

Rationale for Classification of
Combustible Gases, Vapors, and Dusts with
Reference to the National Electrical Code

(U.S.) National Materials Advisory Board (NRC)
Washington, DC

Prepared for

Occupational Safety and Health Administration
Washington, DC

Jul 82

Rationale for Classification of Combustible Gases, Vapors, and Dusts with Reference to the National Electrical Code

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Commission on Engineering and Technical Systems
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BIBLIOGRAPHIC DATA SHEET		1. Report No. NMAB 353-6	2.	3. Recipient's Accession No. DRA7 263179	
4. Title and Subtitle Rationale for Classification of Combustible Gases, Vapors, and Dusts with Reference to the National Electrical Code				5. Report Date July 1982	
7. Author(s) Committee on Evaluation of Industrial Hazards				6.	
9. Performing Organization Name and Address National Materials Advisory Board National Academy of Sciences 2101 Constitution Avenue, N.W. Washington, D.C. 20418				8. Performing Organization Rept. No.	
12. Sponsoring Organization Name and Address Occupational Safety and Health Administration Department of Labor 200 Constitution Avenue, N.W. Washington, D.C. 20210				10. Project/Task/Work Unit No.	
15. Supplementary Notes				11. Contract/Grant No. J-9-F-5-0070 210-78-0120	
16. Abstracts Electrical equipment that operates in an environment containing combustible materials must conform to requirements presented in Article 500 of the National Fire Protection Association's National Electrical Code (NEC). These requirements reflect the degree of combustion hazard created by the particular chemical compounds present in the equipment environment, and compounds are classified in groups that are indicative of the perceived explosion hazards. The Committee on Evaluation of Industrial Hazards of the National Research Council's National Materials Advisory Board has classified many hundreds of compounds in accordance with current NEC groupings. Although some tests were conducted on selected key compounds, the committee primarily considered the chemical similarity of compounds and other known flammability properties and relied heavily on the experience and intuition of its members. The committee also has recommended that the NEC grouping of dusts be changed in some ways and has reclassified dusts (CONT.)				13. Type of Report & Period Covered Final	
17. Key Words and Document Analysis. 17a. Descriptors Gases and Vapors Dusts National Electrical Code Classification Westerberg Apparatus				14.	
17b. Identifiers/Open-Ended Terms				15. Supplementary Notes	
17c. COSATI Field/Group				16. Abstracts	
18. Availability Statement This report is for sale by the National Technical Information Services, Springfield, VA 22151			19. Security Class. (This Report) UNCLASSIFIED		21. No. of Pages 25
			20. Security Class. (This Page) UNCLASSIFIED		22. Price

20. Abstract (cont'd.)

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For the longer range, the committee recommends that industry or an appropriate U.S. government agency fund a research program for the purpose of generating a realistic, easily applied method for classifying gases, vapors, and dusts.

**RATIONALE FOR CLASSIFICATION OF COMBUSTIBLE GASES,
VAPORS, AND DUSTS WITH REFERENCE TO THE NATIONAL ELECTRICAL CODE**

**Report of the
Committee on Evaluation of Industrial Hazards**

**THE NATIONAL MATERIALS ADVISORY BOARD
Commission on Engineering and Technical Systems
National Research Council**

**Publication NMAB 353-6
NATIONAL ACADEMY PRESS
Washington, D.C.
1982**

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competences and with regard for appropriate balance.

The report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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This study by the National Materials Advisory Board was conducted under Contract No. J-9-F-5-0070 with the Occupational Safety and Health Administration and continued under Contract No. 210-78-0120 with the National Institute of Occupational Safety and Health.

This report is for sale by the National Technical Information Service, Springfield, Virginia 22151.

Printed in the United States of America.

ABSTRACT

Electrical equipment that operates in an environment containing combustible materials must conform to requirements presented in Article 500 of the National Fire Protection Association's National Electrical Code (NEC). These requirements reflect the degree of combustion hazard created by the particular chemical compounds present in the equipment environment, and compounds are classified in groups that are indicative of the perceived explosion hazard.

