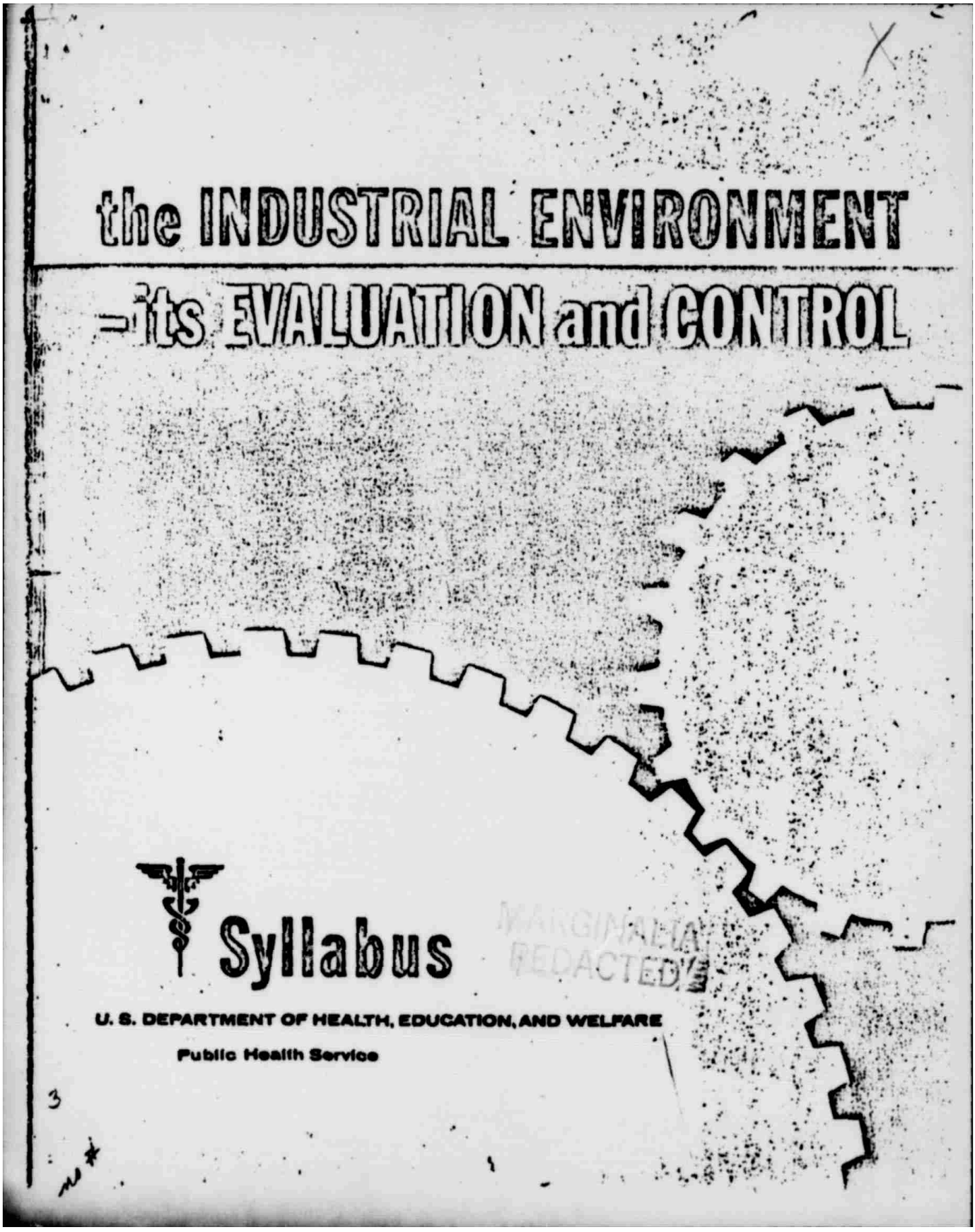
the INDUSTRIAL ENVIRONMENT

—its EVALUATION and CONTROL



Syllabus

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

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the Industrial Environment .... its Evaluation and Control

Syllabus

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DUST COUNTING TECHNIQUES

Introduction

The method of impinger sampling and light field counting commonly used in the United States is empirical and has remained essentially unchanged for the past two or three decades. In practice, water, alcohol, or a mixture of the two is employed as a sampling medium in standard or midget impingers. After sampling, a portion of the liquid medium containing the collected dust is removed from the impinger flask and is placed in a counting cell. Particles of dust settle to the floor of the cell and the number of particles from a specific volume of liquid, and thus from a measured volume of sampled air, are counted. All particles which have reached the floor of the cell by the time of counting and are visible by light field optical microscopy with a 10 power objective lens are included in the count.

