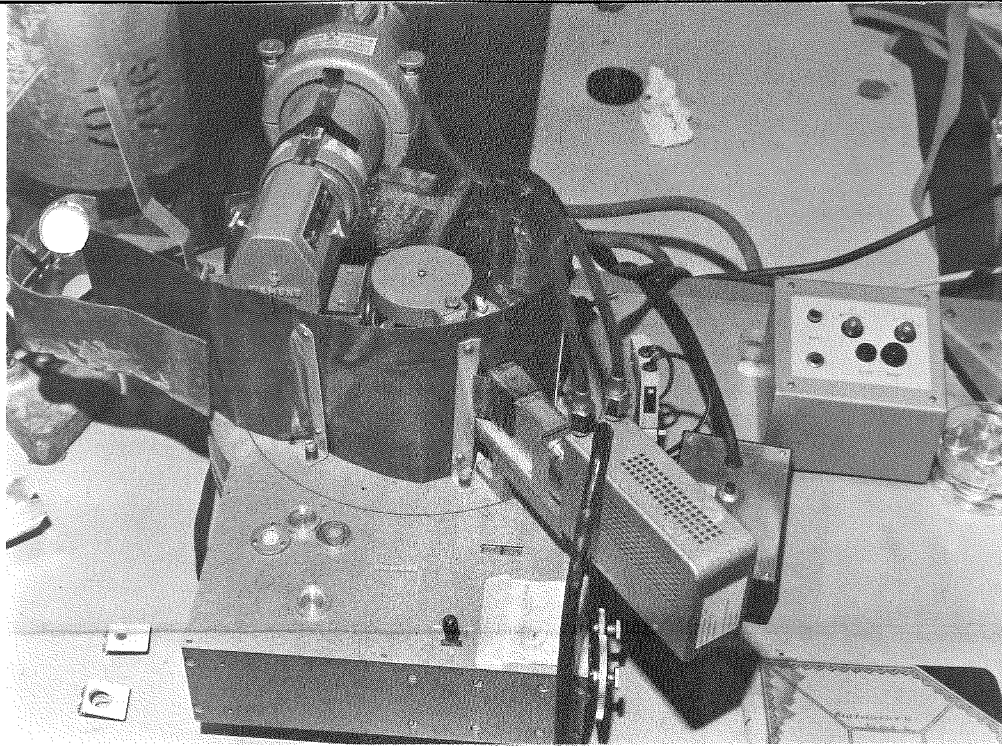
CAUTIONARY RULES

Tube housing leakage shall not exceed 0.5 milliroentgens per hour at a 5 centimeter distance from the surface of the tube housing with the beam ports blocked. Also, radiation originating from the high voltage power supplies shall not exceed this limit.

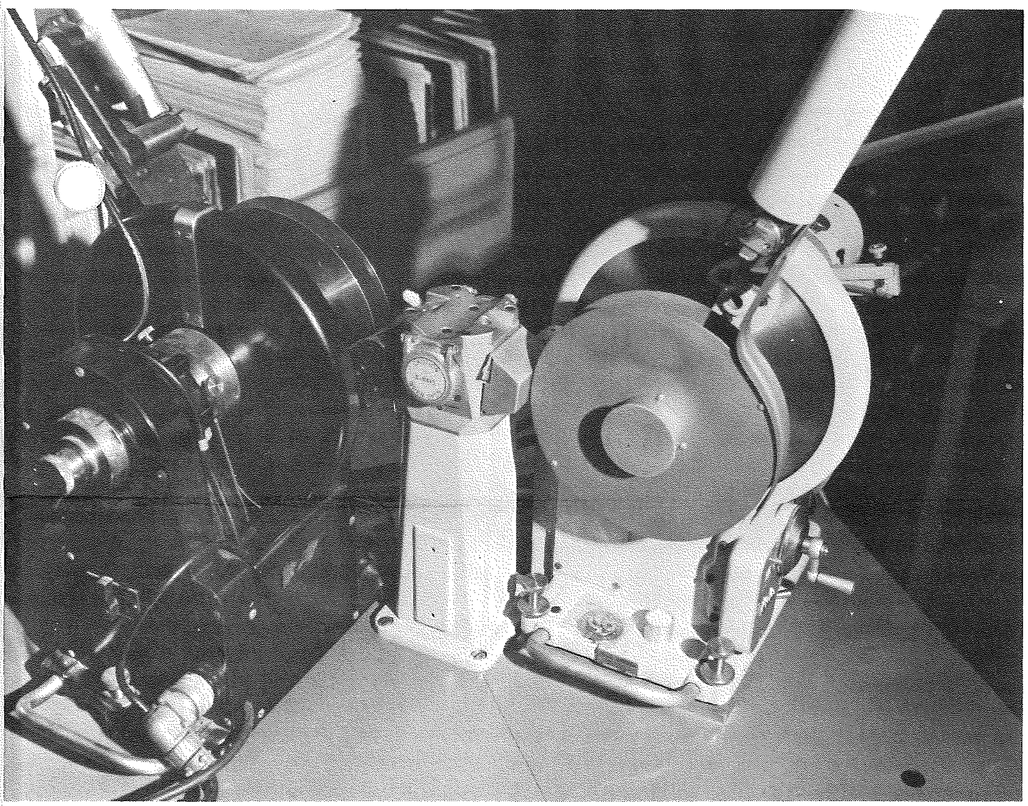
For instruments in which the primary X-ray beam is completely enclosed, the radiation shall be less than 2 mR per hour at a distance of 25 centimeters from the cabinet surface. For enclosed equipment, interlocks must be provided on all access panels which will terminate exposure and prevent operation while the panel is removed.

