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Symposium on Threshold Limits

Present Trends in MAC's

Introduction by WARREN A. COOK, Associate Professor
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THE THINKING today on the concept of threshold limits of injurious materials, designated by whatever term, has passed through an evolution to a gratifying maturity.

Initially the need to know how little of a toxic substance might remain in an industrial atmosphere without injury to those exposed was insistently apparent. Such information began to be supplied through correlation of concentrations of injurious substances with observed effect on the health of the worker for such materials as granite dust[1] and lead compounds.[2] Results of short-time animal experiments had been available even before the present century from such investigators as K. B. Lehmann[3] and later from Yant and others at the U. S. Bureau of Mines,[4] with the classic combined long-exposure animal experimentation and occupational study on benzene by Greenburg[5] in the middle twenties.

As these threshold limit values became more numerous and were more widely applied, it is perhaps not surprising that misconceptions and aberrant usages occurred. Some persons erred in considering the levels more precise than the facts justified; others rejected them because the values could not precisely fit all conditions of exposure and physiological response. And the detractors were for a while more vociferous and seemed possibly to be more sound than the protagonists.

With time, there has been a separation of the valuable advantages of the threshold limits and the improper use of them. Nowhere is the present concept of threshold limits more ably and competently expressed than in the papers and discussions of this Symposium.

That the discussants might not have the very last word, it may be permissible for this prologue to assume in part the prerogative of an epilogue! The following commentaries appear pertinent.

The last publication of the American Standards Association Z-37 Committee on Maximum Acceptable Concentrations of Toxic Dusts and Gases[6] is reported correctly as 1949 by Sachs who deplored the lack of revision of the 1941 Standard for benzene at the obsolete level of 100 parts per million. It is to be noted that this ASA Committee is now active in the revision and publication of MAC Standards for many of the materials on which information is available.

The term "maximum acceptable concentrations" was adopted by the ASA Committee for a number of reasons. The word "acceptable" does not connote the legal control inherent in the words "allowable" and "limit," but rather a simple acceptability without further implication. Also, the expression, MAC, has been widely used over the years and is now a part of the language. In fact the Germans adopted a wording which gives the abbreviation, MAK, so that this term may be used in international conversation. Their words as used in the title of a paper by Oettel[7] are "Maximale Arbeitsplatz-Konzentration." It is understood that this same expression is being used in the "MAK" tables of the German Association for Worker Protection.

Presented at the Joint Session of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION—AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS at the 1955 Industrial Health Conference, Buffalo, April 26, 1955.

However, there can be no really valid objection to the term "Threshold Limits" used by the committee of the American Conference of Governmental Industrial Hygienists or to "Hygienic Guides," the term adopted by the American Industrial Hygiene Association committee. This Symposium would not be complete without reference to the availability of the excellent AIHA Hygienic Guides to which reference is made elsewhere in this Journal.

One of the most perplexing problems in arriving at threshold limits is posed by the cancerigens. Stokinger's statement in this Symposium is the first publication on this phase of the subject. However, the use of the procedure suggested by Stokinger as applied to nickel carbonyl has already drawn some fire. Quoting in part from a private communication from Oettel whose publications[7,8] on "MAK's" include a well-considered presentation of the general subject: "We suggest that consideration be given to indicating the suspected cancerigens with an asterisk with reference to a footnote that the hazard exists and consequently especially effective control measures be instituted. No man can say today which concentration of the several industrial substances is actually required to be cancerigenic . . ." This statement follows his objection to the present listing by the ACGIH of nickel carbonyl as 0.001 ppm on the basis of its alleged cancerigenicity, which incidentally Oettel's extensive experience with the substance causes him to doubt, while failing to include any acknowledgement of the known cancerigenicity of arsenic, chromates and asbestos. Says Oettel "In this I see a great danger. The lists should in any event remain logical."

Waters' discussion of Brandt's paper occupies the final pages of this publication of the Symposium, but it is believed that Waters would not wish his comments to be considered the last word on the subject of threshold limits—rather that his observations are limited essentially to the use of these values in legal codes, rigidly fixed by statute. As the last word in this Symposium, this introductory refers the reader to the concluding paragraphs of the paper by Brandt for his discussion of the philosophy of threshold limits.

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The Need for Threshold Limits

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Probably one of the most basic needs in human endeavor is for man to have an orderliness set to his manner of thinking. Everyone has a need for discipline, for boundaries to be drawn, and for limits to be defined. It does not matter that the only use for some of the limits so defined may be to ignore them; they have still served their purpose as a point of aim for individual interpretation. If this seems cryptic, an example concerning a common substance may be cited.

Almost everyone is familiar with the threshold limit values for silica—for dust with a free silicon dioxide content above 50%, the limit is given as five million parti-

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cles per cubic foot of air (MPPCF), for dust with a free-silica content below 5%, the limit is 50 MPPCF, but 20 MPPCF is the value assigned for dusts with 5% to 50% free silica. It is rather difficult to understand how lungs could be so selective as to react with fibrosis if air containing more than 5 MPPCF of a 50% silica bearing dust was inhaled, but would be expected to remain healthy if a 40% silica content dust at the level of 20 MPPCF was similarly inhaled. It would be of doubtful accuracy for each industrial hygienist to interpolate on the curve of this wide range and apparent discrepancy. It has always seemed better practice to abandon the middle limits and when necessary forward a report (concerning dusts with a free-silica content of about 40%) that "dust with such a dangerously high content of free silica should be maintained in the working environment at less than 5 MPPCF." For agencies who have not conducted any research or original investigation along these lines, this might have been a precarious position under attack. Fortunately, the trend is toward revision of the limit for silica-bearing dusts.[1]

An Essential Tool

Actually, threshold limits satisfy the need for a tool essential to the protection of the health of the worker. The quantity of technical information concerning the biological actions of old and new chemicals is so vast that no single practitioner of industrial hygiene can be expected to be able to assimilate more than a very small fraction of this mass of material. A list of guide values prevents the chaos that would result if each investigator conducting plant surveys had to depend on his own comparatively restricted experiences and background. Two of industrial hygiene's sister specialities are admirable demonstrations of the benefits of having, and the disadvantages of not having, an approximate measurement of hazard. In radiological health and radiological safety the maximum permissible exposure value, blessed by national and international committees, has made possible much of the rapid adoption of various radiological techniques, uses of radioisotopes, and forays into the field of nuclear energy.

In air pollution investigation and control, lack of standards for permissible levels of atmospheric contaminants has seriously hampered wise administration of air pollution control practices, and has made it almost impossible to weigh the effects of these contaminants on the public health.

The need for threshold limit values *and the manner of use* is quite different for the staffs of governmental or official agencies and for persons employed by private industry or working with research laboratories, universities or foundations. Official industrial hygiene agencies must have a screening device to apply to literally thousands of industrial processes which are encountered in the day-to-day field work, from one year to the next. A screening device may very well be a single parameter but it should be used only for the purpose of suggesting more intensive and detailed study where the parameter is significantly exceeded. In multiphasic screening for chronic disease, the patient whose survey film is suspect for tuberculosis, cancer of the lung, or abnormal heart outline is referred to his private physician or to an appropriate clinic for more definitive diagnosis.

In discussing any screening test procedure, the question of false negatives versus false positives is certain to be reached. When the risk is permanent disability or death, the governmental industrial hygienist is so conditioned that he favors the side of the false positive; he tends to be too strict rather than too lenient.

For private industrial purposes, the threshold limit values satisfy the need for engineering bench marks. "Almost 100% confidence can be placed in the threshold limits where they are being used for evaluating and controlling of an industrial environment. This is particularly true in the use of these limits as a base line for calculating control design specifications in that the usual engineering factors of safety are included in such designs. It should be remembered that under this connotation the base line for comparison need not be extremely accurate. Naturally, the more accurate the figure is, the better economy that can be realized in engineering a control."[2] One of the deans of industrial hygiene and toxicology, restated this point of view as, "We need a yardstick even if it's only a rubber yardstick!"

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Henry Smyth has given the most nearly complete description of the toxicological data required to satisfy all needs.[3] (1) What uniform concentration is tolerable eight hours a day for a working lifetime? (2) What correction in the average must be made for brief peak concentrations? (3) What single brief exposure to a high concentration is tolerable each day when there is no exposure the rest of the day? (4) What biological test upon the workman can measure his actual intake of the chemical at his job? (5) What are the earliest symptoms and objective signs of excessive exposure and how severe can they become before removal from exposure fails to prevent permanent injury? (6) What is the best treatment for the effects of excessive single exposure or excessive repeated exposure?" For a few industrial materials, all of these questions can be answered. The threshold limit values attempt to supply the answer only for question one. The introductory preface to the list advises caution in interpreting even this single answer. The introduction to the 1954 list has probably been well read. The preface to the 1948 list warrants repetition: "While it will doubtless be very advantageous to have what might be called permanent or standard maximum allowable concentration values, it must be borne in mind that all our values at the present time are fluid and subject to annual revision. They should not be adopted as fixed or legal values, but merely as guides to assist us in defining more or less safe working conditions. . . It must be borne in mind that these values are not indices of toxicity and are not intended to approach that value. Accordingly, the comparative toxicity of these compounds cannot be established on the basis of their numerical maximum allowable concentration value.

"People vary greatly in their response to drugs and toxic substances. Therefore, it is a figment of the imagination to think that we can set down a precise limit below which there is complete safety and immediately above which there may be a high percentage of cases of poisoning among those exposed.

"With these facts in mind the Committee has set values below which it is fair to expect reasonable protection and above which it is reasonable to expect that we can have occasional cases of poisoning."[4]

With so clear a statement of purpose on the books, it has always been somewhat baffling that several persons speak with bitterness and disdain about the threshold limits list. In all fairness, it must be admitted that the acrimony arises because the advice in the foregoing statement has frequently been disregarded and some regulatory agencies have not only allowed but have assisted the entrance of the threshold limits into the sacred and rigid precincts of the law. This is an unfortunate resting place for a scientific instrument that requires constant adjustment and calibration.

A number of excellent papers have been written on maximum allowable concentrations and threshold limits. In the interests of progress this panel discussion should be more than a review of bibliography. It should be a reflection of the opinions of the ACGIH-AIHA joint membership and some expression of their perspective on the threshold limits, their needs and their suggestions for changes or additions. Accordingly, a simple one-page questionnaire on the value of threshold limits was sent to the members of the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists (excluding those in foreign countries). A copy of the questionnaire appears on the next page.

Response to Inquiry

ONE THOUSAND AND FIFTY questionnaires were sent out, of which 340 were returned by the February 10 deadline. Fourteen of these were discarded since they were simply courtesy returns with the questions unanswered.

Of the 326 completed forms, the expressions of "confidence" in the Threshold Limits were divided as:

Confidence	Number of Replies
100%	53
80%	173
50%	37
Less than 50%	9
Qualified	54
Total	326

The group of *qualified* answers were essentially those who wrote they could not apply a numerical rating to their reactions to the threshold limit values or who said they

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The Need for Threshold Limits

(1) How would you rate your confidence in the ACGIH Threshold Limits? (check one)
100%___ 80%___ 50%___
Less than 50%___

(2) Do you think we *need* a list of Threshold Limits? Yes___ No___

(3) What standards of performance would you prefer?

(4) When you use or instruct as to the use of Threshold Limits, what qualifications or reservations (if any) do you advise?