The Standard Method

The number of dust particles which may be detected in a defined volume of air from a dusty working place depends upon the method of detection used. Many methods for making such determinations have been proposed and many are used. All are empirical in some degree; there is yet no practical absolute method for assessing the number concentration of atmospheric dust. The Threshold Limit Values published by the American Conference of Governmental Industrial Hygienists, are guides by which we can judge the hygienic significance of exposures to mineral dusts. The method of assessing exposures for interpretation by these guides is specified, and since the method is empirical departures from the method can greatly influence the results. If there are departures from the standard method in measuring exposures, the results cannot be interpreted by use of the Threshold Limit Values.

Prepared by: Robert L. Harris, Jr.

The standard method presented at the fifth meeting of the National Conference of Governmental Industrial Hygienists in 1942[1] is as follows:

"Standard Impinger Sampling and Counting Technique

I. Application. For the determination of the atmospheric concentration of an insoluble inorganic dust such as that associated with the production of lung fibrosis, the particle size of which is generally below 10 μ and, from the hygienic standpoint, is not of interest below 0.5 μ. This method is not recommended for the determination of organic dusts, metallic fumes, vapors and gases.

II. Sampling instrument. The sampling instrument shall be the standard impinger, operating at a rate of 1.0 cfm at 3" Hg negative pressure (U. S. Public Health Service or modified form), or the micro-impinger operating at 0.1 cfm at 12" H_2O negative pressure (U. S. Bureau of Mines).

III. Flow-producing apparatus and flow meter. Any type of suction apparatus may be employed, provided it is capable of maintaining the rate of flow with ± 3 percent of the rated capacity, i.e., 1.0 cfm for the standard and 0.1 cfm for the micro-impinger, and is provided with a calibrated flow meter and indicating gauge. The use of a constant-flow orifice is recommended with the compressed air ejector and an automatic negative pressure regulator with the motor or hand-driven pump. If an indirect indicating gauge is used, it shall be checked against a U tube or gas meter at regular intervals.

IV. Counting cell. The standard counting cell shall have a liquid depth

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of 1.0 mm. Counting cells less than 1.0 mm deep down to 0.1 mm may be employed, provided the liquid depth is reported with dust concentration data thus obtained.

V. Microscope and accessories

A. The microscope shall be a standard biological instrument or its equivalent, preferably with an adjustable tube length. It shall be provided with an Abbe condenser with iris diaphragm, 16 mm objective 7.5 or 10x ocular.

B. The counting area shall be defined by an ocular grid or by rulings on the counting cell. It shall have an area equivalent to ¼ sq. mm in the counting cell and shall be divided into 25 sub-squares.

C. The microscope tube length shall be adjusted so that the counting area corresponds to ¼ sq. mm in the counting cell, or, in the case of a fixed tube length, the ruled area shall be equivalent to ¼ sq. mm ± 3 percent. The counting area shall be accurately measured by means of a stage micrometer and recorded with the dust concentration data.

D. Illumination shall be provided by means of a 15 W substage lamp, placed directly under the condenser or a 75 W microscope lamp, placed approximately 10" from the plain mirror. A 'Daylight' filter shall be used.

E. A microprojector of the type described by the Bureau of Mines[1,2] may be used instead of the preceding system.

The microscope of the microprojector shall be the same as the preceding microscope, except that a 20 or 25 ocular shall be used.

The counting area shall be defined by rulings on the translucent screen. It shall have an area equivalent to ¼ sq. mm in the counting cell and shall be divided into 25 subsquares, each of which may be further subdivided into not more than 10 similar (equal area) rectangles.

The distance between the microscope, with tube length adjusted to 160 mm, and the screen shall be such that the magnification of images upon the screen is 1,000 diameters. The microscope tube length shall be adjusted so that the counting area, or 50 cm square ruling on the screen, corresponds to ¼ sq. mm in the counting cell, or, in the case of a fixed tube length, the ruled area on the screen shall be equivalent to ¼ sq. mm ± 3 percent. The counting area shall be accurately measured by means of a stage micrometer and recorded with the dust concentration data.

Illumination shall be provided by means of an automatic-feed (preferably 4.5-6 ampere direct current) carbon arc lamp so arranged to supply adequate illumination on the screen. A suitable heat filter (water cell or heat-absorbing glass) shall be used between the lamp and the microscope.

