STATISTICS IN COMPLIANCE

Abstract

Both in the sampling of the occupational environment and the decision making processes regarding compliance or noncompliance with mandatory exposure standards, appropriate statistical sampling plans and statistical decision criteria are utilized. Early attempts to apply statistical theory to the occupational health field are presented along with recent work by the National Institute for Occupational Safety and Health. Examples are presented of statistical sampling and decision plans promulgated as regulations by federal agencies.

The differences between statistical theory for noncompliance (governmental enforcement agencies) and for compliance (employers) are discussed and practical considerations are presented. The selection of an appropriate level of risk for the statistical tests and the interaction between the protection levels afforded the employer and employee is discussed.

Mandatory occupational health standards have been promulgated in the United States (29 CFR 1910.93) with the intent of most adequately insuring, to the extent feasible, that no employee will suffer material impairment of health or functional capacity. Presently, for asbestos and vinyl chloride, employers are charged with monitoring and measuring employee exposure at locations and intervals and in such a manner as may be necessary, for the protection of their employees. The employer must promptly notify any employee who has been or is being exposed to these toxic materials in concentrations which exceed those prescribed by the applicable occupational health standard and also must institute corrective action. In addition, the National Institute for Occupational Safety and Health (NIOSH) is engaged in a joint project with the Occupational Safety and Health Administration (OSHA) which will result in regulations requiring monitoring of employee exposure to all the substances under 29 CFR 1910.93.

With these mandatory health standards has come the reality of necessary governmental enforcement. Duncan[1] has broadly defined enforcement as all those steps taken by a governmental agency to attain the desired level of quality. These steps for OSHA of the Department of Labor in enforcement under the Occupational Safety and Health Act of 1970 consist of administrative procedures, engineering judgement, court proceedings, and voluntary compliance programs.

A simplistic legal approach toward the enforcement of these mandatory occupational health standards proceeds as follows. A sampling and analytical test method for the measurement of an employee's exposure to a particular hazardous substance is developed. The test method is used to measure a particular employee's exposure. If that measurement exceeds the standard, there has been a violation of the law. This simple point of view neglects the number and duration of samples that were taken to estimate the employee's exposure. This approach also neglects the variability of the environment the samples were taken from and inter- and intra-laboratory variability of the analytical method. Finally, there is no consideration of how many samples will be required of the enforcement agency or the employer to attain a specified level of effectiveness for the sampling program.

For example, if a compliance officer found an average air concentration of 105 ppm based on 5 samples at a location in a plant and the standard was 100 ppm, then by the simple legal approach he would be obligated to issue a citation. Suppose the citation was

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contested and the compliance officer was asked under cross examination if he was certain the standard had been exceeded. If he was aware of the statistics that underlie environmental sampling he would have to answer no and of course the citation would be dismissed

Both the sampling of the occupational environment and the decision making processes regarding compliance or noncompliance with the mandatory health standards must be performed utilizing appropriate statistical sampling plans and statistical decision criteria. Early proposals to apply statistical theory to the occupational health field will be presented along with recent work by NIOSH. The differences between statistical theory for noncompliance (governmental enforcement agencies) and for compliance (employers) will be discussed and statistical considerations presented.

Tomlinson[2] in 1957 applied the concept of sequential testing to the problem of compliance monitoring relevant to an average concentration standard in British coal mines. Tomlinson recognized the large within shift and shift-to-shift variability of the average airborne dust concentration. Roach[3,4] introduced the concept of utilizing the upper confidence limit on the arithmetic mean of a group of grab samples to determine the compliance status of an occupational environment. Roach, however, assumed a normal distribution for the samples and later work[6] has shown that it is better to assume the lognormal distribution. Roach made the very important point that any sampling procedure, no matter how carefully performed, can only estimate the true average concentration that existed in the occupational environment.

NIOSH first proposed the use of statistics for compliance monitoring in the carbon monoxide criteria document.[5] The procedure given for grab sample data was also based on the assumption of normally distributed data. Leidel and Busch[6] of NIOSH have presented procedures for noncompliance monitoring which calculates the 95% lower confidence limit of the arithmetic average of a group of samples from the occupational environment. Both normally and lognormally distributed data are considered. The procedures include recommendations for the duration of samples and the optimum number of samples to be taken on a single day. The advantage of a full-period sample (or consecutive samples) over the mean of several grab samples is also demonstrated.

There is considerable precedent in federal regulations for the inclusion and referencing of statistical methods in mandatory product and health standards. Methods have been given both for governmental enforcement and private industry compliance monitoring programs. The Consumer Product Safety Commission (CPSC) has included very specific sampling and decision plans in several of its product standards. The FF 4-72 Flammability Standard for Mattresses[7] gives details for a manufacturer's compliance program and allows submission of alternate sampling plans by industry. The commission felt that these plans would protect the public against unreasonable risk and that they were reasonable, technologically practicable, and appropriate. These are goals that any sampling and decision plan must achieve. The Commission accepted the concept that the enforcement agency must assume the burden of demonstrating noncompliance by showing, with a high level of statistical confidence, that noncompliance did in fact exist. The CPSC included a sequential sampling plan in its Test for Eye Irritants (16 CFR 1500.42) (see ref. 8) and a table for lot size, sample size, and failure rate for testing clacker balls in 16 CFR 1500.86 (see ref. 9).

The U.S. Public Health Service has issued a Drinking Water Standard (42 CFR 72, Subpart J) that specified a minimum sampling frequency and a sequential decision plan. The Food and Drug Administration's eyeglass impact standards (21 CFR 3.84) state that manufacturer shall test a statistically significant number of lenses from each production batch.

In the field of industrial hygiene, NIOSH requires that manufacturers of certified gas detector tube units must maintain a quality control program based on MIL-STD-105D or 414 (42 CFR 84). The Institute's certification procedures are based on these sampling plans. The Institute has also proposed that these plans be used for certification of personal protective devices (42 CFR 83) (see ref. 10).