(5) Other Comments

(6) May I quote you by name? Yes___ No___

Name____________________
Title____________________
Affiliation____________________

had, for example, 100% confidence in some of the values and little or no confidence in other values, particularly values for some newer substances assigned because of chemical or structural similarity to a material with a well-documented value. At this point it should be emphasized that many, many responses were careful to explain that their confidence rating was for the "value"; that their confidence in the Committee on Threshold Limits was unqualified.

The question, "Do you think we *need* Threshold Limits?" was answered

Yes	323
No	3
Total	326

In the qualified answers, in the comments and in the suggestions for other standards of performance, there were many pleas for regrouping of data and for additional information. These were expressed in many different ways but lent themselves to a few major headings. There were 103 requests that the list indicate whether the value was an "injury" value or a "nuisance" or "comfort" value; there were 73 requests for a notation as to whether the value was based on animal experimentation or human experience; 75 persons desired a short exposure value, a one-hour tolerance or a value for "peaks"; 32 wanted information on multiple exposures, synergism or additive effects; and 28 thought the references should be printed along with the assigned value.

These suggestions may be summarized as follows:

Requests for	Number	
Comfort threshold (nuisance level)	61	103
Chronic toxicity threshold (injury level)	42	
Animal experimentation or human data	73	
Short exposure threshold, one hour, peaks	75	
Synergism, multiple or additive exposures	32	
References on list	28	

Several of these comments and requests were embodied in enclosed reprints, long letters and telephone calls. With all this active and militant thinking, there should be no great fear that threshold limits will be applied blindly or that a numerical value will ever entirely replace thoughtful, scientific appraisal of the many factors that must be considered concerning the health of the worker and the status of the workroom environment. Especially, the need for medical examination and a determination of the general physical condition of the worker seem well understood.

What to be Expected of ACGIH List

One pertinent question remains to be answered. What can logically be expected of a list, revised annually, compiled by a committee, each member of which is earning his living at a full-time job? One of the major values of the list is that it is revised annually, and new substances added as data are forthcoming. The excellent Z37 series prepared by the American Standards Association contains much more information than appears on the Threshold Limits list. However, of the toxic dusts and gases group there have appeared 15 leaflets, the most recent of which was entitled, "The Allowable Concentration of Methyl Chloride" which was published January 5, 1949. "The Allowable Concentration of Benzene" was approved and published January 15, 1941 and states the permissible concentration as 100 parts per million parts of air by volume. So far as is generally known no revisions of this ASA figure have appeared although it is commonly agreed that the 1954 ACGIH value of 35 parts per million is a far safer working figure and one that is practical.

If it would not unduly burden the Committee on Threshold Limits it would be advantageous to have a regrouping of the listed values according to comfort thresholds and chronic toxicity thresholds. And where they exist and are easily verified, it would be most helpful to have a special group of one-hour tolerances or peak short-time permissible exposures. The combined membership of today's audience might give consideration to the publication of a monograph on threshold limits which could very well be a compilation of fundamentally sound material which has already been published. The monograph could include the papers already referred to in this article, with perhaps several others that are equally well known.[5,6,7,8]

No list of values and no amount of regrouping and no increase in the number of background references can relieve the industrial hygienist of the responsibility of acquiring sufficient education and training to do his job properly and to think for himself. It seems desirable to add here another reference, "Education in Radiation Protection,"[9] the Janeway lecture delivered by Lauriston S. Taylor. The words spoken by Mr. Taylor while directed particularly to the field of radiation exposure apply just as well to any industrial chemical exposure. He states:

"The young radiologist should be educated in the background and significance of permissible dosage or exposures and should at all times retain a sense of proportion and a sense of humor relative thereto. For example, the present permissible exposure for the whole body is 300 milliroentgens per week (measured in air). This figure was determined from a limited amount of clinical and biological data to which was applied a series of well educated guesses, and yet we may find a person's weekly exposure recorded as, say 163 milliroentgens—a figure that few, if any, practical clinical instruments can measure with an accuracy of better than ± 10%. Again, if a film badge (accuracy ± 20%) shows a reading of 260 milliroentgens for one week, are we to be alarmed? And are we to be complacent with a duplicate reading of 200 milliroentgens taken in the same place for the same week? Actually both readings are the same within experimental limits of error and we should be alarmed in both cases not primarily because the readings differ but because the exposure in each situation may be unnecessarily high. It is only rarely that working conditions at a radiation level far below the permissible dosage cannot be obtained with but little inconvenience or added expense.

"The aim should be to see how low a practical operating level can be achieved—not how high a level without transgressing the 300 mr per week medicolegal upper limits set by radiation safety experts. Even the smallest amount of radiation has some effect on the living human body. Even if the harm is normally undetectable by the individual, genetic damage can result from single minute exposures. We must prevent perceptible harm or damage—we should minimize the likelihood of undetectable damage even though we cannot eliminate it entirely."

The fundamental goal should be the improvement of industrial hygiene practice. Threshold Limits, however accurate, and however well-documented, serve only as a guide and a yardstick. No method ever has been, or ever can be, devised that will permit an exact advance prediction of human hazard. The closest we can come is human judgment.

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Prepared Discussion

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DR. SACHS has established that the vast majority of our colleagues recognize their need for a list of threshold limits. She distinguishes between the need of the official agencies for a screening device to apply to thousands of industrial processes they encounter in field work, and the need of the private industrial hygienist for an engineering bench mark for planning and evaluating environmental control. To satisfy each of these needs vapor concentrations must be measured under operating conditions before the threshold limits values can be useful.

There is a third group which uses threshold limits and needs them because nothing better suited to the need is available. Every one of our profession is a part-time member of this group and some are full-time members. Reference is made to the arm-chair industrial hygienist. He may never measure a concentration and he may never observe an industrial operation. He uses threshold limits to advise upon the selection of a chemical for a particular application, to select a suitable application for a little known chemical and to bolster sales arguments for a chemical or mixture of chemicals.

When the industrial hygienist is asked to advise whether acetone, propyl acetate, or methylene chloride would be the safest solvent in a particular application, it may be believed that his answer is based on a profound knowledge of toxicology, but actually he recalls the threshold limits, or refreshes his memory by consulting the list while the questioner waits on the telephone. Then the answer is given as if the list recorded comparative toxicities, perhaps adding a bit of qualitative information on fire hazard and type of injury from an excess.

What better data are available for the arm-chair industrial hygienist than the annual list of threshold limits? He must have some guidance if he is to do more than toss a coin. If he is given a list based on uniformly conducted animal experiment, he is deprived of the benefit of the years of carefully observed and evaluated human experience which is recorded in some of the threshold limit values. Whether we want him to or not, he (and that includes every one of us at times) will use threshold limits as estimates of comparative toxicity to meet his urgent requirement for finding some basis for opinion.

To what extent is he wrong? A threshold limit based on comfort, irritation or good engineering practices certainly is not comparable to one based on pathological effect. But the former limit is certainly lower than one based on injury. The error is on the side of safety if it is stated that material A has a threshold limit based on comfort higher than that of material B which is based on injury, therefore material A should be used in the process.

No matter which material is chosen it will be employed by persons subjected to the same degree of industrial hygiene and medical scrutiny. By choosing the material with the higher threshold limit the probability of safe operation has been increased, even if the basis on which the choice was made is not numerically sound.

There is one important short-coming in this argument which points out an important way in which threshold limits do not meet the needs of the arm-chair industrial hygienist. If the volatility of a material with a high threshold limit is greater than that of a material with a low limit, then in a particular process the less toxic material may be more hazardous, because a greater vapor concentration will be in the atmosphere.

I maintain that the list of threshold limits is our best available source for judgments on comparative toxicity of vapors to humans. It can be improved for this purpose, but there is nothing better for us to use. However, it refers to toxicity, not to hazard. It is the single-phased toxicity of K. B. Lehmann. A table of comparative hazards would go back to Lehmann's two-phased toxicity by combining vapor pressure (or evaporation rate) with toxicity. This table of comparative hazards is what the arm-chair industrial hygienist really needs. It would go a long way toward satisfying all of his needs, particularly if it included information on nature of injury, on the penalty for exceeding the limit and on the degree of hygienic urgency for observing the limit.

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Methods of Establishing Threshold Limits

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THRESHOLD LIMITS are based upon information derived from many and diverse sources. For each evaluation, data developed by many different methods may need to be considered and weighed; and from this sometimes complicated, often contradictory, and rarely adequate, complex of information, a significant value must be developed.

It is customary to append, as reference material, the important published studies from which the conclusions were made. In these studies, particularly if the author felt that his contribution permitted such a judgment, there is often a proposed threshold limit value. Not infrequently, of course, the values suggested by different investigators may disagree. The group which is charged with the responsibility for establishing threshold limits must consider, in addition to the character of the study, such qualities as accuracy, reliability, completeness, and purpose—and, a not insignificant factor, the reputation of the investigator.

The subject, "Methods of Establishing Threshold Limits," has a connotation beyond that of the procedures and techniques reported in the industrial hygiene literature. This has to do with the actual mechanism by which a group or a committee is designated to act as a body for establishing threshold limits, and the principles and practices which actually govern the operation of the committee. In the present evolutionary stage of industrial hygiene, the internal activities of this committee must weigh heavily in any consideration of "methods."

Threshold Criteria

IT WOULD BE worthwhile, if it were possible, to record all of the elements of a deliberation in arriving at a standard. Often, there is considerable material, undocumented, which plays an important role in the evaluation, in addition to the published studies. This may be limited and fragmentary data from industrial or governmental industrial hygiene surveys; or it may be incomplete data from animal experiments; or reports of cases of alleged intoxication from Workmen's Compensation sources.

A still less tangible factor, related to the experience, training, and critical judgment of the individuals performing the evaluation, is the ability to make a variety of extrapolations. In one instance this may involve the estimation of the probable effect in man from data developed in one or more species of lower animals. The experimental toxicology data may be limited to acute or subacute experiments; but even if chronic, long-term studies have been done, the translation from a few years exposure, even though a lifetime for the animal, to the long span of a working lifetime in man is a difficult step. In other cases, the extrapolation may be from experimental or clinical data developed with one chemical to the probable effect of an homologous compound or a material with similar chemical structure.

The behavior of a substance in other fields —as a therapeutic agent, an insecticide, or even as a beverage (as in the case of ethyl alcohol) may contribute important information. The background of the individuals making the judgment, with respect to personal experience ranging from animal experimentation through long-term clinical observation of exposed workmen, with respect to a practical and critical appreciation of the value and limitations of methods for making environmental measurements, determines the ultimate value with which all of these factors, concrete and abstract, are blended to form a valid, practical, and acceptable threshold limit. The more substantial the documented information, the broader the sources of pertinent data, the less the demand for these intangible factors to fill the gaps which are inherent in this kind of procedure.

The absolute test of a threshold limit has

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The behavior of a substance in other fields—as a therapeutic agent, an insecticide, or even as a beverage (as in the case of ethyl alcohol) may contribute important information. The background of the individuals making the judgment, with respect to personal experience ranging from animal experimentation through long-term clinical observation of exposed workmen, with respect to a practical and critical appreciation of the value and limitations of methods for making environmental measurements, determines the ultimate value with which all of these factors, concrete and abstract, are blended to form a valid, practical, and acceptable threshold limit. The more substantial the documented information, the broader the sources of pertinent data, the less the demand for these intangible factors to fill the gaps which are inherent in this kind of procedure.

