ELECTRICAL INSTALLATIONS

IN

HAZARDOUS LOCATIONS

THESIS FOR THE DEGREE OF E. E.

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THESIS

P A R T I

INTRODUCTORY AND HISTORICAL

Containing a short history of the development of rules for the installation of electrical apparatus and wiring in hazardous locations, with special reference to the rules of Article 32 of the National Electrical Code.

Included also is a brief description of the nature of the problem which this Thesis discusses.

INTRODUCTORY AND HISTORICAL

During the past four or five years fire prevention engineers have given increased attention to the design and installation of electrical apparatus and wiring in what are termed "Hazardous Locations." It was found that electrical apparatus which was ordinarily considered safe for relatively non-hazardous occupancies such as dwellings, mercantile buildings and those of similar nature, introduced definite and serious fire and accident hazards into establishments where processes involved the use or production of inflammable volatile liquids, explosive gases, combustible dusts or easily ignitable fibers.

With the marked increase in efficiency in manufacturing methods during the past decade or two, we have seen an increasing use of materials known to be hazardous. Industry sought and found materials and methods for the more rapid application of finishes to automobile bodies, furniture and other manufactured goods. The use of gasoline and other petroleum products has increased many fold. Pyroxylin has come to be employed for ever multiplying purposes. Such increased use of flammable volatile liquids and substances which might be classed as explosive has been attended by numerous fires and explosions involving the loss of many lives and much property.

During this same period we have witnessed the almost universal adoption of electricity for power and lighting purposes. Whereas a comparatively few years ago steam engine power was used to a large extent, electric motor power now prevails. Where formerly the steam power plant was isolated from a hazardous area, we now find the demands of industry specifying individual motor drives which very often place the motors and their controllers directly in the hazardous area despite the attempts of fire protection engineers to isolate them. Fires and explosions caused by the ignition of hazardous matter from electrical arcs and sparks have become frequent and the need for adequate specifications and rules for the design and installation of electrical apparatus and wiring in hazardous locations asserts itself very forcibly.

Attempts to guard against the ignition of these highly flammable substances began with the first attempts of fire underwriters to produce rules providing for the installation of electrical wiring. In fact, the "Underwriters'" Electrical Codes of the early 1890's provided for the use of vapor tight globes for enclosing incandescent lights and their sockets when in rooms where flammable gases may exist. In the National Electrical Code of 1901 we find the subject more

thoroughly covered in Rule 17b which stated: "Switches, cutouts, circuit breakers, etc., must not be placed in the vicinity of easily ignitable stuff or where exposed to inflammable gases, dust or to flyings of combustible material." Following this rule was this fine print note: "In buildings used for starch or candy factories, woodworkers, grain elevators or flouring mills, or other purposes, where fittings are exposed to dust and flyings of inflammable material, cutouts and switches should be placed in an approved cabinet outside of the dust rooms, or if necessary to locate same in the dust room, cabinet must be dust proof and arranged with self closing door."

In subsequent editions of the Code we find similar rules continued and additional regulations included to provide necessary protection for motors located in dusty places. In the 1909 edition for instance, this rule is found in section 8 -"Motors: must be covered with a waterproof when not in use and, if deemed necessary by the Inspection Department having jurisdiction, must be enclosed in an approved case. Such enclosures must be readily accessible, dustproof and sufficiently ventilated to prevent an excessive rise of temperature. Where practical, the sides should be made largely of glass so that the motor may always be plainly visible. The use of enclosed type motor is recommended in dusty places, being preferable to wooden boxing."

This same edition of the Code provides that: "When switches are used in rooms where combustible flyings would be likely to accumulate around them, they must be enclosed in dust tight cabinets."

Thus we see that many of the National Code rules for hazardous locations were formulated, in intent at least, during the early days of electrical development. Efforts were made in succeeding issues of the Code to clarify and extend the rules for these so-called hazardous locations in order to make their application better understood. It was left entirely to the judgment of the inspection authority, without guidance, as to whether or not the locations involved should be considered as hazardous.

With the 1923 edition of the Code came an entire re-arrangement of subject matter by which the Code was divided into a number of Articles, each of which treated a separate division of electrical wiring or apparatus. In this issue we find the formation of Article 32 carrying the title "Extra Hazardous Locations," a single page outline of the precautions necessary when electrical equipment was installed in locations "where highly flammable gases, liquids, mixtures or other substances are manufactured, used or stored, in other than original containers." However, there were still retained in the respective general Articles of the Code the rules requiring the protection of lamps, switches, motors and other apparatus exposed to flammable

dust or flyings. Although this rearrangement of the Code was a step in the right direction, the desired results were not entirely accomplished as the rules were distributed throughout the Code in such a manner that a person desiring complete information on the Code requirements for hazardous locations was put to considerable trouble in attempting to select the rules applying out of a great deal of matter not directly concerned with the problem at hand.

In 1911 the work of preparing the National Electrical Code was passed from the Underwriters' National Electric Association to the National Fire Protection Association (N.F.P.A.) under whose auspices it is still prepared. In addition to the National Electrical Code, the N.F.P.A. sponsors a number of other Codes on fire prevention and protection subjects. A survey of these Codes made by the writer in 1927 revealed that many of them contained specific rules for the installation of electric wiring and apparatus in certain occupancies generally considered hazardous by inspection authorities. Many of these electrical rules differed widely both in wording and intent from the rules in the Electrical Code in spite of the fact that these rules were intended to protect against exactly the same hazards. For instance, it was found that the N.F.P.A. regulations for Dry Cleaning Plants, edition of 1925, provided that all wires for lighting circuits be placed in conduit while the Electrical Code permitted either armored cable or conduit wiring in locations where highly flammable liquids were used. Such differences in rules were found to be quite extensive throughout, and as a result, there was considerable confusion in their application. This may have introduced serious conflicts where municipalities or states had adopted both sets of regulations as parts of their fire prevention ordinances.

Many inspection authorities considered the National Electrical Code, in itself, an insufficient guide for obtaining the proper type of electrical installations in certain hazardous occupancies. The natural result of this opinion was the development of individual special rules and even special codes by municipalities and insurance underwriters specializing in certain hazardous classes of plants. This trend presented a definite obstacle to the adoption of the National Electrical Code as the single American Standard, at least in point of usage. Special rules and special codes work directly against the interests of the much desired uniformity and, hence, it was felt that considerable could be accomplished in the direction of general acceptance by rewriting Article 32 of the Code to include complete rules for all hazardous locations in the one Article. It was also felt desirable to attempt to coordinate the many special rules in other N.F.P.A. Codes in such a way as to make necessary in them only a simple reference to the proper classification in Article 32 of the National Electrical Code.

In 1927, at the suggestion of Mr. A. R. Small, Chairman of the Electrical Committee of the N.F.P.A., the writer who had been appointed Chairman of Article 32 Sub-Committee proceeded, with the help of the members of his Sub-Committee, to make a study of industry in general to ascertain in what industries and to what extent there existed hazardous processes involving or producing liquids, vapors, gases, dusts, fibers or other hazardous substances of a highly flammable, explosive or easily ignitable nature. This study was made through actual inspections of representative plants and by reading available literature on the subject. The published N.F.P.A. Codes treating the various hazardous industries or processes were consulted, for it was felt very desirable to include in the proposed Article 32 the ideas of the writers of those Codes so far as it could be done consistently. All available reports of fires and accidents involving the hazardous conditions under consideration were studied, for from such reports was obtainable the most accurate information on the actual conditions existing in the field.

The report of Article 32 Committee which resulted from this preparatory study was unanimously approved at the February 1928 meeting of the National Code Committee and subsequently adopted by the N.F.P.A. at its annual convention as an amendment to the National Electrical Code. As presented at that time, Article 32 consisted of three classifications, viz: Class I, those locations dealing with flammable vapors, gases and liquids; Class II, those dealing with flammable dusts; and Class III, those dealing with combustible fibers and lint. The latter class was subsequently divided so as to make a fourth - Class IV, which deals with the storage of cotton and other combustible fibers. Except for this latter and a few other minor changes, Article 32 remains as adopted originally and so appears in the latest (1931) edition of the National Electrical Code which has been adopted as an American Standard by the American Standards Association.

From the many favorable remarks which has been heard, the writer is led to believe that the new Article 32 has filled a very definite need on the part of inspection authorities. Considering the relative newness of the rules, their application has been quite general and as a result, it is the opinion that a marked improvement has been made in electrical installation in hazardous locations. Some questions of interpretation have been raised, however, on some parts of Article 32. This is especially true of those parts in which the attempt is made to define the conditions and processes which warrant the particular location involved being classed as hazardous.

Interpretations have also been requested at various times on the meaning or application of certain rules. It is the purpose of this paper to attempt to answer these questions; first, by discussing a number of typical materials and industries for the purpose of determining where and to what extent hazardous

conditions obtain; and second, by going into detailed explanation of each rule, illustrating its application with drawings or photographs of available apparatus or actual installations in the field. Included also are a number of typical fire and accident reports involving hazardous locations which serve to emphasize the importance of the subject.

It should be pointed out that the procedure in the development of Article 32 is reversed from that usually followed. That is, the rules were developed before the electrical manufacturers had suitable apparatus available to comply with them. However, considering the short space of time which has elapsed since the Article was formulated, surprising progress has been made and we now find complete lines of motors and control apparatus of specially approved types readily available on the market. Rapid headway is also being made in the design of suitable lighting fixtures, fittings and other devices specially for hazardous locations.

Standards for the performance of motors, controllers, fittings and lighting fixtures have been developed by the Underwriters' Laboratories as have suitable apparatus and methods for their testing. The manufacturers are making full use of these facilities.

It is gratifying indeed to witness such a complete alignment of interests in this comparatively short space of time in the effort to obtain safer electrical installations in the hazardous industries. A marked tendency toward the reduction of loss of life and property must surely follow.

PART II

CLASSIFICATION

Containing a discussion of
(1) types and characteristics
of hazardous materials and,
(2) industries and processes
using or producing these
hazardous materials, as per-
taining to their classifi-
cation under the rules of
Article 32 of the National
Electrical Code.

CLASSIFICATION

EXPLANATORY

In the formation of the present Article 32 of the National Electrical Code, it became apparent to those responsible for its development that it was necessary to provide the proper forms of apparatus and wiring to suit the particular type of hazardous condition to which they would be exposed. For instance, a motor which could be operated with perfect safety in an atmosphere of combustible dust might not be safe for operation in a location where an explosive mixture of a flammable gas or vapor and air was present. Conversely, while it might happen that a motor suitable for use in an explosive vapor and air atmosphere would be safe for use in a dusty atmosphere, it seemed unfair to require the installation of a motor designed to a more rigid standard than the actual requirements demanded. Therefore, a close study of the nature of each type of hazardous material was necessary to make certain that the type of electrical installation for locations where such material was used, stored or handled was suitable and safe.

While the term "hazardous material" in the larger sense may mean a material which is a hazard to life and property because of its ease of ignition, toxicity, combustibility or susceptibility to spontaneous ignition, we are immediately concerned only with its hazard from the standpoint of the possible effects of ignition of the material (or its vapors mixed with air) by arcs, sparks or high temperatures resulting from the normal or abnormal operation of electrical apparatus and wiring.

Closely associated with the hazard of the material itself is the process or manner in which it is used. To illustrate, let us assume a typical case of varnish or lacquer in which a highly flammable volatile liquid, such as naphtha, is used as the thinner. While such a preparation might be stored with comparative safety in tightly closed containers on the shelves of paint stores or in warehouses, a considerable hazard is introduced when this same varnish or lacquer is used in connection with the spray finishing of furniture or similar goods. Thus, a study of the processes involving the various hazardous materials and the methods by which they are manufactured and used was an important step in the formation of Article 32.

We shall, therefore, proceed to discuss, first the types of hazardous materials, their properties and hazards, and second, the processes, both specific and general, involving their use and handling.

CLASSIFICATION AS TO TYPES OF HAZARDOUS MATERIALS

A survey of the field of commerce and manufacture revealed that the various forms of hazardous matter could be grouped into the following general types:

1. Flammable liquids, which may be divided into two classes, viz:

   (a) Volatile flammable liquids, those giving off flammable vapors at ordinary temperatures.

   (b) Relatively non-volatile flammable liquids, those giving off flammable vapors at temperatures not reached in their ordinary use.

2. Flammable gases, those gases which form flammable or explosive mixtures with air as contrasted with inert gases such as nitrogen, or gases which support combustion such as oxygen.

3. Highly flammable solids, which might more fairly be classed as explosives.

4. Highly flammable mixtures, which in reality are combinations either of a material in one of the foregoing classes with a non-hazardous substance as in the case of rubber cement, or a combination of two or more materials of the same or separate foregoing classes as in the case of pyroxylin lacquer.

5. Combustible dusts, which may be either carbonaceous or metallic in nature, either in themselves easily ignitable or capable of forming explosive mixtures with air.

6. Easily ignitable combustible lints, fibers or "flyings."

7. Combustible light material such as wood shavings or paper trimmings.

It was found convenient to arrange these types of hazardous materials into four groups and treat each as a separate class insofar as electrical rules are concerned. In Section 3201 of the 1931 edition of the National Electrical Code, we find these four classes defined as follows:

Class I locations are those in which flammable volatile liquids, highly flammable gases, mixtures or other highly

flammable substances are manufactured, used, handled or stored in other than their original containers.

Class II locations are those in which (1) combustible dust is thrown or is likely to be thrown, into suspension in the air in sufficient quantities to produce explosive mixtures or (2) those where it is impracticable to prevent such combustible dust from collecting in such quantities on or in motors, lamps or other electrical devices that they are likely to become overheated because normal radiation is prevented.

Class III locations are those in which easily ignitable fibers or materials producing combustible flyings are handled, manufactured or used and which are hazardous through such fibers or flyings collecting on or being ignited by arcing contacts, resistors, lamps or similar apparatus. For combustible fiber warehouses see paragraph e of this section and section 3206 of this article.

Class IV locations are those in which easily ignitable combustible fibers are stored or handled (except in rooms wherein process of manufacture) and which are hazardous through such fibers being ignited by arcing contacts, resistors, lamps or similar apparatus.

It will be noted from these definitions that all of the various types of hazardous materials previously listed are included in what appears to be an entirely logical arrangement. It was possible through this method of classification to draw individual sets of rules for each class in such a manner that all rules of each set apply with few exceptions to all conditions met in the respective class. Such treatment is much to be preferred to one in which an attempt is made to have one set of rules apply to all conditions of use of all types of hazardous materials.

The conditions represented by Class III and Class IV are somewhat alike inasmuch as both treat with readily ignitable materials of the lint type. However, Class IV locations represent those where easily ignitable fibers are stored. The rules under it will be applied chiefly to the large cotton warehouses common in the Southern States at terminal points and the majority of these rules formerly appeared in the N.F.P.A. regulations on "The Storage and Handling of Combustible Fibers." The rules in Class IV are somewhat more rigid than those in Class III for it was felt necessary to take every precaution to prevent ignition of stored fibers in large storages because of the high values of property involved. The N.F.P.A. Committee on "The Storage and Handling of Combustible Fibers" has amended their regulations to include only a simple reference to the rules of Class IV, deleting its own detailed electrical rules.

HAZARDOUS MATERIALS AND THEIR CHARACTERISTICS

In order that the engineer may have a more complete knowledge of the characteristics of the various hazardous materials under consideration, it seems advisable to discuss in some detail some of these characteristics. Matters such as flashpoints, ignition temperatures and flammable limits of vapors have an important bearing on the selection of electrical equipment for locations where flammable liquids will be used. Likewise, ease of ignition is of great importance in the choice of electrical equipment for dusty or linty locations.

It is not intended that the following discussion be considered a complete treatise on the subject. There are many excellent publications available, as will be seen by referring to the bibliography, which cover the subject very completely.

The examples of the hazardous materials given under each type are partial lists only. Space would not permit listing every known hazardous material and its characteristics. However, should the engineer encounter any material of the hazards of which he is in doubt, he should submit the problem to the Underwriters' Laboratories, the National Fire Protection Association or other acknowledged and competent organization for analysis. In the case of hazardous chemicals and flammable liquids, the N.F.P.A. Committee reports and regulations will be found very useful.

Flammable Volatile Liquids

The hazard incidental to the storage, handling and use of flammable volatile liquids is an important and serious matter in many industries. In some instances, such as in dry cleaning operations, these liquids are used in an unmixed state, but the important uses of flammable liquids in industry are represented by their employment as vehicles or solvents for finishes, as constituents of manufactured materials and as solvents for rubber or similar substances for the purpose of reducing them to a plastic state.

The handling of flammable volatile liquids in large quantities has also become a serious problem for the fire prevention engineer. Such handling involves the use of pumps, piping and tanks, which, while introducing relatively little hazard when in proper operation, become major hazards when irregularities such as leakage or rupture of such equipment occurs. Unfortunately, accidents of this type are not uncommon and therefore, electrical apparatus and wiring must be designed with full consideration given to such possibilities.

In order that a clear understanding of the hazards of flammable volatile liquids might be had, it is necessary that one be somewhat familiar with their characteristics. To this end let us first discuss the various terms associated with them. This involves mention of volatility, flash point, ignition temperature, flammable or explosive limits, vapor density, and their definitions.

Volatility is the tendency of a liquid to assume the vapor state, that is, to evaporate. This tendency varies quite widely for the various liquids. For instance, gasoline evaporates much more rapidly than kerosene, while paraffin oil evaporates very slowly. For all liquids the volatility increases with rise of temperature, and for any liquid there corresponds a temperature below which it will not assume the vapor state in dangerous quantity. This temperature then becomes a dividing line above which a flammable or explosive mixture may be formed with the surrounding air by the vapor from the liquid. The determination of this temperature is of great importance in classifying the hazards of a liquid. The flash point test is used when possible in the case of liquids of both high and low volatility, to determine the temperature at which liquid gives off vapors in sufficient quantities to form a flammable or explosive mixture with the surrounding air. This temperature is usually referred to as the flashpoint of the liquid and has long been used by fire prevention engineers as an approximate measure of the fire hazard of the liquid. In cases where a liquid is composed of a mixture of volatile ingredients, the flash point tests made by the conventional closed or open cup methods are not a truly reliable measure of the hazard of a liquid and therefore, the tests must be supplemented by further tests, but discussion of these tests is not within the scope of this work.