It appears that the Environmental Protection Agency (EPA) has never included or referenced statistical data analytical techniques in air quality or water quality regulations. However, Larsen of EPA has discussed the problem in an EPA technical report.[11] Recently Russell Train, EPA Administrator, has expressed a desire to see standard statistical techniques for determining the validity of sample results become common to environmental standards.[12] He felt that methodology of statistical quality control charts has a place in environmental quality control.

When we come to the practical application of statistical techniques to compliance monitoring, a clear distinction must be made between compliance statistics (for the employer) and noncompliance statistics (for the government enforcement agency). The government has to meet the substantial evidence test and has the burden of proving that a health standard has been exceeded on a particular day. This is because the health standards are either average exposure standards defined for an 8-hour averaging period or ceiling exposure standards which at no time shall be exceeded (29 CFR 1910.93). Leidel and Busch[6] have recommended that the 95% lower confidence limit on the measured average concentration must exceed the standard before a decision of noncompliance is reached. This criterion is presently under consideration by OSHA and is shown in Figure 1.

Each employer is required to furnish to each of his employees a place of employee free from recognized hazards likely to cause death or serious injury. The employer must make decisions regarding his exposure measurements in such a manner that he is confident that there is no employee whose average exposure exceeds the average exposure standards and that no employee exposure will at any time exceed the ceiling exposure standards. Exposure data taken on one day or over a period of many days is best discussed by Gale[13] and later by Jones and Brief.[14]

Figure 2 shows several possible ways that an employer could analyze his exposure data. A typical geometric standard deviation (GSD) of 2.5 was assumed for the environmental variability[15] from which the family of lines A, B, and C were generated. Line A represents a maximum limit if the employer decided not to let the average measured exposure exceed an average exposure standard of 200 ppm. However, using line A there is a 50% probability of the true average exposure exceeding 200 ppm. A proposed alternative is line B which represents a data line based on 30 samples where the 95% upper confidence limit (95% UCL) is set at 200 ppm. By using this line as a data boundary the employer is 95% confident that the true average exposure will not exceed a 200 ppm standard. Note that the measured mean of 30 samples must be kept at 148 ppm (about 3/4 of the standard) in order to be 95% confident that the standard is not exceeded by the true mean.

Decisions regarding a ceiling exposure standard are reached differently. Line C of Figure 2 shows a possible decision line for a ceiling exposure standard of 200 ppm. This line theoretically allows 2% of the exposures to exceed the "absolute" ceiling standard of 200 ppm. Of course this analysis assumes the exposure data perfectly fits the theoretical lognormal distribution. In reality, many cumulative exposure curves effectively truncate at higher concentrations and for line C the actual number of exposures exceeding the 200 ppm ceiling standard is probably much less than the predicted 2%. However, this probability cannot be calculated.

Earlier the term "95% confidence level" was introduced in reference to statistical testing. This term arises from the choice of a 5% risk level for the statistical test to be used. The clear advantage of using statistical tests for the decision process regarding exposure standards is that the maximum desired risk levels can be selected in advance and probability curves can be calculated. Bartlett and Provost[16] have shown how standards, tolerances, and risk levels can be interpreted in up to five different ways. Employers, government inspectors, and employees can all interpret a standard in different ways. The interpretations involve sample size, chosen risk levels, and acceptance/rejection criteria.

A way of illustrating the various interpretations is through the power function (PF) curves for each test. Figure 3 qualitatively shows the PF curve for a type of noncompliance test recommended by Leidel and Busch[6] for government agencies. The criterion is that no citation should be issued unless the 95% lower confidence limit (LCL) of the measured mean exceeds the standard. Can the employer state he will be wrongly cited 5% of the time? Certainly not. Only if the true average concentration in his plant is just at or slightly below the standard is there a 5% chance of an unjust citation and this probability drops to essentially zero for true average concentrations under the standard. The term "5% risk level" refers to the specific case of a 5% risk of declaring noncompliance when the true average concentrations is exactly equal to the standard. The term has no meaning anywhere else on the PF curve.

An example demonstrating the use of Figure 3 involves sampling consecutively for 8 hours with three charcoal tubes. The substance involved is MEK (2-butanone) with a Federal Standard of 200 ppm average concentration. By the methods of Leidel and Busch[6] a citation should not be issued until the measured mean of the three samples exceeded the 200 ppm standard by at least 19 ppm. Note that a measured mean is only an estimate of the true mean. If the true mean happened to be 219 ppm there would be only a 50% chance of the employer being cited! The employee might feel that this provided him with an inadequate level of protection.

However, the employer could possibly argue that the choice by the government of a 5% risk level test does not provide him sufficient protection against an unjust citation if the true plant concentration is at or slightly below the standard. The employer could propose that the government use a 1% risk level test and Figure 4 illustrates the effect of this proposal. The probability of a citation for a true case of noncompliance where the true concentration exceeds the standard decreases markedly. For the MEK example given above, where the true average air concentration was 219 ppm, the probability of the government declaring noncompliance drops to about 26% compared to 50% for the 5% risk test. Thus, when the employer's risk is decreased the protection afforded the employee is markedly decreased.

What is the interaction of risk levels for an employer sampling plan? Figure 5 is an PF curve for the type of employer sampling plan represented by Line B of Figure 2. The employer would decide that his plant is in compliance only if the 95% upper confidence limit (UCL) of the measured mean is below the standard. Thus, for a true noncompliance situation where the true average concentrations are slightly above the standard, there is a 5% or less chance of the employer deciding that his plant is in compliance.

In conclusion, we have seen the necessity for using statistical sampling plans and decision theory both in the sampling of the occupational environment and as part of the decision making processes regarding compliance or noncompliance with mandatory health exposure standards. The use of statistical tests means that maximum desired risk levels can be selected in advance and the burden of the sampling program minimized. The selection of a 5% level for both compliance and noncompliance tests is appropriate in that it protects both the employer and employee against unreasonable risk. There is considerable precedent in federal regulations for the use of statistical methodology in compliance enforcement and NIOSH will continue to advocate the use of statistics in this area.