VI. Collecting liquid. Distilled water with or without alcohol (ethyl or isopropyl) shall be used as the collecting liquid. The collecting and subsequent washing and diluting liquids shall show not more than six (6) countable particles in ¼ sq. mm counting area in the cell.

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E. One cell shall be made up from the 'blank' flask for every series of samples.

F. Cells shall not be filled in advance of the time required for settling before counting.

X. Counting

A. Counting shall be done in a darkened room, using artificial illumination in the microscope, as described above.

B. The light and mirror shall be centered so that no shift of position of the particles is seen when focusing up and down. The condenser and diaphragm shall be adjusted to give an even moderate illumination. Each observer should determine and employ the optimum lighting for his eye.

C. Before counting, the field of the microscope shall be examined and, if necessary, the ocular grid cleaned to remove dust particles.

D. The count shall be made in a plane just above the surface of the cell rather than throughout the depth of the liquid. The microscope may be focused up and down by means of the slow-motion adjustment in order to bring individual particles into focus. Before making the count, the cell contents shall be carefully examined throughout the entire depth to make certain that all countable particles have settled.

E. Five fields of ¼ sq. mm in area shall be counted, one in the central part and the other four towards the edges of the cell.

F. Except in the case of abnormal samples, no distinction shall be made between the number of particles above and below 10 μ.

XI. Computation of results. The concentration of dust shall be expressed in millions of particles per cubic foot of air (m.p.p.c.f.), reported to two significant figures only.

Concentration is determined as follows:

$$\text{Conc. (m.p.p.c.f.)} = \frac{(N_s - N_c) \times C.F. \times V_w}{V_a}$$

Where:

N_s = Mean count per field for the sample (5 or more fields)

N_c = Mean count per field for the blank (5 or more fields)

C.F. = Cell factor = 1000/(area of counting field in sq. mm) x (depth of cell in mm)

V_w = Total water volume (equivalent total, when portion diluted, i.e., initial sample volume x dilution factor)

V_a = Air volume sampled in cu. ft. "

EXAMPLE:

Duration of sample time: 5 minutes

Rate of sampling: 0.1 cubic foot per minute

Vol. in flask after washing: 30 ml.

Ratio of added dilution (5 ml in 25 ml flask): 5:1

Cell depth: 1 mm.

Dust count, light field (2 cells) particles less than 10 microns in size

Cell #1	Cell #2
51	48
36	54
44	47
34	40
55	49
220	238

Total #1 220

Total #2 238

458 = 45.8 Av. Total/Field

-5 blank count

40.8 Av. Net count

CALCULATIONS:

$$\frac{\text{Av. Net Count per } \frac{1}{4} \text{ mm} \times 4 \times \text{cu. mm per cc} \times \text{flask vol.} \times \text{extra dil. ratio}}{\text{Cu. ft. per minute sampled} \times \text{sampling time}}$$

$$\frac{40.8 \times 4 \times 1000 \times 30 \times 5}{0.1 \times 5} = 48 \times 10^6$$

particles per cubic foot.

1. Brown, C.E. and Schrenk, H.H.: A Technique for Use of the Impinger Method. Bureau of Mines Information Circular 7026, 20 pp., 1938.

2. Brown, C. E.; Baum, L. A. H.; Yant, W.P.; and Schrenk, H.H.; Microprojection Method for Counting Impinger Dust Samples. Bureau of Mines Report of Investigations 3373, 9pp., 1938.

Even though the method is thus specified, it is possible to adhere to the method yet introduce variables which can affect the results it yields. Some of these will be mentioned in this section. In cases of known variables, it is suggested that until they are accommodated by modification or amendment of the method, the procedure be such that the count yielded be the same as that which would be obtained if an atmosphere of quartz dust, having the same number concentration and size distribution as the atmosphere actually sampled, were sampled and counted in water. In other words, if the method using water as a medium should permit detection of 60 percent of the microscopically visible quartz particles present in the air in a given situation, one should strive to detect also 60 percent of the particles if they should have densities other than that of quartz or be collected in media other than water.

Equipment

The microscope and its use are discussed in Section B-5. Suffice it to say here regarding the microscope that for standard method dust counting a laboratory grade optical microscope with a 16 millimeter, 10 power objective lens is used and that samples are counted by the light field technique.