Apparent Ignition Temperature, as applied to the vapors given off by flammable liquids, is the designation given to the lowest temperature to which any part of a vapor air mixture must be raised by the application of heat, whether in the form of a flame, spark or a hot surface, to produce combustion that will propagate itself. The "apparent ignition temperature" is of great value for comparative purposes, and in indicating dangerous temperature limits of exposure particularly in industrial operations.

Flammable or Explosive Limits. In the case of most flammable liquids, there is a minimum as well as maximum concentration of vapor in air below and above which, respectively, propagation of flame does not occur on contact with a source of ignition. These are known as the lower and higher flammable or explosive limits and are usually expressed in terms of percentage of vapor in air by volume. Between the lower and higher limits, there is a certain concentration that will produce the most intense combustion or explosion of which the vapor is capable. It is this concentration that we attempt to secure, for instance,

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when we adjust the carburetors of automobile engines. The difference between the two limits is known as the flammable or explosive range. For gasoline, as an example, the lower limit has been found to be approximately 1.4% while the upper limit is approximately 6%, giving a range of 4.6%.

Vapor Density is the weight of a given volume of vapor as compared with the weight of an equal volume of air taken as a standard under similar conditions as to temperature and pressure. Consideration of vapor density is important as it is an accurate indication of the behavior of vapors with respect to their movement when released from containers such as tanks or piping. For instance, we have found that gasoline vapor, which is known to be heavier than air, has a tendency to collect in the basements or pits of gasoline filling establishments. Many serious explosions have occurred in such locations because of this tendency and as a result, the rules governing electrical installations in such locations give full recognition to the behavior of gasoline vapor and similarly with other flammable volatiles. The following table gives the relative densities of the vapors of several common volatile liquids:

Table No. 1.

Vapor	Approximate Vapor Density Air equals 1
Alcohol Methyl	1.1
Alcohol Ethyl	1.6
Acetone	2.0
Ether Ethyl	2.6
Benzene	2.7
Gasoline (Mean value)	3.5
Kerosene (Mean value)	4.5

It is well known that when a gas or vapor has a density less than that of air, it will ascend and tend to mix comparatively rapidly with air. On the other hand, relatively heavy vapors will tend to descend and to diffuse or mix with air very slowly. In fact, the velocity of diffusion of a gas or vapor varies inversely with the square root of its density, so the lighter heavier-than-air vapors mix more rapidly than the heavier vapors.

As an aid to fire prevention engineers, the Underwriters' Laboratories have adopted a method of testing and listing flammable liquids which has been widely applied. A complete explanation of this method is contained in a most excellent brochure written by Mr. A. H. Nuckolls, Chemical Engineer of the Laboratories, entitled "Underwriters' Laboratories' Method for the Classification of the Hazards of Liquids." The method, too lengthy to be explained here, involves a general classification

of liquids and embraces the assignment of the various flammable liquids to positions on a numerical scale of hazard ranging from 0 to 110 as follows:

Table No. 2.

General Classification	Numerical Hazard Rating Scale
Ether Class	100 - 110
Gasoline Class	90 - 100
Alcohol (Ethyl) Class	60 - 70
Kerosene Class	30 - 40
Paraffin Oil Class	10 - 20

In explanation of the foregoing table, it should be pointed out that pure ether is given a rating of 100; a standard kerosene with a flashpoint of 100 degrees F. (closed cup tester) a rating of 40; and paraffin oil with a flash of 440 degrees F. a rating of 10.

The general practice of fire prevention engineers has been to regard a flash point of 100 degrees Fahrenheit as the dividing line on which to differentiate the volatility hazards of common liquids, in other words, to regard liquids of the kerosene class, or higher in flash point temperature, as relatively non-hazardous. For general practice, when such relatively low hazard liquids are not heated, but are used at ordinary room temperatures, this is probably a safe guide, but a careful investigation should first be made of the uses and processes involving the liquid before definite conclusions are reached.

In arriving at the numerical hazard classification, full consideration has been given to vapor ignition temperatures. The ignition temperatures of the vapors of most common liquids, particularly those of petroleum products, are considerably above ordinary temperatures and usually high temperature sources of ignition such as arcs, sparks, or flames are necessary to cause fire. There are some vapors such as those of carbon disulphide which have ignition points as low as 212 degrees Fahrenheit

Since the Underwriters' Laboratories originated this method of hazard classification of liquids, many commercial liquid products such as solvents, thinners for paints and varnishes, floor oils and many other have been tested and the results published in the Underwriters' Laboratories' lists. Reference to these lists will inform the engineer regarding the hazard of these products.

In the following table will be found the hazard classification of a number of common flammable liquids, together with their flash points, apparent ignition temperatures and hazard classifications. This table is based on the table appearing in the brochure by Mr. Nuckolls which was previously mentioned.

Table No. 3.

Liquid	Flash Point (Closed Cup) Deg. Fahr.	Apparent Ignition Temperature Deg. Fahr.	Hazard Classification
Acetone (C.P.)	3	1000-1050	90
Acetate, Amyl (Pure)	77	750-800	55-60
Acetate, Butyl, Normal (C.P.)	84	700-825	55-60
Acetate, Ethyl (C.P.)	28	800-925	90
Acetate, Methyl (Anhydrous)	14	850-925	90-100
Acetic Acid, Glacial (99.5)	107	800-925	
Acetic Anhydride (C.P.)	127	600-675	
Alcohol, Amyl (Fusel Oil)	100	700-725	40
Alcohol, Amyl Sec. (Technical)	94	650-725	40
Alcohol, Amyl Iso	114	650-725	35-40
Alcohol, Butyl Iso (106-108°B.P.)	88	700-800	40
Alcohol, Butyl Normal (116-118°B.P.)	100	650-725	40
Alcohol, Denatured (Formula No. 5)	61	750-810	70
Alcohol, Ethyl (Absolute)	54	700-800	70
Alcohol, Methyl (C.P.)	52	800-900	
Alcohol, Propyl Iso (81.5-82.1°B.P.)	61	750-850	70
Alcohol, Propyl Normal (96-98 B.P.)	77	700-800	55-60
Aniline (C.P.)	183	1000-1025	
Aniline, Dimethyl (C.P.)	165	700-750	
Benzol (C.P.)	-4	1000-1060	95-100
Benzaldehyde (C.P.)	147	377	
Carbon Disulphide (C.P.)	-22	212-223	110 Plus
Ether, Ethyl (C.P.)	-49	356	100
Furfural (54-55°B.P./17mm.)	143	600-675	
Gasoline (74-76 A.P.I.)	-45	536	90-100
Hexane (From Petroleum)	-15	500-565	90-95
Nitro Benzene (C.P.)	198	900-950	
Petroleum Ether (40-60°B.P.)	-69	624	95-100
Pyridine (C.P.)	74	900-1100	55-60
Toluene (C.P.)	48	1050-1125	75-80
O-Toluidine (83-85°B.P./15mm.)	202	900-1000	
Xylene (138-139°B.P.)	86	900-1150	

Several additional flammable liquids were included in the original list some of which are ordinarily considered hazardous only from the standpoint of contributing to the spontaneous ignition hazard, a subject with which we are not immediately concerned.

This table is not intended to include all flammable volatile liquids encountered in industry, but does probably contain those most commonly found. Two widely used flammable volatile liquids are the so-called naphtha and benzine neither of which will be found in Table No. 3. In the petroleum refinery industry, benzine is that fraction of the oil which

boils between 158 and 248 degrees Fahrenheit. Its hazard rating is slightly higher than that of gasoline, namely, 100. Naphtha is a term formerly applied to a petroleum distillate of a definite specific gravity, but is now generally used to include any petroleum distillate with a flash point less than 280 degrees Fahrenheit. It also has been given a hazard rating of 100.

The use of the information given in Table No. 3 is best illustrated by assuming a typical case where gasoline is being used as a solvent in an open tank within a building. We find by referring to the table (Table No. 3) that gasoline gives off flammable vapors at a temperature as low as minus 45 degrees Fahrenheit, that is, at much below ordinary room temperatures. We can then expect that a considerable amount of gasoline vapor will be present in the vicinity of the tank, and, unless continually effective means are provided for the removal of these vapors they will diffuse quite rapidly, mixing with the air probably in explosive proportions. All that is needed then, is a source of ignition having a temperature equal to or higher than the apparent ignition temperature of gasoline vapor which, from the table (Table No. 3), we find to be 536 degrees Fahrenheit. An electric spark or arc occurring in the open in this atmosphere would be sufficient to cause ignition as would the temperature reached by the frame of an open motor in event of burnout. Consequently, these factors must receive full consideration in deciding what types of electrical equipment are safe in such atmospheres.

Flammable Gases

Flammable gases form explosive mixtures with air in the same manner as do the vapors of flammable liquids which we have previously discussed. The hazards of the two classes of matter are, therefore, quite similar from the viewpoint of the fire prevention engineer. The same problems of storage, handling and use are present, and as in the case of flammable volatile liquids, it is true that if it were possible to positively confine flammable gases within tanks and piping or within the stoves, heaters, ovens or other devices specially designed to consume the gas, the hazard involved in connection with flammable gases would be slight. However, experience has shown that leaks develop in tanks and piping, that pumps or compressors become defective from wear and rupture, and that very often in the process of manufacture of gas the retorts and other apparatus burst. Naturally, when such an accident occurs within a building, the room or often the entire structure is filled with a highly explosive mixture of gas and air, lacking only a source of ignition to cause havoc. Such occurrences have been only too frequent and electrical hazards have been contributing factors in many of them.

Within recent years we have witnessed the introduction of various hydrocarbon gases in liquified form for use in communities where natural or manufactured illuminating gas was not available. We have also seen marked extension in the practice of piping natural gas to points far remote from the gas fields. These developments have had the effect of introducing explosion hazards, especially in pumping or compressing stations.

In the following table will be found listed a number of flammable gases with their commonly accepted explosive limits, densities and ignition temperatures:

Table No. 4.

	Explosive Limits In Percentage by Volume.	Relative Weight To Air.	Apparent Ignition Temperature Deg. Fahr.
Illuminating Gas	7 - 21	.65	1094
Hydrogen	9.5 - 66.5	.069	1031
Acetylene	3.2 - 52.2	.898	948 - 959
Ethylene	4.2 - 14.5	.967	1071 - 1110
Ethane	3.3 - 10.6	1.0494	950 - 1152
Propylene		1.451	927 - 952
Propane	2.3 - 7.3	1.505	870.8
Carbon Monoxide	16.6 - 74.8	.967	1177 - 1497
Butane	1.6 - 6.5	2.01	806
Methane	5.6 - 13.5	.5576	998.6
Hydrocyanic Acid Gas	5.6 - 39.8		725

Of the liquified hydrocarbon gases used for heating and lighting purposes, butane and propane are very common. These are often sold under trade names as in the case of Blau Gas, named after its inventor. Pintsch Gas is a product made in much the same manner as ordinary coal gas except that petroleum is decomposed rather than coal.

Highly Flammable Solids

In this class we may place many commercial solid substances which might well be called explosives, for in the final analysis, the only distinction between ordinary combustion or burning and explosion is the rate at which the action takes place.

Gunpowder, dry picric acid, nitrocellulose, nitrosophenol, naphthalene and pyroxlyn plastic are prominent examples of highly flammable solids which may be encountered.

In the more usual manufacturing operations, pyroxylin plastic, better known as "celluloid", probably represents the most hazardous material found. It is a material which is used to a great extent for the manufacture of many types of goods, including toilet articles, photographic film, artificial leather, billiard balls, piano keys, and a host of others. Its manufacture and use involves great hazard for its ignition point is extremely low, probably in the neighborhood of 300 degrees Fahrenheit and may, therefore, be ignited by any slight spark or arc, or even by the heat of an incandescent lamp. It burns very rapidly and combustion is attended by the rapid evolution of explosive and poisonous fumes or vapors. It is stated that 1000 pounds of pyroxylin plastic will form from 3000 to 85000 cubic feet of vapor. This decomposition may begin at a temperature much lower than that of actual ignition and with it occurs a gradual rise in temperature which in itself may be sufficient to cause fire. Considerably more will be said on this subject in discussion to follow.

Highly Flammable Mixtures

Many substances, in themselves non-hazardous from the standpoint of ignition points and combustibility, are formed into hazardous materials or mixtures when low flashpoint solvents are used to place them in solution or to form a paste. When the process or use involves the solution of a hazardous material in an equally hazardous solvent, the resultant hazard is usually greatly multiplied.

As a representative mixture of the class first mentioned, we have rubber cement which is usually dissolved in gasoline or naphtha. This type of cement is used in many processes in the rubber industry, often in such a manner that the rooms in which operations take place have a very appreciable amount of gasoline or naphtha vapor present, necessitating adequate artificial ventilation and rigid precautions to remove sources of ignition. Of the second class, where a hazardous solid is dissolved in a flammable volatile liquid, a good example is afforded by pyroxylin spray finishes or lacquers of which "Duco" is a popular trade brand. These finishes or lacquers consist of pyroxylin or nitrated cotton, in themselves hazardous, blended with the desired oil and pigments and mixed with very flammable volatile solvents and thinners such as, ethyl acetate, butyl alcohol, acetone, amyl acetate, benzol and high test benzine. We have already discussed the component parts of such mixtures and the hazards associated with them. More will be said about the general process of spray finishing in another chapter.

Following are a few commonly found mixtures which are classed as hazardous:

Paints, lacquers, japans and varnishes which employ flammable volatile solvents or thinners as vehicles or drying agents.

Rubber cements consisting of gum rubber dissolved in various solvents such as gasoline, naphtha or benzine.

Pyroxylin lacquers or varnishes consisting of pyroxylin or nitrated cotton dissolved in a solvent such as amyl acetate and frequently diluted or thinned with benzol or an alcohol.

Collodion made up of a solution of nitrated cellulose in ether and alcohol or in some other solvent.

Cleaning fluids which are often undiluted benzine or naphtha, although there are some fluids which are non-hazardous, and others which are only hazardous in the same degree as kerosene, such as Stoddard's solvent.

Combustible and Explosive Dusts

Combustible dusts, whether of a carbonaceous or metallic nature, form very explosive mixtures when mixed with air in proper proportions. The theory of dust explosions is very similar to that of flammable vapors or gases. Various dusts have definite flammable or explosive limits as do vapors, and there must be present a source of ignition of sufficient intensity to ignite the dust and air mixtures.

Considerable research and experimental work has been done in an attempt to determine the characteristics of various dusts. As a general thing, it has been determined that any dust from a highly carbonaceous material, or from any material which will burn, will explode under proper conditions. In the carbonaceous dust class will fall dusts such as coal dust, flour dust, starch dust, grain dust and wood dust. While metallic dusts such as of aluminum and bronze are not generally said to be combustible, it is a proven fact that they are explosive under proper conditions.

When a finely divided combustible dust is in suspension in air so as to give access to an abundant supply of oxygen, combustion once started, usually proceeds with explosive rapidity. The force of a dust explosion cannot be appreciated until one has had the opportunity of viewing its effects. The writer has seen reinforced concrete walls seven inches or more in thickness shattered into bits by a grain dust explosion. In a cereal mill explosion, it was reported that debris was found at a distance of more than two and one half miles from the plant.

Dust explosions, especially those which involve grain elevators and flour mills, occur in a series of two or more explosions of increasing intensity. The primary explosion is usually of a minor intensity, but the forces set up are of such a nature as to dislodge other dust which is in turn ignited, producing an explosion of magnified volume and destructiveness.

It is not the intent to discuss at great length the theory of dust explosions. For those who wish to study the problem further, they are referred to an outstanding work on the subject, "Dust Explosions" by Drs. Price and Brown of the U. S. Department of Agriculture.

Statistics show that common sources of ignition of dust and air mixtures have been electric arcs, sparks and overheated electrical machinery or devices. Hence, the need for special consideration of the type of electrical installation which should be permitted in dusty locations.

There are two angles of the case which require treatment as has previously been pointed out; first, those where combustible dust is thrown or likely to be thrown into suspension in the air in sufficient quantities to produce explosive mixtures; and, second, those where it is important to prevent such combustible dust from collecting in such quantities on or in motors, lamps, or other electrical devices, that they are likely to become overheated because normal radiation is prevented. In the first, the rules in the body of Article 32, Class II are designed to prevent ignition of suspended dust by electrical arcs or sparks originating from the operation of switches, fuses and the brushes of motors or the breakage of electric lamps. In the second case we consider the ignition of dust through overheating of motors because normal radiation of heat is prevented by accumulations of dust on the windings of the motors and in their ventilating slots, or the ignition of dust by heat from electric lamps or resistors.

To illustrate, consider a modern flour mill with an up-to-date dust collecting system and adequate housekeeping. It is probable that dust would not accumulate in open type motors to such a degree that overheating would result, yet it would be extremely important to remove to a non-hazardous location motors of the brush type unless the brushes and slip rings were enclosed in dust tight housings or the entire motor enclosed. In this there is present a problem of mathematical probability of an electrical fault occurring at the same moment when dust is in suspension in the air in explosive proportions. More will be said of this later, but for the time, suffice it to offer the suggestion that only the most rigid precautions be enforced to eliminate sources of ignition in view of the human lives and property values which might be sacrificed in event of an explosion coming as the result of too great a dependence on the result of applying the principles of probability.