ACKNOWLEDGEMENTS

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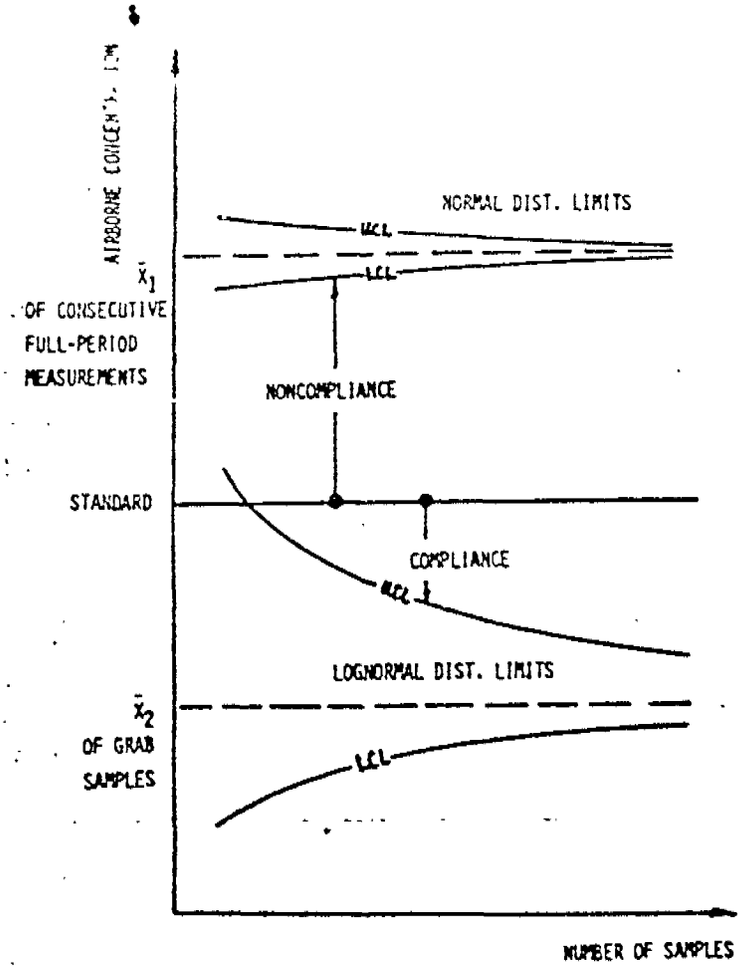

FIG. 1 - COMPLIANCE AND NON COMPLIANCE SITUATIONS FOR TWO TYPES OF SAMPLING STRATEGIES.

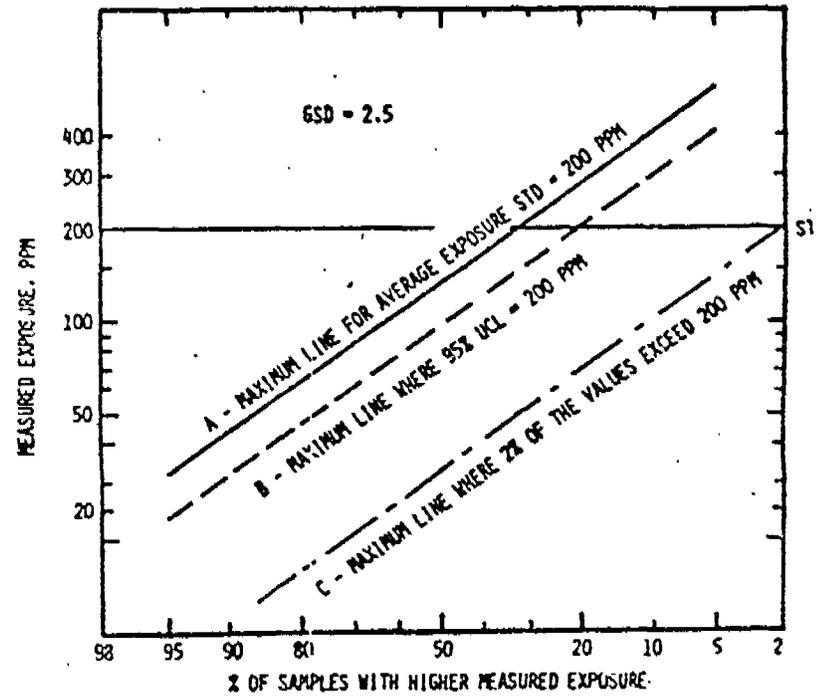

FIG. 2 - THREE DIFFERENT CONCEPTS FOR MAKING COMPLIANCE DETERMINATIONS

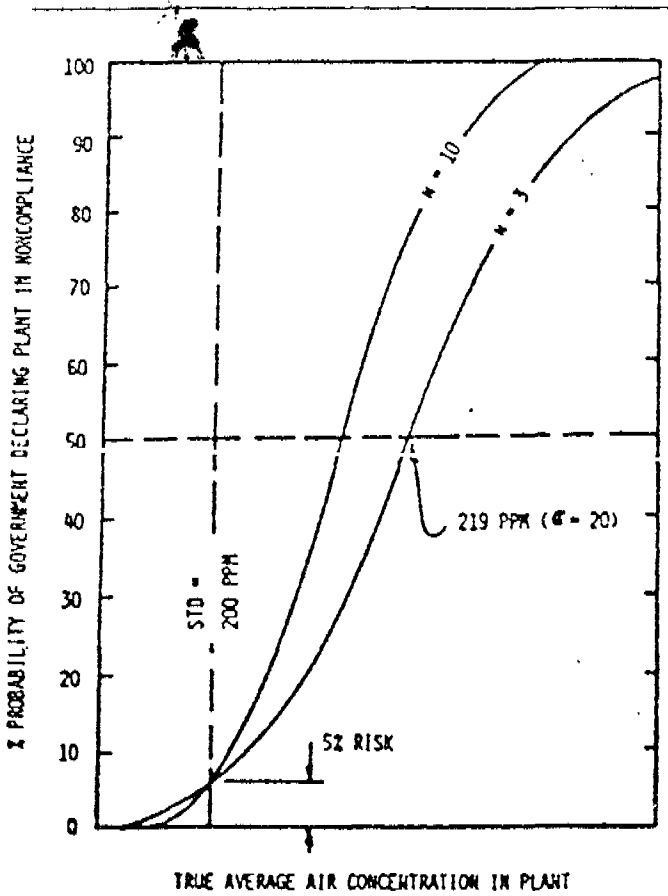

FIG. 3 - POWER FUNCTION (PF) CURVE FOR A TEST OF NONCOMPLIANCE AT THE 5% RISK LEVEL.