Counting Cells

Since dust from the air is captured in liquid medium it is necessary to relate the number of particles from a measured volume of liquid to the number in a measured volume of air. The volume of air which passed through the impinger sampler is known from the sampling procedure. The number of particles captured from this air is then determined by counting those present in a measured fraction of the sampling liquid. This is done with a counting cell. A portion of the sampling medium containing dust is placed in a counting cell of known depth, particles are allowed to settle from the liquid to the floor of the cell for a certain period of time, then the particles on a measured area of the cell floor are counted. The area of the cell floor counted and the depth of the cell define the volume from which the counted particles settled. The characteristics of cells ordinarily used in counting are summarized in Table 1.

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The Dunn cell is made up of three parts: a base plate, a cell plate, and a cover slip. The cell plate is a 1 mm thick glass plate ground on both sides with a round hole through the center. This hole forms the counting cell when the cell plate is sandwiched between the base plate and cover slip. The Dunn cell is relatively easy to clean because of its three piece construction and because there are no concave corners to trap dust.

Table 1. - Characteristics of Dust Counting Cells

Cell	Graticule Used	Cell Depth, mm	Area Usually Counted Per Field mm^2	Volume Usually Counted Per Field mm^3
Dunn	Whipple, Wardlow, or Page	1	0.25	0.25
Sedgewick-Rafter	"	1	0.25	0.25
Hatch	"	0.25	0.25	0.0625
Spencer Brightline Hemocytometer	Ruled in Cell	0.1	0.04	0.004

The Sedgewick-Rafter cell has 1 mm high glass or metal walls cemented to a base plate. This assembly, with a cover glass makes a rectangular cell. Cleaning is a bit more difficult than with Dunn cells because of the concave corners and the cemented joints.

Spencer Brightline hemocytometer cells were developed as blood counting cells. They have no chamber walls, as such; the liquid is held in place by its surface tension. The cell depth is 0.1 mm and the cell floor is lightly coated with rhodium through which a grid pattern is ruled. With the grid ruled on the floor of the cell, an eyepiece reticle to define the area counted is unnecessary. The cells must be handled with care to avoid damage to the rhodium surface; chemical cleaning solution should never be used.

Hatch cells are similar in design to Spencer hemocytometer cells except they have a depth of 0.25 mm and have no metal coating or ruled grid.

For precise work it is wise to measure counting cell depths with a micrometer rather than accept the nominal depth. Variations up to 20 percent of the nominal depth may be found.

Eyepiece Reticles

Reticles placed at the focal plane of the eyepiece are superimposed on the field of view of the microscope. Such reticles with grid patterns ruled upon them are used to define the areas of counting cells in which the dust particles are counted. These grids must be calibrated for each microscope and each lens with which they are used. To measure the size of the grid image, it is compared with a stage micrometer placed on the object stage. The stage micrometer is a plate on which are ruled, with considerable precision, fine lines spaced at 0.1 and 0.01 mm.

There are three common types of reticles used in dust counting. The original is the Whipple reticle (or disc), which consists of a large square subdivided into 100 squares. One square, adjacent

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to the center is further divided into 25 squares. The 100 squares, when used with a 10x objective, subtended about 1 mm^2 on the microscope stage. The standard technique prescribes counting one quarter of this area, or 25 squares. On microscopes which have adjustable tube lengths, the body tube may be adjusted, using a stage micrometer, so that the reticle image will cover exactly 1 mm^2 of the cell floor. This serves only to somewhat simplify the arithmetic.

The grid of a Page reticle is simply one quarter, or twenty-five unit squares, of a Whipple reticle.

One serious drawback of the Whipple and Page reticles is that any dust which settles on them from the air will be in focus and appear in the image of the sample. They can be mistaken for part of the sample. However, these particles on the reticle will stay in focus when the objective is racked up and down, while the particles of the sample will go in and out of focus.

Nevertheless, dust on the reticle is undesirable, and the glass surfaces should be scrupulously cleaned when necessary. However, complete cleaning is nearly impossible, and the microscope manufacturers advise against too frequent opening of the eyepieces. Also, modern lenses bear anti-reflection coatings which are delicate and subject to abrasion. Hence, frequent cleaning and handling may reduce the quality of the optics of a microscope.

A third type of reticle, the Wardlow reticle, was developed to circumvent the problem of dust on the reticle surface. It is a ring with fine filaments stretched across to form the grid pattern. It is extremely difficult to fabricate, and is very, very fragile. At present, there is no commercial source for these reticles.

Counting Technique

The sampling medium should be free of particulate material - "free of particulate material" means that a blank sample, treated in the same way as were regular samples except that it was not used for sampling, shows less than about 6 particles per field count in a counting cell. This usually requires distillation and filtration through membrane filters. For best control two impinger flasks should be reserved as blanks, and carried with the sample flasks in the field.