Following are typical examples of dusts which have been definitely classed as explosives:

Grain Dusts	Spice Dust
Rice Dust	Cocoa Dust
Starch Dust	Sulphur Dust
Flour Dust	Hard Rubber Dust
Wood Dust	Dextrine Dust
Coal Dust	Sugar Dust
Cork Dust	

Easily Ignitable Combustible Fibers

Easily ignitable combustible fibers have proven to be decidedly hazardous materials due to the ease of ignition and the speed at which flames spread through them when once ignited. When a fibrous material such as cotton is distributed in the form of lint or "flyings" in a thin film over machinery and building members, a fire travels with almost explosive speed through the entire room. Such fires are usually called "flash fires."

When fibers are compressed into bales and wrapped with burlap, the apparent hazard would seem to be reduced. However, in baled storage there is usually sufficient loose lint protruding from the bales to permit travel of fire over the surface with amazing speed. Very often smouldering fires are left in individual bales after the primary flash fire, and these are very difficult to extinguish.

Many vicious fires have occurred in the large terminal cotton warehouses, especially in those of the less modern type where the warehouses are of several acres in area without fire cut-off partitions. Large property values are usually present.

In manufacturing operations involving combustible fibers such as in the picking department of cotton mills, in mattress factories and in upholstery works, the primary hazard is somewhat increased due to the fact that the materials are handled in light, loose form offering ample surface for ignition and combustion. However, the amount of material present is considerably less than in the terminal warehouses and, therefore, the actual property loss may be somewhat smaller.

In cotton ginning plants we find cotton in a very loose form and in the gin building it is not usual to find much lint clinging to machinery, building members and lamp cords. The amount of cotton in the gin house at any one time is usually small, but a fire once out of control is difficult to extinguish. The bad fire record of cotton gins attests to the hazards involved.

Electrical hazards occupy a prominent position in the list of causes of fires in the combustible fiber industry. The breakage of electric lamps, overheated motors, sparks from motors and short circuits have all been prominent figures in disastrous fires. The need for a superior type of electrical installation for such industries has been clearly shown.

While cotton is probably the most common of the combustible fibers, others are of importance. The following list includes most of those commonly found:

Cotton	Tow
Sisal or Henequen	Cocoa Fiber
Ixtle	Oakum
Jute	Baled Waste
Hemp	Kapok
Spanish Moss	Excelsior

Combustible Light Material

In this class are included paper, wood shavings, wax-coated papers and similar materials which, while comparatively easily ignitable, are not to be considered as hazardous as the others previously discussed. In some types of industries, however, the amount of material present renders the hazard a real one, as a fire once started in transmitted with considerable speed, especially when the material is in loose form.

In the case of paper, we do not have the hazard of collection of the material in the windings of motors,on lamps, or within switch boxes as might be the case with wood shavings or sawdust. Therefore, the classification of the hazards of this type of material, from our viewpoint, is not as definite as in the case of other types of hazardous materials.

The engineer is required to make a complete study of possible conditions in each instance in order to determine what precautions should be taken in the choice and installation of electrical equipment. Ordinarily, only reasonable enclosing of sparking apparatus is necessary to provide the needed safeguards.

CLASSIFICATION
AS TO
INDUSTRIES AND PROCESSES

General Procedure

Having discussed the characteristics of the various hazardous materials we shall now consider the industries and processes which produce, use, or otherwise handle these materials, in an attempt to determine where and to what extent special consideration must be given to the selection and installation of electrical equipment.

In the fine print notes following the definitions in Section 3201 of the 1931 edition of the National Electrical Code, some guidance is given to the engineer to assist him in determining in what industries or processes the hazards specified in the bodies of the definition were likely to occur. These fine print notes suggested the following for the respective classes.

Class 1. This class may include such locations as some parts of dry cleaning and dry dyeing plants, pyroxylin plastic manufacturing plants, spray painting establishments, gas plants, varnish manufacturing plants, and establishments or industries involving similar hazardous processes or conditions.

Class 2. This class may include such locations as some parts of flour mills, feed mills, grain elevators, starch plants, sugar, cocoa and coal pulverizing plants, and establishments or industries involving similar hazardous processes or conditions.

Class 3. This class may include locations such as some parts of cotton and other textile mills, combustible fiber manufacturing plants, cotton gins, clothing manufacturing plants, cotton seed mills, woodworking plants and establishments or industries involving similar hazardous processes or conditions.

Class 4. This class may include locations such as warehouses in which are stored or handled combustible fibers, such as cotton (including cotton linters and cotton waste), sisal or henequen, ixtle, jute, hemp, tow, cocoa fiber, oakum, baled waste, kapok, Spanish moss, excelsior and other similarly readily ignitable fibers.

It is obvious that it would be impractical to attempt to list all hazardous industries or processes in these fine print notes and endeavor to point out with any degree of exactness the extent of the hazardous area. Some of the more prominent examples of industries and processes are included, how-

ever, which were for the purpose of giving the engineer some idea as to what type of hazards were intended to be covered by each respective class.

As the introductory rule of Article 32, (Rule 3201a), there appears the following: "The provisions of this article are intended to apply to locations in which the authority enforcing this Code judges the apparatus and wiring to be subject to the conditions indicated by the following classifications. Where the apparatus and wiring are installed in rooms or sections in which the particular hazardous conditions do not prevail, such wiring and apparatus may be of the type approved for such locations. For garages see Article 33." From this rule it is seen that the authority enforcing the Code is charged with the responsibility of determining where and to what extent the apparatus and wiring are subject to the hazardous conditions. Without some knowledge of the hazards of materials and the processes involving their use, the engineer or inspector enforcing the rules will encounter considerable difficulty. The second sentence of this rule suggests the possibility of so isolating electrical apparatus from the hazardous area that it will not be subject to the hazardous conditions. Considerable use is made of this alternative where all machines are required to operate coincidentally in which the motors and controllers, for instance, can be located in a separate power room cut off from the hazardous area. However, in instances where machines are not required to operate at the same time, such isolation of motors may cause serious hazards to be introduced by the many additional bearings, belts and possibly clutches that would be required. In other words, the result of removing one form of hazard from a hazardous area may cause the introduction of additional hazards of a more severe nature. Overheated bearings, static electricity generated by moving belts and friction sparks in clutches have proved to be frequent causes of fires and explosions. The construction of motor rooms or other enclosures may entail considerable expense and so the advantage, from an economic standpoint, may often favor individual motor drives using motors approved for use in hazardous locations. As applied to motor controllers these might also more economically be of the type approved for hazardous locations and placed in the hazardous area, when controllers are few in number or are so widely distributed that grouping in a specially built control room is impracticable.

The power losses occasioned by the additional bearings, belts and clutches and the convenience attached to individual motor drives are also an important consideration in determining whether or not motors should be isolated from the hazardous area.

In the fine print notes quoted above it should be noted that use is made of the words: "May include such locations as some parts of," and a word or two in explanation of this phrase may be valuable. Probably the best illustration is afforded by considering a dry cleaning establishment. In the first place, if such an establishment employed none but a nonflammable solvent or cleaning fluid such as carbon tetrachloride, it would not be considered a hazardous location and,

therefore, would not be subject to the rules of Article 32. However, if a flammable volatile solvent such as naphtha were used and the establishment were divided by standard fire cut-offs into several departments, only those departments where the naphtha vapors were present in the atmosphere would be considered as hazardous locations.

This would usually eliminate, if cutoff as mentioned, the receiving department, the dusting room, the boiler room and the shipping department, but there would remain in the hazardous classification the dry cleaning room, drying room, spotting room and the solvent storage and recovery departments, all subject to the rules of Article 32, Class I locations.

From the above analysis it is clear that considerable study must be given individual cases because of the many factors which have bearing on the matter of classification. It is admittedly a difficult task to arrive at definite conclusions if the plant has not been placed in operation. However, there are several general suggestions which may serve as aids. These include:

1. A thorough study of the processes involved including an investigation of the liquids, gases or solid substances which are to be used, scrutinizing these materials from the standpoint of ease of ignition, volatility, explosibility and general hazard rating.

2. A careful checking of the machines or devices which are to be used. This to determine whether or not the hazardous materials will be confined within tanks, drums or piping, or whether or not there will be a possibility of leakage into the open room, either during normal operation or through accidents.

3. An inspection of the layout of buildings, either from building plans or by actual visual inspection. This to determine whether one small section of the plant should be thrown into the hazardous classification or whether or not the hazardous conditions extend to all parts.

4. Consulting and co-operating with other inspection authorities, particularly Underwriters' special hazards inspectors and engineers who are familar with conditions in establishments of a nature similar to those under consideration.

5. Frequent reinspections of plants involving hazardous processes or conditions to determine what conditions prevail during actual operation.

6. A study of statistics and reports on fires and accidents suffered in properties where hazardous processes are involved.

Matters such as ventilation, mathematical probability, housekeeping, confinement of hazardous materials and cutoffs also have important bearings on classification and extent of the hazardous area. Possibly a few remarks on these factors as affecting classification, will not be amiss.

Special Considerations

Ventilation: In previous discussion it has been pointed out that vapors, gases and dusts have definite explosive or flammable limits. Obviously then, it would be practical to arrange a natural or artificial ventilation system which would reduce the amount of the vapor, gas or dust in a room or building so that the resulting mixture would be below the lower flammable limit of the vapor, gas or dust involved. The N.F.P.A. regulations on "Blower and Exhaust Systems" provide the necessary instructions for the installation of suitable artificial ventilation systems, which regulations have been adopted by the various N.F.P.A. Committees dealing with hazardous processes or industries. These are generally applied to new construction and probably deal with the situation quite satisfactorily.

In actual practice, however, it would be folly indeed to place full confidence in such a ventilating system to remove enough of the vapors, gases or dusts to render the remaining mixture below the lower flammable limit under all conditions. Unusual weather conditions, the failure of the ventilating system, and the probability of insufficient capacity of the ventilating system under adverse conditions, are factors which might be the indirect cause of a serious explosion if complete faith were placed in the ventilating system.

Natural ventilating systems, consisting of vent pipes directed to the out of doors from the hazardous areas are even more unreliable. Conditions of humidity, direction of wind, and wind velocity greatly affect the value of natural ventilation and, therefore, it cannot be depended upon to consistently do the work for which it was designed.

In practically all instances, the engineer is forced to eliminate from consideration entirely, the possible value of ventilating systems in his attempts to determine the extent of a hazardous area.

Mathematical Probability: It is obvious that in order to obtain an explosion a number of conditions must prevail coincidentally. First, there must be an available supply of flammable vapor, gas or dust; second, a supply of oxygen; third, the vapor, gas or dust must be in admixture with oxygen (or air) in proportions within the flammable or explosive limits; and fourth, there must be present at the moment the mixture is within the flammable or explosive limits a source of ignition of sufficient intensity to ignite the mixture.

What then is the mathematical probability that all of these conditions might obtain at the same moment? In extreme cases

it is probable that this would not occur 99 times out of 100, yet at the 100th time, conditions might be just right for a disastrous explosion or fire which might destroy many human lives and thousands of dollars in property value.

The writer has knowledge of many instances where motors burned out or electric lamps were broken in extremely dusty atmospheres in grain elevators without an explosion, due, probably, to an "over rich" mixture of dust and air, that is, one above the explosive limit. Had the mixture been less "rich", undoubtedly an explosion would have occurred. It is probably due to this condition of widely varying mixtures that explosions in grain elevators are not even more frequent than records indicate.

No one can presume to estimate the mathematical probability of coincidence of conditions necessary to an explosion of vapor, gas or dust mixtures and, therefore, the engineer should not consider this factor in selecting apparatus or making installations where the conditions <u>may</u> be present at any time. It is far better to err on the side of safety than to gamble against the probability of conditions being such as to produce an explosion.

<u>Housekeeping:</u> The standard of cleanliness maintained in a plant has an important bearing on the fire hazard. This applies to the electrical fire hazard as well. It is a foregone conclusion that opportunity for ignition by an electrical arc in a factory manufacturing articles from pyroxylin plastic where waste material is permitted to accumulate on floors and work benches, is much greater than in a similar factory where waste is promptly deposited in covered metal receptacles.

Similarly, in a flour mill of modern design, with an adequate dust collection system and with a high standard of housekeeping, one could probably install an open squirrel cage motor with perfect safety on some floors of the mill building, as excessive accumulations of dust in the motor windings would not occur. Yet in a flour mill of less modern design, with an inadequate dust collection system and under poor supervision, one should expect even an open squirrel cage motor to be a serious electrical fire hazard.

Thus, on this basis, the engineer would feel justified in discriminating between two factories involving identical fundamental manufacturing hazards so far as a proposed electrical installation is concerned. On the other hand, he has no assurance that the favorable conditions of housekeeping, supervision and general arrangement will be continued indefinitely, and were he to approve a type of installation based on a high standard of maintenance, a change in management might cause conditions to decline to such a degree that the most rigid standard of electrical construction would not be sufficient.

Faced with such considerations, the engineer must, to a large extent, disregard housekeeping, maintenance, and general supervision in determining the type of apparatus and wiring to be installed. The only possible exception is to permit open squirrel cage motors in certain parts of flour mills and feed mills as will be discussed later.

Confinement of Hazardous Materials: In many types of processes hazardous materials are handled in what are designed to be entirely closed continuous systems. These may be so designed primarily in the interests of economy as in the case of volatile liquids where a closed system is necessary to avoid loss by evaporation. In other instances the materials are so handled in order that working conditions for employees might be improved and in others to reduce fire hazards. Usually an effort is made to keep such systems in good order and free from leaks. Yet, with even the best of maintenance, leaks develop, containers are ruptured or piping bursts because of mechanical disturbances. Should such accidents happen in a room or section of a building, which might not otherwise be classed as hazardous, such a location would immediately be subject to classification as a hazardous area.

As an example, let us consider a bulk gasoline unloading station where gasoline is pumped from tank cars to storage tanks. The pumps, usually electric driven, are generally located in a small pump house. In normal operation there is little gasoline vapor present in the pump house, but should a pipe connection develop a leak or the pump packing "blow", the pump house would immediately be filled with explosive vapor. Should an open arc from a switch or a motor occur at that moment, an explosion would surely result.

Thorough study must be given individual cases to determine just how much special dispensation should be given processes where the hazardous materials are handled in closed continuous systems. Here again the best guide is to err on the side of safety in case of any doubt.

Fire Cut-Offs: The modern manufacturing plant does not usually consist of a single area as in the older types of plants. Due to efforts of fire prevention engineers, factories are now built so as to distribute the various processes or facilities into several separated buildings, or into several rooms or departments in the same building, each cut off from the next by standard fire walls. The first thought in this action was to separate the raw and finished products from the hazardous manufacturing operations. With the introduction of unusually hazardous finishing processes, such as spraying and dipping, we find a trend toward further division by confining these hazardous finishing operations to separate rooms or sections cut off from the remainder of the actual manufacturing section. Thus, rather than grading the entire factory on the basis of the most serious hazard, namely that associated with spray or dip finishing processes, it is possible

to grade the factory as a whole on the basis of a portion being high hazard (the finishing processes), a portion medium hazard (the assembling and forming processes), and a portion low hazard (the storage of non-hazardous raw and finished products.)

The benefits of such sub-division extend to the electrical installation also, as under the conditions stated in the preceding paragraph it would be necessary to follow Class I rules, probably only in the room or section containing the finishing processes, while in the actual manufacturing section it is probable that only the rules of Class 3 or even of only the general Articles of the Code need be applied, and in the case of the storage sections only the latter.

Therefore, the arrangement of the factory, refinery, mill or whatever the plant may be has much to do with the extent of the hazardous area.

In the less modern plants, it is not uncommon to find a hazardous process in the midst of other operations with no attempt at isolation. In such cases the engineer is justified in considering a large portion of the plant as being in the hazardous area depending on the nature of the hazardous process. As an example, let us consider an old style mattress factory. In such a plant the fiber and tick stock is probably stored in one end of the room from which the fibers are fed into pickers by hand and then blown into the ticking until the desired quantity has been inserted. The sewing is then completed and the mattress carried to the storage and shipping department. It is difficult to imagine any part of such a factory which would not have a liberal quantity of fiber lint clinging to woodwork, machines and other objects and for that reason the engineer would probably specify compliance with Class 3 rules.

As has been stated previously, it is difficult to forecast the extent of the hazardous area, but in the following the writer will review some of the prominent industries and processes and attempt to advise regarding classification and extent of the hazardous area.

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INDUSTRIES AND PROCESSES AND THEIR CLASSIFICATION

FINISHING PROCESSES

In our consideration, finishing processes include the application of protective and decorative coatings to metal or wooden manufactured articles. Such coatings may be of paint, varnish, japan, lacquer or enamel and may be applied by brush, by dipping or by spraying. In general, and except for pyroxylin lacquers, the hazards of these finishing materials are those associated with the use of highly flammable volatile solvents and thinners such as benzine, alcohol, substitute turpentine, benzol, amyl, acetate and others.

In the case of pyroxylin lacquers employing a base of cellulose nitrate either gun cotton or pyroxylin, the hazard is multiplied due to the fact that not only are the vapors of the solvents and thinners almost always highly flammable, but the bases themselves are of what might be termed an explosive nature.

In large scale manufacturing operations, it is practically imperative that these highly volatile thinners and solvents be used, for modern efficiency would not permit the use of the slow drying oils such as linseed or similar oils alone, and depend entirely on absorption of oxygen from the air for drying or hardening of the finish.

Very often specially built ovens or closets are provided for the drying or baking processes and these are frequently heated to hasten evaporation of the solvent and thinner.

In most of these finishing operations there are present, therefore, definite hazards in the form of highly flammable vapors in the atmosphere in and surrounding the application and drying departments, its extent depending upon the effectiveness of the ventilation system.

Not all finishing materials should be classed as highly hazardous from our viewpoint. For instance, some enamels consist of drying oil varnishes containing finely ground pigments without highly flammable thinners or solvents and are not classed as hazardous from the standpoint of easy ignition. Others of the non-hazardous class are water-japans and paints containing only drying oils and pigments. But it should be emphasized that the addition of hazardous thinners to any of these materials, such as is necessary to promote quick drying, immediately transfers them to the hazardous class. The engineer should make careful investigations as to the type of material which is to be employed.

