I

UNITED STATES ATOMIC ENERGY COMMISSION

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STANDARD PROCEDURES FOR ASSESSING
AVERAGE DAILY AIR CONTAMINANT EXPOSURES

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May 2, 1955

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II

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A B S T R A C T

A procedure is presented for rapidly and efficiently evaluating average occupational exposures to hazardous environmental factors. This procedure has been used by HASL for several years and has been proved both effective and accurate. Typical examples of dust exposure evaluation are presented with forms suitable for collecting and recording data. Methods and calculations are discussed.

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STANDARD PROCEDURES FOR ASSESSING AVERAGE DAILY
AIR CONTAMINANT EXPOSURES

Professional industrial hygienists are concerned with the control and prevention of occupational disease resulting from many factors in the environment of the plant or laboratory worker. One class of such factors involves atmospheric contaminants in the form of dusts, fumes, gases, mists and vapors which may directly affect the health, comfort, and efficiency of the worker. Threshold limit values or Maximum Allowable Concentrations (MAC) adopted by the American Conference of Governmental Industrial Hygienists, American Standards Association and other groups have been used with some caution by the industrial hygienist as a yardstick in estimating the degree of airborne hazard. The MAC's have been established by industrial health surveys; analogy with substances of known toxicity and by animal research experimentation.

Surveys involving airborne contamination of workers environs have been used by the industrial hygienist to:

1. Determine the exposure of working personnel to airborne pollutants.
2. Evaluate the rate of generation of the airborne contaminant by the process or equipment.
3. Provide a basis for engineering control of the airborne hazard.
4. Check the effectiveness of existing controls and procedures.
5. To maintain an accurate record of personnel exposures for the protection of both the individual employee and employer, and to determine permissible levels.

Prior to any attempt to engineer control for airborne hazard, some effort must be made to define the type and extent of the hazard. An industrial hygienist with broad experience can generally make a reasonable evaluation of a process and the materials involved and from such a superficial study, estimate the potential hazard. This sort of estimate, at best however, is only semi-quantitative and for accuracy and economy should be followed by a careful instrumental determination of the extent of the airborne contamination.

The evaluation of the degree of contamination of a plant atmosphere is accomplished by means of carefully selected air samples. The industrial hygienist or surveyor normally obtains three types of samples when performing a survey. They are:

1. General Air Samples - Those obtained in the general plant environ.
2. Breathing Zone - Those obtained in the breathing zone of a worker during the performance of a particular job or task.
3. Operational or Process Sample - Those obtained directly at or over an operation to pinpoint the direct source of airborne pollutant.

For a given operation, each of the three types will usually differ from the others by many orders of magnitude. It is therefore, obvious that no one type will adequately define a hazard.

Various laboratories use different numbers of these samples in different combinations; and place varying degrees of emphasis on each. In the Health and Safety Laboratory we have concluded, from an evaluation of several procedures, that accurate repetitive exposure results are obtainable only with a rather

complex procedure. This has been used over a long period by laboratory personnel and has been found to provide the necessary information with scarcely more manpower than much more superficial reviews would require.

In order to obtain accurate exposure information, a study is first made of the plant processes; and all the operations performed by each different employee are lumped to represent each significant job. After initial evaluation of the process steps, the surveyor sets up his air sampling equipment at all representative locations in the general plant area to obtain long term average air concentrations. The period of sample collection for these samples is long enough to level out all surges and is usually 20 to 60 minutes; the length of time depends upon conditions of operation, aerosol concentrations, sampling rate of the vacuum equipment and analytical laboratory techniques.

While the general air samples (GA's) are being collected, the surveyor makes a careful time study of each of the operations requiring evaluation to obtain a gross breakdown of the job components. The job breakdown is followed as a guide for timing the samples, and air samples are obtained covering each component of that operation. The surveyor then, while the GA samples are being collected, obtains samples of the air as close to the operators nose as possible while the operator is performing the individual tasks as outlined in the job breakdown.

These breathing zone samples (BZ's) are taken for periods of 30 seconds to 30 minutes depending on conditions of operation and aerosol loading, although the time is usually that which the operator spends in performing the job component. Throughout the sample collection period, the behavior of the operating

personnel is noted and recorded by the surveyor. Emphasis is given to good or poor industrial hygiene practices and work habits on the part of the men under study.

Process samples are taken in conjunction with the GA's and BZ's in order to pinpoint the source of the contaminant. This makes the design of control procedures much easier and more accurate.

In any case, a minimum of three samples is taken to represent each condition being evaluated. After sampling, each sample is sealed in an individual envelope and returned to the laboratory for analysis. The sample data sheets contain not only information pertinent to the sample but any other reactions of the surveyor to the operating conditions.