Sample Ageing

There is an important time factor involved in making the counts. Dusts may agglomerate or flocculate in the liquid suspension, and some small particles may slowly go into solution. For this reason the standard method calls for counting impinger samples within 36 hours after sampling. It is preferable to count them within 24 hours, or even 12 hours, after sampling. This can be troublesome when in the field.

As a check on this ageing process, in one project, some 100 samples were counted first in the field within 24 hours of being taken, then counted again after returning to the laboratory about 1 to 2 weeks later. Calculations were made to determine the limits within which a data pair should fall if the counts were statistically the same. Only 25% of the counts were within the 50% limits, and only 55% were within the 90% limits. Also, there was a weighting toward lower counts in the aged samples; 65% of the samples showed lower counts in the laboratory than they did in the field.

Dilution of Sample

The liquid in the impinger sampling flask must be made up to a known volume while washing down the impinger nozzle. The result desired is a concentration in the liquid that will give a count of 50 to 200 particles per counting field. If, after making up to 15 ml for a light midget impinger sample, or as much as 25 ml for a heavy sample, further dilution is necessary to bring the count

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below the desired maximum, dilute the liquid further in steps of not less than one volume of sample to ten volumes of dilution medium. Use at least 10% of the total sample to be diluted in making the dilutions, and in any case not less than 5 ml. Shake the sample well before making the dilution. Use dust-free sampling medium (actually the medium for which a blank count is known) as the diluting medium.

Preparation of Cells

The cells must be clean. First wash them with a good grade of laboratory glassware detergent and rinse well with tap water. Rinse several times with distilled water then rinse well with dust-free water. Finally, rinse well with dust-free alcohol, or, if the cell is to be used immediately, rinse with a portion of the sample. Cells to be stored may be wiped after the alcohol rinse, but should not be wiped after the sample rinse when ready for use. Use an exceptionally lint-free cloth such as clean linen, or a high grade of lens tissue, for wiping the cells. Ordinary lens tissue is not satisfactory. Cells may be stored also in dust-free alcohol.

To fill a cell, assemble it with the cover slip pushed to one side to leave an opening for the tip of a pipette. Shake the sample flask thoroughly to disperse the dust evenly in the liquid, and transfer a portion to the cell with a clean pipette. Getting the cover slip pushed into place without including air bubbles in the cell takes practice.

Settling Time

Common practice is to allow particles to settle 25 to 30 minutes per millimeter of cell depth before counting. For the count to include all particles of one micron equivalent diameter, for example, a sufficiently long settling time must be allowed for all particles of this size to settle through the depth of the cell. Calculation by the Stokes' law equation of the settling time for a 1 micron diameter regularly shaped quartz particle in water at 25°C yields a value of about 25 minutes per millimeter. The same calculation for ethyl alcohol as a medium yields a value of about 33 minutes per millimeter. It is reasonable to assume that these calculated values are the basis for the commonly used 25 to 30 minutes settling time for cells 1 millimeter in depth.

Not only alcohol and water, but their mixtures as well are used as the collecting medium in impinger sampling. These two materials when mixed form a complex and their mixtures do not follow the simple linear mole fraction-viscosity relationship, but have viscosities substantially greater than either of the components. The viscosity of a 50 percent ethyl alcohol-water mixture, for example, is 2 to 2½ times greater than that of either alcohol or water. One would calculate for such a mixture that fewer than half of the 1 micron quartz particles in the cell will settle 1 millimeter in the commonly employed 25 to 30 minute settling time.

The density of the material sampled has a very marked effect on the required settling time and seems to be ignored in many instances. Required settling time varies inversely with the difference between density of the settling particle and that of the liquid medium. One can calculate, for example, that a coal particle with a density of 1.4 grams per cubic centimeter (g/cc) will settle in water only about one-fourth as rapidly as a quartz particle of the same size with a density of 2.6 g/cc, and that only about one-tenth of the 1 micron particles of density 1.4 g/cc, in a 50 percent ethyl alcohol-water mixture, will settle to the floor of a 1 mm depth counting cell in 25 minutes. The use of shallow counting cells is indicated in such situations so reasonable settling time may be used.