In the application of the coatings, the following methods are used:

The Brush Process is used more commonly in small scale operations and the work usually dried in the air without special heat. Therefore, it is common to find benzine, substitute turpentine or other volatile thinners freely used.

The Dipping Process used in both small and large scale operations consists of submerging the articles in an open tank of the coating material. The degree of hazard as before is dependent on the type of thinner used, naphtha, benzine and alcohol being the most common. When higher flash point thinners, such as kerosene or turpentine are employed, the hazard is materially lessened, but the vapors of all are flammable to a greater or lesser degree. After the articles have been dipped, they are usually placed or hung on continuous conveyors which travel through a heated drying oven to hasten evaporation of the thinner. In smaller plants the articles may be dried by the "batch" method in which the articles are simply hung on racks in drying ovens or cabinets and removed when dry. In either case, a considerable amount of flammable vapor is present within the oven or dryer. While some dependence is placed on artificial or natural ventilation for the removal of the vapors, it is imperative that all sources of ignition be removed or guarded.

The Spray Application of coating materials has come into very wide use and its growth has been attended by numerous fires and accidents. Spraying is usually done in booths or under hoods, all ordinarily equipped with positive artificial means of ventilation. The booths vary in size from that required to accomodate small articles of furniture to the mammoth tunnel type booths required for railroad coaches and automobile bus bodies. Air brushes are used to secure an even and smooth finish. The coating material may be paint, varnish, japan or enamel consisting of a mineral, resinous or oil varnish usually thinned with a flammable volatile liquid such as alcohol, naphtha, benzine, or substitute turpentine to permit of ready flow. But more hazardous from our standpoint are the pyroxylin varnishes or "lacquers" which have already been mentioned. When such materials are used in spray finishing, we not only have the atmosphere charged with the vapors of a highly flammable solvent or thinner, but also with a fine dust or residue which is in itself an explosive. This dust or residue is highly combustible and very easily ignitable, decomposing at low temperatures, often spontaneously. It is found that the dust forms a coating on the interior of the spray booth or hood and in the vent pipes connected to it, necessitating extreme caution to prevent ignition. The hazard of this type of lacquer is considerably reduced when a base of cellulose acetate is used rather than cellulose nitrate, but we still have the hazard of the thinner to contend with. Much could be written regarding the hazard of pyroxylin spraying operations, but space does not permit.

All rooms or departments containing finishing processes, including the drying or baking ovens, should be considered as candidates for classification as Class I locations except those where non-hazardous finishing materials are used. A possible exception might also be made in the case of small scale operations where only a quart or two of the finishing material is exposed at a time and applied by the brush method.

In factories where the painting, dipping or spraying operations are of considerable volume, separate cut-off rooms are provided for the storage and mixing of the paints, varnishes and lacquers. Here we usually find open containers in which the mixing is done and as a result, when flammable volatile thinners are used, we can expect that considerable explosive vapor will be present, the amount depending upon the efficiency of the ventilating system. Where pyroxylin varnishes are used the hazard is, of course, much greater. Often the stirring, mixing and clarifying of these materials are done mechanically by motor driven agitators. It is necessary that these rooms be considered as Class I locations and all lighting and power apparatus and wiring installed accordingly.

The flammable volatile liquids used as thinners and solvents, and sometimes the varnishes also, when used in large quantities are generally stored in underground tanks outside of buildings. This necessitates the employment of pumping apparatus to transfer the liquids from the tanks to the mixing room. The hazard of this operation is similar to that described under "Paint and Varnish Manufacturing" in this thesis to which section reference should be made.

The extent of the hazardous area is a matter for conjecture. When spray booths or hoods, which effectively confine the vapors and residue and which are adequately ventilated, are used, it is probable that the hazardous area may be considered to extend to a distance of from ten feet to twenty five feet, depending on arrangement, beyond the spraying operations. In the case of dip tanks and drying ovens, it is necessary to consider the entire room containing this equipment as a Class I location, for with open dip tanks it is probable that the hazardous vapors will diffuse quite thoroughly throughout the room, especially in event of failure of the ventilating system.

THE PETROLEUM INDUSTRY

The petroleum industry may be divided into several divisions as follows:

1. Production in the oil fields.
2. Transportation by pipe lines, tank cars or ships.
3. Refining.
4. Storage.
5. Distribution.

In the first division we are dealing with crude petroleum which should be considered a hazardous flammable liquid as the lighter petroleum vapors are given off at ordinary temperatures. Due consideration must therefore be given the proper installation of electrical apparatus in or about places where these vapors are likely to be present in explosive mixtures. In the oil fields such locations are likely to be the enclosed pump houses at the rigs or elsewhere where pumps are driven by electric motors and in which electric lighting may be employed. Such pump houses and any other similar buildings are to be designed as Class I locations. Motor driven pumps located in the open without enclosure would probably not be in a hazardous atmosphere due to the dilution of the mixture by the free circulation of air. However, it is possible that the burning out of an open type motor would cause sufficient heat to ignite the oil or its vapors and therefore, the use of motors approved for Class I locations is to be recommended even when in the open.

In the second division, transportation, there is little application of electrical safety rules except in the case of long pipe lines where pumping or booster stations are located at intervals along the course of the pipe line between the oil fields and the refinery. The pumps of such stations are often electric motor driven and this, with the fact that the stations are usually electric lighted, warrants the room or compartment in which the pumps are located being classed as Class 1 locations and the electrical equipment needs to be installed accordingly.

In the refinery, the third division of the industry, we find first, the hazards of pumping the oil from the pipe lines to storage tanks, and the precautions suggested in the preceding paragraphs apply. From these storage tanks the crude oil is pumped to steam or fire heated stills where the oil is distilled fractionally, producing the lighter liquids such as benzine and naphtha first, then gasoline and on down to the residue of paraffin and tar. The process of "cracking", has come into considerable use. This process is, in effect the destructive distillation of certain components of petroleum to secure a preponderance of certain products, in late years, notably motor gasoline. The hydrocarbon gases, ethane, propane and butane are evolved when petroleum is heated and, when these are collected from the stills and compressed, they yield a liquid usually called cymogene. The principal constituent is butane, a gas at ordinary temperature and pressures, and this as well as ethane and propane are readily flammable. These gases are used for heating and lighting and as refrigerants. Attention is called to the discussion under "Compressed Gas Systems." Redistillation apparatus is often provided to effect greater purity and uniformity. To remove offensive sulphur odors often present in the raw gasoline and kerosene and to improve color, deodorizing and decolorizing facilities are provided, usually consisting of large upright shells called "agitators" where the liquids are treated with acid, water and neutralizing wash. These "agitators" are generally associated with other towers where filtration, neutralizing and other treatment proceeds. After final treatment, in accordance with the needs of the particular grades of products, the liquids are pumped to the storage tanks. From these tanks the oils are withdrawn for distribution by tank cars or trucks. With the exception of offices, shops, lubricating oil warehouses and probably laboratories, there are few, if any, buildings of an oil refinery which should escape classification as Class I locations. There is much handling of oil by pumps and, although internal combustion or steam engine power is used to a considerable extent, electric power is gaining in use. Electrical hazards have long been recognized in oil refineries and an attempt has been made to protect against these hazards by isolating motors and control apparatus so as to place them outside of the hazardous area, but this is not always a convenient procedure.

In the fourth division, storage, we find the various petroleum oils stored in buried or above ground tanks at the refinery and at the bulk or wholesale distributing stations. There are no electrical hazards conneted with such storage except in the process of pumping oil from tank cars to the storage tank. Centrifugal or rotary pumps are used for this duty and these are usually motor driven. In some cases, these pumps and motors are placed in the open without enclosure, but more often are located within pump houses or even in a warehouse used jointly as a storehouse for lubricating oils, salesroom and as a shelter for the pumps and their driving motors. Attempts have been made to divide the pump house into two compartments, one containing the pump and the other its motor and control apparatus. Unless the partition so dividing the pump house is practically vapor-tight, it should not be depended upon to prevent the passage of vapors from the pump compartment to the motor compartment. The proper protection of the shaft opening also presents an obstacle which is difficult to surmount. One method often used is to place the motor and its control apparatus outside of the pump house in the open air, but this is not convenient nor practical in many cases. It is certain that the room or compartment containing the pump or pumps must be classed as a Class I location with regard to both the lighting and power installations. Attention should be called to the concluding section of this paper on "Loss Record" which lists several fires and explosions originating in oil pump houses from electrical causes.

In the distribution of petroleum products, the fifth division of the industry, we are concerned first, with the delivery of the gasoline or kerosene or other liquid petroleum products to the buried tanks at gasoline filling stations or industrial plants. Such delivery is generally accomplished by tank trucks which are filled by gravity or by pump from the bulk station tanks or tank cars, and emptied into the buried tanks. The hazard of pumping is similar to that discussed in the preceding paragraph and needs no further comment. With the introduction of motor driven gasoline discharge devices, (or meter pumps), into automobile filling stations, a considerable hazard might have been introduced had not fire prevention engineers been quick to sense the need for compliance with rigid standards regarding the nature of the motor, and its wiring and control apparatus with which the device is equipped. The standards of the Underwriters' Laboratories specify compliance with Class I rules before approval of discharge is given. In the ordinary filling station we usually find the discharge devices or pumps on an "island" under or immediately beyond a canopy attached to the station shelter or office. The hazardous area, coming under the rules of Class I locations may be assumed to be confined to the discharge devices or pumps themselves and does not extend to the interior of the shelter. The construction of the discharge devices and their wiring will be considered later in this paper. When discharge devices are installed within garage buildings, the rules of Article 33 "Garages", of the National Electrical Code apply and, therefore, this phase of the problem will not be discussed here.

PAINT AND VARNISH MANUFACTURING

Paint consists principally of a pigment and a vehicle with which are usually included "driers" and solvents. In the preparation of the pigments there are no electrical hazards from the standpoint of Article 32 except for possible minor dust explosion hazards in the pulverizing of carbonaceous material in the preparation of black pigments. The various drying oils used in the manufacture of paints are of high flash point type and therefore do not easily give off flammable vapors. However, to reduce the viscosity of paint to permit of ready application, a volatile solvent is used, commonly turpentine, but often more flammable volatiles such as naphtha and benzine. In the manufacture of paints, special precautions need be taken so far as the electrical installation is concerned, only in that section where the thinners are added and in that where the finished paint is strained and placed in

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containers. The thinning is done in tanks equipped with mechanical stirring apparatus, usually motor driven. The presence of these flammable volatile thinners in more or less open containers and tanks results in the evolution of a considerable amount of vapor in the room or section where these materials are handled and, therefore, the application of the rules of Class I is required. In small plants the thinners may be received and dispensed out of drums. Reserve supplies are usually stored in a detached building, and if the drums are kept sealed no special precautions are needed with regard to any electrical apparatus installed in the storage house. If drums are opened in this detached building, the lighting installation and any other electrical wiring or apparatus in it must comply with the rules for Class I locations. In large paint factories, the thinners are handled in quantities large enough to warrant their purchase in tank car quantities. This involves storage in outside buried tanks and a pump installation to transfer the liquid into the main factory as needed. The pump house or compartment, whether within or outside the main building, becomes a Class I location and must be treated accordingly.

Varnishes are of several types including natural varnish, oil varnish (which dries by oxidation), spirit varnish (which dries through evaporation of solvent), pyroxylin varnish, and water varnish, Some of these are often referred to as enamels, japans and lacquers. Inasmuch as there are no unusual electrical hazards associated with the preparation or use of natural and water varnishes, we shall not discuss them here. Oil varnish is produced by melting resin, boiling with a drying oil, thinning with turpentine or other solvents, cooling, filtering, ageing and finally packing in containers. The process of adding the thinner is practically identical with that discussed in the manufacture of paint. Obviously, the hazards are identical to those of paint manufacture from our viewpoint, and the rooms or sections from the point where the thinners are introduced up to the point where the containers are sealed must be considered as Class I locations.

Spirit Varnishes are made by dissolving a resin such as rosin or shellac in alcohol, acetone, benzine or turpentine. The preparation is accomplished by placing the resins and solvents in revolving wooden drums or in a wooden tank kept agitated until the resins are thoroughly dissolved. The usual straining and packing process follows. The use of large quantities of flammable volatile solvents requires compliance with the rules for Class I locations throughout, excepting the warehouses where the resins and sealed containers of the finished products are stored. The handling and storage of the solvents are of a similar nature to that discussed under paint manufacture and the hazards are identical.

Pyroxylin Varnishes or Lacquers, as they are more frequently called, are made by dissolving a cellulose nitrate, either guncotton or pyroxylin in a solvent. Amyl acetate or "banana oil" is the solvent most commonly used. To this solution, flammable volatile thinners such as benzol or alcohol, are usually added to obtain free flow of the liquid, especially when intended to be used in spray painting processes. The process of manufacture is extremely hazardous and usually more stringent requirements than those imposed by the rules for Class I locations are observed. There are several types of special japans, varnishes and enamels manufactured, including clear pyroxylin lacquers for coating brass articles. In some instances bronze or aluminum powders are combined with clear pyroxylin lacquer to produce decorative effects. The preparation of the lacquer is attended with the same hazards as discussed under pyroxylin varnishes with the addition of the dust explosion hazard when the bronze or aluminum powders are prepared.

DRY CLEANING AND DRY DYEING

The removal of dirt, grease and stains from clothing, textiles, rugs and other similar articles by the use of a liquid solvent is known as dry cleaning. While non-flammable solvents, such as carbon tetrachloride, are sometimes used for small scale cleaning, the use of a flammable volatile solvent such as naphtha is almost universal in dry cleaning operations due to its effectiveness and quick drying qualities. Efforts have been made to develop a high flash point cleaning solvent, and of these Stoddard's solvent is an example. This material is used to some extent, but because of its reported slow drying and clinging odor it is not entirely satisfactory. Therefore, in the large majority of dry cleaning plants, we can expect the use of a highly flammable volatile solvent.

There are four common methods of dry cleaning as follows:

1. "Scrubbing" by immersion and agitation in the solvent in open vessels.

2. "Scouring" by brushing the article with the solvent or solution.

3. "Spotting" by the local application of the solvent or solution to remove spots or stains, usually to supplement methods 1 or 4.

4. "Washing" by immersion and agitation in the solvent in closed containers.

Scrubbing is the method employed when the character of the articles to be cleaned is such as to prevent their being cleaned by the more usual method of "washing". Such articles are placed in a tub or other vessel containing the solvent where they are scrubbed by hand. Various insurance regulations and governmental ordinances have imposed severe regulations on the use of this method, one of which states that not more than a total of three gallons of flammable volatile solvent shall be exposed in open containers. Even with amount of solvent there is considerable explosive vapor in the atmosphere of the room and necessarily such a room comes definitely under the Class I classification.

The Scouring method entails hazards similar to those of scrubbing. However, in this method the article to be cleaned is laid on a table and scoured or brushed with a hard brush and the solvent, usually naphtha. As in the preceding method the amount of flammable solvent permitted to be exposed is limited to three gallons, and as before, this room also should be classed as a Class I location.

Spotting as before stated, is usually an adjunct to the other methods of cleaning to remove spots not removed by the other methods. It consists of applying the solvent locally to spots of grease, paint or dirt. Very often a mixture of solvents, such as one of naphtha and carbon tetrachloride or alcohol and carbon tetrachloride, is used to produce a solvent of high flash point. However, there is no assurance as to the composition of such mixtures and, therefore, to be safe, one should treat them as hazardous liquids. After the articles are "spotted" they are hung on racks to dry and are then pressed. Although fire prevention regulations stipulate that the flammable solvents used shall be limited in quantity to one quart, and this in safety cans, it may be reasonably expected that there will be considerable explosive vapor in the spotting room, especially where a considerable volume of cleaning is done and therefore, the spotting room should be regarded as a Class I location. The spotting method is that commonly used in small pressing parlors and in small hat cleaning establishments. It is not intended that such small establishments be made subject to all of the rules for Class I locations, but reasonable precautions should be taken to avoid electrical arcs or sparks in the vicinity where the flammable solvent is used. Numerous fires of electrical origin have occurred in such hat cleaning places.

The Washing method is the one most commonly employed and is probably of most importance to us due to the involved nature of the process. In this method the articles to be cleaned are tagged, searched for foreign materials, and then placed in a dusting machine where loose dirt is removed. The articles are then placed in the washing machines. These are machines in the form of cylinders arranged to revolve and having openings capable of being tightly closed, for the insertion of the articles to be cleaned. When the articles are in the machine the cylinder is partially filled with the solvent, usually naphtha, and the cylinder revolved for a certain time. The solvent is then drawn off and the clothes removed and placed in an extractor. The extractor consists of a basket arranged for rotation within a metal shell, in effect, a centrifugal drier. This is the first drying operation, after which the articles are transferred to drying tumblers where the drying is completed. The drying tumbler consists of a cylinder of wire screening enclosed within a tight metal housing. Heated air is circulated through the housing while the cylinder is revolved by mechanical means, causing the articles to be tumbled about while exposed to the heated air. This air is exhausted to the outside. After drying by this method is completed, the articles are removed, spot-cleaned, if necessary, and then pressed. The regulations of the N.F.P.A. provide that if the drying equipment is not in a separate building, that it be in a room cut off from that containing the washers by a standard fire wall.

An important part of dry cleaning operations is the recovery of the solvent and the facilities used in handling the solvents. Regulations require that flammable solvents be stored in buried tanks. This requires pumps with a system of piping leading from the tanks to the washers. After the liquid has been drawn from the washers, it is necessary that it be clarified to permit its being used again. The centrifugal clarifier is used for this purpose, it being located near the washer when the continuous system of clarification is used. For further purification of solvents, stills, condensers and settling tanks are used.