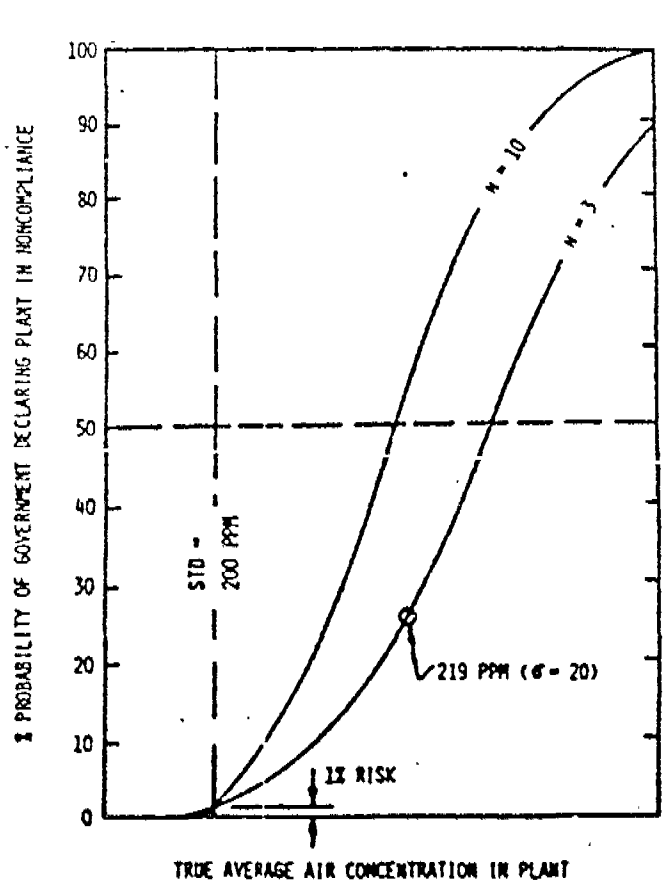

FIG. 4 - POWER FUNCTION (PF) CURVE FOR A TEST OF NONCOMPLIANCE AT THE 1% RISK LEVEL.

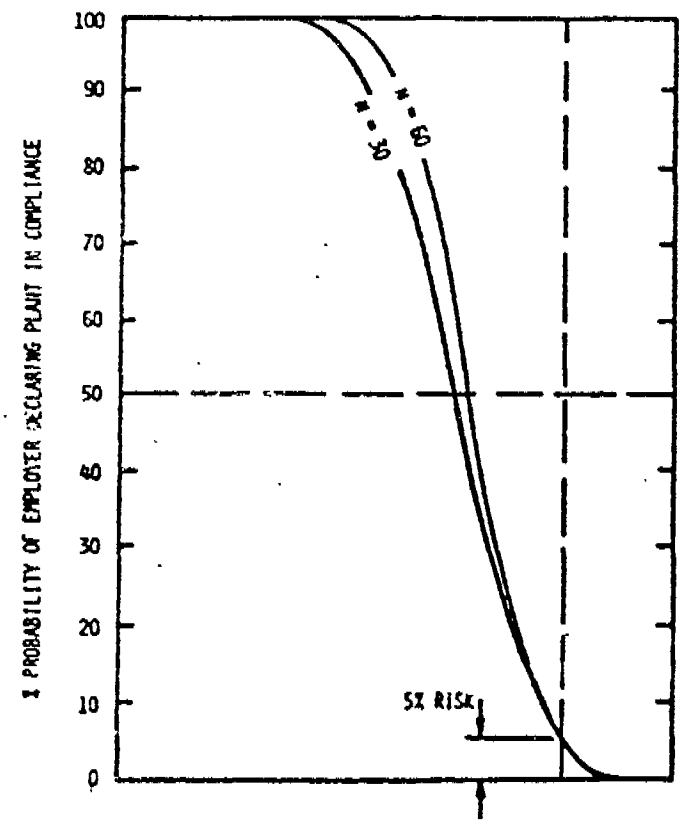

FIG. 5 - POWER FUNCTION (PF) CURVE FOR A TEST OF COMPLIANCE AT THE 5% RISK LEVEL.

CHAPTER 3

Sampling Strategy

INTRODUCTION

Chapter II discusses the considerations that may lead to the decision that there is sufficient likelihood that a health standard is being violated to justify the collection of samples. When this decision is made it is necessary to devise a sampling strategy for the particular situation which will permit a decision regarding noncompliance to be made as efficiently as possible. In the sense of a health standard, noncompliance means that the standard was exceeded for certain for the period appropriate to the standard on the occasion of the inspection.

DECISION PROCESS

The development of an appropriate sampling strategy for a given situation requires decisions involving the following three factors:

a. Location of the samples
b. Period of the samples
c. Number of samples

These decisions are made within several constraints including the way the standard is defined, the particular work situation and the capabilities of the sampling and analytical methods.

Selection of the exact sampling strategy within the range available for each of the factors should be made so as to optimize the likelihood of finding noncompliance if it exists with maximum efficiency in terms of field and laboratory effort.

This strategy takes into account the sample collection and analytical errors which are inevitable in any environmental measurement and the sampling error which will occur when random measurements of a varying environment are made. In statistical terms a null hypothesis that the establishment is in compliance is assumed. Samples are then collected and the data analyzed to see if it is possible to reject this hypothesis with appropriate certainty. For this situation, the following concepts apply (See Fig. 1)

The Type I error, which is a measure of any uncertainty that noncompliance does in fact exist, should be kept as small as possible so that we are certain that noncompliance decisions are correct. However, for a given environmental condition and measurement system, the effect of reducing the Type I error is to increase the Type II error, that is, to increase the likelihood of not finding noncompliance when noncompliance does actually exist. For almost all industrial hygiene measurements Type II errors are greater than Type I errors. For example, if the Type I error is held to 5%, the Type II error could be as large as 30% in some situations; reducing the Type I error in this instance to 1% could result in a Type II error of as much as 80%. Thus the Type I error must not be made unreasonably small since this results in a very large Type II error with consequent lack of protection to the employee. The somewhat complicated statistical methods in Chapter VI have been chosen for the purpose of minimizing Type II error for a given Type I error.