The Committee on Evaluation of Industrial Hazards of the National Research Council's National Materials Advisory Board has classified many hundreds of compounds in accordance with current NEC groupings. Although some tests were conducted on selected key compounds, the committee primarily considered the chemical similarity of compounds and other known flammability properties and relied heavily on the experience and intuition of its members. The committee also has recommended that the NEC grouping of dusts be changed in some ways and has reclassified dusts according to the modified version of the code. Nevertheless, the committee has serious reservations about the entire classification procedure and the precepts on which it is based, and these are discussed in this report.

For the longer range, the committee recommends that industry or an appropriate U.S. government agency fund a research program for the purpose of generating a realistic, easily applied method for classifying gases, vapors, and dusts.

PREFACE

As a result of requests from the Occupational Safety and Health Administration and National Institute for Occupational Safety and Health, the Committee on Evaluation of Industrial Hazards was organized by the National Materials Advisory Board (NMAB)* to make an extensive evaluation and classification of many gases, vapors, liquids, and dusts. The committee's expertise is comprised of chemistry; combustion phenomena; knowledge of codes, standards, and regulations; electrical engineering; and industrial practices.

The original charge to the committee was to classify these chemicals according to Article 500 of the National Electrical Code (NEC); this was done and reported in a series of earlier reports. However, in the process of studying and evolving techniques for classification while staying within the constraints of the NEC, many points were raised that the committee could not include in its earlier reports but that it considered to be germane to the subject of classification. As a result, the committee decided to issue this report.

The task of drafting the report was undertaken by J. Arthur Nicholls. The Chairman wishes to express his deep appreciation to Professor Nicholls for his painstaking and thoughtful effort. The Chairman also is indebted to the other members of the committee, the liaison representatives, and technical advisors and to Stanley M. Barkin, NMAB Staff Scientist, and other staff members of the NMAB for their unflagging support. The Chairman also acknowledges with pleasure the wholehearted support he has received from his staff at the Naval Research Laboratory during the course of the committee's activities, particularly Mrs. Evelyn Childs who has been of great help, particularly in the earlier stages of the committee's activities.

Homer W. Carhart, Chairman

* The National Materials Advisory Board is a unit of the Commission on Engineering and Technical Systems of the National Research Council. Its general purpose is the advancement of materials science and engineering in the national interest. It fulfills that purpose by providing advice and assistance to government agencies and private organizations on matters of materials science and technology affecting the national interest, by focusing attention on the materials aspects of problems and opportunities, and by making appropriate recommendations for the solution of such problems and the exploitation of the opportunities.

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Chapter 1

INTRODUCTION

BACKGROUND

Electrical equipment and wiring often are located in areas where fire or explosion hazards exist. The properties of the flammable vapors, liquids, or gases or the combustible dusts that may be present as well as the likelihood that a flammable or combustible concentration will exist are considered in classifying these areas. Article 500 of the National Electric Code (NEC) addresses this matter and dictates the kind of electrical equipment that must be used in specific locations.

According to the NEC, Class I locations are those where flammable gases or vapors may be present in the air in concentrations sufficient to be ignitable or explosive, and Class II locations are those where combustible dusts may be encountered in concentrations sufficient to be ignitable or explosive. These classes therefore refer to physical forms of materials. The NEC also defines locations by divisions that reflect the likelihood that a material will be present in flammable or combustible concentrations. These divisions therefore classify areas. Class I flammable gases and vapors and Class II combustible dusts also are assigned to groups (A, B, C, or D and E, F, or G, respectively) according to their properties.

Given this framework, it is important that a specific material be classified properly considering both the degree of safety required and the cost of overprotection. It clearly is essential to preclude the likelihood of explosion; however, overly stringent classification can result in considerably higher costs that, in some cases, make an operation impractical. The classification procedure therefore must be based on reasonably sound guidelines.