It is clear that in all of the locations of a dry cleaning plant so far mentioned, there is present or likely to be present, a considerable quantity of flammable vapors. Necessarily then, they must be classed as Class I locations, including the rooms containing the washers, extractors, tumblers, clarifiers, stills, condensers and pumps. Ventilation is important, and in the more modern plants considerable effort is made to obtain proper ventilation. Motor driven fans are used, these being either mounted in the wall or in the ventilating ducts. Dry cleaning plants have long been recognized as a hazardous class, for many state and municipal ordinances even yet prohibit the installation of motors and controllers in dry cleaning and drying rooms. However, in many instances these ordinances are being amended permitting the installation of electrical apparatus, provided the requirements of Class I are met. This will permit the use of individual motor drives on the various machines, eliminating what may have been more severe hazards introduced when group drives were used, and the motor located outside of the hazardous area. This latter practice usually involved long line shafts with numerous bearings and considerable rapidly moving belting, thus presenting the possibility of overheated bearings and static discharges from belting, both of which have been the cause of many fires and explosions in dry cleaning plants. Of the areas or sections which might not be considered subject to Class I rules are the delivery room the receiving and dusting room and the boiler room, provided these are so cut off as to be free from flammable vapors.

Dry Dyeing is the process of dyeing materials or articles in a solution of dye colors and flammable liquids. This necessitates the use of drying equipment and the operations are attended by the evolution of flammable vapors in the room or section in which the dyeing operations are carried on. Such rooms or sections should be classed as Class 1 locations.

GAS WORKS

Illuminating gases used in this country are of two varities, known as coal gas and water gas.

Water Gas is manufactured usually by the Lowe process which depends upon the decomposition of water in the form of steam in contact with incandescent coal or coke contained in a generator. The gases so produced are led into contact with a spray of partially vaporized oil and the two are passed over highly heated surfaces, first in a carburetor and finally in a superheater, resulting in the gasification of the oil vapors fixed in the presence of non-luminous water gas. This forms a thoroughly fixed and permanent carbureted water gas. The generator, carburetor and superheater are steel shells lined with fire brick with suitable openings for charging and firing. The gas is now ready for purification which is accomplished by the washer, to remove tar; the washer, scrubber, to effect further removal of tar; the condenser, to cool and purify the gas; the shaving scrubber, to remove moisture from the gas and take out what little tar remains. The gas at this point contains carbon dioxide and sulphuretted hydrogen which are removed by oxide purifiers sometimes located within a building, but in newer installations in the yard partly buried. The gas now passes through meters into the familar gas holders and thence into the pipe distribution system.

Coal Gas is made by the destructive distillation of coal in retorts externally heated. The retorts are filled with gas coal and allowed to heat for five or six hours. The heat causes the evolution of the volatile gases leaving behind incandescent coke which is drawn off, cooled and finally dumped in the yard. The gas, as it leaves the retort, passes into a standpipe, the outlet of which dips below a water or weak ammonia seal in what is termed the "hydraulic main." This causes the gas to be cooled somewhat as well as causing the removal of the bulk of the tar and ammonia liquor. A large drum is attached below each hydraulic main in which the tar collects. An exhauster fan now draws the gas through a condenser which further cools the gas and removes more of the tar and ammonia. The balance of the tar is removed by the tar extractor through which the gas now passes. The scrubbers come next in the process, these being for the purpose of separating out the naphthalene and ammonia that remains. As in the water gas process, the oxide purifiers effect final purification in removing hydrogen, sulphide, carbon disulphide and carbon dioxide and the gas is now passed through meters and thence to the storage holders ready for distribution. As byproducts in the manufacture of coal gas, coke, tar and ammonia liquor are derived. The latter is sometimes reduced to ammonium sulphate by distillation and surface contact with sulphuric acid, and sold in the solid form. The tar is shipped to chemical plants where it is used as the basis for the production of a variety of dyes and other chemicals.

The possibility of leakage of gas is present continually during the process of gas manufacture, especially in the condenser building, purifier room, meter room, valve and governor rooms. Special precautions to remove all sources of ignition are imperative. All parts of gas plants should be regarded as Class I locations with the exception of the office building, shops, change and locker building and similar buildings not associated with the actual production of gas. In some coal gas plants, facilities are provided for the crushing of coal and in both water and coal gas plants considerable quantities of coal are handled. It is very probable that in some of the less efficiently arranged plants the dust conditions incidental to this handling of coal are such as to warrant classifying the coal handling and coal crushing departments as Class II locations.

CHEMICAL WORKS

General

Owing to the extremely large variety of chemicals being manuafctured and the many and varied types of processes employed, it is obviously impractical to attempt to include herein a discussion even approaching completeness. Chemical works, as such should not all be thrown indiscriminately into the hazardous classification. Many are concerned with the production of heavy chemicals of a non-hazardous nature. Some may produce relatively non hazardous products, but the processes or materials employed in their making may be extremely hazardous. On the other hand, the materials, and often the methods, used in the manufacture of a distinctly hazardous product, may be of a relatively dafe nature. Hence, the need for detailed study of each individual case as it appears, to determine what the hazards are and what precautions need be observed in the selection and installation of electrical equipment. There are some types of processes which are sufficiently general and important to warrant brief discussion.

The production of the acids, nitric, sulphuric and hydrochloric, as well as the less common boric, hydrofluoric and phosphoric acids, is not usually attended by hazards of ready flammability in materials or products and, therefore, little if any, application of the rules of Article 32 is involved in the works where they are made. This is also true of many of the heavy chemicals and alkaline salts such as sodium sulphate, sodium bisulphate, alum, sodium carbonate (except when made by the electrolytic process which may introduce the hydrogen explosion hazard), and others.

Ammonia Manufacturing

Ammonia is manufactured by several processes including the synthesis method which is dangerous because of the free hydrogen evolved during one step of the process and the production of coal gas as the base from which the needed gases are obtained. The sections where this work is carried on are clearly Class I locations due to the extremely explosive nature of hydrogen and to a lesser degree, coal gas. The cyanamid process is used to a considerable extent and, briefly, consists first, of forming lime by the calcining of limestone in a kiln. The lime and coke is then fed into electric furnaces thus forming calcium carbide which is pulverized and brought together with nitrogen in the presence of electric heat to form cyanamid. The nitrogen used in this method is usually produced by partial distillation of

liquid air and therefore, a plant for the purpose of liquifying and distilling air is an adjunct to the main process. Ammonia gas is formed in the next step by introducing water and caustic soda into a large steel cylinder called an autoclave which is then charged with powdered cyanamid. The autoclave is then sealed and the reaction started by means of steam and it then continues by its own heat. The final step involves the neutralization of nitric acid with ammonia and the evaporation of the solution to secure the salt, ammonium nitrate, which is crystallized and dried. With the cyanamid process are associated several forms of electrical hazards which require the application of the rules of Article 32. First, the handling and pulverizing of coal which may introduce dust explosion hazards in the section of the plant where this is done, thus requiring compliance with rules for Class II locations. The production and handling of calcium carbide may entail the evolution of acetylene should it come into contact with water, hence, the need for application of the rules under Class I to prevent ignition and subsequent explosion. The danger point for ammonium nitrate is 330 degrees Fahrenheit and should the material become too dry it can be easily ignited by a spark, flame or overheating. Considerable electrical apparatus is installed in plants producing ammonium nitrate by the cyanamid process, due to the use of electric furnaces and the rules for Class I locations should be followed as far as they apply.

Wood Distillation Products

The distillation of wood in closed retorts is an important chemical process as there is produced, in addition to charcoal, either by condensation or auxiliary chemical processes, a wide variety of valuable materials. These include acetic acid, wood alcohol, carbon monoxide, methane, acetone, metacetone, aldehyde, acetylene, naphthalene and hydrogen. In strictly chemical works, the gases, carbon monoxide, methane and hydrogen are piped back and burned under the retorts. The liquid which results from the condensation of the volatiles driven from the wood by distillation is a complex material known as crude pyroligneous liquor. This, in the form of the condensate, separates into three layers, namely, tarry oils, pyroligneous acid and tar, each of which may be drawn off at different levels in the condensers. From the tarry oils and tar, creosote and tar oils are obtained. The pyroligneous acid is commonly treated with lime or sodium carbonate and distilled to give wood alcohol and brown acetate of lime, or is distilled to give wood alcohol first, following which the acid is neutralized with lime to form gray acetate of lime. These acetates are often involved in further processes to form acetone, acetic acid and other chemicals or solvents. Frequently the acetates are shipped and further treated at a separate plant.

The hazards, from our viewpoint, associated with wood distillation plants are those represented by the presence of the vapors of alcohol, acetone and naphthalene. The handling and storage of liquid alcohol and acetone are also hazardous, requiring electric motor driven pumps in many instances. All sections of a wood distillation plant from the retorts to storage and shipping department should be considered as Class I locations. Shops, office buildings, laboratories and similar buildings where the hazardous conditions are not present are naturally eliminated.

Coal Tar and Its Products

As in the case of wood tar, a host of varied products are obtained from the tar produced from the destructive distillation of coal. Coal tar is a by-product of coal gas plants and is also secured from by-product coke ovens. The industry may be divided into four parts which we shall discuss individually.

Coal Tar Distilling Plants, the first division, are generally in conjunction with gas or coke works and the chief operation is that of distilling. By the first distillation processes the coal tar is separated into several fractions, namely; light oil, middle or carbolic oil, heavy or creosote oil, anthracene oil and residual pitch. The light oil is redistilled, washed and purified and then fractionally redistilled, yielding benzol, toluol, xylol and solvent naphtha, all flammable volatile liquids. Some of these such as benzol or benzine are used as raw materials for intermediate dyestuffs and explosives. The middle oil is usually permitted to settle in large pans, allowing crude naphtha to crystallize out. These crystals are then washed, melted and purified in agitators with sulphuric acid and neutralized with caustic soda. It is finally redistilled and becomes the final white product familiar to us in the form of moth balls. It is a hazardous material as has been previously pointed out. After the naphthalene has been taken out of the middle oil there remains phenol and cresol. This is treated with caustic soda, causing the phenol to separate as an oily layer which is drawn off fractionally, distilled and redistilled. Neither phenol nor cresol are particularly hazardous, but the former, more commonly known as carbolic acid when in the refined form, is used in the manufacture of high explosives and dye stuffs. The heavy oil is generally used as a preservative for wood railroad ties and piling without further treatment and is known to the trade as creosote. The anthracene oil is permitted to settle in pans and after artificial cooling yields anthracene, a crystalline substance. This is washed in solvent naphtha and purified by treatment with caustic, distillation and further washing with naphtha. Anthracene is the base for alizarine dyes,

a valuable group and is not in itself hazardous from our viewpoint. The pitch, the residue of the coal tar, is cooled when drawn from the still and solidifies in the barrels used for its shipment. It is employed for roofing materials and road making.

It will be noted that practically throughout the process of coal tar distillation, we are dealing with the distillation and handling of flammable volatile liquids and in the case of naphthalene, with a highly flammable solid. Special efforts are made to divide the plant into a number of fire areas, either by the construction of separate buildings or by fire walls. Class I rules should prevail for the installation of electrical equipment in all departments except those where the heavy oil and pitch are handled, provided these are likely to be free from explosive vapors. The power house, offices, laboratories are likewise exempted as they are usually outside the hazardous area. Some consideration may have to be given to the electrical installation in the power house if pulverized fuel is used. In this case, a portion of the power house may be classed as a Class II location.

Coal Tar Intermediates, the production of which forms the second division of the industry, involves processes which develop raw materials or bases for the manufacture of explosives, dyestuffs and tanning materials from the coal tar distillates which were discussed in the preceding section. Hence, the term "intermediates." The manufacture of these intermediates is carried on in plants or units more or less separate and distinct from others. The more important coal tar distillates used in the manufacture of intermediates are benzol, toluol, naphthalene, phenol, and anthracene. The operations and processes by which intermediates are prepared are so great in number and nature that volumes could be written on that subject alone. It should be emphasized, however, that in most cases, flammable volatile liquids or highly flammable solids are involved, necessitating extreme caution in the selection and installation of electrical apparatus and requiring compliance with Class I rules in all locations where these hazardous materials or their vapors are likely to be present. Careful study of specific processes and plants is necessary to form an accurate opinion of the conditions which may be expected.

Coal Tar Dye manufacture is the third division of the coal tar industry and, as in the case of the intermediates, there is a vast number of dyestuffs and a wide variation in the processes by which they are made. Without going into detail, it should be mentioned that the manufacture of most dyes is attended by hazards ranging from those involving the use of flammable

solvents to those where nitration processes are used which result in materials which are at times high explosives. As an example, nitro dyes are made from the nitration products of phenol and include the explosive picric acid. The grinding of dyes to reduce them to powdered form may also introduce severe hazards from our viewpoint, as there may be present in the room or section where the grinding is done considerable finely divided flammable dust. Here, as in the case of intermediates, the engineer is forced to study each case individually. In some instances, more rigid precautions than those prescribed by the rules for Class I locations may needs be applied, even to the extent of excluding all electrical apparatus from certain locations.

Coal Tar Explosives whose production represents the fourth division of the industry, are made by the nitration of distillates or intermediates such as benzol, toluol or phenol which yield mono-nitro benzol, tri-nitro-toluol (T.N.T) and picric acid respectively. Necessarily, extreme care is taken to remove all sources of ignition when these materials are made and handled, and in this connection, due attention is given to the installation of electrical apparatus. In some cases, even electric lights are placed outside the hazardous area with glass covered openings provided to permit the entrance of light into the hazardous area. The manufacture of these explosives is usually in the hands of firms which are thoroughly aware of the hazards involved and who take upon themselves full responsibility for the safety of employees and property.

General Organic Chemical Processes

In the production of organic chemicals generally, there are several processes which might well be discussed briefly at this point in an endeavor to assist the engineer to determine the treatment of proposed electrical installations.

Sulponation is the process of treating a hydrocarbon with sulphuric acid, sometimes encouraged by the application of heat and pressure. Materials commonly sulphonated are benzol and naphthalene, and in the process one can expect the evolution of flammable vapors.

Chlorination is the process of treating a hydrocarbon with hydrochloric acid in kettles or closed retorts. Toluol and benzol are frequently involved in chlorination processes, and in many cases their vapors, which are explosive, escape into the room and may be ignited by flames and electrical sparks or arcs.

Nitration consists in treating an organic material with mixed sulphuric and nitric acid. Here again we have a condition where the flammable vapors of the material, such as benzol, toluol or phenol may be liberated into the room.

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Reduction may be described as the removal of oxygen from a compound and, in organic chemical processes, this is often done by use of zinc dust. In the process, flammable liquids as solvents may be used and, therefore, the possibility of explosive vapors being liberated is present.

Distillation is perhaps the most common process found in chemical works. Stills are used in connection with the refining and purifying of a large variety of materials. Ruptures of stills through corrosion, weakness or excessive pressures are not unknown and such accidents taken with breakage of piping liberates in many cases, large quantities of explosive vapors.

Sublimation is the process of distilling a material in which the condensate is deposited in the form of solid particles. The sublimation of naphthalene is a typical example. The solid particles are often in the form of a finely divided dust and when these escape from the subliming chambers or connections the room may be filled with the fine explosive dust or vapors.

Fusion is the melting together of substances in fire heated pans or kettles. The fusion of sulphur and anthracene is a typical process. The hazard of the fusion process is probably not as great from our standpoint as some of those previously described, but this depends on the materials used.

Grinding of dyes and other chemicals is a process frequently used. The grinding is done by ball mills, hammer mills and, sometimes buhr mills. Where the materials ground are of a metallic or flammable nature, the dust explosion hazard is active, especially in event of liberation of the dust into the room. It is usually quite impossible to maintain the grinder and its connections perfectly tight so the issue of dust in some quantity is common.

Dryers are used to a considerable extent in some types of chemical plants. The hazard connected with their use is dependent on the nature of the materials being dried. If flammable solvents or materials which give off flammable vapors are used, dryer and room in which it is located should be judged as a Class I location.

Pumps and Piping represent equipment very commonly found in most chemical plants, due to the great amount of handling of liquids and vapors which is necessary. Leaks and rupture of such equipment are frequent and when the materials handled are of a flammable nature, considerable hazard is introduced. The electrical hazard is morepronounced here than in the case of some other processes, due to the fact that the pumps are frequently motor driven. Obviously, the places where pumps handling flammable materials are installed, should be considered Class I locations.

<u>Extraction Processes</u> are used to some extent in the separation of certain vegetable oils or extracts from the crushed meals, plants or fibers in which they are contained. The process involves the use of flammable solvents such as benzol or naphtha for placing these oils or extracts in solution. The oils or extracts and solvents are then separated by distillation. Naturally, processes of this kind are regarded as hazardous due to the liklihood that the explosive vapors of the solvents will be present in the rooms or sections where the process is carried on. The storage and handling of the solvents are also to be considered. The rooms or sections containing extraction processes should be regarded as Class I locations.

Alcohol Production

Alcohols are manufactured commercially chiefly by the fermentation of grains and vegetables and from petroleum by various processes. Methyl or wood alcohol, which is obtained from the destructive distillation of wood, as a byproduct of the beet sugar industry, or by the synthesis of carbon monoxide, is the exception. The list of alcohols contain sixteen different types, including one methyl, one ethyl, two propyl, four butyl, and eight amyl alcohols. The characteristics of most of these have already been discussed under "Flammable Volatile Liquids" and their properties as regards flash points, apparent ignition temperatures, and hazard grading will be found listed in Table Number 3.

It is not intended to discuss in detail the various methods of manufacture, but it should be pointed out that the production of many alcohols is attended by hazards which deserve the consideration of fire prevention engineers. Some of the alcohols, notably, methyl, ethyl, propyl, secondary butyl and tertiary butyl, have flash points within range of ordinary room temperatures or lower and therefore, their vapors may be easily released into the rooms where they are handled to form explosive mixtures. The amyl alcohols, with the exception of the tertiary amyl, have flash points of 100 degrees Fahrenheit or higher, and so in their unheated state are not as hazardous as the other alcohols. However, in some processes, even the amyl alcohols may produce hazardous conditions which require special attention.