The absolute test of a threshold limit has not been, and probably will not be achieved if the measure of validity is strictly construed in terms of a completely "safe and healthful" environment for the occupational lifetime of an individual. Practically, criteria much less complete are accepted, although the trend is to the constant improvement of our methods for evaluating long-term and more subtle effects. These more remote parameters of injury are seen in the extreme in the study of radiation effects, where consideration is given to such factors as shortening of the total life span, and of genetic effects involving future generations. With the great majority of physical and chemical agents, we must be content with threshold limits predicated upon less extensive and less subtle end-points.

If threshold limits, even with their present imperfections, are accepted as useful and desirable, they must continue to be fabricated from information which is sometimes inaccurate, frequently controversial, and always incomplete. In this discussion, no attempt will be made to define a pattern of acceptability for the various elements of evidence which may be considered in establishing threshold limits (this might be paraphrased as "threshold criteria" for threshold limits). This will vary with the purpose for which the limits are intended, the character of the group making the judgment, and the need for such standards. At this point, it might be suggested that the various bodies which are responsible for establishing standards, attempt to define in general the purposes, criteria for acceptability, and limitations of their function—and perhaps, specifically indicate the basis for their judgment in individual instances where important factors other than the appended reports played a significant part. The publication of this information would not, of course, still all criticism, but it would obviate much of the criticism which is based upon unfamiliarity with the manner in which a decision is made. It is paradoxical, that the greater the need for a threshold limit (in terms of the numbers of individuals actually being exposed, and the severity of exposure) the greater the justification for accepting a tentative standard on inadequate and incomplete information. This practice is defensible, of course, only if this initial guiding limit is continuously and critically tested by a competent clinical study of the exposed people.

Sources of Information

THE TWO GENERAL sources from which significant information is developed are the experimental laboratory where the exposure is deliberate, and the actual plant operation, where the exposure is incidental (sometimes accidental). The establishing of threshold limits depends increasingly upon a balance of information developed from both these areas. The more complete the laboratory investigation, the greater the security of the tentative standard for plant exposures. The inherent uncertainty of extrapolation from the experimental data necessarily places the final judgment upon the clinical evaluation of the exposed workmen.

Industrial hygiene laboratory methods run a gamut from the simple, preliminary "screening" procedure using a few small animals to a relatively involved, carefully controlled, clinical experiment in which human subjects are deliberately exposed to a toxic agent. The studies with lower species should define a range from minimal or no effect through severe injury and lethality, and should indicate the various physiological and pathological mechanisms of injury. The exposure levels for the human subjects usually attempt to define levels associated with "discomfort," "minimal," and "earliest reversible" effects.

There is no formula at present by which it is possible to estimate the pattern or amount of laboratory experimentation which will be required of this component in establishing a threshold limit. In general, the more novel the physico-chemical properties of the agent, the more distantly related to other materials which have had industrial hygiene evaluation, the greater the amount and variety of toxicological procedures which must be employed. The direction and extent of further studies must be determined as the pattern of toxicological investigation unfolds. The importance of the various routes of absorption, the relationship of divided dose administration to the single effective dose, the relative primary irritation and sensitization potencies, the behavior in relation to such factors as species of test animal, age, sex, concurrent disease, are only a few of the important items which must be considered in deciding the importance of the role which a particular animal study may play.

Some of the experimental toxicological findings which suggest caution in evaluating a study may be noted. A lethal dose curve whose slope is gradual may overlap the curve of the physiological function upon which the threshold is to be based. A scattered configuration of delayed deaths suggests multiple effects or secondary pathology which may be difficult to evaluate. A substance which is a sensitizer or allergen, even though indicated solely by skin sensitization tests, may produce systemic or specific internal organ sensitization. Marked variance with respect to severe injury or lethality among several species of test animals, increases the difficulty of extrapolation. The failure to reproduce the disease pattern already identified in human subjects definitely limits the significance of animal studies. Less clearly identified effects, such as involvement of the central nervous system, or injury which is not easily reversible, such as aplastic anemia, signal caution.

Experimental methods with deliberate exposure of human subjects to low levels of a toxic agent are finding increasing usefulness in establishing threshold limits. Initially, many of these tests were concerned with irritation or discomfort levels, and although no injurious effects were noted in animals exposed to higher concentrations, the human experiment values were frequently the determining factor in setting a threshold limit. A possible fallacy in this reasoning lies in the quite common experience of finding conditions in plant operations which are quite irritating or uncomfortable to a person first entering the environment but which are tolerated without complaint—or even, in some cases, with a positive expression of benefit—by the acclimated workmen. In such an instance it is difficult to decide which result is significant, the controlled short-term study using, usually, subjects whose experience with industrial conditions may be very limited, or the testimonial evidence of workmen, especially if unsupported by evidence which confirms the absence of injurious effects.

Other applications of the controlled human-subject experiments may develop more important information. The studies of retention of a toxin (with the long-term investigations of lead and fluorine as classic examples) must play an important role in the establishment of threshold limits for these substances. The obvious advantage in this technique lies in the accuracy with which the relation can be established, as contrasted with the more difficultly controlled experience in the plant. More of these studies on a long-term basis are needed, but the cost in effort and in dollars imposes distinct limitations.

This type of experimental approach is of value in determining the earliest (and still reversible) changes in certain physiologic functions, such as vascular instability as measured by blood pressure changes, or metabolite excretion, as in the urine sulfate partition with benzol absorption. The objective, of course, is to recognize a reversible, functional change which, if unchecked, may lead to permanent injury. A practical difficulty may develop as the acuity of test procedures increases, since the changes frequently are not specific for the toxin but may occur with many other factors which affect the body—as for example, an excess of alcohol. On the other hand, special application of statistical methods to group exposures may make these techniques one of the most acute methods of signaling injury.

Value of Data on Worker Exposures

THE CONCEPT that a careful and comprehensive study of the exposed workmen is the most significant factor in establishing a threshold limit, merits repetition. In practice, however, the number of substances for which such complete studies have been reported are few. A number of factors operate against such long-term, comprehensive investigations. The cost of an adequate clinical program, carried on over many years and with continuing negative results, requires the support of an unusually intelligent and understanding management. The development of environmental measurements so as to be effective for correlation with the clinical findings requires a high degree of cooperation and planning between clinical and industrial hygiene activities. And, finally, the job of organizing the extensive data, of deciding that the results are significant, particularly if they are negative in the sense that no injury is found, and of preparing for publication (since there is no Journal of Negative Data), demands of an investigator courage to the point of being foolhardy.

Of the various types of information which can be obtained from actual industrial exposures, the unsupported testimony of workmen and supervisors, even though accompanied by accurate measurements of environmental factors, is generally so unreliable as to merit little weight in establishing a threshold limit. Individuals who are unable to tolerate the work conditions, or those who have actually become ill and left the job, may have been eliminated so gradually that recognition of the cause and effect relationship may not have developed in the remaining personnel. Furthermore, human nature is such that under these circumstances the men remaining on the job are apt to dismiss the others who left as being "too weak to take it."

As in the case of planning a program of experimental laboratory methods for evaluating a toxic agent, the in-plant clinical survey and environmental analysis must develop in relation to the specific hazard. To the basic elements in the medical examination may be added a variety of special test procedures selected to detect the earliest changes in physiologic function. If little is known about the kind of toxic reaction which may develop, a "shot-gun" approach may be justified with the hope that one or more of the battery of tests will signal a harmful effect. As knowledge of the earliest reactions to specific agents increases, the selection of the most sensitive test procedures becomes more practical, and more reassuring.

The recognition of an occupational disease is frequently much simpler than the proof that a particular exposure is free from any injurious effect. As exposures to toxic materials are decreased from levels which can injure in a relatively short time, a point is reached where the signs and symptoms may develop only after a very long exposure time, and the disease so mild as to challenge the best diagnostic program. We can note again the studies with radiation, where minimal shortening of the life span with relatively low exposures can be demonstrated in experimental animals but would be impossible to detect, with our present techniques, in the human subject.

Clinical Observations

THE BROADER the base of the clinical investigation which is associated with a finding of no injury or no significant injury at a particular exposure level, the greater the reliability of the conclusion. To the critical investigator, however, the job is never complete, never without some area in the study which could not have been strengthened or improved. The period of the study can extend into many years, and yet the end point can remain uncertain.

As other techniques are added to the evaluation program—such as studies of morbidity and absenteeism, reasons for dispensary visits, and analysis of cause of death—the problem of interpretation becomes increasingly complicated. An example may be cited in which two young women employees in the same small department developed leukemia within a few months of each other. This occurrence was readily accepted as a chance finding because both girls had clerical positions with no possible exposure to an industrial toxin. Had this occurred following a common exposure, however brief or minor, to a new chemical with a long and unfamiliar name, it is quite likely that medical testimony would have been developed, in a Workmen's Compensation hearing, attributing the disease to the exposure. The effect of the incident might well have extended beyond the cost of compensation and into the area of threshold limits by the publication of a case report. A fine discretion is required in recognizing the first or isolated instances of injury to a new chemical and yet avoiding the inclusion of cases solely on legal or social motivation.

In a study of the long-term effects of a solvent, records were kept of the causes for dispensary visits. A slightly higher incidence of gastrointestinal complaints was found in the exposed group, and since this had been reported previously by others, it seemed significant. However, the incidence of respiratory complaints was as much lower for the exposed individuals. In an interpretation, it would have been equally proper to assume that the solvent vapors "protected" the individuals against respiratory disease, and that this beneficial effect might offset the gastrointestinal difficulties. As might be suspected, when these relations were put to the test of statistical signifi-

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cance, both could have been due easily to chance alone.

A final word is in order concerning the methods for developing data by which the environment is described—the conditions of exposure. As much variability can be, and is, encountered with this function as with the methods for laboratory experimentation and in-plant clinical examinations. The accuracy and reliability of the analytical techniques, the relation of the time and site of sampling to the true exposure, the presence of other agents which might modify the single action of the toxin under study are some of the many factors which must be critically examined in the light of their usefulness for correlation with a given set of experimental or clinical findings.

It is obvious that there is no single method or pattern of methods which can satisfy the varied requirements for establishing threshold limits. It is equally obvious that even though rigid standards were described which would satisfy a discriminating jury of scientists, the available data for establishing threshold limits for all but a very few substances would fail to satisfy such limits. The real use for threshold limits, as a guide for industry in the control of exposures and as a measure for action by governmental agencies, demands a continuing improvement in the quality and quantity of the methods by which truly valid criteria may be achieved.

Prepared Discussion

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DR. STERNER has discussed the great difficulties attendant on developing adequate data for threshold limits, the many imponderables in their interpretation, and their unsatisfactory and necessarily always incomplete nature. All these considerations should certainly be thoughtfully considered and strongly stressed, because errors in judgment cannot be afforded. But lest these many considerations seem so formidable to many potential investigators as to prevent their needed contributions (which was far from Dr. Sterner's intention) or depress the more experienced contributors, it should be immediately pointed out that there are at least two practical and very helpful means of overcoming certain deficiencies inherent in the basic data. One is the safety factor, the other, the periodic re-evaluation of the threshold limit values. The safety factor has been built into most of the values in the threshold limits list.* The factors 2, 5, 10 or even greater have been applied to some values. There are, of course, some notable exceptions, such as the present value for trichloroethylene, for which the threshold limit is the absolute ceiling, but generally such instances are rare. In general, the greater the uncertainty in the data's applicability to human industrial exposure, the larger the factor applied. This lowering of the limit value by an arbitrary safety factor may at times provoke some controversy, because now the value becomes one of opinion, not fact. Be that as it may, the safety factor incorporated in the air standards gives increased assurance of safety to many doubtful values.