SCOPE OF THE STUDY

The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor requested that the Committee on Evaluation of Industrial Hazards of the National Research Council's (NRC) National Materials Advisory Board (NMAB) classify several hundred gases, vapors, and dusts in accordance

with the NEC groupings. The list of materials to be considered was later expanded with support from the National Institute for Occupational Safety and Health (NIOSH).*

The work of the committee relative to gases and vapors resulted in two reports: Matrix of Combustion-Relevant Properties and Classification of Gases, Vapors, and Selected Solids (Report NMAB 353-1) was published in 1979 and classified certain chemicals based on physical and flammability data. Classification of Gases, Liquids, and Volatile Solids Relative to Explosion-Proof Electrical Equipment (Report NMAB 353-5) was published in 1982 and classifies additional chemical compounds.

The committee established two panels to deal with combustible dusts--one to classify the dusts and one to recommend the test methods needed to determine dust classification parameters. The conclusions of the Panel on Dust Test Equipment, amended and approved by the committee, were presented in 1979 in Test Equipment for Use in Determining Classifications of Combustible Dusts (Report NMAB 353-2). The classification of dusts by the Panel on Classification of Combustible Dusts, amended and approved by the committee, was published in 1980 in Classification of Combustible Dust in Accordance with the National Electrical Code (Report NMAB 353-3). Another report that combines the material from these reports and revises it to account for changes in the NEC that were made in the 1981 edition and that reflect some of the recommendations of the committee is in preparation (NMAB 353-4).

SUBJECT OF THIS REPORT

During the course of its study, the Committee on Evaluation of Industrial Hazards recognized that there are actually thousands of chemicals and materials of interest and that others are being introduced in the commercial market at an unprecedented rate. It believes that over time, the classification of many of these chemicals and materials will become necessary, which will pose a formidable problem. Not only is it not feasible to test every single chemical among the many thousands that are of interest but also there are apprehensions about the adequacy of the testing techniques currently used. Thus, the committee believes that it is most

*The chemicals and materials to be classified originally included those subject to an earlier NRC study for the U.S. Coast Guard and those listed by OSHA in the Federal Register on June 27, 1974 (pp. 23541-3). The list subsequently was expanded (with NIOSH support) to include the gases and vapors listed in Fire Hazard Properties of Flammable Liquids, Gases, Volatile Solids, Manual 325M issued by the National Fire Protection Association (NFPA) in 1977. The dusts to be classified were those listed in 1976 in the NFPA's Fire Protection Handbook (pp. 3-107 to 3-114).

desirable to be able to classify chemicals on the basis of known or easily determined physical and chemical properties. It further believes that some capability for this type of classification exists but much improvement is needed.

In this report, the committee reviews the classification procedure used to date and the current basis for the NEC Article 500 groupings.* The difficulties, weaknesses, and inconsistencies it encountered in using the procedure are discussed, and suggestions for near-term modification of NEC Article 500 are presented. Steps that can be taken over the long term to develop a sounder and more easily applied classification process also are recommended.

*The physical processes involved in the ignition and explosion problem are such that gases and vapors present a problem quite different from dusts and they are therefore treated separately.

Chapter 2

THE CLASSIFICATION PROCESS

GASES AND VAPORS

Coast Guard Study

The work of the NMAB Committee on Evaluation of Industrial Hazards is an extension of earlier work done for the U.S. Coast Guard by the NRC Committee on Hazardous Materials. The Coast Guard study committee examined the flammability properties of certain chemicals and classified the materials according to NEC Article 500 (Committee on Hazardous Materials 1975a and 1975b). The committee's classification reflected the best judgment of its members concerning the expected flammability behavior, combustion properties, and the chemical structure of the compounds. In conducting its study, however, the group found it helpful to divide the chemicals into families (i.e., homologous series of compounds). Some ambiguity was introduced because some chemicals fell into more than one family and because the breakpoint between classification groups within a family was not known. To resolve the latter problem, the Coast Guard study committee had Underwriters Laboratories Inc. (UL) conduct tests on a number of representative chemicals. The Westerberg explosion test vessel was used and the results of these tests have been reported in detail (Alroth et al. 1976).