After the aerosol samples are analyzed, exposure data forms are prepared. These sheets provide the surveyor with a fairly detailed time study of each operation. Included on this sheet are:

1. Operator's designation.
2. Number of men/shift; number shifts/day.
3. Operation or job component.
4. Time per operation.
5. Number of times the job component is performed per operating shift.
6. (T) Total time per individual job per operating shift.
7. Number of Aerosol samples collected for BZ or GA samples.
8. Representative average aerosol concentrations: LOW, MAXIMUM, AVERAGE
9. Product of the average concentration times time for each operation
(G x T).

There is suitable space for noting the time spent in various general locations i.e. process, production laboratory areas, locker and lunchroom facilities, and even areas outside of the immediate plant proper.

Concentrations in each of the above areas is defined by means of general air samples and the time spent by each operator at each location per day is recorded.

The average weighted concentration per full working day of the operator is computed by dividing the sum of the products of concentration times by the total time per work shift.

$$\left[\sum \left(\frac{T \times C}{T_{\text{Total}}} \right) \right]$$

Figure 1 shows a typical Job Analysis Sheet.

The Job Analysis Sheet serves as a useful work tool. First, it has a convenient layout for recording and assembling data from which the average daily concentration value can be readily calculated. Second, the sample concentrations and concentration times time values show those particular tasks or general areas where the operator received an excessive exposure. For example, during the operation consisting of pushing slugs through the centerless grinder for 150 minutes, the operator was exposed to an average concentration of 400 gamma/M³ with a high of 520 gamma/M³. In addition, by virtue of his spending 105 minutes in the general centerless grinder area, the operator received an average concentration of 120 gamma/M³. The two examples described, accountings for 255 minutes (53% of total working time) provided the centerless grinding operator with a concentration times time value of 73,000 or 81% of his total daily dose. This not only serves

to show the surveyor those operations or areas that specifically need reduction in concentration but provides him with a means of pinpointing the source of contamination from the standpoint of engineering direct control of the hazard.

Assessing average daily exposures of plant personnel by the standard procedures described is a successful proven method of appraisal. The method has also been applied to any other type of exposure evaluation. Advantages of this procedure are:

1. Procedures that have been described can be used to evaluate all types of exposures in process plants, laboratories and institutions in which a potential hazard exists.
2. These job analyses or evaluation sheets can be used in determining the need for individual operational controls.
3. A permanent dated exposure record can be established for each plant operation which can be upheld from a legal standpoint.
4. The average weighted exposures can be used to determine the need for medical attention, job rotation or other control action pertinent to the individual operator.
5. An economical and convincing result is available for demonstrating to top management quantitatively and qualitatively where hazardous materials have been liberated from the process stream.

Using these standard survey procedures, a three man team of the Industrial Hygiene Branch, HASL, normally survey three huge plants involved in the production of uranium metal from the raw ore in approximately a work week. In these plants, daily weighted exposures of more than 600 personnel performing more than 100 different jobs are determined.

Figure 1
JOB ANALYSIS SHEET

OPERATOR: Centerless Grinder 3 MEN/SHIFT: 2 SHIFTS/DAY: 6 MEN/DAY

OPERATION OR OPERATING AREA	TIME PER OPERA. (MIN)	OPERA. PER SHIFT	TIME PER SHIFT (MIN) (T)	NO. OF SAMP- LES	CONCENTRATION Gamma /M ³			AVG CON'C.* TIMES TOTAL TIME (T X C)
					LOW	HIGH	(C) AVG.	
BZ- Pushing X slugs thru grinder	1.5	100	150	5	80	520	400	60,000
BZ- Cleaning X slug	0.25	100	25	5	25	70	50	1,250
BZ- Stamping X slug	0.5	100	50	5	85	200	100	5,000
BZ- Transporting case of 25 slugs to adjacent storeroom	10	4	40	3	52	150	90	3,600
BZ- Cleaning grinder	15	1	15	3	90	150	100	1,500
BZ- Tool shed	10	2	20	3	1	10	4	80
GA- Centerless grinder area			105	8	70	275	120	12,600
GA- Locker			15	3	40	100	60	900
GA- Lunch and Smoke Area			60	3	38	115	72	4,320

*Adjusted to two significant figures

ΣT 480

$\Sigma (T \times C)$ 90,000

$$\Sigma \frac{(T \times C)}{\Sigma (T)} = \underline{188}$$

$$\text{Gamma/M}^3 = \underline{1.6}$$

TIMES THE MAXIMUM
ALLOWABLE CONCENTRATION.