Generally, the process of alcohol production involves the use of distilling and condensing apparatus, clarifiers and a variety of pumps for handling the liquids at various stages. In the manufacture of some of the amyl alcohols pentane is used and, as this is an explosive gas considerable care is necessary to remove possible sources of ignition in the rooms where it is used. The engineer should be prepared to consider as Class I locations practically all parts of most alcohol manufacturing plants with the exception of the usual shops, offices, laboratories and the warehouses used for the storage of non-hazardous raw materials.

From the alcohols are manufactured a host of useful materials including many of the commercial solvents, paint and varnish thinners, preservatives, pharmaceutical articles, soaps, fruit essences and perfumes. From some of the amyl alcohols, various acetates, such as amyl acetate, important in the pyroxylin lacquer industry, are derived Fusel oil, a constituent of the residue remaining after the ethyl alcohol is recovered in fermantation alcohol production, which is important in the manufacture of amyl acetate and fruit essences. Essentially then, factories employing quantities of the various types of alcohol should be carefully analyzed to determine the extent of the hazards and where the rules for Class I locations should apply.

Production of Typical Organic Chemicals

Ethyl Acetate is produced by the distillation of acetic acid or sodium acetate and ethyl alcohol in the presence of sulphuric acid. The flash point of the product when pure is 28 degrees Fahrenheit. It is used as a solvent in the preparation of fruit flavors and in perfumery manufacture. Both the base (ethyl alcohol) and the finished products are classed as hazardous.

Ethyl Chloride is made from trimethyl aniline distilled from the refuse of beet sugar works, or may be produced by distilling ethyl alcohol with sodium chloride and sulphuric acid. The product is used as a refrigerant and as a local anaesthetic and is a flammable volatile liquid flashing at ordinary temperatures.

Ether or Sulphuric Ether is manufactured by mixing ethyl alcohol with an equal amount of concentrated sulphuric acid, cooling and then heating to the boiling point. More alcohol is then added and the resulting vapor condensed, ether being separated from the condensate. Ether has many uses; as an anaesthetic, as a solvent for nitro-cellulose compounds, and for artificial silk manufacture. Its flash point is very low and forms very explosive mixtures with air. Both the raw material (ethyl alcohol) and the finished (ether) are hazardous flammable liquids.

Ethyl Bromide is made by adding red phosphorous to absolute ethyl alcohol, then adding bromine and distilling. It is used in medicines and as a refrigerant, and while

usually considered as a flammable volatile liquid, it is difficult to ignite its vapors because of the fact that they are very heavy and do not diffuse readily. The manufacture of the material is hazardous,however, due to the use of ethyl alcohol.

Miscellaneous Industrial Chemicals. There is on the market a large number of liquids, pastes and solids which are either hazardous in themselves or hazards are associated with their preparation. These include shoe dressings, stove polishes, varnish removers, clothes cleaning liquids, fumigants and insecticides, deodorizers and many others. Very often these contain solvents of a flammable volatile nature and, hence, the processes by which they are prepared are attended by definite explosion hazards.

Pharmaceutical and Fine Chemicals

The manufacture of pharmaceutical and fine chemicals, including patent medicines, drugs, perfumes, fruit essences and similar materials may be hazardous, especially when solvents such as alcohol or essential oils in solution with hazardous liquids are employed in their preparation. Various alcohols form the bases of many fruit essences and the process is usually attended by the evolution of explosive vapors in the sections where the alcohols are handled. In the preparation of some drugs or medicines, the grinding of herbs, roots and chemicals is a part of the process and where this is done on any pretentious scale, the possibility of dust explosion hazards is introduced. Extraction by flammable solvents is also a common process.

Each plant of this type using flammable volatiles should be considered by itself to determine the extent of the hazardous area and where the application of the rules for Class I locations is needed. Where grinding is done to any extent, it is probable that the engineer will be justified in applying the rules for Class II locations to the grinding department to protect against the dust explosion hazard.

In the larger pharmaceutical and fine chemical plants, the variety of products manufactured is often very wide, and in many cases, the same apparatus is used for the production of several materials. Therefore, in judging what hazards prevail in a room or department, consideration should be given to every probable process or material which will be used in that room or section.

ARTIFICIAL SILK MANUFACTURE

Artificial silk, of which Rayon is a popular trade brand, is made by several processes. In general, all of these processes, however, adhere to the fundamental principle of preparing a viscous solution of cellulose and forcing it through minute orifices or dies to form filaments which are then coagulated by a chemical solution. These filaments are then "thrown" in much the same manner as natural silk is processed and made ready for weaving by dyeing, weighting and winding on bobbins or shuttles.

The raw material used for the manufacture of artificial silk is cellulose in the form of wood pulp or raw cotton, the latter being usually in the form of linters obtained from cotton seed oil mills. When wood pulp is used, the wood stock is received in the form of logs from which the bark is removed and then cut up into fine chips. These chips are treated with sulphite of lime under heat and pressure, then bleached and washed much in the same manner as employed in the paper manufacture.

The hazards of the processes thus far, from our viewpoint, are represented by the storage, handling and cleaning of cotton linters requiring the application of Class III and Class IV rules. When the wood cellulose process is followed there appears the probability of necessitating the classification of the wood chipping or grinding department as a Class III location, unless effective means are provided to remove waste and dust so as to prevent their accumulation in the motors and other electrical apparatus.

After the cotton or wood pulp is prepared, the process proceeds by one of several general methods which we shall discuss separately.

<u>The Viscose Process</u>, generally speaking, consists of treating high grade bleached wood pulp with a solution of caustic soda. After a certain period of time the excess soda is removed by passing the mass through rollers, following which the pulp is placed in shredders. During this operation the temperature must be held down to less than 69 degrees Fahrenheit. The ripening process follows in which the material is kept for a period at a temperature of 70 degrees Fahrenheit. The next step in the process is extremely hazardous as it involves the treatment of the pulp by carbon bisulphide in churns or mixers, resulting in its conversion to a substance known as cellulose xanthate. This is further treated with water and caustic soda, in the course of which it is kept cool, and after thorough mixing and agitation it is in the form of a viscous liquid. This is allowed to ripen and settle to remove all traces of foreign materials or impurities. It is now ready

for conversion into filaments or threads which is done by forcing it through minute orifices into a hardening or coagulating bath of diluted sulphuric acid. The threads are then wound on glass spools ready for "throwing" and other finishing. The hazard peculiar to the viscose process is the use of carbon bi-sulphide, a liquid which is probably the most hazardous liquid used in manufacturing processes. Its hazard rating is 110 plus and its vapors form very explosive mixtures with air. In practically all viscose factories in this country, the carbon bi-sulphide treatment is carried on in separate buildings well detached from the main plant. The supply of this liquid is stored in buried tanks from which it is pumped into the treating plant as needed. The buildings containing the carbon bi-sulphide, as well as any containing pumps or other equipment handling the carbon bi-sulphide, are subject to the strict application of the rules for Class I locations.

Cellulose Acetate Silk is made by the treatment of cleaned, bleached, cotton linters with a mixture of acetic anhydride, acetic acid and sulphuric acid in churns kept cool by refrigeration, where the mass is worked for several hours. The material is then removed and permitted to ripen for several hours, during which time the reaction takes place. The cellulose acetate so made is precipitated out by placing the mixture taken from the churns into tanks, adding water and allowing it to stand quietly. The solid cellulose acetate is separated from the liquid, which is acetic acid, by centrifuging and is then washed, centrifuged, granulated and dried. In this condition the material will not burn. The next step involves the solution of the acetate in acetone, following which it is filtered through cotton batting. It is then ready to be formed into filaments in the same manner as in the viscose process, except that the hardening bath is not used. The threads solidify as soon as they reach the air and are placed on reels as they emerge from the dies. Outside of the hazards associated with the storage, cleaning and handling of cotton linters which we have previously discussed, the hazards of acetate silk manufacture are those associated with the use and recovery of acetone in one step of the operation. Acetone is a hazardous flammable volatile liquid, giving off explosive vapors at temperatures as low as three degrees Fahrenheit. Although the acetone is usually stored in underground tanks and is handled by pumps through closed systems of piping, the possibility of rupture or leakage is present. Therefore, the rooms or sections from the point where the acetone is introduced to the point where the filaments are formed, and including the pump houses containing the acetone handling pumps, should be considered as Class I locations.

Nitro Silks are made by what is called the Chardonnet process using cotton linters as the basis. The cotton linters are cleaned and bleached and then are nitrated by a mixture of sulphuric and nitric acids. The nitrated cotton is throughly washed, dehydrated and then dissolved in a mixture of ether and alcohol. After settling and filtering, the solution is forced through glass nozzles of minute diameter into a bath of weak sulphuric acid from which it is reeled onto glass spools, removed to an alkaline denitrating bath, washed, bleached and dried. The hazards of the nitro process are threefold: First, the storage, cleaning and handling of cotton linters, a matter which has already been discussed. Second, the nitration of cotton which is to be regarded as a serious hazard, and the locations where this process is carried on should be regarded as Class I locations. In this connection, it should be noted that the silk is not denitrated until after it has been formed into threads. Third, the use of ether and alcohol for dehydrating and dissolving the nitrated cotton which involves storage and handling of these flammable volatile liquids with incidental possibility of liberation of their vapors. Recovery of the solvents may also be a part of the process. Consequently the departments where these liquids are used or handled should be classed as Class I locations.

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PYROXYLIN PLASTIC INDUSTRY

Manufacture of Proxylin Plastic

Pyroxylin Plastic or Celluloid, as it is more commonly called, is a solid solution of pyroxylin and another substance, usually camphor. Pyroxylin, the more active ingredient, is classed in general with gun cotton, and is probably a mixture of cellulose of higher nitration.

The raw stock consists of pure cotton or what is more commonly used, a special grade of tissue paper. If cotton is used, the process involves its cleaning, bleaching and drying. Hence, the hazard of combustible flyings is present where it is stored and handled which makes it necessary to apply the rules for Class III locations. When tissue paper is used, it is cut and shredded into small pieces and blown to dry rooms or to mechanical dryers where it is dried until the moisture content is from 1 to 2%. Unless rigid precautions are taken to maintain cleanliness, accumulations of the dry material can be easily ignited by a spark. It is probable that in many cases the rules for Class III locations should apply to the cutting and drying departments.

The next step in the process is the nitrating operation which may be done by any of several methods, but in general all consist of treating the cotton or paper cellulose with a mixture of nitric and sulphuric acids, often helped by mechanical agitation. The nitrated cellulose or pyroxylin, as it is termed, is now washed, centrifuged and rewashed a number of times, then bleached if an "Ivory" product is desired, and sometimes reduced to a pulp in a beater mill. After leaving the wash house the pyroxylin contains about 40% of moisture, and in this state is non-hazardous. The next step is a drying process which is done by, (1) pressing and blotting in hydraulic presses, (2) by pressing and alcohol displacement, or (3) by pressing, blotting and hot air drying, in which operation camphor is usually added and the mixture pressed between blotting paper or cheesecloth. In the dry houses, the pyroxylin is in a state in which it becomes very hazardous, more so than the finished product, and extreme care is needed to prevent ignition. Usually rules more rigid than those prescribed by Article 32 are adhered to even to the extent of requiring that electric lights in vapor proof globes be placed outside windows to provide artificial illumination. In the case of method (2) above, the hazards are those involved in the presence of the flammable vapors of alcohol and usually include alcohol recovery processes.

The next step is the removal of the cheesecloth, an operation known as stripping. As the pyroxylin at this point is extremely dry and dangerous, stripping is done in a separate building containing no electrical equipment. In some plants the pyroxylin may be dried before being mixed with camphor and it is necessary to break up the pressed cake by use of a breaker, consisting of two revolving rolls fitted with spikes or a ball mill. Here again the pyroxylin is in a dangerous state on account of its dryness and extreme precautions are necessary to prevent ignition. All electrical equipment is usually placed outside of the hazardous area.

The next step is the mixing process which is probably the most hazardous of any. The mixing machines are similar in appearance to bread mixers and into these the pyroxylin and camphor are placed together with a solvent such as wood alcohol or acetone and denatured alcohol, to effect a more intimate contact or solution between the pyroxylin and camphor. Stabilizers for neutralizing any acid which might remain are added with the solvent. After the pyroxylin is thoroughly dissolved the plastic mass is removed and placed in a warm room to permit partial conversion, and this is later completed by rolling and pressing. In this mixing process we have the hazards of flammable volatile solvents in addition to that of dry pyroxylin, and more than usual precautions should be taken. The mixture burns readily with a high degree of heat evolving explosive flammable gases or vapors. The mixing houses are definitely Class I locations, and the rules for this class should be strictly followed for any electrical installations in mixing houses. As a matter of fact, motors and controllers, switches and such equipment are usually located outside of the mixing houses in a motor and control room, and even then are to be of the type approved for Class I locations.

After the mixing process, the plastic mass, sometimes softened with a solvent, is worked in rolls and colors are added when a colored product is desired, and then placed in hydraulic presses. If rods or tubes are to be made, the stock from the rolling mill is processed in an extruding machine, a steam heated cylinder, operating by forcing the stock through a die by hydraulic pressure. Where sheets are desired, a sheeting machine, similar to a machine shop planer, is used which cuts the blocks received from the presses down to required size. The sheets, rods and tubes are then hung in dry houses to season and are finally straightened and polished. All through these latter processes we are dealing with pyroxylin plastic, a hazardous material with considerable alcohol vapors present. Necessarily, the storage and handling of alcohol is involved as is, in most cases, the recovery of alcohol from the various processes where it is used. It is obvious that the roll and press departments, the shaping department and the dry houses are definitely Class I locations, as are the solvent handling and solvent recovery buildings or sections. Portable lights should not be permitted where pyroxylin plastic is manufactured or stored, as the heat of the light, even though enclosed in a vapor proof globe, is sufficient to cause decomposition and possibly ignition of the plastic with which the light may come in contact.

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Manufacture of Articles From Pyroxylin Plastic

Many articles are manufactured from pyroxylin plastic or celluloid, among which are photographic and motion picture films, artificial leather, toilet goods, drafting tools, such as triangles and tee square facings, box toes for shoes, eye shades, eyeglass rims, advertising novelties, and many others. The processes involve the use of sheet or formed pyroxylin plastic and usually equipment for the utilization of scrap pyroxylin plastic. Often these factories are operated in connection with the plants producing the plastics, but as separate units. The storage of the pyroxylin plastic in large quantities, together with the forming of articles and their storage, renders the hazards of such factories of a serious nature. Coupled with this are the hazards connected with the storage, handling and use of solvents, and the reworking of pyroxylin plastic scrap, all of which are similar to those we have previously discussed. Rigid requirements are imposed by fire inspection authorities on the matter of storage of pyroxylin plastic, and all precautions are taken to prevent ignition. The rules for Class I locations apply in full to factories of this type, except in those sections where the pyroxylin plastic or articles made from it are not stored or used, which would probably exempt offices, power houses and similar locations. Due to the low decomposition and ignition temperatures of the material, portable electric lights should not be used, due to the possibility of their being left lying on the material and thus cause fire. In factories where only a small part of the space is utilized by processes involving pyroxylin plastics, the hazardous area is generally taken to extend to a distance of twenty feet from the particular process.

Owing to the fact that Article 34 of the National Electrical Code rules on electrical installations where cellulose nitrate motion picture films are manufactured, exposed, developed, printed, rewound, repaired, and stored, we shall not discuss these requirements here. Under "Hospitals" in this thesis, the matter of electrical installations in X-Ray film storages will be discussed.

THE COTTON INDUSTRY

The cotton industry from the point where the cotton is picked in the field to the point where it is woven into cloth, is attended by the hazard represented by the production of considerable easily ignitable lint or "flyings." In loose fluffy condition, the bulk cotton is also readily ignitable. Necessarily then, every precaution must be taken through the entire process to prevent the ignition of the loose cotton, the lint, and even the thread and cloth while on the looms.

In the following the various divisions of the cotton industry will be discussed briefly.

Cotton Gins

When the cotton is picked in the field, it is transported by wagons or trucks to the gin for cleaning, removal of the seed or ginning, and packing in bales for shipment. The small country gins are usually frame buildings of highly combustible nature and often without fire protection of any kind. The country gin plant generally consists of three main buildings, viz: the seed cotton storage building where loose cotton is stored in open bins or compartments to await ginning; the gin building where the ginning machines, cleaners, boll breakers and presses or balers are located; the seedhouses into which the cotton seed, which is taken out of the cotton, is stored, awaiting shipment. In the larger gin plants, separate cleaning buildings are provided and sometimes a boiler house is added. In the larger and more modern gin plants the buildings are of brick or steel construction, considerably reducing the fire hazard. In the process of receiving and ginning of cotton, a large amount of loose, easily ignitable lint is exposed. In the gin building proper, it is common to see lint clinging in films to walls, timbers, machines, electric light pendant cords, and to other equipment. Inasmuch as such lint is easily ignited by a static spark, the importance of removing electrical sources of ignition should be clear. Cotton lint, when ignited, burns rapidly, rather as a flash fire. Cotton ginning plants, including all buildings other than the office, boiler house and shop, should be considered as Class III locations. In some cases, especially in the so called one story gins, the motors are so located that accumulations of lint in the windings results in a severe hazard. In such cases, the motor should be of the enclosed type or provided with an enclosure as specified in rule 3205e. In most gins it is a practical procedure to isolate the power equipment from the lint hazard by placing it in a separate power house. This is much to be recommended.