Present Committee's Approach

The present NMAB committee followed procedures very similar to those of the Coast Guard study committee but attempted to rely most heavily on the physical, chemical, and flammability properties of the chemicals. Therefore, tests of additional chemicals in the Westerberg apparatus were conducted. This effort was described in an earlier report (Committee on Evaluation of Industrial Hazards 1979a) that lists relevant combustion properties and the classifications for a number of chemicals in the form of a matrix. The matrix itself is catalogued by chemical families. The report includes classifications for materials not previously considered and updates the classifications of the Coast Guard study committee and classifications by NEC/UL.

Westerberg Apparatus

In arriving at the classifications, it is assumed that the electrical equipment is of the explosion-proof type. That is, it is assumed that the combustible gases or vapors surrounding an enclosure will enter the equipment and can be ignited. The equipment will withstand the stresses arising from the explosion. Following the explosion, however, the hot pressurized combustion products can escape through gaps in the equipment (e.g., the clearance around a shaft) but must not ignite the surrounding combustible atmosphere. An explosion proof enclosure, therefore, is typically a heavy-walled construction with tight-fitting flanged or threaded joints.

The Westerberg apparatus simulates the flange gap of an explosion-proof enclosure. The permitted clearances depend on the properties of the particular chemical present. The Westerberg apparatus utilizes a primary, or charge, vessel and a receiver vessel. A rectangular opening of adjustable size separates these two containers. The width (length of path for gas passing over the flange) of the rectangular opening is held constant but the gap size is adjustable. A given chemical, mixed with air, is introduced into the primary and receiving vessels at atmospheric pressure. The mixture is ignited in the primary vessel and measurements (usually pressure) then are made in the receiver to detect whether the mixture is ignited in that chamber. Various fuel-air ratios are tested. The gap size is adjusted from experiment to experiment until the largest possible gap size that still precludes ignition in the receiver is found. This gap size then is called the maximum experimental safe gap (MESG). Thus, an extremely sensitive chemical, such as hydrogen, will have a small value of MESG and is put in Group B. Ethyl ether, somewhat less severe, has a larger but still small MESG and goes into Group C. Hexane has a much larger MESG and goes into Group D. Accordingly, other chemicals are put into Groups A, B, C, or D depending on their MESGs.

Pressure rise also is measured in the charge vessel because the gaps in actual operating equipment can be enlarged due to the internal explosion. This maximum pressure is considered with MESG to assign a chemical to a group. Other variables tested in the Westerberg apparatus include location of the ignition point, initial turbulence of the mixture, and ignition and pressure rise due to flame acceleration (sometimes called run-up or pressure piling) in a pipe attached to the charging reservoir.

Although equipment of differing sizes and shapes are used, similar techniques are employed in other countries for similar purposes.

In the absence of MESG information, recourse is often made to the minimum ignition energy or minimum igniting current for use in classification (Carhart 1972).

Processes Involved

The committee believes a classification procedure that is not apparatus dependent is desirable. This dictates either that the ordering of the chemicals be completely independent of the apparatus used or that enough be known about the processes involved to permit analytical corrections to be made to account for system effects. Certainly that level of understanding does not exist at the present time. The Westerberg apparatus is only one particular apparatus and there are many simultaneous effects operative at one time. In looking forward to potential future classifications, it is enlightening to consider some of these processes.

Upon ignition in the primary chamber, a flame moves through the unburned mixture at the flame speed for that particular fuel-air mixture. The flame speed depends primarily on thermal conductivity, diffusivity, chemical kinetics, adiabatic flame temperature, pressure, temperature, and degree of turbulence. The pressure in, and hence outflow from, the primary vessel rises at a rate dependent on the geometry and volume of the vessel, the flame speed, and the size of the opening between the two vessels. If the ignition point is away from the opening, compressed and heated unburned gases flow through the opening followed later by the combustion products. With ignition right at the opening, burned gases flow immediately into the receiver. The gases lose heat to the walls in the opening and introduce some pressure drop. These gases flow into the receiver and mix, probably turbulently, with the mixture there. The rate at which they mix, and thereby the rate of temperature rise in the receiver mixture, depends on the flow conditions, the size of the opening, and the shape (aspect ratio) of the opening. Meanwhile, the pressure in the receiving tank rises at a rate dependent on the rate of inflow, the tank volume, and the heat losses to the walls. Ignition of the receiver mixture may or may not occur depending on the details of this mixing and heating process and the ignition characteristics of the mixture. An added complication is that of pressure piling (mentioned earlier) wherein the initial ignition is located outside of the primary chamber. Gas dynamic processes, with wave acceleration, can lead to more rapid rates of pressure rise in the main primary chamber and, hence, can produce a differing result. Such piling could be a problem because of the use of threaded rigid conduit to wire explosion-proof electrical equipment. Some electrical equipment (e.g., motors) also may have a geometry which may make piling a problem.