If alcohol or mixtures of alcohol and water, are used as impinger sampling

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medin, the problem of settling time is compounded by the fact that under some psychrometric conditions the composition, and therefore the viscosity, of the sampling medium will change substantially during the course of sampling. One cannot, then, use the value for viscosity of the medium selected for sampling in the calculation of settling time. In studies of midget impinger sampling under controlled psychrometric conditions by Division of Occupational Health personnel it was found that the composition of water-ethyl alcohol mixtures changed relatively slowly with increasing sampling time in a cool environment, and was not greatly affected by humidity. At high ambient temperature the change in composition with increasing sampling time was marked, however, and was strongly influenced by humidity. The higher the temperature, the higher the humidity, and the higher the initial concentration of ethyl alcohol, the greater was the rate of change of composition during sampling. In a warm, humid environment (90°F, 85 percent relative humidity) a sampling medium which initially was commercial 95.5 percent ethyl alcohol was reduced by evaporation of alcohol and consensation and absorption of water to about 60 percent alcohol after 20 minutes of sampling.

Studies of change in composition of other alcohol-water mixtures during sampling under various psychrometric conditions have not been made. Examination of vapor pressure data for alcohols indicates that normal propyl alcohol-water mixtures are unlikely to change as markedly in composition as are mixtures of ethyl alcohol and water under the same psychrometric and sampling conditions, while isopropyl alcohol-water mixtures are expected to change in a manner intermediate between the two. Mixtures of normal or isopropyl alcohol in water, like those of ethyl alcohol and water, show positive deviation from the mole fraction-viscosity relationship of ideal mixtures. The viscosities of these alcohols and their mixtures with water are substantially higher than those of ethyl alcohol and its water mixtures. This results in proportionately longer calculated settling times for dust particles than are obtained for corresponding ethyl alcohol-water mixtures at the same temperatures.

Thus, the counting of samples with a fixed settling time without regard to medium viscosity or particle and medium densities, can, under certain circumstances lead to substantially different results from a pair of samples collected in different media even though the samples may contain the same numbers of particles. This variation will be of little practical significance if the sampling medium is water or ethyl alcohol and not a mixture of the two, if the samples are from cool or moderate environments, if the samples are of short duration, if the densities of the dust particles are about the same or greater than that of quartz, and if the particle size distribution of the sample is such that there is not a preponderance of particles very near in size to the lower limit of detection by the optical system used in counting. On the other hand, great variation in counts from different media may occur if several of these conditions are not met and arbitrary settling times of 20 to 30 minutes per millimeter are used. In the absence of other standard procedures it is suggested that settling times be so chosen that the counts yielded will be the same as would have been obtained had the particles been quartz settling in water for 30 minutes.

The problem of counting variation is further compounded by the fact that some observers with high visual acuity, and by careful adjustment of the optical system specified for the method, can detect some particles as small as about 0.5 micron in size; others may seldom detect particles smaller than 1 micron. Because the impinger sample counting technique includes all of the smallest particles which can be detected, visual acuity of the observer is a factor and

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it appears that inter-observer variance cannot be eliminated except by the selection of counting personnel.

Using a hand talley, count all the particles in the 25 squares of the field selected. The smaller particles are difficult to see, look carefully to make sure that all of them are counted. Count in a systematic fashion, somewhat like reading a printed page - jumping around the field will cause the observer to lose track of which particles have been counted, and lead to spurious counts.

Count 5 fields, selected at random, in each cell. Random selection means that the fields are not chosen, since conscious or subconscious biases in choosing may alter the count. A good practice is to remove the eye from the eyepiece while moving the stage from one field to the next.

Calculation of Concentration

With the average particle count per field known the concentration of dust in terms of millions of particles captured per cubic foot of air sampled (mppcf) can be calculated. Although the calculation is shown in the description of the standard method, it is repeated here in slightly different form for emphasis. Known are:

1. Average particle count per field (field count)
2. Average blank count per field (blank count)
3. Cell depth in mm
4. Field area in mm^2
5. Final volume of liquid in impinger flask, ml
6. Volume of diluted sample per volume of sample taken from impinger flask (dilution ratio, ml/ml)
7. Volume of air sampled (rate in cfm multiplied by duration of sample ft^3)

One may calculate then:

$$\frac{\text{Total number of particles in sample}}{\text{Sample air volume, } ft^3} :$$

$$\text{particles/ft}^3$$

This quotient, particles per cubic foot, divided by the factor 10^6 yields the number of millions of particles per cubic foot of air, mppcf. The known factors listed above may be used for this calculation:

$$\frac{(\text{field count-blank count, particles})}{(\text{field area, } mm^2)\,(\text{cell depth, mm})} \times$$

$$\frac{(1000\ mm^3)}{(\text{one ml dilute sample})} \times$$

$$\frac{(\text{total ml dilute sample*})}{(\text{ml from imp. flask for dilution})} \times$$

$$\frac{(\text{total ml sample in impinger flask})}{(\text{vol. of air sampled, } ft^3)\ 10^6} =$$

mppcf

*This ratio is the "dilution factor."