In the selection of sampling strategy, it is important to use those methods, such as full period samples, which result in as low as possible Type II error so as to increase the likelihood that compliance does exist when noncompliance is not found.

LOCATION OF SAMPLES

For most types of standards, with certain exceptions noted below, the location of the sample must be such as to yield a reliable estimate of the exposure of an employee.

Personal Samples

Direct exposure measurement is most efficiently accomplished by attaching the sam-

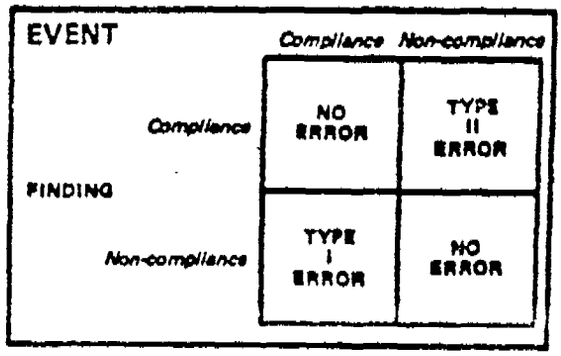

Figure 1

pling device directly to the employee using [illegible] of deliberate tampering with the sample are rare, it is important for the CSHO to keep the employee wearing the sampling device under sufficient observation to insure the validity of the sample. If tampering is suspected the sample should be rejected.

Hand Held Samples

For certain substances there are at present no collection techniques which permit the use of personal samplers. In this case it is necessary to adopt the second alternative of following the employee as closely as possible holding the sample device inlet as close to the employee's breathing zone as possible.

General Air Samples

Those samples taken in the general workplace at a fixed location somewhat independent of the movements of the employees are called general air samples and are permissible only when one of the following conditions is met.

a. When it is reasonable to assume that essentially the same exposure exists at the sampling location as in the employee's breathing zone. This may be the case, for example, when employees are moving freely throughout a workplace which contains many diffuse sources of air contaminant emission.

b. When the standard is defined in terms of a general air concentration instead of the exposure of the employee.

c. In certain special cases where additional material is needed for analtyical purposes, such as for the determination of percent quartz in the same atmosphere to which the employee is exposed. In these cases, the employee's exposure is not determined by the fixed location sample but rather by a personal or breathing zone sample. The general sample is used only for the purpose of determining the nature of the containment to which the employee is exposed. It is important in this instance to be certain that the atmosphere in which the general air sampler is located is the same atmosphere to which the employee is exposed.

d. When a number of general air samplers can be located in such an array as to permit the calculation of an employee's exposure given the locations and times of movement of the employee whose exposure is being measured.

EMPLOYEE SELECTION

The selection of the employee whose exposure is to be measured is based on the initial concept that the object of the inspection is to determine as efficiently as possible if a state of noncompliance exists. For that reason the exposure of the employee who, based on the judgment of the industrial hygienist, is presumed to have the maximum risk in each exposure situation, is measured.

When a number of exposure situations exist, resulting from different processes or emissions requiring different controls, a maximum risk employee should be selected for each situation in which noncompliance is likely. The exposure of other employees may also be measured so as to eliminate the possibility that the maximum risk assumption was in error. It is not, however, necessary or efficient to measure the exposure of employees who are known to have lower exposures than those employees at maximum risk.

Occasionally, the employee being sampled leaves the area of exposure for another area in which it is presumed that there is a low (or no) exposure. In this event several approaches could be taken. First, the sampler may be left on for the whole period including lunch or any other low exposure period since this will not affect the validity of the 8-hour average and it may happen that some exposure occurred during this period. Alternatively the sampler may be removed during any period of assumed low exposure and then the average for the 8-hour period may be calculated assuming zero exposure during the unsampled period.

EIGHT-HOUR AVERAGE STANDARDS

The majority of the standards in the regulations are for the average exposure of a worker over an 8-hour period. These standards are referred to as TWAs' although the time weighted average method of calculation may not be the preferred method of determining the 8-hour average.

Full Period Single Sample

When it is possible within the constraints of inspection time and sampling method available to collect a single sample represen-

tative of the employee's exposure over the full period for which the standard is defined, this sample is referred to as a full period single sample. It has the advantage that the environmental variance occurring during the sample period does not influence the accuracy of the data since the sample is a direct measure of the entire period appropriate to the standard. A disadvantage is that it is more time consuming since it is necessary to begin sampling at the beginning of a shift and continue to the end. Also, separate samples are necessary for the measurement of peaks. In general, the measurement (sampling and analytical) error associated with the sampling method is known and as a consequence it is possible to obtain valid confidence limits in the result of a single sample. If the measurement error is not known, it may be necessary to devise a means of collecting simultaneous samples of the exposure of a single employee.

Example: A personal sampling pump with a respirable dust sampling head is attached to an employee at the start of his shift at 7:00 a.m., turned off from 11:30 a.m. to 12:00 p.m. (lunch) and turned on again from 12:00 p.m. to 4:30 p.m. The sample collected constitues a full period sample for the determination of quartz exposure.

Full Period Consecutive Sample

Even when it is not possible to collect a single sample over the full period for which the standard is defined, it may be possible to collect a series of consecutive samples which completely cover the entire period. The average of these samples weighted in proportion to the sample period yield a result which is equiavlent to the full period single sample. The accuracy of such a result may be even greater than for a full period sample since the collection of more than one consecutive sample has the result of reducing the effective sampling and analytical error. As in the case of full period single samples the measurement error is generally known. When it is not, it may be determined by some simultaneous sampling scheme.