The re-examination of the listed values by the committee provides annually for readjustment of all values, whatever their sanctity, upon submission to the committee of new and experimentally supported findings. Repeated scrutiny and re-appraisal of this sort can lead finally only to assignment of safe values on which complete reliance can be placed. The committee welcomes all such information.**

Need for more Data

IN THIS CONNECTION another point implied in Dr. Sterner's discussion should be strengthened—namely, the need for more data substantiating the choice of safe exposure levels based on industrial experience. Much useful information is undoubtedly in the files of many plants. Indication of this was the fine evidence on six industrial sub-

*The incorporated safety factor in the threshold limit values, although added at times because of uncertainty in the value as related to human exposure, often actually provides an appreciable margin of safety. For this reason the correctness of the term "threshold limit" may be questioned. It might more properly be replaced with "air hygiene standard."

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stances derived from many years of plant experience that came to light last year at these meetings from the presentation of Herbert J. Weber.[1] Others should have similar material that should be brought to the attention of the Threshold Limits Committee. Like Weber's material, all of it need not be novel or presented to show need for changing existing limits; equally valuable are data confirming existing limits. As never before, interest in the value of the control of industrial environments is being shared by management generally. Greater numbers of industrial hygienists than ever before are being engaged by industry. Is it too much to hope that meetings such as these will orient the thinking of properly placed industrial hygienists to secure much needed plant information to aid in the choice of safe limits of human exposure?

The type of information needed may be listed as follows: (1) Air concentrations should be determined for the substances under study through a complete cycle of plant operations and with reasonable regularity in order to obtain a true picture of the range and fluctuations of exposure. (2) The data should have good accuracy. (3) The observations should be carried out over a reasonable period of time—a minimum of five years. (4) The air concentration data should be correlated with a good medical program. A pattern for such work is that of Dr. Sterner's 10-year study of workers exposure to butyl alcohol.[2]

There is a real need for more data based on industrial experience. The often-heard statement "the threshold limits are nothing but educated guesses" unquestionably reflects the wish at least that more data be firmly based on industrial experience to substantiate the choice of limits. As a member of the Threshold Limits Committee, I was concerned over the statement and took the trouble to review each substance in the threshold limit list for 1955 as to the basis for choice of the level. The results are shown in Table I. It is possible that everyone would not arrive at precisely the same figures, but I believe that their magnitude would not be much altered. Although the table shows that the educated guesses account for a relatively small number, it does confirm the often expressed feeling of the need for more solidly based levels. Table I shows a number of other interesting facts: (1) that most of the values have some sort of scientific basis; (2) that each level has been documented either by Warren A. Cook,[3] or by the Committee on Threshold Limits; (3) that tb: values based on animal experiments account for the largest number, 42%; but (4) that values having some industrial basis account for 1/3 of the total.

TABLE I.
BASIS FOR CHOICE OF THRESHOLD LIMIT VALUE*

Study Type	No. of Listings	Percent Total Listings (223)
Animal	94	42
Industry	51	23
Animal & Industry	23	10
Man	25	11
"Educated Guess"	21	9
Animal & Man	9	4
Source uncertain	3	1

*Based in part on COOK, W. A., *Ind. Med.* 14:936, 1945, and from documented material of Threshold Limits Committee A.C.G.I.H. 1953-1955.

The values ascribed to the "man" category arise from two sources—that of Nelson, et al,[4] and those more recent publications of the Dow Chemical workers, Irish, Rowe, Spencer, Adams et al.

The "Educated Guess"

A FEW WORDS should be said in defense of the "educated guess." A review of the values described as guesses indicates in the instances in which sound information has later become available that the "guess" was remarkably good. Two prominent examples only will suffice—hydrogen fluoride and uranium. A safe exposure level for hydrogen fluoride was set at 3 ppm on the very limited evidence supplied by a study in animals by Ronzani in 1909.[5] Last year a report[6] culminating many years of study of fluoride exposure in the aluminum industry, involving thousands of air and urine analysis for fluoride and studies of roentgenographic changes in bone, showed without question that air levels double the accepted limit gave rise to perceptible changes in bone in only a few individuals, and only after many years of exposure, thus validating the wisdom of this "educated guess."

In the case of uranium, an engineering bench-mark had to be "guessed" at early in the days of the Manhattan Project. After a review of the quite limited animal data on uranium then available, Dr. Stafford Warren suggested that the "safe" exposure level for uranium be the same as that for lead, 0.15 mg/cu.m. After $500,000 and many years had been spent in research, the safe levels of exposure to uranium compounds were found to bracket this value very closely.

Levels for Cancerigens

THERE is still one group of substances for which some method should be devised for establishing safe air standards—the industrial cancerigens. How shall we establish the limits for this type of substance? Thus far the question has been sidestepped completely. As a result, with one exception, nickel carbonyl, limits taking into consideration potential cancerigenicity have not been assigned. Several industrial substances are known or suspected cancerigens; many more are suspect on the basis of animal experiments. As a suggested method of approach, the following is offered: To the level judged safe for other types of systemic injury add a safety factor for carcinogenicity. The magnitude of the safety factor is suggested to be from 100 to 500. This provides at least a second power of 10, which, from the well-known dosage-response hypothesis, provides at least a fourfold longer interval before effects may be expected to occur, or conversely at least a response with ¼ the intensity. This manner of approach has been used for nickel carbonyl. A tentatively safe level for systemic effects from repeated daily exposure has been set at 0.1 ppm; one-hundredth this level, or 0.001 ppm was set for nickel carbonyl on the basis that nickel poisoning gives rise to a substantial increase in the incidence of lung cancer. It is realized that unfortunately the safe limits for all industrial cancerigens cannot be so readily resolved. This is especially true of dye intermediates, such as benzidine and naphthyl amines whose major route of entry is not commonly via the lungs but through the skin and gastrointestinal tract. These are laundry and protective equipment problems not solvable by air control.

There are undoubtedly substances to which the suggested procedure may not strictly apply, but imperfect as it may be, the suggested method is felt to be a step in the right direction and serves better to curb exposures to industrial carcinogens than considering the problem too difficult to cope with at the present time.

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Engineering and Chemical Application of Standards

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THE WHY AND HOW of threshold limits for air contaminants have been discussed by the preceding speakers. The logical next and final consideration is the use or application of these limits in preventing occupational diseases, in avoiding complaints from exposed employees, in maintaining employee efficiency, and in promoting good housekeeping.

To engineers engaged in industrial hygiene, threshold limits provide the reference line or bench mark upon which all considerations and calculations for the control of air contamination are based. It is characteristic of engineers and of others in the physical sciences to want to reduce to numbers the problems with which they deal, because only then can they be attacked in a precise manner. It has never been clear in my mind whether engineers enter this profession because of their love for and adeptness with numbers, or whether they acquire their desire to work with numbers as a result of pursuing the engineering discipline. Nor is it important to the subject matter of this paper to know which is the cause and which the effect. Suffice it to recognize at this time that this quality is omnipresent in engineers, and if industrial health problems arising out of environmental conditions are to be prevented or controlled, the physiological responses of the industrial employees will have to be translated into some physical yardstick readily understood by engineers whose function it is to regulate the environment in the best interests of the worker and of production.

Threshold limits serve several very useful purposes in the industrial health picture. Through careful studies of the air at existing operations or in existing plants, they permit deciding whether a health hazard is present or not, and if present, how severe it is. They are quite useful to the discerning physician in determining whether the health impairment of an exposed worker is attributable to his employment, and in this respect may exert significant influence on the disposition of occupational disease claims.

Where a health hazard from air contamination has been found to exist, threshold limits frequently are the guidepost indicating which avenue of control to follow to achieve a satisfactory solution to the problem. Having ascertained the avenue to follow, the threshold limits provide the only scientific basis as to how far we must journey to arrive at the desired destination.

Having alluded briefly to the principal roles played by threshold limits in industrial hygiene, let us now examine each one of these more carefully and consider their application in industry.

Evaluating Potential Health Hazards

In this age of mechanization and high speed production, there are many places in industry where some of the materials being handled, consumed, or processed escapes into the air. Whether this airborne contaminant constitutes a health hazard depends upon its concentration in the air breathed by exposed persons as related to its inherent harmfulness. The concentration of the material in question in the breathing zones of employees is capable of rather accurate measurement. If the harmfulness of the contaminant is known, also, in terms of a safe atmospheric concentration (the threshold limit), the presence or absence of a health hazard is apparent. In this way threshold limits are applied widely in industry to decide where better control of the environment is needed and where it is not needed.

Assisting in the Diagnosis of Illness

Not infrequently, there is a discouraging duplicity of symptoms manifested by persons suffering from different illnesses, especially in the early stages. If the symptoms exhibited by an employee are compatible with those that might be produced by the air contaminant to which he has been exposed as well as with several other stimuli of non-occupational origin, comparison of the concentration to which he actually was exposed with an accepted threshold limit for this same material is of inestimable value in arriving at the most probable cause of the illness. If the exposure exceeds the threshold limit and the symptoms are indicative of illness from such exposure, the occupational hazard may well be the cause. If, however, the atmospheric concentration of contaminant in the breathing zone of the worker has been well below the threshold limit, it suggests to the examining physician that all other possible causes must be explored thoroughly before a diagnosis can be made.

This application of threshold limits sometimes reaches out into the compensation courts. The employee's personal physician, having only the complainant's description of his job rather than factual data to guide him in the diagnosis, not infrequently will arrive at an erroneous conclusion. Controversial medical opinions are introduced in evidence at the hearing, and the carefully measured atmospheric concentration of the material in question as compared to the threshold limit for this material is the only bit of uncontested scientific information that the referee has available on which to decide the case. This is not to say that the controverted cases usually are decided on

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this basis. Other factors, many of which are not scientific in nature, play a part in the adjudication of such compensation cases. Nevertheless, testimony of this kind has been helpful in arriving at the truth in some cases, and there is hope that an increasing amount of importance will be attached in the future by compensation courts to evidence of this kind, as more and more experience is accumulated to support the threshold limits and as knowledge of this useful tool becomes more common in compensation circles.

Control of the Hazard

It is in the control of atmospheric contaminants that threshold limits find their most important application in industry. The judicious use of threshold limits in selecting and designing control measures and equipment will result in satisfactory working conditions at a minimum in cost and interference with production. Possibly the best way to add clarity and reality to this general observation is to implement it with conspicuous examples.

Given: a production type degreasing operation in which the parts are cleaned mechanically by immersion in a tank of carbon tetrachloride. The tank is provided with a local exhaust system, but is so wide that considerable of the grossly contaminated air at the remote side is spilling into the workroom air and nearby employees are exposed to vapor concentrations in the order of 250 ppm. Problem: how best to correct this condition.