Cotton Compresses

After the cotton leaves the gin plant in banded burlap wrapped bales, it is shipped to compresses where the bales are pressed into bales of smaller volume. These compresses are sometimes separately owned units, but are often a part of a large terminal cotton warehouse. In any event, the hazard is practically identical, for the usual compress plant includes facilities for the storage of large quantities of baled cotton. Cotton in bales, as was pointed out previously in this thesis, while wrapped in burlap or similar material, has considerable loose lint or fiber protruding from the bale covering. This lint is easily ignited by any spark or heated metal, as from the breaking of electric light, and this fire flashes from one bale to the next with great rapidity. In the neighborhood of the compressing machine proper, there is often considerable loose cotton and, therefore, the hazard is that vicinity is of a greater degree. Compresses and their associated warehouses should be treated as Class III locations, the rules of which class are intended to guard against ignition of this cotton lint from electrical sources.

Cotton Warehouses

Warehouses used for the storage of cotton present hazards identical with those described in the immediately preceding section. In the case of warehouses at terminal points where the cotton is stored, pending shipment by sea or rail, the buildings are extremely large and are several acres in area. The hazard is multiplied because of this, as a flash fire once started, can easily travel the entire length of the warehouse before any form of automatic fire protection would operate. In some cases, compresses are provided at these terminals which further reduce in volume or re-compress the bales received from the first compress. The same comment as made under "Compresses" applies in this case. It should be emphasized that under average business conditions, the values of stored cotton involved in these warehouses are extremely high and, therefore, the expense attached to making an electrical installation in them safe is very much warranted.

In the case of cotton storage warehouses operated in connection with textile mills, the hazard is identical to that in the terminal warehouses, but it is probable that in the majority of instances, the values involved will be considerably less. However, in textile mill warehouses, a fire originating there may communicate to the mill proper and destroy valuable machinery, so the lack of value in the warehouse is often more than compensated for.

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All warehouses used for the storage of cotton should be considered as Class IV locations and the electrical installation made accordingly.

Cotton Mills

When the baled cotton is received at the cotton mill proper, either from its own warehouse or from terminal points, it goes first to the opener room where the bands and burlap wrapping are removed from the bale. The cotton, somewhat loosened, is then fed into an automatic feeder, the spikes of which feed the cotton uniformly into a blower system leading to the picker room, or what is more usual, feeds the cotton into an opener picker which further loosens the stock and is then fed into the blower system. Arriving into the picker room the cotton is passed through pickers which further loosen the cotton, straighten the fibers to some extent and remove dust, dirt, and short fibers. The picker machines are made in a variety of types which need not be discussed here. However, it should be mentioned that the picker room is regarded as the most hazardous location in a cotton mill, due to the presence of dust, refuse, and loose cotton. In breaker and lapper pickers, the dust, short fibers, and dirt are blown to a dust room or into a cyclone collector for disposal. Dust rooms are necessarily hazardous.

The laps of cotton from the pickers are now trucked to the card room where they are passed through carding machines, the purpose of which are to further remove dirt, short fibers, and to straighten the fibers so that they will be in approximately parallel lines. Lint renders this room hazardous, but probably not as much so as picker and opener rooms. From this point the cotton passes through various machines and processes such as draw frames, slubbers and fly frames, to prepare the cotton for spinning, which is done on machines called ring frames or mules. Some lint or fly is produced by these machines with corresponding hazard introduced. Where cotton yarns are manufactured, an additional process known as combing is necessary, this being done between the carding and drawing processes. The warp is now prepared and this is placed in the harness of the weaving machines or looms. There are several types of looms and various refinements or side processes for producing certain kinds of yarn or cloth, but these need not be discussed here. After the cloth is woven it goes to the cloth room for inspection, napping, if needed, and folding.

The hazards of a textile mill are, of course, represented chiefly by the lint or "fly" produced. This is easily ignitable and results in flash fires. However, the hazard decreases from the

picker room through the process until the cloth is woven. However, through the entire process care should be taken to prevent sparks or heated metal from incandescent lights or resistors coming into contact with lint. Special care is needed in the opener and picker room where there is considerable loose cotton and much "fly." Strict adherence to the rules of Class III locations should be had in electrical installations in the opener and picker rooms and probably some parts of the carding room. The dust room should be regarded as a Class II location. In the draw frame room, the section where the slubbers or "flyers" are located, the ring frame and mule spinning rooms and the loom shed, it is probable that with reasonably good housekeeping, that only the machines and their immediate vicinity need be considered as Class III locations, the entire purpose being to prevent ignition of lint and "fly" by electrical arcs, sparks or heated parts of equipment. The electrical "stop-motions" for looms and other machines have been quite serious offenders in causing ignition of lint. Therefore, attention should be given to the construction of such devices to prevent emission of sparks or arcs. The value involved in a textile mill in the way of machinery is quite considerable. Hence, prevention of fire is of great importance.

Cotton Seed Oil Mills

Reference should be made to discussion of this subject under "Vegetable Oil Industry."

FABRIC AND PAPER COATING PLANTS

General

The production of rubberized fabrics, linoleum, oil cloth, pyroxylin coated fabrics, roofing materials, wall paper, and coated paper is usually attended by hazardous conditions because of the character of the materials employed, and the manner of application and drying. Flammable volatile solvants are used to a considerable extent in the preparation of the coating material, and the vapors of these solvents are present throughout the spreading and drying operations. Where pyroxylin coated fabrics are made, the hazards are more serious, due to the character of the coating materials employed. In the following we shall discuss briefly the production of the various coated fabrics and papers.

Linoleum

There are two types of linoleum, the felt base and the burlap base. The felt base linoleum is usually prepared by coating in calendar rolls the sized felt with paint to form the undercoating which is then festoon dried in large dryers. Designs in a varnish paint are now applied, and the sheets placed in rack dryers after which process they are trimmed and rolled up. In the burlap base linoleums, burlap, canvass or other cloth is coated with a mixture of ground cork, fillers, linseed oil and paint, and hung festoon fashion to dry. Designs are then printed or inlaid, and after rackdrying, the sheets are trimmed and rolled.

Among the hazards of linoleum factories are those introduced by the grinding of cork, and as cork dust is explosive, it is desirable that the room where this grinding is done be considered as a Class II location. The preparation, mixing and application of paints and varnishes, and the subsequent dyeing processes involve hazards which warrant the locations where these processes are carried on being classed as Class I locations due to the presence of the vapors of flammable volatile thinners used in the paints and varnishes. If a pyroxylin varnish is used, the attendant hazards are greater. The same comment applies to the printing room where designs are applied by use of naphtha thinned paints, and where the finished sheets are dried. The warehouses for the storage of raw and finished materials are not usually considered in the hazardous area.

Oil Cloth

This product, as considered here, consists of a cotton cloth treated with a vegetable drying oil, or compounds containing

chiefly these oils, used for wagon covers, tents, and tarpaulins. When decorated for table covers, colors, varnishes and other materials may be used to give the final finish. The coating compounds vary with different processes and products, but very often they contain naphtha or other volatile thinners. Also, when varnishes are used, the hazard of the use of flammable solvents is introduced. The process of coating the cloth is continuous. The cloth is run through rolls through a dip tank or trough containing the compound, and thence directly into steam heated dry rooms where the coated cloth is hung in festoons. The classification of the coating and dry rooms, which will probably be the only hazardous locations from our standpoint, depends on the character of the compounds and varnishes used. If the use of flammable volatile thinners or solvents is involved, these locations should be placed in Class I. In this case, the problem of storage, handling and mixing of the compounds with the flammable volatile liquids is also involved, and necessarily the sections where this is done should also be considered as Class I locations.

Pyroxylin Coated Fabrics.

The process of producing pyroxylin coated fabrics, which product is sometimes referred to as artificial leather, is undoubtedly the most hazardous of the coated fabric class, due to the character of materials employed. The pyroxylin is received in the form of smokeless powder from surplus stocks, as film or novelty pyroxylin stock, or as nitrated cotton linters. The coating works may receive these in the form of a jelly, but whatever the form, the storage and handling of these materials involve severe hazards. The solution of the pyroxylin in solvents, and the addition of loading and coloring material are processes usually required to be isolated. The coating is applied to the cloth by use of a spreader machine. The cloth is run over a roller immediately above which is a "doctor" or knife to cause an even spreading of the mixing as it is fed onto the cloth. After passing the "doctor", the coated cloth is run over a long heated table for drying, and is finally reeled up in rolls. These spreader machines and drying tables are often enclosed to permit ready removal of the vapors, or, in some cases, to permit recovery of solvents. Throughout the process there is the possibility of considerable "droppings" and residue about the machines, and hence the hazards are of a serious nature.

Practically all parts of such a plant, including the sections used for the storage and mixing of the pyroxylin and solvents, the spreader room, and the dryer room, should be considered as Class I locations.

Roofing Materials

In the manufacture of roofing materials such as tar or asphalt coated paper, paper felt or ashpalt shingles, the chief hazard, from our viewpoint, is that associated with the heating of tar or asphalt to high temperatures (400 to 500 degrees F.), at which temperatures it is probable that flammable vapors will be evolved.

In the impregnation process, the paper or felt is passed through vats containing the heated tar or asphalt, and then festoon dried in steam heated dryers.

The preparation of roofing cements is often an auxiliary process of roofing plants. Such cements are usually the tar or asphalt in solution with a flammable volatile solvent. Hence, there is present the hazard of vapors of an explosive nature in the rooms where the cement is mixed and placed in containers, as well as that attending the handling and storage of the solvents.

Wall Paper

There is little hazard connected with the production of ordinary wall paper where the process consists simply of applying linseed oil paints to heavy sized paper by means of figured rolls. If flammable volatile liquid thinned inks are used, the hazard is measured by the care taken in the mixing of such inks. Probably the mixing room in most plants should be considered as a Class I location. Where varnish coatings are applied to the paper after printing, the coating room where this varnish is applied should be considered a Class I location due to the probable presence of flammable vapors from the thinners in the varnish. There is likely to be considerable waste paper trimmings in the neighborhood of the printing machine, and in the less modern plants this immediate vicinity should probably be considered as a Class III location.

Wax Coated Paper

In coating paper with paraffin, the paper is usually run through a trough or small vat containing heated paraffin, and then passed over chilled rolls to festoon drying racks. When paraffin is heated, flammable vapors may be given off and this fact should be weighed when plants of this type are under consideration. In some cases, flammable volatiles are added to the paraffin to thin the coating, in which case the coating room definitely becomes a Class I location. In some types of

plants there may be considerable trimming of the coated paper which would cause accumulations of refuse. In such instances the application of the rules for Class III locations is advised.

Rubber Coated Fabrics

Refer to section entitled "The Rubber Industry."

THE RUBBER INDUSTRY

Manufacture of Rubber

Crude rubber is received at rubber manufacturing plants in two forms: as a "biscuit" which is smoked sap or a latex in solid form, and as liquid latex with a small amount of preservative, commonly ammonia, in solution. When the "biscuit" is received at the factory, it is passed through various washing, compounding and calendering processes, none of which involves any appreciable hazard from our standpoint. As it comes from the calendering process the rubber is in the form of sheets in a soft and sticky condition and can be moulded into any desired shape. The rubber is now vulcanized and cured, but these do not represent any hazardous operations, except that in event of use of carbon bisulphide for vulcanizing, a most serious hazard is introduced, for the vapors of this liquid are extremely flammable. Fortunately, it is a material seldom used for this purpose.

Probably the most serious hazard in the rubber industry is that associated with the churning process. Churn rooms are found in various classes of rubber plants. Here rubber is dissolved in a flammable solvent, usually gasoline, benzine, or naphtha, in churns which are covered iron tanks containing an agitator or paddle to stir the mixture mechanically. The solvents are brought to the churns in open cans, or pumped into it from outside storage tanks through a closed system of piping. Although the churns are usually kept closed, they are frequently opened permitting the solvent vapors to pass into the room. In some cases the escaping vapors are recovered by a solvent recovery process. Necessarily, churn rooms should be considered as Class I locations, as should the places where pumps for handling solvents are located. The solvent recovery stills and condensers are usually required to be in a separate room or building, but wherever located, the recovery room is a Class I location.

In some classes of the rubber industry, varnishing of the finished articles is done, especially in the case of rubber footwear manufacture. The varnish usually consists of linseed oil, gum, and sulphur thinned with gasoline. This varnish is often applied by dipping. The rooms or locations where the varnishing is done, where the mixing of the varnish is carried on, and where the flammable solvent, gasoline, is handled should all be considered as Class I locations.

In many rubber plants a considerable amount of old rubber or "shoddy" is reclaimed to be mixed with the crude rubber as received from the plantations. The reclamation processes do not usually present any great hazards from our viewpoint, so

the ordinary type of electrical installation may be permitted in the sections where the reclaiming operations proceed. However, if a churning process, such as discussed above, is operated in conjunction with it, the location where the churns are placed must be considered a Class I location.

Rubber Coated Fabrics

The coating of cloth with rubber is an important and usually a hazardous process, due to the fact that the "dough" which is used to impregnate the fabric consists of rubber dissolved in gasoline or other flammable volatile solvent. The "dough" may be applied by a spreader machine, or by frictioning on a calendar machine. A third method which is coming into use is known as the latex process, -- that is, atomizing the latex or rubber sap and causing it to be deposited on the fabric. This method is safer than the spreader and calender method because it does not require the use of solvents. It is not yet generally used, however.

In the spreader method, the most common, the "dough" made by a churning process is fed to a spreader machine. This machine consists of a roller above which is a knife or "doctor", and the fabric is fed between the two from a reel. As the cloth passes through, the "dough" is placed on it at a point just behind the spreader knife. The cloth emerges with a coating of the "dough", passes over a long steam heated drying table, and is then hung in festoons in a dry room for vulcanizing and curing. Here it is subjected to the fumes of sulphur chloride, generally diluted with carbon bisulphide, benzol or carbon tetrachloride.

Double texture goods are made by coating the surfaces of two sheets and then pressing them together as they leave the spreader. Coated fabrics are sometimes decorated by printing with gasoline thinned ink, and are sometimes varnished, which naturally introduces the hazard of flammable vapors from the thinners in the varnish. Some double texture fabrics are given a coating of paraffin, alum, vaseline and naphtha, a process called "spot-proofing" to make the fabric more moisture proof.

The hazards of the spreader method are evident, and it is clear that the churn room, the spreader and dryer rooms, the printing room, and the spot-proofing room are to be considered as Class I locations. If the gasoline and the solvents are supplied by pump from outside tanks, the pump room is also placed in the Class I classification.

In the friction method where the compound rubber is pressed into the fabric in a calender machine, no hazard is involved as the rubber so used does not contain a solvent.

Dipped Goods

A large variety of rubber goods, including rubber gloves, nipples, and similar thin elastic articles, are made by the dipping process. The usual procedure consists of dipping metal or pyroxylin plastic forms into a solution of rubber and gasoline, or other solvent, raising them to dry, and then repeating the operation until the desired thickness of rubber is obtained. The rubber solution or rubber cement is contained in open dip tanks, and this results in the evolution of large quantities of flammable vapors. The process naturally involves the storage and handling of considerable amounts of gasoline, as well as the preparation of the cement by the churning method. Necessarily, the churn room, solvent pump room, and the dipping room must be considered as Class I locations.

Automobile Tires

The manufacture of tires, from our point of view, is hazardous because of the large quantities of rubber cement used in some types of processes. However, this cement is used in large work rooms and applied by brush, so with reasonable care, the hazard can be controlled to such an extent that it is not considered necessary to designate these work rooms as Class I locations. However, the churn rooms, where the cement is prepared, are definitely Class I locations, and if the quantity of gasoline or other solvent used is such as to require storage tanks and pumps for handling, the pump room should also be regarded as a Class I location.

Hard Rubber

Hard rubber is made in the same manner as soft rubber, except that the vulcanizing process is carried farther. There is no great hazard in the process from our viewpoint. However, in many hard rubber plants there is considerable reclaiming of waste material. In this process the hard rubber is ground into a fine powder for the purpose of mixing with new raw material. Hard rubber dust has been found to have explosive qualities and, therefore, the section of the plant where the grinding and handling of the pulverized rubber is done should be subjected to classification as a Class II location.

THE LEATHER AND SHOE INDUSTRY

Manufacture of Leather

Up to the point where leather is received by the shoe manufacturer there is little hazard involved from our point of view with the exception of the barking mill used to grind bark for the tanning operation. Bark dust is explosive when mixed with air in the proper proportions and, therefore, the bark mill department should be considered as a Class II location if within the tannery buildings. Another notable exception should be made in the case of the preparation of lacquered leather in which pyroxylin lacquers are used to give desired finishes to the leather. This is usually done in spray booths and, therefore, the same comments as made under section "Finishing Processes" apply. The locations where such spraying is done are definitely regarded as Class I locations, as are the mixing and storage rooms for the lacquer.

Patent Leather

The application of a glossy varnish to the surface of a leather results in a product which has been designated as "patent leather", but sometimes referred to as japanned or enameled leather. The production of patent leather is usually accomplished at a plant separate from the tannery. Before the varnish is applied, the tanned hides are degreased, which is also frequently done at separate plants. The degreasing process consists of immersing the hides in tanks filled with naphtha for several hours, after which the naphtha is drained off and warm air blown through the tanks to dry the hides. The leather is then removed, air dried, and finally shipped to the finishing plant. Sometimes the degreasing process is not followed, but only in cases when a pyroxylin base varnish is used for the primary finish coat. Obviously, degreasing plants are Class I locations due to the presence of large quantities of naphtha vapor.

In the finishing plant, the hides are first buffed and mounted on frames, and the priming varnish coat applied. This is a naphtha thinned oil varnish, and is applied by heavy brushes or poured on. The hide on its frame is now placed in a drying oven, and when dry is lightly stoned and then given a second coat of varnish similar to the first, except that it is thinned to the point where it can be applied by brush. Colors are added to this varnish. It again goes to the drier and upon removal a second time is lightly stoned and then brushed to remove dust. The varnish is now applied with great care to avoid uneveness. After application is completed, the hides are placed in large bake ovens where they are left over night and then removed to the outside of the building for exposure to air and sunlight, or placed in a special room and exposed to ultra-violet light. In some cases a pyroxylin base daub is used in place of the first coat, in which case the general hazards of pyroxylin finishes apply.