Example. Personal samples are collected on an asbestos worker as follows:

SAMPLE NO.	TIME
1	7:00 a.m. (Start of shift)-8:00 a.m.
2	8:00 a.m.- 9:30 a.m.
3	9:30 a.m.-11:00 a.m.
4	11:00 a.m.- 1:00 p.m. (turned off and covered for 30 min. during lunch)
5	1:00 p.m.- 3:30 p.m.

The time weighted average of the results of these samples is a full period consecutive sample for asbestos.

Partial Period Samples

When time does not permit sampling over the full period for which the standard is defined, it may be possible to make a determination of noncompliance based on a partial period sample if the standard (See Chapter VI) is adjusted by a factor (Fig. 2). This factor is calculated from the certain knowledge that the concentration during the period not covered by the sample could not be less than zero. Thus, for an 8-hour standard of 1 mg/m^3, a sample which yielded a result which indicated that 2 mg/m^3 was certainly exceeded over a 4-hour sampling period would indicate noncompliance.

Example: Collection of a personal sample for lead exposure was started at 9:00 a.m. and continued until the end of the shift at 3:00 p.m. The equivalent 6-hour standard for comparison with the mean of the result is obtained by multiplying the 8-hour standard by the factor from Table 1.

Grab Samples

In some cases it is impossible, due to limitations in such measurement methods as sound level meters or detector tubes, to collect either a single or a series of consecutive samples whose duration approximates the period for which the standard is defined. It is still possible to determine noncompliance based on some number of short period Grab Samples taken in a random or unbiased fashion during the period appropriate to the standard. When this method is applied the measurement system random error need not be known. However, since this method is subject to a large Type II error it is necessary

that the standard be exceeded by a considerable amount in order to make a decision that noncompliance exists. Since the duration of such grab samples is unrelated to the period of the standard, some choice of sampling period is possible. The minimum sampling duration given in Chapter V is determined by the sensitivity of the analytical method. Simple durations longer than minimum yield little advantage since a sample as much as 10 times as long as the minimum sample would reduce the variance by less than 30 percent. This is, of course, assuming that it is not possible to take samples long enough to apply the full period consecutive or partial period sampling schemes. As the number of samples collected in this procedure increase, the ratio of the average of the samples to the standard, required to arrive at a decision of noncompliance, decreases. These ratios are shown in Fig. 3. As can be seen, considerable improvement is obtained by taking at least four samples but rather little additional improvement is accomplished beyond seven or eight samples. Therefore, in general, the optimum number of short period samples is between four and seven. Below four samples the sample average must be so far above the standard as to result in an unnecessarily conservative judgment of noncompliance whereas above seven samples the small decrease in variability obtained is not normally justified when compared to the time and effort required to obtain and analyze additional samples. This leads to a statistical criterion which economizes on sampling for a given degree of confidence.

Grab samples should be collected over the period for which the standard is defined at random intervals. This is accomplished by dividing the day into periods equal to the sample duration and selecting, from this schedule of possible sampling occasions, the intervals at which the four to seven or whatever number of samples are to be collected, by some random process as, for example, a table of random numbers. Results from random sampling by this method are valid even when cycles or trends occur during the period of the standard. It is valid to sample at equal intervals, for example, once every half-hour or every hour, if there is reason to believe that the mean concentration in the workplace is constant, that is, that the contaminant levels in the workplace vary randomly about a constant mean and that fluctuations are of short duration relative to the duration of the sample. When this assumption cannot be made the random sample period selection process should be used. If it is not possible to collect samples at random intervals over the entire work day, the result calculated from the grab sample procedure may be interpreted as in the case of the partial period sample. Alternatively professional judgment regarding the concentrations occurring in the unsampled portion of the day could be applied.

Example: It is necessary to evaluate possible noncompliance with the standard for phosgene using detector tubes. Each detector tube sample takes five minutes to collect. It is intended to collect 10 samples out of the possible 96 samples in the eight-hour period.

a. The starting random number of 70 (col 13, row 26) is selected from the table of random numbers (Table 1) by making a pencil mark on the page without looking.

b. The following 10 numbers were selected by reading vertically down and excluding all numbers of 96 and any duplicates. 70, 22, 34, 75, 67, 25, 74, 73, 31, 96.

c. Number the 5-minute intervals during the eight-hour period 1-96 and sample during the periods with the 10 numbers selected.

The mean of these 10 results may be analyzed by the procedure for grab samples given in Chapter VI.

Time Weighted Sampling

In certain instances, where the process has a very definite cycle of a period longer than the sampling period and it is possible to make the assumption with certainty that the air contaminant concentrations are varying with the cycle and only random variations are occurring within phases of the cycle, it is possible to apply the following formula to the determination to the 8-hour average.

$$C = \frac{C_1 T_1 + C_2 T_2 - C_n T_n}{8}$$

where

T_n = time period of a phase of the cycle (Note $\Sigma T_n = 8$ hours)

C_n = mean concentration of the contaminant during time period T_n.

In the application of this formula it is necessary to treat each consecutive time period T_n as the period for which the standard is defined. The procedures 1, 2, 3 or 4 as appropriate may then be used in each period T_n to determine the concentrations C_n. That is, if only short period samples were possible and four 2-hour phases were defined by the process, then some number, preferably between 4 and 7, short samples could be taken during each of these 2-hours phases to determine the concentration during each phase and its associated lower confidence limits. The formula could then be used to determine 8-hour average concentration from these values and statistical procedures which are beyond the scope of this manual could be used to calculate the lower confidence limit of this 8-hour average. The practical application of this time-weighted sampling procedure is much more complicated than the use of either procedures 1, 2 or 3 and only rarely is it an improvement upon the procedure described in 4 above:

Example. A plastic casting operating is observed to have the following schedule:

TIME	PHASE
7:00 a.m.- 9:00 a.m.	Mixing
9:00 a.m.-10:30 a.m.	Casting
10:30 a.m.-11:00 a.m.	Cleanup
11:00 a.m.-11:30 a.m.	Lunch
11:30 a.m.- 1:30 p.m.	Mixing
1:30 p.m.- 3:00 p.m.	Casting
3:00 p.m.- 3:30 p.m.	Cleanup

If it is possible to assume that the nonrandom variations in the concentrations of allyl glycidyl ether occur only from phase to phase, then the TWA method may be used.

a. Collect four grab samples randomly during each phase (mixing, casting, cleanup) for a total of 21 samples.

b. Calculate the mean of each phase.

c. Calculate the average concentration for the eight-hour period from

d. Special statistical procedures, not given here, are required to determine the lower confidence limit for C. It is not likely that this confidence limit will be much smaller than that obtained by taking a smaller number of samples at random over the whole eight-hour period. A much tighter lower confidence limit could be obtained if it were possible to take longer samples and use either the full or partial period strategies.