Committee Concerns

The above discussion makes it obvious that many simultaneous interacting phenomena are at play and, hence, that one aspect of the experimental apparatus could have a pronounced effect on one chemical and very little on another. This aspect of the problem gave the committee much reason for concern since it clearly recognized that the testing technique was arbitrary. Nevertheless, much dependence was put on MESH measurements if they were available. This information then was tempered with consideration

of maximum pressure and pressure piling. In most cases, however, the MESH was not available and then recourse was made to classifying by noting similarities among individual members in chemical families, the knowledge and experience of the members of the committee and others, and admittedly, "seat of the pants" decisions in many instances. The process certainly was not absolute or exact and cannot be applied easily in future classification efforts.

A subgroup of this committee compared the MESH results obtained in the Westerberg apparatus with those obtained in the 20-ml and 8-1 spherical vessels developed in the United Kingdom and West Germany. The 20-ml vessel is the standard apparatus recommended by the International Electrotechnical Commission. In a number of cases the results differed by a factor of three. Furthermore, one of the compounds showing a drastic difference was diethyl ether, which, in the United States, is the standard compound used as a reference to separate Groups B and C. Comparisons were made between the various apparatuses used as to characteristic combustion times and blowdown (exhausting) times, and drastic differences were noted. The foregoing investigation has been described by Strehlow et al. (1979). Subsequent to this work, H. Phillips (private communication) also made comparisons and found that the apparatus not only affected the MESH but also changed the position of many chemicals in the ordering of the hazard level. He attributed much of the difference to the relatively low receiver volume of the Westerberg apparatus.

It is clear to the committee that many questions remain about the accuracy of the classifications made and, hence, to be made. It recognizes that a comprehensive and full scientific treatment of the problem would be very protracted and costly; however, it believes that there would be great merit in expending considerable effort on the problem.

In the meantime, the committee, recognizing its temporal nature, considered that since its "expertise" developed through the present studies would be scattered on disbanding, undertook to propose classifications for a much larger group of chemicals and materials than requested by OSHA. For this purpose they chose the 1500 some chemicals found in NFPA Manual 325M (1977) as being reasonably representative of those in or likely to be in commerce at present or the near future, and is presently classifying them. Their results will be published when the study is completed (NMAB 553-5).

DUSTS

In classifying dusts according to NEC Article 500, the a priori condition is established that the electrical equipment involved be sufficiently tight to preclude entry of the dust. However, small amounts of dust are likely to get into the enclosure when it is opened for equipment servicing. Thus, a hazard arises from the possibility of ignition of a dust cloud or dust layer by a hot surface and by electrical faults caused within

equipment by small amounts of electrically conductive dust, with the resultant electrical disturbance burning through the enclosure or forcing hot particles out of the enclosure through openings. The combustion and electrical characteristics of the dust would therefore be expected to be important.

Earlier Classification Schemes

In the past, maximum operating temperatures were specified for electrical equipment to be operated in the presence of certain types of dust and to classify the dusts in very general terms. Group E consisted of the metallic (electrically conductive) dusts; Group F, of the carbonaceous (semiconductive) dusts; and Group G of the agricultural (nonconductive) dusts. These conductivities were not quantified.

The Committee's Approach

When OSHA requested that a number of dusts be classified, the Committee on Evaluation of Industrial Hazards sought to derive a procedure more quantitative in nature. A review of the few dusts classified in Class II, Groups E, F, and G, of NEC Article 500 indicated that the layer ignition temperature and electrical conductivity of the dusts were the important factors. Accordingly, the committee established its Panel on Dust Test Equipment to recommend test methods. The recommended methods are described in detail in the committee's 1979 and 1981 reports.