Obviously the condition can be corrected by rebuilding the exhaust system and increasing its capacity, or by changing to a less toxic solvent. Imagine how insecure you would feel in facing this problem if there were no threshold limits to guide you. You would not have any idea how much reduction in vapor concentration is necessary to eliminate the health hazard. Even if a less toxic solvent were substituted, there would be no way of knowing whether it alone will solve the problem or whether improved process ventilation is needed, and if an increased exhaust rate is needed, how much increase is required. To be on the safe side you probably would change to a safer solvent and redesign the exhaust system with 100% capture as your goal.

How much simpler it is with threshold limits to provide a scientific basis for consideration. Obviously the exhaust system could be redesigned to capture all the vapor rising from the tank surface and from the withdrawn parts. This would have the serious disadvantage of increasing markedly the consumption rate of the solvent, carbon tetrachloride. Since methyl chloroform has physical characteristics very similar to carbon tetrachloride, if it were used instead of carbon tetrachloride the atmospheric concentration of vapor would be about the same, and since the threshold limit for methyl chloroform is 500 ppm, the problem would be solved. However, this solution carries with it a substantial cost disadvantage, methyl chloroform being more expensive than carbon tetrachloride. Therefore, let's consider using trichloroethylene or perchloroethylene in place of carbon tetrachloride. It too costs more than carbon tetrachloride, but because of its lower volatility the consumption rate will decrease if much of the loss takes place via the air entering the exhaust system. But what about solving the health hazard. The threshold limit for trichloroethylene and for perchloroethylene is 200 ppm and the vapor concentration was found to be in the order of 250 ppm when carbon tetrachloride was used. Because of the lower vapor pressure of the proposed substitutes, the amount of vapor getting into the room air will be much less and the exposure of the workers will be reduced to a value well below 200 ppm. Thus by employing the yardstick of threshold limits, two easy and certain solutions are found to this problem without difficulty.

It may be well to emphasize at this point that other important considerations must not be overlooked. All factors must be borne in mind whenever one is faced with an air contaminant control problem. Sometimes careful selection of a substitute will not not only bring the health hazard under control but also will increase the operating rate, or decrease the consumption rate of a process ingredient thereby achieving considerable cost advantage as a byproduct of the change. By way of illustration, the slower evaporation rate of perchloroethylene as compared with carbon tetrachloride not only minimized the potential health hazard at a specific gravity test-

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ing operation but also resulted in an annual saving of about $3000 in the cost of the liquid consumed. This, in spite of the fact that perchloroethylene is much more expensive per unit of measure than is carbon tetrachloride.

Criteria in Substitution

THE APPLICATION of threshold limits in the control of health hazards by substitution is such a useful tool that several other examples will be cited.

Solvent degreasers and cleaners are used so widely, and frequently so erratically, that it is difficult to be certain that adequate control precautions are being observed at all times, especially if the solvent in question is relatively toxic. For this reason industry is engaged in a search for effective solvent cleaners which inherently are much less toxic than those in common use today. Because carbon tetrachloride has qualities which make it an exceptionally satisfactory solvent from the functional viewpoint, it is in constant demand by all operating people who are not fully aware of its danger. However, reputable jobbers and vendors of proprietary solvents of all kinds have become increasingly conscious of the health considerations attending the use of their products and have been selecting their product ingredients on the basis of toxicity expressed in terms of threshold limits. It is heartening to note how commonly the suppliers of solvent degreasers and cleaners are using the valuable yardstick of threshold limits to concoct ever safer products to satisfy the complex degreasing and cleaning demands of industry.

It appears to us that we are on the doorstep of a new era which will see great advances in solvent cleaning safety, thanks to threshold limits. It would be remiss at this time not to mention that methyl chloroform promises to be the carbon tetrachloride of tomorrow. If properly inhibited to prevent its corrosive action on certain metals, it appears to be the perfect answer for those cleaning and degreasing jobs on which only carbon tetrachloride has been acceptable in the past.

Threshold limits have played and continue to play a key role in the control of the hazard associated with abrasive blasting of all kinds. Originally, sand was used for all abrasive blasting. This created a serious health hazard on the part of the operators and nearby employees, and not infrequently it posed a serious wear problem on nearby machinery which had not been protected during the blasting. The problem was soon brought under control for most production-type blasting by housing such operations in well ventilated rooms, chambers or booths. In addition, steel grit was substituted for sand on most work of this kind if the grit was recoverable and reusable. Because of the high cost of steel grit as compared with sand, it was not readily accepted for work in which most or all of the grit was lost. More recently, however, several types of grit have been placed on the market which are by-products of the metal smelting and refining industry. While not as economical as sand, they are much less expensive than steel grit. These substitute blasting grits came into use because the probable health hazard attending their use is much less than is the case with sand, in terms of the threshold limits of the ingredients and the amounts present. Selection of the particular by-product grit to be used on any blast cleaning job is made on the basis of availability and the probable health hazard as expressed by the threshold limits of the ingredients and the amounts present.

But the application of threshold limits on abrasive blast cleaning jobs does not end here. Since most blast cleaning jobs are not done mechanically in well ventilated booths and require respiratory protection for the operator, threshold limits enter the consideration as to the proper respirator to be worn. Supplied-air respirators or helmets require a supply of air of respirable quality under pressure. Consequently for isolated jobs where a separate blower or semi-compressor would be required to furnish air to the respirator, conventional dust respirators of the mechanical filter type may provide adequate respiratory protection depending upon the harmfulness of the dust produced as determined by the threshold limits of the grit ingredient and those of the surface being cleaned. In reverse order, of course, sand may be used with safety if the blaster can conveniently wear a supplied-air helmet and a source of respirable air for the respirator is readily available.

It must not be inferred from the fore-

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going that threshold limits *per se* of a process material or the ingredients thereof determine the extent of a health hazard. The atmospheric concentration of the contaminant in the air to which the employee is exposed is equally important. But when considering a type, or class, of operations in which the employee's exposure does not vary tremendously, as a rule, from one operation to another, substantial changes in the threshold limits of the process material ingredients overshadow the smaller variations that take place in atmospheric concentration of the contaminant. This is not to say that all abrasive blasting operations produce the same concentration of dust in the ambient air, but rather that, all other things being equal, a change in the nature of the blasting material will not affect the dust concentration nearby as profoundly as it will the applicable threshold limit, if the substitute material is well chosen. For example, it is extremely unlikely that steel grit or even a substitute grit produced as a by-product in the glass or in the smelting industry and containing less than 5% free silica would create as severe a hazard as does sand in blast cleaning of unpainted surfaces. Obviously, if painted surfaces are blast-cleaned, a new factor enters the picture which may well overshadow the composition of the grit. However, here again threshold limits would be consulted in conjunction with the dust concentration to determine (1) the severity of the health hazard, (2) whether there is any advantage in using a more expensive substitute grit, and (3) what is required in the way of personal protection.

Threshold limits are especially useful in designing for the control of air contaminants in all cases where the sources are of such nature, location and distribution as to permit effective control by general ventilation. In the case of solvents or other liquids being used in a room, the required ventilation rate can be calculated very easily if the consumption rate of the liquids is known. The same is true for particulate matter if the rate of dust generation is known, or if information is available as to the dust concentration and ventilation rate prevailing at a comparable operation elsewhere. By employing the threshold limit for the dust in question, the ventilation for the operation under consideration can be calculated readily, rather than guessing what it should be or following some rule of thumb. In all existing shops or rooms where air contaminants are present in objectionable concentration, the threshold limit of the contaminants in conjunction with the current general ventilation rate (which can be measured) permits calculating accurately what is needed in the way of fans to eliminate the objectionable or potentially harmful conditions. Threshold limits remove much of the conjecture otherwise involved in problems of general ventilation for purposes of dust, fume and gas control.

Classification of Material for Control Purposes

EVEN THOUGH it is desirable to consider each problem separately, not infrequently it is expeditious to set down rules governing the control of hazards created by many operations that differ considerably in type. In such instances the toxicity of the process materials and the by-products in terms of their threshold limits may be grouped and used in conjunction with similar groupings of the other variable factors influencing the hazard, to arrive at a set of relatively few rules to cover the whole gamut of operations in question. For example, let us consider open-surface tank operations of all kinds, whether they be pickling, degreasing, alkali-cleaning, painting, plating or other treatment. By dividing all the materials involved in these operations into three groups according to their threshold limits and into similar groups on the basis of the other governing factors, it was possible to classify all possible types of open-surface tank operations into four classes as regards the ventilation rate required at the tank for adequate control of the contaminants released.[1,2] Without threshold limits to serve as a guide it would have been well nigh impossible to develop these few rules governing so many different materials and operations.

Similar codification is under consideration by American Standards Association Committee Z-9—Exhaust Systems—for other groups of processes and operations having like industrial hygiene aspects, as, for example, bulk materials handling, surface coating operations, mechanical cutting and abrading operations, and abrasive blasting operations. Without threshold limits, such codification would be beset with unending research, consultation and guesswork of such magnitude as to make consummation dubious and as to place the final result under serious suspicion.

Experience

THERE is much merit in the proverb "the taste of the pudding is in the eating." Therefore, past experience may well be examined in the use of industrial hygiene standards to prevent occupational illnesses. In this respect, the literature is most disappointing, not because the experience has been unfavorable but rather because the literature contains few reports of first hand investigations into this relationship. The one which probably best demonstrates the use of threshold limits and the results achieved may be found in the report by McConnell, *et al.*, on the occupational disease experience in the government-owned ordnance plants during World War II.[3] Since it was my privilege to take part in this program from its inception, I can speak of it with some feeling.

When the United States first began ammunition production at an increased rate about 1940, very little information was available on the toxicity of TNT of such nature that would permit setting a threshold limit. TNT consumption in the U. S. in the period between 1918 and 1940 was essentially nil and threshold limits were not nearly so common as they are now. That TNT is toxic was not questioned, for according to the best information available about 17,000 persons in ammunition plants were poisoned, 475 of them fatally, during World War I. It was this sad experience coupled with the related problems of absenteeism, inefficiency and manpower shortage that led the War Department to undertake jointly with the U.S. Public Health Service an aggressive industrial health program in all ammunition plants. Inasmuch as the most serious potential problem was TNT, it was decided at the outset to conjure up a maximum allowable concentration for this substance, the standard to be based on the little information available as to its toxicity, comparative physiology, and the concentration that was known to be achievable by good engineering practice. This "educated guess" turned out to be 1.5 mg/m^3, a value still in common use. Reference to the report by McConnell, *et al.*, shows how closely the incidence of illness from TNT paralleled the exposure curve. Owing to the tremendous scarcity of the equipment needed for engineering control of the fumes and dust, such as motors, fans, and sheet metal for piping and hoods, the weighted-average level of 1.5 mg/m^3 was not reached until the latter part of 1944. However, the fatalities from TNT were held to 22 for the entire period of the war[4] and the total number of lost time cases was only 56 as of May 1, 1945, the end of the report period covered in reference 3. The incidence of early symptoms of TNT poisoning was quite high, and there is little doubt that the number of lost-time cases as well as fatalities would have been much higher if it had not been for the excellent periodic medical examination program then in effect in the ammunition plants, especially in the loading plants where the exposures were the worst. It is interesting to note that the case rate of early systemic effects was close to 500 per 1000 man years of exposure for the first six months of 1943 when the weighted average exposure to TNT was about 2.7 mg/m^3, and about 1/5 of this rate for the last six months of 1944 when the exposure had been reduced to about 1.4 mg/m^3.