SHORT PERIOD STANDARDS

For some standards a short period limit of usually less than one hour is defined. These standards include the ceiling limits, certain standards for which both an 8-hour average and an excursion or short-term limit is defined and certain peak limits for which no time period is defined. In order to insure uniformity in the determination of noncompliance in the case of those standards for which no sampling period is defined, the minimum sampling time as given in Chapter V should be used.

In all cases the interpretation of a short period standard is that noncompliance exists when the standard has been exceeded for the period for which it is defined or some longer period. When both short and long period standards are defined for a given substance, a sampling strategy should be adopted which allows for the evaluation of both.

The selection of the location at which the sample should be collected for short-period limits is the same as for 8-hour average limits in that the exposure of the employee must be measured either directly or indirectly unless the standard is set in terms of general workplace concentration, and the employee whose exposure is measured should be selected from among the maximum risk employees. In addition to these criteria for selection of the location, the sample should be collected at a time when the maximum exposure is presumed to occur.

Since short period limits are rarely defined for periods of more than 30 minutes, the procedures described under Full Period Single Sample and Full Period Consecutive Sample for 8-hour average standards may almost always be used and the Partial Period Sample and Grab Sample techniques are rarely if ever necessary. The time weighted average procedure described under Time Weighted Sampling is not applicable.

TABLE I

SHORT TABLE OF RANDOM NUMBERS

05	57	23	06	26	23	08	66	16	11	75	28	81	56	14	62	82	45	65	80	36	02	76	55	63
57	78	16	06	57	12	46	22	90	97	78	67	39	06	63	60	51	02	07	16	75	12	90	41	16
23	71	15	03	82	04	87	29	01	20	46	72	05	80	12	27	47	15	76	51	58	67	05	80	54
42	67	98	41	67	44	28	71	45	08	19	47	76	30	26	72	33	69	92	61	95	23	26	85	76
05	83	03	84	22	62	83	27	48	83	09	19	84	90	20	20	50	87	74	93	51	62	10	23	30
60	46	18	41	23	74	73	51	72	90	40	52	95	41	20	89	48	98	27	38	81	33	83	82	94
32	80	64	75	91	98	09	40	64	89	29	99	46	35	69	91	50	73	75	92	90	56	82	93	24
79	86	53	77	78	05	62	37	48	82	71	00	78	21	65	65	88	45	82	44	78	93	22	78	09
45	13	23	32	01	09	46	36	43	66	37	15	36	04	88	79	83	53	19	13	91	59	81	81	87
20	60	97	48	21	41	84	22	72	77	99	81	83	30	46	15	90	26	51	73	66	34	99	40	60
67	91	44	83	43	25	56	33	28	80	99	53	27	56	19	80	76	32	53	95	07	53	09	61	98
85	50	76	93	86	35	68	45	37	83	47	44	92	57	66	59	64	16	48	39	26	94	54	66	40
66	73	38	38	23	36	10	95	16	01	10	01	59	71	55	99	24	88	31	41	00	73	13	80	62
55	11	50	29	17	73	97	04	20	39	20	22	71	11	43	00	15	10	12	35	09	11	00	89	05
23	54	33	87	92	92	04	49	73	96	57	53	57	08	93	09	69	87	83	07	46	39	50	37	85
41	48	67	79	44	57	40	29	10	34	58	63	51	18	07	41	02	39	79	14	40	68	10	01	61
03	97	71	72	43	27	36	24	59	88	82	87	26	31	11	44	28	58	99	47	83	21	35	22	88
90	24	83	48	07	41	56	68	11	14	77	75	48	68	08	90	89	63	87	00	06	18	63	21	91
98	98	97	42	27	11	80	51	13	13	03	42	91	14	51	22	15	48	67	52	09	40	34	60	85
74	20	94	21	49	96	51	69	99	85	43	76	55	81	36	11	88	68	32	43	08	14	78	05	34
94	67	48	87	11	84	00	85	93	56	43	99	21	74	84	13	56	41	90	98	30	04	19	68	73
58	18	84	82	71	23	66	33	19	25	65	17	90	84	24	91	75	36	14	83	86	22	70	86	89
31	47	28	24	88	49	28	69	78	62	23	45	53	38	78	65	87	44	91	93	91	62	76	09	20
45	62	31	06	70	92	73	27	83	57	15	64	40	57	56	54	42	35	40	93	55	82	08	78	87
31	49	87	12	27	41	07	91	72	64	63	42	06	66	82	71	28	36	45	31	99	01	03	35	76
69	37	22	23	46	10	75	83	62	94	44	65	46	23	65	71	69	20	89	12	16	56	61	70	41
93	67	21	56	98	42	52	53	14	86	24	70	25	18	23	23	56	24	03	86	11	06	46	10	23
77	56	18	37	01	32	20	18	70	79	20	85	77	89	28	17	77	15	52	47	15	30	35	12	75
37	07	47	79	60	75	24	15	31	63	25	93	27	66	19	53	52	49	98	45	12	12	06	00	32
72	08	71	01	73	46	39	60	37	58	22	25	20	84	30	02	03	62	68	58	38	04	06	89	94
55	22	48	46	72	50	14	24	47	67	84	37	32	84	82	64	97	13	69	86	20	09	80	46	75
69	24	98	90	70	29	34	25	33	23	12	69	90	50	38	93	84	32	28	96	03	65	70	90	12
01	86	77	18	21	91	86	11	54	65	48	75	26	94	51	40	51	53	36	39	77	69	06	25	07
51	40	94	06	80	61	34	28	46	28	11	48	48	94	60	65	06	63	71	06	19	35	05	32	56
58	78	02	85	80	29	67	27	44	07	67	23	20	28	22	62	97	59	62	13	41	72	70	71	07
33	75	88	51	00	33	56	15	84	34	28	50	16	65	12	81	56	43	54	14	63	37	74	97	59
58	80	37	45	62	09	95	93	16	59	35	22	91	78	04	97	53	80	20	01	38	93	13	92	30
72	18	12	95	33	87	99	32	63	65	40	17	92	57	22	68	98	79	16	23	53	56	56	07	47
22	21	13	16	10	52	57	71	40	49	95	25	55	86	95	57	25	25	77	05	38	05	62	57	77
97	94	83	67	90	68	74	98	17	22	33	01	04	33	49	38	47	57	61	87	15	39	43	87	00
09	03	68	53	07	29	27	31	86	53	39	34	88	87	04	35	80	69	52	74	99	16	52	01	85
22	95	61	42	05	05	72	27	28	18	09	85	24	59	46	03	91	55	38	62	51	71	47	37	38
81	96	78	90	47	41	38	35	32	95	85	00	26	72	85	23	22	30	70	51	53	93	23	84	80
41	01	20	31	21	57	57	05	00	47	26	10	87	22	45	72	03	51	75	23	38	38	56	77	97
66	01	12	15	08	02	18	74	55	39	21	53	63	41	77	15	07	39	87	11	13	25	62	19	80
23	33	77	60	29	09	25	09	42	28	07	15	40	67	56	29	58	75	84	06	19	54	31	16	53
54	13	39	19	29	01	97	73	71	61	78	03	24	02	93	86	53	76	74	23	08	98	84	08	23
75	16	85	64	64	93	85	63	08	84	15	41	57	84	45	11	70	13	17	09	47	80	10	13	00
36	47	17	03	79	03	92	85	13	42	95	48	27	37	99	93	81	94	44	72	06	95	42	31	17
29	81	03	21	91	23	76	72	84	98	26	23	66	54	85	83	95	14	82	57	17	99	16	23	99