The committee also formed its Panel on Classification of Combustible Dusts to classify dusts based on their known or easily determined physical, chemical, or combustibility properties rather than on exhaustive testing. The panel, with the entire committee, proceeded to classify hundreds of dusts (listed in the 14th edition of the NFPA Fire Protection Handbook) according to the 1978 NEC but with the guidelines for Groups E, F, and G being the electrical resistivity, ρ , of the dust or of the parent material. The panel used the following dividing lines:

- Group E - $\rho \leq 10^2$ ohm-cm,
- Group F - 10^2 ohm-cm $< \rho \leq 10^8$ ohm-cm, and
- Group G - $\rho > 10^8$ ohm-cm.

Combustion properties of the dusts also were considered. A study of existing information showed that if 10^5 ohm-cm were taken as the dividing line between conductive and nonconductive dusts, very few dusts would fall near that dividing line (i.e., practically all dusts are either much more or much less conductive than 10^5 ohm-cm).

The panel proceeded further and proposed a new method for classifying dusts that eliminated Group F and that specified a maximum surface temperature for the electrical equipment which was lower than the measured

dust layer ignition temperature by some differential value (e.g., 25°C). The proposed method considers whether a dust is combustible (explosives, pyrophoric materials, and oxidizers are excluded) and then utilizes combustibility properties for classification purposes. Two ratings, originally introduced by the U.S. Bureau of Mines, were used: ignition sensitivity and explosion severity (see Section 3 Chapter 8 in NFPA Fire Protection Handbook 14th Edition, 1976). If both numbers were below a certain level, the explosion hazard was deemed to be low and the committee recommended that electrical equipment suitable for Class II locations would not be required. If one or both of these ratings were above the prescribed level or if available information were insufficient, the committee recommended that electrical equipment suitable for Class II locations would be required. The group would then be determined by the resistivity--i.e., if the resistivity is $<10^5$ ohm-cm (conductive), the dust would be Group E; if the resistivity is $\geq 10^5$ ohm-cm (nonconductive), the dust would be Group G.

Using this recommended procedure, the committee reclassified the dusts it had classified using the NEC guidelines. The classification as well as the combustibility properties of the dusts were presented in the committee's 1980 and 1981 reports.

Processes Involved

As with gases and vapors, the committee classified dusts using the best available information knowing that some approximations and uncertainties were involved. For example, one recommended criterion for whether to classify or not involves the parameter, ignition sensitivity. This parameter is the product of the ignition temperature, the minimum ignition energy, and the minimum explosive concentration for standard Pittsburgh coal dust divided by that product for the dust of interest. (Thus a number greater than 1.0 indicates that the dust is more ignition sensitive than the Pittsburgh coal dust and vice versa.) Certainly there is cause for concern in the application of this parameter. For one thing, all three variables enter to the same power, which is highly unlikely. Secondly, the minimum ignition energy and minimum explosive concentration were determined long ago in the Hartmann apparatus (Jacobson et al. 1961) and these measurements are now known to be subject to appreciable errors (Hertzberg et al. 1981).

Similarly, explosion severity involves the product of the maximum pressure and the rate of pressure rise normalized by the Pittsburgh coal results. Again, these values were obtained in the Hartmann apparatus and the grouping of parameters is worrisome.

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Chapter 3

CONCLUSIONS AND RECOMMENDATIONS

NEED FOR A BETTER CLASSIFICATION SYSTEM

In accordance with the request and financial support of OSHA and NIOSH, the Committee on Evaluation of Industrial Hazards classified hundreds of combustible gases, vapors, and dusts in accordance with NEC Article 500. The study was not intended to involve the establishment of new procedures (the committee was to do the best possible with the tools and information at hand); however, during the classification process certain ways to make definite improvements were identified.

The committee recognizes that there are many weaknesses and inconsistencies in the present system and that much improvement is possible over the long term. Accordingly, it recommends that industry or an appropriate U.S. government agency finance a multiyear research study to provide a sound engineering basis for the classification process and to develop a simple classification procedure that will not require the services of a specialist or a new panel. Amplification of this recommendation and the philosophy behind it is in order. Perhaps this is best explained by discussing the gases and vapors case.