The control program in the ordnance plants during World War II would have been inestimably more difficult, and there is little doubt in my mind that the final report would portray a different story, a much sadder one, from that told by McConnell, *et al.*, if there had been no standard for TNT. In the face of the dire shortages of equipment needed directly by the Armed Forces, and other equipment needed to produce the weapons of war, authorization to divert some of this material for dust control purposes would have been out of the question in the absence of a threshold limit to indicate how badly and where such equipment was needed. As in many other factors affecting our daily life, standards are the very foundation of industrial hygiene. Without them the engineer in this field is placed in the same position as the boy who is sent to the hardware store by his father to buy a "big" bolt. The boy would have as good a chance of getting a bolt of the right size as an engineer would have of preventing the vast majority of occupational illnesses and complaints if there were no threshold limits.

In conclusion a few remarks are in order dealing with the philosophy of and justification for threshold limits, and are added here because they serve as a reply to the criticisms often leveled at industrial hygiene standards.

It is not unusual to hear that these limits are useless, if not even dangerous, because in the event that the atmospheric concentration is measured inaccurately, reliance on the standards creates a false sense of security on the one hand, or needless alarm on the other, depending upon whether the measured result is in error downward or upward. It requires little mental gymnastics to realize that this is equivalent to concluding that there is no sense in asking your grocer for a dozen oranges simply because he may make a mistake in counting them. By definition, threshold limits are those concentrations of contaminants which in the light of current knowledge will not cause harm to persons exposed continuously day in and day out during the normal working hours. Reference is to the concentration actually existing, not to some value that the investigator might conclude exists. Concentrations can be measured accurately, but to do so requires skill, understanding, patience and energy. It is rather discouraging to note how frequently conclusions are based on wholly inadequate data. It is not surprising either that the concentrations frequently "measured" have little relation to the true weighted average concentration.

The philosophy of threshold limits is that each one represents a concentration of the substance in question that will have no demonstrable adverse effect on the health of exposed persons. Not all persons react the same to stimuli of this nature, but rather any given population follows approximately an average random distribution pattern as regards response to atmospheric contaminants. That is to say, there is an occasional person at one end of the curve who is unaffected by relatively overwhelming concentrations and there is an occasional person at the other end who is affected by extremely low concentrations. To prevent any adverse effect upon every last man may require such low concentrations as to be impracticable. The threshold limit is merely a concentration that intersects the random distribution curve at a very low point. How low this point is for any substance cannot be stated. That it is not the same for all materials is obvious, and that it serves to prevent harm to all but a relatively few is obvious, also. Serious or irreparable damage to the occasional person who falls to the left of the threshold limit on the random distribution curve can be avoided by an appropriate medical examination program.

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Prepared Discussion

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In an endeavor to safeguard the health of the worker and the public from exposure to harmful substances, two basically different types of standards have evolved. One type—the threshold limit, or maximum allowable concentration—is the performance-type of standard. The other, about which little has been said by the previous speakers, is the engineering type of standard.

To make the distinction between the two types of standards more concrete, take the specific example of a stave-type tumbling mill (Fig. 1) in a ferrous foundry. Into it are placed castings with sand both clinging to their outer surfaces and in their internal cavities in the form of cores. The express purpose of placing these castings into the mill is to clean them of this sand. The mill is, therefore, by its very nature, a device designed and operated to cause sand to leave the castings and enter the ambient air. While it is true that most of this sand will

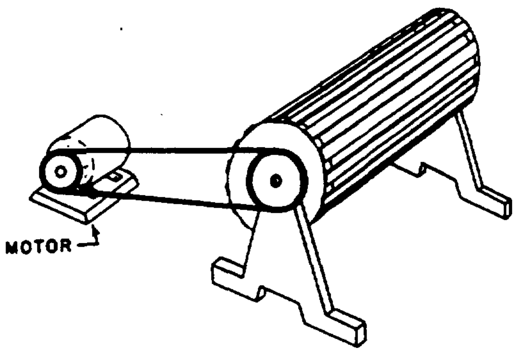


Fig. 1.
Stave mill.

fall to the floor under the mill, it is equally true that a tremendous number of free silica particles will become air-borne by the process. From the viewpoint of the performance standard, it is necessary to keep the atmosphere of the cleaning room below the threshold limit for free silica by whatever means the owner of the foundry may choose to employ.

Engineering Standards

FROM THE VIEWPOINT of engineering standards, the reasoning is somewhat as follows:

A. It is widely recognized in the foundry industry that stave mills are bad dust producers and require enclosure.

B. The industry, by trial and error, has developed a satisfactory type of ventilated enclosure (Fig. 2) which not only keeps the dust out of the workroom, but also keeps the floor below the mill free of much of the sand that would otherwise accumulate there and have to be carted away.

C. This type of enclosure, having been adopted by most of the industry, should therefore become the standard of the entire industry.

D. An engineering standard should therefore be written so specifying this enclosure with respect to structure and ventilation that any foundryman building an enclosure meeting these specifications will achieve dust control of his stave mill (Fig. 3).

Applicability of Standards

LET US EXPLORE some of the arguments for and against each of these approaches. Both aim at the same objective—the safeguarding of the worker. The principal ar-

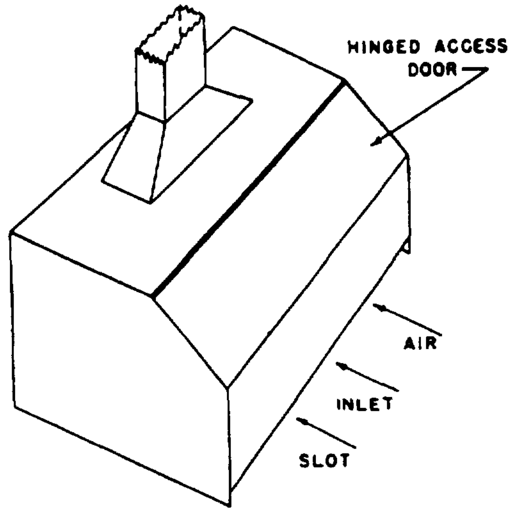


Fig. 2.
Stave mill enclosure.

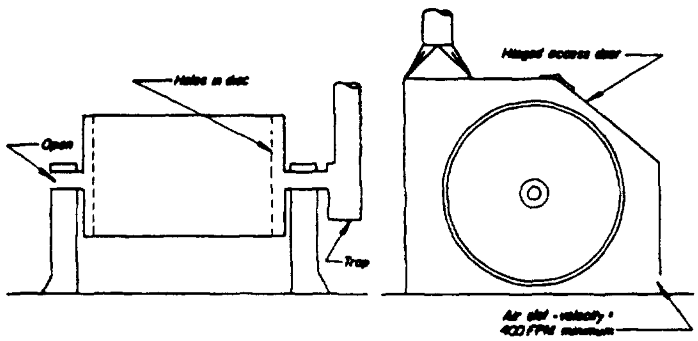
gument in favor of the performance standard is that it is noboby's business except the owner's as to how he achieves control of the hazard, just so long as he does, in fact, succeed in so doing. The corollary argument against the use of the engineering standard is that there is no positive guarantee that once the owner has invested his money in an enclosure conforming to the standard specification, the exposure of the workers in the cleaning room will be below threshold limit.

The same logic can be used to plead the case for the engineering standard. The dust load in the cleaning room air comes from many sources in addition to the stave mills (Fig. 4). If some of these sources remain uncontrolled after the stave mill has been enclosed and ventilated according to standard specification, it is entirely possible, even probable, that dust concentration in the room will remain above threshold despite entirely satisfactory dust control by the stave mill enclosure. Engineering standards thus have the inherent capacity to allow a step by step orderly approach toward the ultimate goal of achieving below-threshold concentrations in all parts of the plant at all times.

New Construction

ASSUME that a new foundry is being designed. To apply performance standards, the foundry must first be built, placed in operation, and then subjected to air sampling and analysis. No reputable and well-informed engineer would design this new plant without seeking the engineering standards for the control of dust from the cleaning room equipment and applying them to the best of his ability. In this situation, argument arises, not as to the need for such engineering standards, but rather as to their accuracy. Should the opening for air be 3½" or should it be 4"? If the standard says 900 cfm, and the designer is firmly convinced that 450 cfm are sufficient, he should be prepared to back up his independence of judgment by later proof that concentrations are below threshold in the completed workroom when the lower value of cfm is employed.

But what if the designer reluctantly makes the capacity 900 cfm to conform to the standard? Is there equal necessity for the sponsors of the standard to guarantee compliance with the threshold limit? The difficulty of so doing in the possible presence of extraneous sources of the contaminant that have already been mentioned almost invariably makes it impossible for the sponsor to undertake such guarantees.



SECTION THRU HOLLOW TRUNNION TUMBLER

Duct velocity = 5000 FPM.
• Entry loss = 2.0 to 4.0 VP (depends on design)

STAVE MILL (END SECTION)

Duct velocity = 3500 FPM minimum
Entry loss varies with take-off 0.25 - 0.50 VP

EXHAUST VOLUMES

Square mill side diam in	Round mill I.D. in inches	CFM	
		Trunnion	Stave*
	Up to 24 included	430	800
Up to 24 incl.	24 - 30	680	900
25 to 30 "	30 - 36	980	980
31 to 36 "	36 - 42	1330	1330
37 to 42 "	42 - 48	1750	1750
43 to 48 "	48 - 54	2200	2200
49 to 54 "	54 - 60	2730	2730
55 to 60 "	60 - 66	3300	3300
61 to 66 "	66 - 72	3920	3980
67 to 72 "		4600	4600

*For lengths over 70", increase CFM proportionately

Fig. 3.
Tumbling mills.

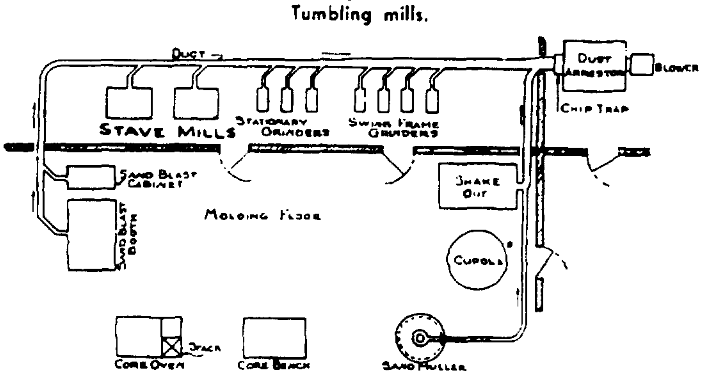


Fig. 4.
Floor plan showing layout of equipment including stave mills.

Double Jeopardy

WHERE the engineering standard is a tool in the hands of an enforcement agency, the user of such standards frequently fears that he is placed in double jeopardy. He has to comply with engineering standards with which he may disagree, and then, having employed all such standards in every operation, may still be not in compliance with the performance standards. The wise enforcement agency will let it be known that it will not permit such double jeopardy to occur, and that any factory owner who adheres throughout to the best engineering standards known to the agency will not be asked to re-do the job.