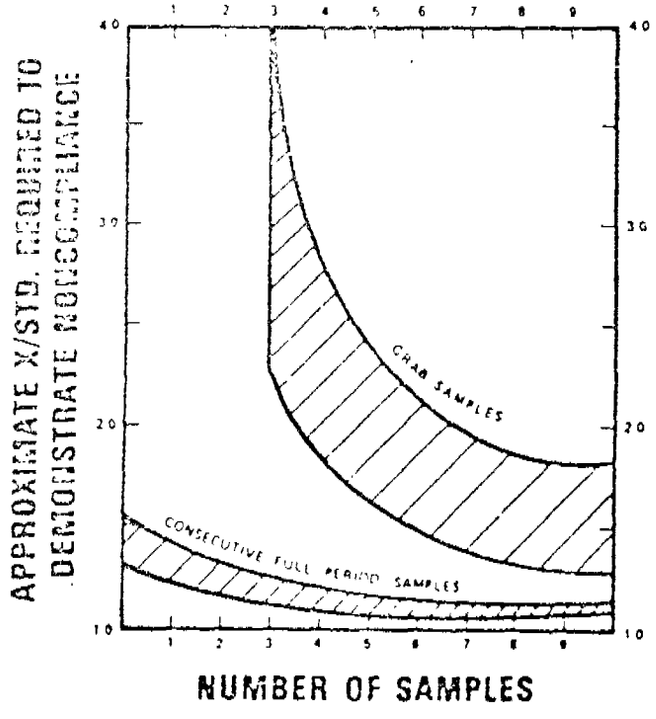

TABLE 1

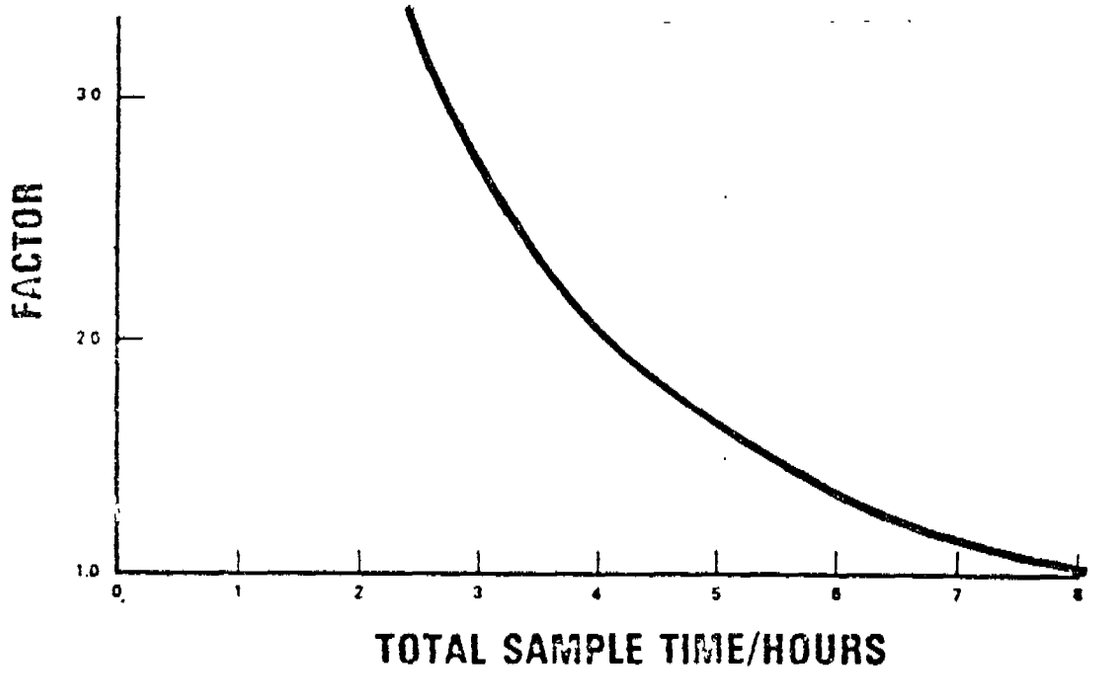

FIGURE 2

ASI 00023713