POTENTIAL APPROACH FOR CLASSIFICATION OF GASES AND VAPORS

First, considerable thought and attention should be given to the appropriate criteria to be used for classification. The reason for classification of chemicals is to prevent disasters originating from the use of electrical equipment in potentially flammable atmospheres. There are three common ways to do this in North America: by use of explosion-proof equipment, by use of intrinsically safe equipment, and by pressurizing or purging. Only the first method of protection is of concern here (although it is recognized that there is also need for safety chemicals for use with intrinsically safe devices and that the correlation between arc ignition properties and MESH results in essentially equivalent grouping for both methods). As noted above, when explosion-proof equipment is used, it is assumed that gases and vapors can penetrate the housing and can be ignited therein but that the equipment is designed and constructed to contain the energy released by the explosion to the extent that the fire or hot gases will not escape with enough energy to ignite a flammable mixture of the same

gas or vapor surrounding the equipment. Therefore, for test and evaluation purposes, the concept of an opening between two vessels appears sound for the gases and vapors case, but it is not certain that the MESG as determined in the devices used today is the most appropriate or most important criterion for classification. The cross sectional area of the opening appears to be important since it affects the pressure in the primary vessel and the mixing, heating, and pressurization characteristics in the receiver vessel. The shape of the opening also could be important.

Following the establishment of criteria, it would be well to formulate an idealized model for the testing apparatus for the purpose of generating an overall analytical description. In this model, the variables should include size of the primary and secondary chambers,* size and shape of the opening between them, and the physical, chemical, and combustion properties for some arbitrary gas or vapor. Within this idealization, turbulence, pressure piling, and various ignition source locations would not be considered. These variables are very system-sensitive whereas the purpose here is to rate the relative sensitivities of the various chemicals. The problem should be formulated analytically in its entirety. Concurrent experiments on a particular aspect of the problem should be conducted and the results used to develop the theory. The analytical model should be simplified considerably by involving order of magnitude considerations, relative sensitivities or insensitivities to certain parameters, simplifications in the physics and chemistry, etc. In some cases the lack of knowledge of combustion characteristics could be handled through knowledge of the properties. Although these simplifications would introduce some loss of "rigor," integrity in an engineering application sense would be maintained and, of course, the problem would be much more tractable mathematically. The resultant solution could conceivably result in a prediction as shown in Figure 1.

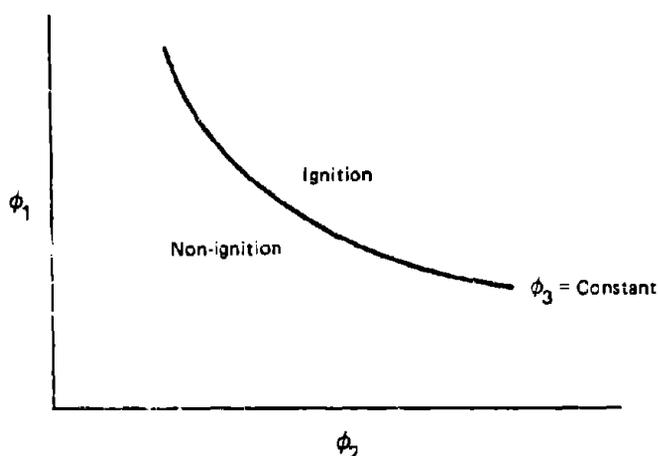


FIGURE 1 Prediction of ignition.

*In practice the secondary chamber is usually very much larger than the primary chamber, i.e., it represents the room in which the equipment is located.

The ϕ s are functions that can depend on the geometric variables as well as the more important physical and chemical properties.