What, then, is the plight of the workingman caught in the middle? Is he likely to become a pawn, forced to work in an unhealthful atmosphere because the sponsoring agency is unwilling to admit a mistake as to the effectiveness of its engineering standards? We are indeed fortunate that the quality of *our* engineering standards is so high that such cases occur infrequently. Where they do occur, they are almost always borderline cases with respect to the threshold limit and are well within the factor of safety built into the threshold limit itself.

Emission Standards

The relationship between performance and engineering standards for in-plant atmospheres has its counterpart in that between atmospheric and emission standards in the field of air pollution. A major difference is that, whereas there are a large number of accepted threshold limits for in-plant atmosphere, there are almost no standards commonly accepted for the outside atmosphere.

The emission standard is very much in the same position as the engineering standard for in-plant controls in that adherence to it by one specific stack does not guarantee the cleanliness of the air of the surrounding community. Thousands of factories have put in-plant engineering standards to the test and proven that when every source of contaminant release is controlled as specified by the applicable engineering standard, the result has been to maintain the factory atmospheric contaminant concentration below the threshold limit. Such beautiful demonstrations, which are easy when the atmosphere in question is confined by four walls and a roof, become almost impossible to find in the open air over cities and towns. However, it is reasonable to believe that what works in a small confined space will also eventually work in the largest of confined spaces, that having the inevitable inversion ceiling as a roof and four topographical or meteorological side walls.

Standard for the Open Air

Let us look once again at the principal argument for performance standard in the in-plant situation, *i.e.*, that it is nobody's business but the plant owner's as to how he achieves control of the hazard—so long as he does so. Is this doctrine equally applicable to the air over a city? It hardly seems so. No individual owner or group of owners could or would be willing to take the responsibility for the maintenance of a specified level of contamination of the air of the community in which they operate. They would quickly recognize the many factors over which they do not have the same measure of control that exists inside the factory building. For them, the emission standard is a boon.

Here the argument is not with the concept of the emission standard, but with its numerical value for a particular installation. One of the most interesting developments of the past decade along these lines has been the fact that public utility power plant designers have consistently specified equipment for fly ash control to meet emission standards much more stringent than public regulatory bodies have required. Industrial foresight and conscience is in this, and a number of other industrial hygiene and air pollution control fronts, well ahead of public regulatory demands.

Conclusion

In both these areas, this is the hope of the future. The dictum of a Massachusetts court of many years ago that the best plants in an industry may reasonably be used to set the standard for the entire industry provides the real key to future progress. America is blessed with real industrial leadership and statesmanship. Neither industry's leaders and statesmen nor the public will tolerate the acceptance of standards which are below the best that industry can, by example, provide.

Summary

There are two general types of standards—performance type standards and engineering standards. The former specify threshold limits. The latter specify the performance of a particular piece of equipment. Arguments are given pro and con as to the relative merits of these two approaches to the same objective—the safeguarding of the worker. The engineering standard approach is particularly valuable in new construction where no equipment

exists at which to measure atmospheric concentration before designing safeguards. The similarity of engineering standards for the in-plant situation to emission standards for atmospheric pollution control is noted.

Prepared Discussion

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THIS COMMENT and discussion of the excellent paper presented by Dr. Brandt will be directed to the legal aspects of the application of threshold limits in the form of maximum allowable concentrations for the control of air contamination.

May I identify myself as one who has served as counsel for industrial organizations; and while my views may be prejudiced on their behalf, I feel that the industrial point of view is important in our discussion of this matter.

It is needless to say that today industry is prepared and wishes to accept full responsibility for the control of potential hazards incident to employment. Simply stated, it is good business both from the financial standpoint and also in the promotion of industrial relationships for employers to concern themselves with the protection of employees from all types of industrial injuries, be they accidental or resulting from occupational disease. The ultimate cost of compensation for such injuries may well exceed the cost resulting from installation of effective methods for engineering and medical control, aside from the fact that the employer's relation to his employees is promoted when employees know that the employer is doing everything practical to effect protection.

Question arises to the propriety and advisability of the adoption of codes of industrial hygiene defining maximum allowable concentrations of toxic materials. The word "code" is defined as follows: "A body of law established by the legislative authority of the state, and designed to regulate completely, so far as a statute may, the subject to which it relates." The adoption of codes having the full force and effect of law is unnecessary, inadvisable, and may well lead to unfortunate problems of administration to which brief reference may be made.

Under the constitutions of the various states and the powers granted to state Departments of Health and state Departments of Labor, there exists adequate authority for such departments to effectively control any hazardous condition injurious to health. As a practical matter, there is no legal need for the adoption of codes prescribing maximum allowable concentrations. It is fair to state that state Departments of Health and state Departments of Labor administering divisions of industrial hygiene have enjoyed the confidence of the public, including both management and labor, and our several state departments have been and are doing excellent jobs in the administration of their affairs. Therefore, the use of maximum allowable concentrations should be in the nature of serving as a guide to industry with particular reference to engineering standards. Industry has and will continue to seek the advice of proper state departments to control hazardous conditions effectively, and the desired objectives will be obtained through education and dissemination of information through the cooperation between state divisions of industrial hygiene and industry rather than the attempted enforcement of a given code as a matter of law.

Dr. Brandt and Mr. Stern have discussed in detail the practical uses of threshold limits with the purpose of eliminating or controlling occupational hazards. With all of the information presently available to science, it is seriously to be questioned whether the present schedule of recommended maximum allowances of concentrations are scientifically correct. True, they represent the best thinking of those scientists who have studied the problem; however, it is a fact that from day to day, industrial processes are changing, new chemical compounds are coming into commercial use, and tomorrow some new problem may be presented to industry and to public administrative agencies entirely different from any that may have been presented before. Industry welcomes technical information with respect to the existence of occupational hazards. They will continue to welcome technical advice as to practical methods of control. It must be remembered that industry seeks the maximum production of its materials at minimum cost; and if our competitive system is to be retained and business is to succeed, bureaus of industrial hygiene must assist in the attainment of this goal by the simplest and most inexpensive methods possible.

No one would contend that it is the duty of the hygienist to tell the manufacturer how to run his business. Many industrial processes are so secretive and complicated and developed over an extended period of years that it is frequently impossible for an industry within a limited period of time to rearrange that production process to give effect to all of the methods of control that the hygienist would recommend. What is needed is cooperation between state departments and manufacturers, not additional laws on our statute books that may be used to the prejudice of state departments as well as manufacturers.

There is one other thought which is worthy of consideration. Assuming that threshold limits of maximum allowable concentrations are established by law, the administration of such codes may prove to be embarrassing to state departments charged with their administration and to industry at the instance of organized pressure groups of representatives of the public, labor unions, or possible competitors. Assuming the adoption of codes, it is a fact that occasional violations may occur resulting from breakdown in machinery or equipment. Immediately the manufacturer is placed in the position of having violated the law although such violation may be absolutely unintentional and may be readily corrected. State Departments of Health and Labor do not need to be told by any organized group as to what they can or should do in the administration of their functions. Therefore, a better result will be obtained if use is made of the information developed by our scientists as to permissible concentrations not because some law requires this be done, but because it is simply good business to comply.

Encyclopedia of Instrumentation for Industrial Hygiene

INDUSTRIAL HYGIENISTS and workers in allied fields will be interested to know that the heralded encyclopedia on industrial hygiene instrumentation is now generally available. The book is divided into seven sections, each of which includes a comprehensive review of instrumentation in the area being considered, technical papers on special problems or types of instruments used, and descriptions of available instruments, mostly commercially available. The sections include the seven areas of instruments: for measuring air contaminants in occupied spaces; for use in laboratories; for air pollution and meteorology; for air velocity and metering; for sound and vibration; for ionizing radiations; and for ultra violet, visible and infrared energy.

This Encyclopedia brings together in one place a fund of specific information on instruments within the scope of the book. It was produced through the combined efforts of personnel of the University of Michigan, manufacturers' research directors and designers, authorities in the several areas of instrumentation, and a staff of experts assigned by the U. S. Public Health Service to assemble and edit the contents of the book. The comprehensive reviews include progress in the individual field of instrumentation, problems presented, limitations of present instrumentation, and needs not met by instruments now available. The descriptions of available instruments include the name of the instrument; name of the manufacturer; intended and special uses and adaptations; operating principle; physical description; performance data, such as sampling rate, range, sensitivity; inteferences, limitations and safety hazards; price; operating instructions; calibration instructions; maintenance instructions; photographs, line drawings or wiring diagrams; bibliography.

The material in the book comprises some 1243 pages, 9 x 12 inches, with 1400 illustrations, charts and diagrams. Copies may be obtained through the University of Michigan Publication Distribution Service, Ann Arbor, Michigan. The book is priced at $30.00.

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Recent Industrial Hygiene Developments

—A SYMPOSIUM—

THE FOLLOWING papers were presented at the Joint Session of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION and the American Conference of Governmental Industrial Hygienists, at the 1956 Industrial Health Conference in Philadelphia, April 24, 1956.

In the Field of Air Pollution

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PROBABLY the most significant development in the past year in air pollution as it may affect industrial hygiene or any of the health-related sciences is the passage of Public Law 159. Public Law 159, which was signed by the President on July 14, 1955, authorized a comprehensive program of community air pollution research and technical assistance to the States, communities, and other organizations. The act declares "the policy of Congress to preserve and protect the primary responsibilities and rights of States and local governments in controlling air pollution, to support and aid technical research, to devise and develop methods of abating such pollution, and to provide Federal technical services and financial aid to State and local government air pollution control agencies and other public or private agencies and institutions in the formulation and execution of their air pollution abatement research programs." The law authorizes the expenditure of funds not to exceed $5 million per year for a period of five years. In 1956, $1,722,000 was appropriated. For fiscal year 1957, $3,000,000 has been requested.

The community air pollution program within the Public Health Service is carried out by the Divisions of Sanitary Engineering Services and Special Health Services. The technical work of the Division of Sanitary Engineering Services consists of technical assistance, training, and demonstrations related to engineering and is carried out at the Robert A. Taft Sanitary Engineering Center. The Division of Special Health Services has the responsibility for the determination of the health effects of air pollution. The technical studies, particularly as they relate to toxicology and medical effects, are being performed at the Occupational Health Field Headquarters. The primary objective of the toxicologic studies is determination of the toxic effects of such air pollutants as ozone, nitrogen oxide, and sulfur derivative hydrocarbons on test animals. Much of the medical research is being carried out through contractual arrangements with universities and private organizations. These relate primarily to studies of the biologic effects of air pollution on health. Included are studies of the feasibility of using tissue culture and tissue enzymes to evaluate the toxicity of different air pollutants. A third project at the National Institutes of Health involves the statistical determination of geographic variations in the leading causes of death. This information, when correlated with environmental findings, will provide leads for community epidemiologic studies of air pollution.

Because of the diverse interest of many federal agencies in air pollution, an interdepartmental committee on community air pollution has been organized. The Departments of Agriculture; Commerce; Defense; Health, Education, and Welfare; and Interior; and the Atomic Energy Commission and National Science Foundation are represented on the committee. This committee will provide liaison between and coordination of federal activities relating to air pollution. It will review from time to time the policies and programs related to community air pollution of the federal agencies, the general status of technical knowledge concerning air pollution, particularly with regard to the area and scope of needed research and other technical activities and advise the Surgeon General thereon. At the

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first formal meeting of the committee, held in November, 1955, the areas of interest and responsibility of each of the participating agencies were determined. Public Law 159 vests the primary authority for air pollution studies in the Public Health Service but authorizes it to cooperate with and finance studies of other federal departments.