In these equations one can see that units may be alternately cancelled from the numerator and the denominator to yield a number in the units of mppcf.

$$\frac{(\text{Field count - blank})}{(\text{area in } mm^2)(\text{depth in mm})} = \text{parts/mm}^3$$

$$\frac{(1000\ mm^3)}{(1\ ml)} = \frac{mm^3}{ml}$$

$$\frac{\text{ml dil sample}}{\text{ml from flask}} = \text{dilution factor } \frac{(ml)}{(ml)}$$

$$(\text{parts/mm}^3)(mm^3/ml)(\text{dil factor}) \times$$

$$(\text{tot ml in imp}) = (\text{tot parts in smmp})$$

$$\frac{\text{total parts in sample}}{(\text{vol air, } ft^3)\ 10^6} = \text{mppcf}$$

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Statistics of Counting

Another variable in the method of counting dust is inherent in the distribution of particles in the counting cell. The statistics defining this distribution have been reported by Chapman and Ruhf[2]. Ordinarily, two cells from each impinger sample are counted; marked disagreement in counts is an indication of counting or other error. By use of the statistical methods reported by Chapman and Ruhf, two series of curves have been calculated by which the precision and reliability of two cell counts of the same impinger sample can be judged. They are based only upon the statistical distribution of particles in the cell and do not include other counting variables. These curves are shown in Figure 1.

The family of curves with positive slope permits one to judge the likehood of a blunder in the counting of one of the pair of cells. They represent the expected differences, within selected limits, of counts from two cells of the same sample and are calculated by the equation:

$$t = \frac{X_1 - X_2}{\sigma\Delta x}$$

Where:

$$\sigma\Delta x = \sqrt{\frac{\sigma x_1^{\,2}}{N_1} + \frac{\sigma x_2^{\,2}}{N_2}}$$

$$= \sqrt{X_1 + X_2} \quad \text{When } (N_1 = N_2 = 1)$$

t = The ratio x/σ for defining normal distribution areas (e.g. for the limit for agreement ½ of the time the fraction of the total normal curve area is 0.50 and a table of normal areas yields the value t = 0.675)

X = Number of particles counted per cell

$\sigma\Delta x$ = Standard deviation of difference in cell counts, Poisson distribution

σx = Standard deviation of particle count per cell

N = Number of counting trials per cell (1 in this case)

To illustrate, the point in Figure 1 defined by a high cell count of 60, paired with a low cell count of 40, falls to the left of the locus which limits the range within which pairs of counts are expected to fall nine-tenths of the time. Disagreement of this magnitude resulting only from distribution of particles in the counting cell is expected less than one-tenth of the time in correctly counted pairs of cells. In the absence of other criteria it is suggested that a third cell be counted when counts of the first two fall outside the nine-tenths limit.

The reliability of the count for a sample depends upon the total number of particles counted in all cells from the sample. When judgment has been made that the counts of a pair of cells are acceptable, the reliability of their mean can be judged by use of the loci having negative slopes in Figure 1. The values shown are reported by Chapman and Ruhf and may be calculated by the equation:

$$t = \frac{M_x - \bar{X}}{\sigma m}$$

$$\sigma m = \frac{\sigma x}{\sqrt{N}} = \sqrt{\frac{\bar{X}}{N}}$$

t = The ratio x/σ for defining normal distribution areas. For 95% level the value t = 2 is used. (t = 1.96 is a more precise value).

M_x = True mean for number of particles counted per cell.

$\bar{X}$ = Observed average number of particles counted per cell.

σm = Standard deviation of the mean particle count per cell, Poisson distribution.

N = Number of cells counted (2 in this case).

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In the illustration cited in the preceding paragraph the mean cell count is 50; the curve in Figure 1 shows that the true mean of these cell counts is expected to be within about ±20 percent of this observed mean 95 percent of the time. A mean cell count of 200, or a total count of 400, in a pair of cells with acceptable agreement will have a true mean within ± 10 percent of the observed mean 95 percent of the time. About 400 particles, the actual number depending on the needed reliability, seems to be a reasonable minimum number to be counted in an impinger sample under ordinary circumstances. Use of curves such as those of Figure 1 permits definition and limitation of the distribution variable in counting.