The analytical model thus generated could then be used to critique the experimental results obtained from the United States, United Kingdom, and German tests, making some allowance for details of the apparatus. The model should then be exercised by calculating the results for a few chemicals from Groups A through D. Physical dimensions of a test apparatus then could be chosen that would have only a minimal system effect on any chemical to be tested and, further, assure that the required size and material of the apparatus was reasonable. The apparatus could then be built and a number of representative chemicals tested in it. These results could then be checked with the predictions and with the ratings obtained in the past. Additional iteration between tests and theory could then be invoked to give final improvement to the model. At this point, a reasonably realistic model could be used to classify chemicals through use of their physical, chemical, and flammability/combustion properties. For example, the classification scheme could be:

<u>Size of Opening, S</u>	<u>Group*</u>
$S < a$	A
$a < S < b$	B
$b < S < c$	C
$S > c$	D

The opening, which might be spacing or area, could be calculated from the model and thus classify various materials in a simple manner. In those cases where the properties are not well known, tests could be conducted in the universal chamber.

RECOMMENDATIONS FOR ADDITIONAL WORK ON DUSTS

As described in the foregoing, the committee proposed a modified procedure for classifying combustible dusts in accordance with the National Electrical Code. This proposed classification scheme involves the use of two factors, ignition sensitivity and explosion severity. For any given dust, if both of these factors are sufficiently low, electrical equipment suitable for Class II locations would not be required. However, if one or both of the factors are above a certain prescribed value, the dust would be

*The committee recognizes that classification of chemicals into four groups is very arbitrary as is the dividing line between groups. (Nature does not divide chemicals into large distinct groups, all nicely separated by chemical properties.) However, codes (i.e., NEC Article 500) are needed and such arbitrary decisions must be made for application to the marketplace.

classified according to its resistivity into Group E or G and special electrical equipment would be required. As discussed earlier, these two factors are somewhat arbitrary and hence it is likely that some dusts would be classified incorrectly. The consequences of such a mistake could be a hazardous situation or the needless use of more expensive electrical equipment. In view of this, along with the fact that a great number of dusts will require classification in the future, the committee recommends that the classification scheme for dust be improved.

A general "engineering" approach to the better classification of gases and vapors was described in the previous section. It is recommended that a similar philosophy be used for dusts but, of course, the technical aspects would differ. The ideas of ignition sensitivity and explosion severity are probably still valid and useful but the formulation should be derived from an approximate "engineering type" analysis. Most assuredly, the variables that are predicted to be important in the two factors, as well as the way they enter the rating, will be different than currently defined. Realization of these more soundly based rating parameters should then allow for more accurate and straightforward classification of dusts.

Curricula Vitae of Committee Members

HOMER W. CARHART received B.S., M.A., and Ph.D. degrees in chemistry at Dakota Wesleyan University, University of South Dakota, and the University of Maryland, respectively. After teaching chemistry at Gallaudet College, he joined the Naval Research Laboratory where he is, at present, head of the Chemical Dynamics Branch.

FREDERICK R. EIRICH was educated at the University of Vienna receiving M.A., D.Sc., and Ph.D. degrees in physical chemistry. During his academic career he was employed at the University of Vienna, Cambridge University, the University of Melbourne, Bristol University, and the Polytechnic Institute of New York. He is presently distinguished professor of polymer chemistry at the latter institution.

LELAND J. HALL obtained a B.S. in electrical engineering at Illinois Institute of Technology. He was chairman of the National Fire Protection Association's (NFPA) Code Making Panel 14--Electrical Code and a member of other NFPA panels. Before retiring he was manager of the Engineering Department of Mill Mutual Fire Protection Bureau.

ERNEST G. MAGISON received a B.S. in electrical engineering at Tufts University. He has been active in standards writing activities of the Instrument Society of America, National Fire Protection Association, International Electrotechnical Commission, particularly those relevant to preventing ignition by electrical equipment. Mr. Magison is a senior engineering fellow and manager, Regulatory Affairs, Honeywell Process Control Division and an adjunct professor at Drexel University.

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PETER J. SCHRAM has a B.S. in electrical engineering from the University of Wisconsin. He has served on National Fire Protection Association and Instrument Society of America panels. His industrial employment comprises over 20 years of experience at Underwriters Laboratories, Inc. and his present position as chief electrical engineer at the National Fire Protection Association.

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