For open beam X-ray diffraction, spectrographic and fluorographic equipment, the following safety devices should be incorporated in the design, or added to modify existing equipment:

1. X-ray diffraction cameras shall have the appropriate ports arranged so that the camera collimating system must be in place before the X-ray tube can be energized or the shutter can be opened.
2. An adapter between the X-ray tube and the collimator of the diffractometer camera or other accessory shall prevent stray radiation from escaping.
3. Safety interlocks should never be used as routine cut-off switches during normal operation. They must be operated as safety devices only, and tested periodically. When the interlock system does turn off the X-ray beam, it shall be necessary to reset the "on" switch at the control panel to resume operation.
4. Tube head ports which are not in use should be secured in a closed position and interlocked to the X-ray generator or warning system.
5. Visible flashing lights or other signals shall operate only when any potential hazard exists or a



X-ray fluorescence instrument with makeshift radiation protection. Adequacy of protection depends on each application.



X-ray diffraction instrument with two goniometer attachments. Note that the shutters are not interlocked.

malfunction is indicated.

6. The shutter indicator shall be conspicuously displayed to disclose the "open" or "closed" position of the shutter.
7. The instrument shall display a conspicuous warning label such as "CAUTION RADIATION — THIS EQUIPMENT PRODUCES X-RADIATION WHEN ENERGIZED."
8. A red warning light shall indicate "X-RAY ON" when the equipment is producing X-rays.

ADMINISTRATIVE PROCEDURES

For each industry, facility or educational institution, a person shall be appointed to be responsible for radiation safety. This individual will not normally operate the X-ray equipment. This person shall be designated as the Radiation Safety Officer. His responsibilities will include the following:

1. To insure that operational procedures are followed.
2. To provide instruction in safety practices for all persons working with the X-ray equipment, as well as those working in the immediate area.
3. To maintain a personnel monitoring system.
4. To review, approve, and supervise modifications or replacement of parts for the X-ray apparatus.
5. To comply with regulatory rules and regulations of governmental agencies, including the registration of equipment with the Michigan Department of Public Health.

OPERATORS

No individual shall be permitted to act as the operator of X-ray analytical equipment until he has received training in radiation safety and has been approved by the Radiation Safety Officer. The operator must also demonstrate competence in the use of the machine and radiation survey instruments. He shall be responsible for all procedures associated with the equipment.

OPERATING PROCEDURES

A set of operating procedures shall be posted on or adjacent to the machine, written in understandable concise language.

PERSONNEL MONITORING

Operators of X-ray diffraction and spectrographic equipment shall be provided with finger or wrist radiation monitoring devices. Any and all persons coming in contact with this equipment shall be required to wear monitoring equipment all the time. Personnel coming in contact with this equipment should be warned of the nature and type of physiological effects that may be expected when overexposed to radiation.

CONCLUSION

Suffice it to say that adequately designed X-ray instruments, good administrative procedures, and well trained personnel would have eliminated the causes for all of the radiation incidents which have come to our attention over the years.

BULLETIN BOARD . . . .

Environmental Design

This was the theme and purpose of the recent 19th annual Industrial Ventilation and Air Pollution Control Conference held February 15-20 at the Kellogg Center, M.S.U. 396 engineers and ventilation contractors participated this year in design courses aimed at better control of the in-plant environment and reduced emission to the outside. As usual, the largest group was from Michigan, but in all 28 states were represented plus a contingent of Canadians from Ontario, Quebec, Manitoba, Newfoundland, and British Columbia.

Noise in the News

"Occupational Air Contaminants and Physical Agents" is the title of Michigan's new occupational health rules which became effective February 15, 1970. Included in these are rules governing occupational noise exposures. Based on nationally-recognized standards, and practically identical to those of the Walsh-Healey Public Contracts Act, they apply to all places of employment. Copies of the rules are available upon request.

Air Pollution Districts

Robert Miller is now located in our Southfield district office, telephone (313) 358-1400, to complement our air pollution program in the southeast area of the state. Bob will soon be joined by a second air pollution engineer.

On January 2, L. J. Holmes and R. VandeBunt joined our Grand Rapids district office, (616) 356-3459, to handle the air pollution program on the western side of the state.

Carbon Tetrachloride

Many persons still do not realize how toxic carbon tetrachloride really is or still believe that it must be used, regardless. A new listing of substitute solvents is now available from our laboratory upon request. They will do the same job with less hazard.

Approved Respirators

Respiratory protective equipment is required for some tasks and is desirable for others. You can be sure that the respirator you buy has been tested and approved for the specific contaminant that is your concern by consulting the latest listing of approved respirators. A copy is available from us upon request.

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