In addition to research—both through direct operation and contracts—another important activity has been technical consultation to the States and communities. Personnel were assigned to the California State Department of Public Health to aid in a special study of the Los Angeles problem and to assist in the development of a statewide program. Other personnel have been assigned by the Sanitary Engineering Center to the Los Angeles Air Pollution Control District to assist in the conduct of a specialized aerometric survey and oil refinery studies. Another cooperative effort involving special studies of air pollution in the Louisville, Kentucky area has been initiated to study the source and character of air pollutants in that area. This study, which is expected to be completed in two years, was initiated in January, 1956.

Direct research operations at the Sanitary Engineering Center included extension of the national air sampling network to a total of 45 cities and 74 sampling stations. Analysis of the material being collected includes determination of the weight of material collected, identification of 17 metals, certain anions and organic fractions as well as the radioactivity levels. Twenty-six research projects are under way at the Sanitary Engineering Center. These include research to establish the relationship between atmospheric pollution and meteorologic variables, studies of the performance and design factors involved in controlling air pollution from incinerators, and development of control devices utilizing fabric filters. Eight studies are under way to develop methods for determining the composition of air pollutants and for the development of instruments for air pollution measurement. Work also includes a detailed examination of certain air samples, studies of economic costs of air pollution, and studies of control in several industries.

In addition to its directly conducted research activities, the Public Health Service is supporting air pollution studies in other federal agencies. The U. S. Weather Bureau, U. S. Bureau of Mines, and National Bureau of Standards are all undertaking important studies. The Weather Bureau, for instance, is studying the meteorologic parameters contributing to the severity of air pollution. The Bureau of Mines is investigating the incineration of combustible wastes, evaluating sulfur dioxide removal processes, and studying the effluents from automobile exhausts. The Bureau of Standards is developing methods for sampling and analysis of air pollutants and is studying the interreactions of air pollutants at the source and in the atmosphere. Negotiations have also been completed with the Library of Congress to provide a continuous abstracting service and to compile an annotated bibliography covering all phases of the air pollution literature.

Utilizing the grants mechanism of the National Institutes of Health, to date, 20 air pollution research grants, totaling $481,359 have been awarded. Of these, six are in the field of physical science and engineering and the remaining 14 are concerned with the health effects of air pollutants.

Training will be eventually another major activity under Public Law 159. To date, the Sanitary Engineering Center has held several seminars for State and local personnel. The fact that 95 people from 31 States, 14 cities, and five countries attended the September, 1955 seminar indicates the widespread interest in air pollution. Another technical seminar was held in 1956 which concerned itself with atmospheric sampling, analytic procedures, sampling theory and techniques, and air pollution meteorology. A third seminar is planned for May, 1956.

These developments, all related to the passage of federal legislation in the air pollution field, will probably stimulate expanded research activities in air pollution, not only by federal agencies but by private organizations as well. In passing this legislation Congress recognized that the Federal Government had a responsibility in research and development but it left the control of air pollution in the hands of local authorities and private enterprise. The research being stimulated by this law promises to have the same beneficial effect in the air

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In the Field of Noise

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NOISE CONTROL is demanding an increasing portion of the Industrial Hygienist's time and, therefore, justifies an overall look at recent developments.

Management Acceptance

ONE OF THE most significant developments in the past year has been the acceptance by management of the facts that (1) they have a noise problem, (2) it is serious enough to warrant action, and (3) the responsibility of protecting employee health and safety from excessive noise belongs to management. In most cases we no longer need to spend valuable time convincing management, but are at liberty, in fact, encouraged, to pursue methods of controlling noise.

AIHA Noise Manual

THE AIHA recognizes the need for a practical manual to guide Industrial Hygienists in controlling industrial noise. To fill this need they have formed a noise committee and charged it with the responsibility of preparing such a manual. Subjects covered by this manual will probably be:

(1) Physics of sound.
(2) Measurement of sound.
(3) Man's physiological reaction to sound.
(4) Hearing conservation.
(5) Engineering control of sound.

Second drafts of each chapter of this manual have already been completed and it is expected that the final draft will be completed for the 1957 annual meeting. It is not too late to include suggestions or data to help make this manual of maximum usefulness. K. M. Morse, of the U. S. Steel Corporation, chairman of this committee or any committee member as listed in the current issue of the *Quarterly*, will be glad to accept any contribution. Of particular interest would be examples of noise control treatments tried and found successful. No one of us has had experience with all types of noise problems but by pooling our accomplishments all should benefit.

More Information Now Available

ORGANIZATIONS outside our own AIHA have been active during the past year in making available recent technical and practical information on noise control. Many organizations are involved but time permits the mention of only a few.

ASSOCIATED INDUSTRIES OF NEW YORK STATE, in their annual meetings on noise control, present papers on practical solutions to noise problems. These papers are presented by representatives of various companies and are published in the *AIHA Quarterly*. Each year these meetings increase in value as the activity in noise control increases.

THE NATIONAL NOISE ABATEMENT SYMPOSIUM held yearly at the Illinois Institute of Technology presents a similar program except of a more technical nature. The proceedings of these meetings are published in *Noise Control*.

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY sponsors a conference on noise control about every two years and the one this past year was exceptionally good in that an attempt was made to provide the Industrial Hygienist with practical data for field application. Proceedings of this conference were also published in *Noise Control*.

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Since the magazine *Noise Control* has been already mentioned twice, it might be in order to say that this quarterly publication has established itself during the past year as a valuable reference for Industrial Hygienists who are concerned with controlling industrial noise. It provides technical and practical data on all phases of the problem.

Machinery Noise Specifications

IN OUR HASTE to get existing noise problems under control we must not overlook the preventive side of the problem as far as new construction or machinery replacement is concerned. Manufacturers are awakening to the fact that noise production characteristics of a machine are important specifications. Some are taking steps to provide such data. It is quite generally accepted that noise power output is the best specification for predicting the noise production characteristics of machines, for specific conditions of installation. Most acoustical engineers agree that the echo-free room, i.e., anechoic chamber, provides the best environment for making measurements of sound power output. However, few manufacturers feel they can afford such facilities. As a result, organizations such as the American Institute of Electrical Engineers (AIEE), National Electrical Manufacturers Association (NEMA), American Fan Manufacturers Association (AFMA), Industrial Unit Heater Association (IUHA) and the American Society of Heating and Air Conditioning Engineers (ASHAE) are investigating less costly means of measuring sound power output. There is indication that this might be accomplished in the next year or two. In the meantime, some companies are using some adaptation of the American Standards Association (ASA) Apparatus Noise Measurement Standard together with some noise criteria to identify excessively noisy equipment. By bringing this to his attention, the manufacturer is rapidly being made to realize that noise is a competitive problem. It is interesting to note how readily other manufacturers can get in line as soon as one solves the noise problem. The manufacturer of electric motors provides a good example. As soon as one manufacturer proved that quiet motors were practical, others found they could also meet the demand. As a result, you can now select a motor that will not create a noise problem.

Our job is to warn our companies against buying new noise problems. The first step in preventing this is to supply Design and Purchasing Departments with noise specifications for machinery.

Automatic Audiometer

TO ASSIST in hearing conservation programs where large numbers of hearing tests must be made, a new audiometer has been developed called the automatic audiometer. With this device the patient takes his own audiogram after having been given a few simple instructions. One operator can supply the instruction necessary to keep three automatic audiometers in operation. Indications are that to justify automatic audiometry, enough tests to keep three machines in operation are required.

Impact Meter

EVEN THOUGH less is known about the relation between hearing damage and exposure to impact noise than for steady state noise, fairly accurate field measurements of impact noise is desirable if we expect to develop damage risk criteria or evaluate corrective measures. Until recently, field measurements of impact noise was too complicated to attract widespread use. The General Radio Corp. now has available an instrument called the Impact Noise Analyzer which gives promise of improving this condition. This instrument is simple to operate, easily portable, relatively inexpensive, can be used with frequency analyzers and provides fairly accurate measurements of impact noise. It is hoped this instrument will be valuable in the study and control of impact noise which has been sadly neglected up to now.

To summarize these recent developments:

1. Management is accepting the noise problem and is looking to us for the answers. It is our move now to get the job done.

2. AIHA will soon have available a manual on noise control which should be a guide in solving industrial noise problems. This should considerably reduce the necessity of searching through many sources for the answers to your problems.

3. Organizations outside the AIHA are

also active in this field. While it is practically impossible to cover them all, it is wise to keep an eye on a few to provide as broad a coverage as possible.

4. Don't buy new noise problems. Promote the use of machinery noise specifications to emphasize the importance of the noise problem.

5. If you have many audiograms to take, consider the automatic audiometer; it might save you money and provide more uniform data.

6. If you have impact noise problems, you should consider the use of an Impact Noise Analyzer.

Only a few of the recent and important developments in the field of industrial noise control (as far as the Industrial Hygienist is concerned) have been discussed. The interest shown in this field today indicates that new and significant developments will be forthcoming in increasing numbers. If one is to keep abreast of this new and rapidly developing field, constant vigilance of current literature will be required.

In the Field of Radiation

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IT IS NOT possible to cover all the developments in the field of radiation in the course of this paper, but after discussing the subject with several persons in this field, I have concluded that the following are probably the most significant.

Many developments have been primarily "administrative," that is, they deal with the development of regulations, codes and standards and the matter of agency jurisdiction over health and safety.

In June, 1955, a conference was held on the subject of health physics, and as a result of that conference, a preliminary organization of professional health physicists was formed.

In July, 1955, the AEC published its proposed standards for protection against radiation as part of Article 10 of the Code of Federal Regulation. Although other parts of the same Title may also be based upon a need to consider the hazardous aspects of atomic energy, Part 20 will be among the first Federal occupational health codes to be enforced by a Federal agency. Many interesting new concepts in radiation protection are included in the AEC's proposed code. It is expected that a revised draft will be forthcoming shortly.

Many papers on radiation protection were submitted to the International Conference on the Peaceful Uses of Atomic Energy, which was held in Geneva in August, 1955. The legal and administrative aspects of the problem received a great deal of interest.

In December, 1955, the American Standards Association called a National Conference on Standardization in the Field of Nuclear Energy to review its program in this area and to obtain the thinking of a large cross-section of industry, government, labor and others on the need for additional American Standards Association activities.

As a result of this meeting, a Planning Committee was established to review the present status of standards and recommend appropriate action. This Committee met in full session on February 15, 1956, and this meeting was followed by meetings of the various subcommittees. Reports of these subcommittees were analyzed on March 15, 1956, at a meeting attended by the subcommittee chairmen and the Chairman of the Planning Committee. The major recommendation was for the American Standards Association to establish a nuclear standards board.

In December, 1955, the National Bureau of Standards issued Handbook No. 61 on the regulation of radiation exposure by legislative means, which contained the recommendations of the National Committee on Radiation Protection concerning the development of acts and regulations on the part of state government.

In March, 1956, the New York State Health Department and the New York State Labor Department radiation protection regulations became effective.

This same month, the United Nations Radiation Committee had its first meeting and elected officers. The next meeting will be in about five months. This Committee was established in December, 1955, by the United Nations as a committee of specialists from 15 nations to collect information on radiation levels and radiation effects on man

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