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1. Transactions of the Fifth Annual Meeting of the National Conference of Governmental Industrial Hygienists. Subcommittee on Standard Methods, Washington, D.C., 1942.

2. Chapman, H. M. and R. C. Ruhf. Dust Counting Reliability, Amer. Ind. Hyg. Assn. Quarterly, 16: 201 (1955).

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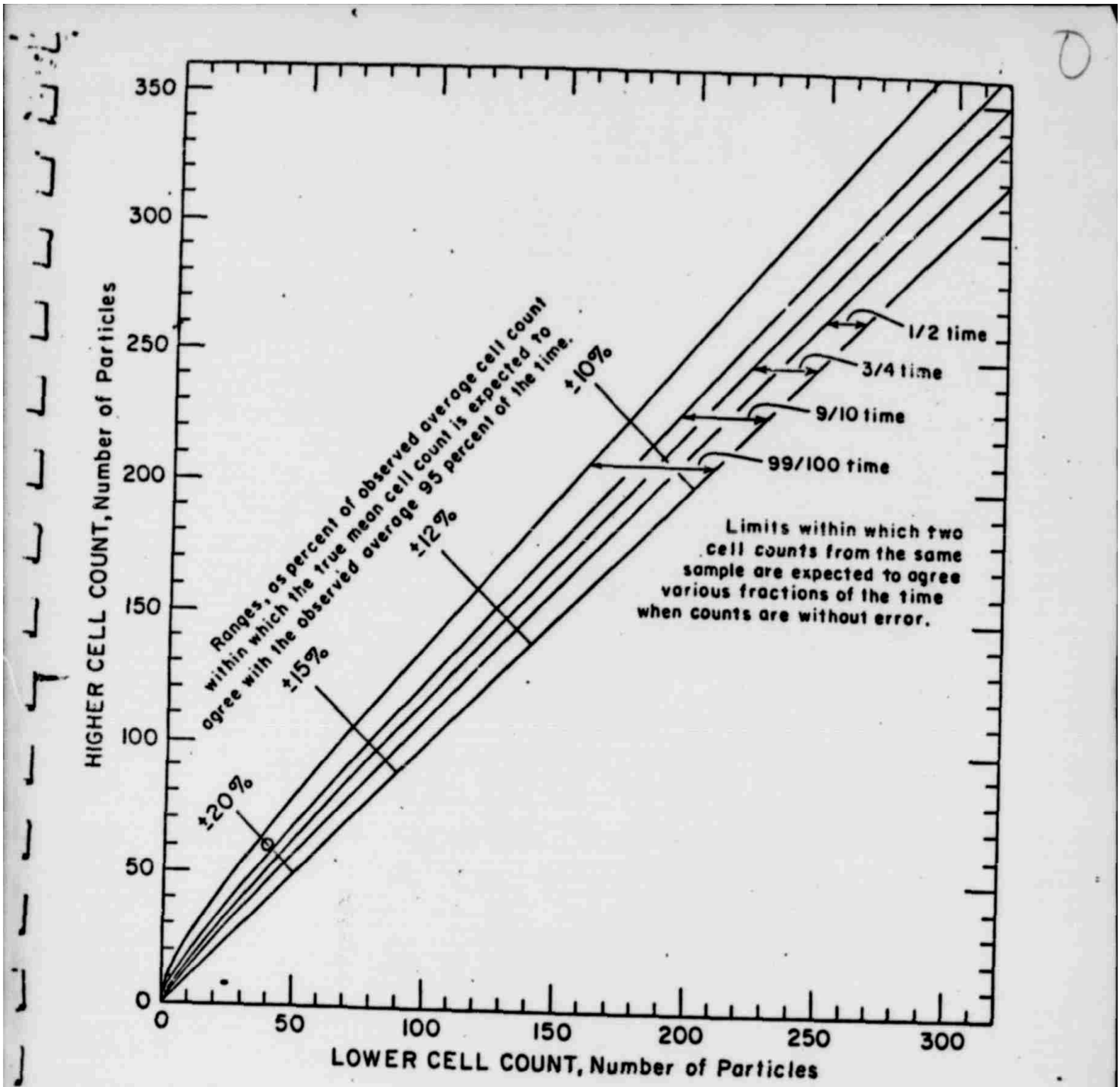


Figure 1. - Precision and Reliability of Independent Counts of Two Cells from the Same Impinger Sample.

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