It is obvious that the large scale production of patent leather is attended by hazards which are of a nature similar to those described under "Finishing Processes", and the same comments as to the required type of electrical installation apply.

Shoe Manufacture

In the process of manufacturing shoes, we are concerned almost entirely only with the use of various types of cements, water-proofing liquids and finishes. The cements, many finishes and water-proofing liquids, contain flammable solvents and thinners such as gasoline or naphtha. In the well ordered plants, the use of these materials in the main factory is well controlled, and all mixing and storage of main supplies are confined to a detached building. This detached building should be regarded as a Class I location and the electrical installation made accordingly. Except in extreme cases, it should not be necessary to class workrooms in the main factory as hazardous locations unless heels are covered with pyroxylin plastic (celluloid) or box toes of this material are used, in which case the precautions mentioned under "Pyroxylin Plastic" should be followed to prevent ignition of this material in use and storage. Where heels are covered with leather or satin, rubber cement is used in large quantities. Fire prevention engineers recommend that this operation be carried on in a cut-off room used for no other purpose, and this room regarded as a class I location. Wood or leather heels are sometimes finished with a pyroxylin lacquer applied by the spray process under metal hoods. When this is done such processes should be governed by comment under "Finishing Processes." In cleaning white kid shoes, ether is sometimes used, and as this is a flammable volatile liquid, the process is usually required to be carried on in a cut-off room treated as a Class I location. Patent leather finishes consisting of nitro cellulose dissolved in amyl acetate, acetone, or alcohol, are used and, especially in the case of cheap shoes, the quantities treated may be large due to the fact that the entire shoe is dressed with it. In such cases the work should be done in a separate room which should be regarded as a Class I location.

There is a certain dust hazard connected with shoe factories, but this is usually well controlled and probably compliance with Class II rules is not justified except so far as protection of lights in dust rooms is concerned.

RECOVERY OF SOLVENTS

In many industrial processes considerable quantities of solvent vapors are released into the rooms in which the processes are located. The need for protecting the health of employees normally exposed to such vapors, as well as the economic waste represented by the loss of solvents by evaporation, has led to the development of various systems of solvent recovery. Quite wide application of such systems has been made in the division of the rubber industry producing rubber coated fabrics, in dry cleaning, in the smokeless powder industry, to some extent in the manufacture of artificial silk, and in others.

In general, the method employed for the recovery of solvents consists of means for collecting the vapors at the points where they are released and conveying them to the recovery plant. Here they may be condensed to liquid form by direct condensation, by absorption by charcoal, silica gel, or other solids, by absorption by liquids, or by a combination of these methods. Distillation, condensing, clarification, and pumping apparatus is usually associated with solvent recovery processes to purify the recovered solvents.

A popular type of recovery system is that employing a charcoal absorption process. In such an installation, ventilating hoods are placed over, or often complete enclosures provided around, the machines or process from which the vapors escape. Draft pipes connect these hoods or enclosures to a common air trunk which leads to the solvent recovery building where the fan establishing the suction is located. The vapor and air are delivered to the absorber which contains a bed of specially prepared charcoal. After the charcoal has reached its absorptive capacity, the vapors from the header trunk are diverted and high temperature live steam is turned into the bed of charcoal. This steam carries the solvents out in the form of a condensate, and is collected in a receiver from which the solvent can often be drawn off separately due to differences in specific gravity. Where the difference in specific gravity between the solvent and water is not great, recourse must be taken to distillation methods for separation, thus involving the use of stills and condensers.

As has been stated, there are several other methods of solvent recovery, but the foregoing is representative of the nature of the hazard involved. Fire prevention engineers recommend that the recovery apparatus be located in a well detached building, but wherever located, the solvent recovery department should be regarded as a Class I location.

NATURAL GAS AND COMPRESSED GAS SYSTEMS

Natural Gas

In some parts of the country, natural gas is still available and is used to a considerable extent for lighting and heating purposes. Often the gas is transmitted long distance through overland pipe lines to points where it is sometimes mixed with manufactured gas before being introduced into the distributing mains. In these long distance pipe lines, it is necessary to provide pumping or booster stations at intervals along the line to obtain the necessary pressures to permit flow. The production of natural gas is largely one of pumping, and the pump compressor houses, together with those buildings employed at the gas wells or at the pipe line pumping stations for containing the meters, gauges, regulators, and valves may, at some time, contain explosive mixtures of gas and air. Therefore, these buildings or rooms should be considered as Class I locations.

There are several hydrocarbon gases which might be referred to as byproducts of the natural gas industry. Among these gases are methane, ethane, propane and butane, which are obtained by the fractional distillation of liquified natural gas. Where such operations are carried on, the hazardous area is extended to include the compressor and still rooms used to liquify and distill the natural gas, as both the material and products form explosive mixtures with air. The rules for Class I locations should be applied to these hazardous areas.

Compressed Gas Systems

The hydrocarbon gases mentioned in the previous paragraph, especially propane and butane, are placed in heavy steel cylinders in liquid form and in that form are quite widely used for heating and lighting. There is also considerable activity in the petroleum industry in the production of these liquified hydrocarbon gases in which butane and propane are obtained from cymogene, the light naphtha distillate from petroleum oil which is largely butane. Most of these liquified gases are sold under trade names and these are usually mixtures of propane, butane and, in some cases, other hydrocarbons. As an example, the liquified gas known as "Fuelite" is a compressed liquified gas containing 50% butane and 50% propane, and is shipped in heavy steel cylinders at a pressure of 200 pounds. "Protane" is a proprietary gas and is shipped in liquid form in tank cars under its own vapor pressure of about 20 pounds per square inch.

Compressed gas systems are of two types: Class A systems are those introducing only gas into the buildings; and Class B

systems those introducing liquid into buildings and which is vaporized at the burners. It is not intended to explain in detail the operation of these systems, but it should be mentioned that the rules of the N. F. P. A. provide for the installation of the cylinders outside of main buildings, and where enclosed, the enclosure shall be lighted only with incandescent lights in vapor proof globes and shall contain no switches or other spark producing devices. In effect this states the requirements for Class I locations, which the enclosure should be considered to be.

Acetylene Gas Systems

Acetylene gas systems employing generators for the production of the gas on the premises are of several types, those with generators for installation within main buildings, and those in which the generators are required to be placed in a detached building. The generators are usually required to be recharged without the aid of artificial light, but should any special dispensations be made in this regard, the minimum requirement in generator houses or enclosures should be to regard them as Class I locations.

HOSPITALS

There are two hazardous locations in hospitals which require special attention as to the nature of any electrical installation which may be made in them. The first of these is the X-ray film storage room or vault when nitro-cellulose films are employed. When acetate film is used the hazard is not any greater than that attending the storage of paper, but unfortunately nitrate film is still used to a large extent. Rigid rules are usually enforced as to the nature of the vault or room used for the storage of nitrate films in hospitals, especially since the Cleveland Clinic fire in 1929 when 122 persons lost their lives. It is not expected that any electrical equipment other than lights will be installed and it is required that these be enclosed with vaporproof globes and guards. Due to the low decomposition and ignition temperatures of nitrate films, portable lamps, whether protected or not, should not be permitted to be used in film storage vaults. The switch controlling the fixed lights should preferably be located outside the vault, but if inside, should be of the type approved for Class I locations.

The second hazardous location in the hospital is the operating room with which is often associated the anaesthizing room and a sterilizing room. Such rooms are classed as Class I locations due to the use of flammable gases or vapors such as ether, propylene, ethylene, and ethyl chloride for anaesthetical purposes. Nitrous oxide, also used as an anaesthetic, is a supporter of combustion like oxygen and forms explosive mixtures with the gases and vapors mentioned. While not given general publicity, it is reported that many serious and often gruesome explosions have occurred in operating rooms. The arrangement of the operating rooms, or more correctly, departments, is such that the sterilizer room and the room where the patient is given the anaesthetic, which is sometimes separate, must be included in the hazardous area, owing to the rapid diffusion of the explosive gases or vapors.

Some work has been done by manufacturers of electrical equipment toward the design and construction of lighting fixtures, sterilizers and other equipment for use in these locations, but there is much yet to do. Adequate lighting is of prime importance in operating rooms, but it is also important that lights be protected to prevent their breakage. This can be done by locating the enclosed lights at or near the ceiling or by providing large specially protected enclosed units over the operating room. Any motors used should necessarily be of the type approved for Class I locations for the specific use intended. All switches or other spark producing devices should be placed outside of the hazardous area, but if within, should be of the explosion resisting type. Electric sterilizers will probably have to be specially designed for use in the hazardous area, as in actual practice the sterilizing room must communicate conveniently with the operating room

and, therefore, will probably contain flammable gases or vapors in explosive mixtures with air. The writer has knowledge of at least one manufacturer who is at work on this problem.

The use of live electrical cautery represents a problem difficult of solution, but it is probable that by reasonable care and by using non-flammable anaesthetics when live cautery is employed, that trouble from this source can be avoided.

GRAIN ELEVATORS

Grain elevators may be said to be of three general types, each of which performs an individual service in the business of marketing grain and preparing it for milling or other utilization. These are:

1. Country grain elevators,
2. Terminal grain elevators,
3. Mill elevators.

While the construction and equipment of all three classes may, in many cases, be very much alike, there is enough distinction in their respective purposes to warrant discussing each class separately.

Country Grain Elevators

This type of elevator will be found usually in agricultural districts and is used for the purpose of receiving grain from the trucks or wagons of farmers, storing it for a period ranging from a few days to several months, and finally shipping it either to a terminal elevator or to a flour mill, feed mill, or some other factory where it is converted into finished products. In some country elevators, the facilities are extended to provide for the cleaning, drying and often grinding of grain for feed. In case of the latter activity, the elevator approaches the feed mill in nature.

The grains handled by country elevators may include one or more of the following: wheat, oats, corn, barley, rye, flax and rice. Beans and peas, while not classed as grains, are handled by some grain elevators. When corn is handled, it is usually received in cob form, that is unshelled, in which case corn shellers and the necessary auxiliary machinery for shelling corn are included.

The majority of country elevators are of combustible construction, although in the past few years many of the reinforced concrete fire resistive type have been built. The usual elevator consists of the following divisions:

1. The driveway or dump shed where the grain is received and dumped into a receiving hopper under the floor. Conveyors of the spiral or belt type then carry the grain into the basement of the main elevator building.

2. The elevator building proper, which consists of a number of bins for the storage of the grain. A part of the area, usually equal to the space which would normally be taken by one bin, is used to house

the elevator legs (continuous belt vertical bucket conveyors), the stairway and often the man hoist. Surmounting a portion of the structure is the cupola or "texas" which contains the upper portion or "heads" of the elevator legs, the distributor used to direct the grain discharged by the elevator leg to anyone of the several bins, and the necessary spouting. A basement is commonly provided under at least a portion of the main elevator building and here are located the lower portions or "boots" of the elevator legs, the corn sheller usually if one is provided, and the necessary conveyors for carrying the grain from the dump and bin to the elevator boots. If facilities for cleaning grain are provided, the cleaner, commonly, the shaker type, equipped with air suction, is located in the first floor of the building or, as is more often the case, in the cupola. If feed grinding is done, the grinder is located in the first floor, in the basement or may be placed in a small addition.

3. The office building which may be attached to the driveway or be detached from all buildings.

4. The warehouse often provided for the storage and retailing of flour, sacked feeds and general supplies. This building, if present, is sometimes detached, but more often attached to the elevator buildings and frequently contains the office.

5. The grain drier building, usually a separate structure, but commonly attached to the elevator building proper.

6. Auxiliary buildings such as the dust house, corn cob house and coal sheds.

Figure No. 1 illustrates a typical country grain elevator as found in the wheat growing sections of the Northwest and Southwest.

In operating a country elevator, the grain is first weighed in the wagon or truck and then dumped into the hoppers or dump in the driveway of the elevator. The conveyors carry the grain into the basement of the main elevator building where it is discharged into the boot of an elevator leg by which it is elevated to the upper part of the cupola. The grain is then discharged into a spout and directed to the desired bin through a distributor. If cleaning facilities are provided, the grain is directed from the elevator head to the cleaner where chaff, loose dust and other foreign material are removed, and then is re-elevated and distributed to the desired bin.

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Naturally, during the process of receiving, elevating, cleaning and spouting of grain, considerable dust is removed from the grain and in spite of all efforts to confine it, much of it is thrown into suspension in the air and deposited finally on floors, ledges and timbers as well as on machinery, motors and other equipment. This dust is largely of a carbonaceous nature, probably to a large extent starch, and therefore combustible and explosive. The dust from beans and peas can be regarded as less hazardous, generally, than that from true grains as it consists principally of sand or earth.

In the country grain elevator there are two types of hazards present. The first is that represented by an explosive mixture of combustible dust and air being present when the plant is in operation. While dust explosions are not as frequent in country elevators as one would expect, they are not unknown by any means. Probably the fact that the construction is more or less open has the effect of reducing dust explosion possibilities. The second type of hazard and the one which gives by far the greatest proportion of loss is that associated with the collection of combustible dust in the windings of open motors, in resistors, in motor controllers, and on unenclosed incandescent electric lights. The collection of this dust in the windings of motors results in the impairment of ventilation to such a degree that the motor finally overheats, the insulation breaks down and the resulting arcs ignite the dust. The communication of fire is then rapid because of the accumulations of dust in the neighborhood of the motor and usually throughout. Grain dust can be readily ignited when permitted to accumulate on an unenclosed electric light and the burning dust may then fall into dust on the floor and cause rapid spread of fire.

Of the various divisions making up the country elevator plant, all parts of the main elevator building, the driveway and the drier house, if there is one, should be regarded as Class II locations. The office and the warehouse are usually reasonably free from dust and special treatment of electrical installations in those locations is not necessary although it is recommended that only rigid conduit wiring be employed for any light or power installations which may be made.

While the older country elevators employ group drives for all machinery, the machinery in the newer elevators is almost entirely individually motor driven. The practice of isolating electric service equipment, motor controllers, and fuse panels to a dust-free location has been followed to a large extent in newer installations. In other words, the service switch and fuses, meters, fuse panels and magnetic type motor controllers are placed in the attached office or in the warehouse, which, being comparatively non-hazardous locations, permit the use of ordinary dust-proof equipment. Dust-tight push button control stations are then placed at the desired points in the

elevator proper. This arrangement is much to be desired from the fire prevention point of view and also produces a less expensive installation than if the equipment were placed in a dusty location and the rules for Class II locations followed.

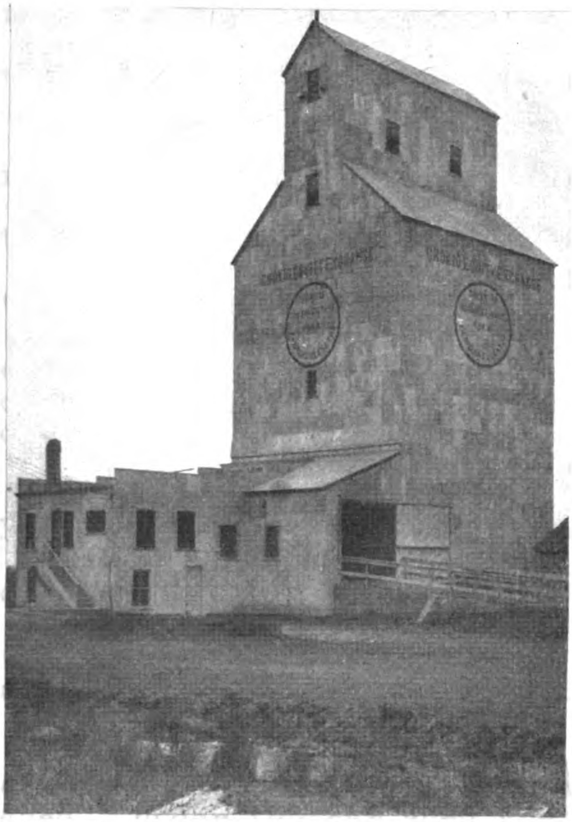


Figure No. 1.
A Country Grain Elevator

This elevator is typical of those found in the wheat growing states of the Northwest and the Southwest. This is a frame iron-clad structure with the office attached to the driveway. In elevators so arranged, the electric service equipment, remote type motor controllers and panelboards can often be conveniently located in the office thus isolating them from the hazardous area and permitting use of standard equipment.

Terminal Grain Elevators

The purpose of the terminal grain elevator is to receive the grain from country elevators or from other terminal or transfer elevators and store it pending shipment to flour mills or other purchasers. The grain is received by boat or railroad cars and may be shipped in like manner depending on the transportation facilities available.

Equipment for the cleaning of grain is usually provided, and in some,driers, washers and bleachers are included.

The newer terminal grain elevators are of fire resistive concrete or steel construction, but there are still a relatively few of the old type wooden elevators remaining.

Many dust explosions have occurred in elevators of the terminal class, some of them, such as that which wrecked the Northwestern Elevator in Chicago in 1921, being in the nature of major disasters. The values involved are high and the construction and arrangement such that a serious explosion usually results in great loss of life and property.

The usual terminal elevator consists of a number of divisions which are detailed below. Reference to Figure No. 2 will assist in obtaining a more clear idea regarding their arrangement and construction.

A terminal elevator as ordinarily built and arranged consists of the following sections:

1. The car shed where cars of grain are loaded and unloaded. Under the car shed are usually unloading sinks or hoppers from which lead belt conveyors in tunnels directly communicating with the basement of the elevator or work house.

2. The marine legs, either stationary or movable, by which grain is removed from the holds of vessels and discharged either directly into the work house or elevator through spouts or discharged onto a belt conveyor enclosed within a gallery directly communicating with the work house or gallery.

3. The work house or elevator proper where the grain is received from the car sheds or marine legs. Here the grain is raised to the upper parts of the building, discharged into a garner bin, thence into the scale hopper where the grain is weighed. From the scale hopper the grain may be discharged either onto belt conveyors for distribution to the bins or tanks or may be spouted to cleaners or separators

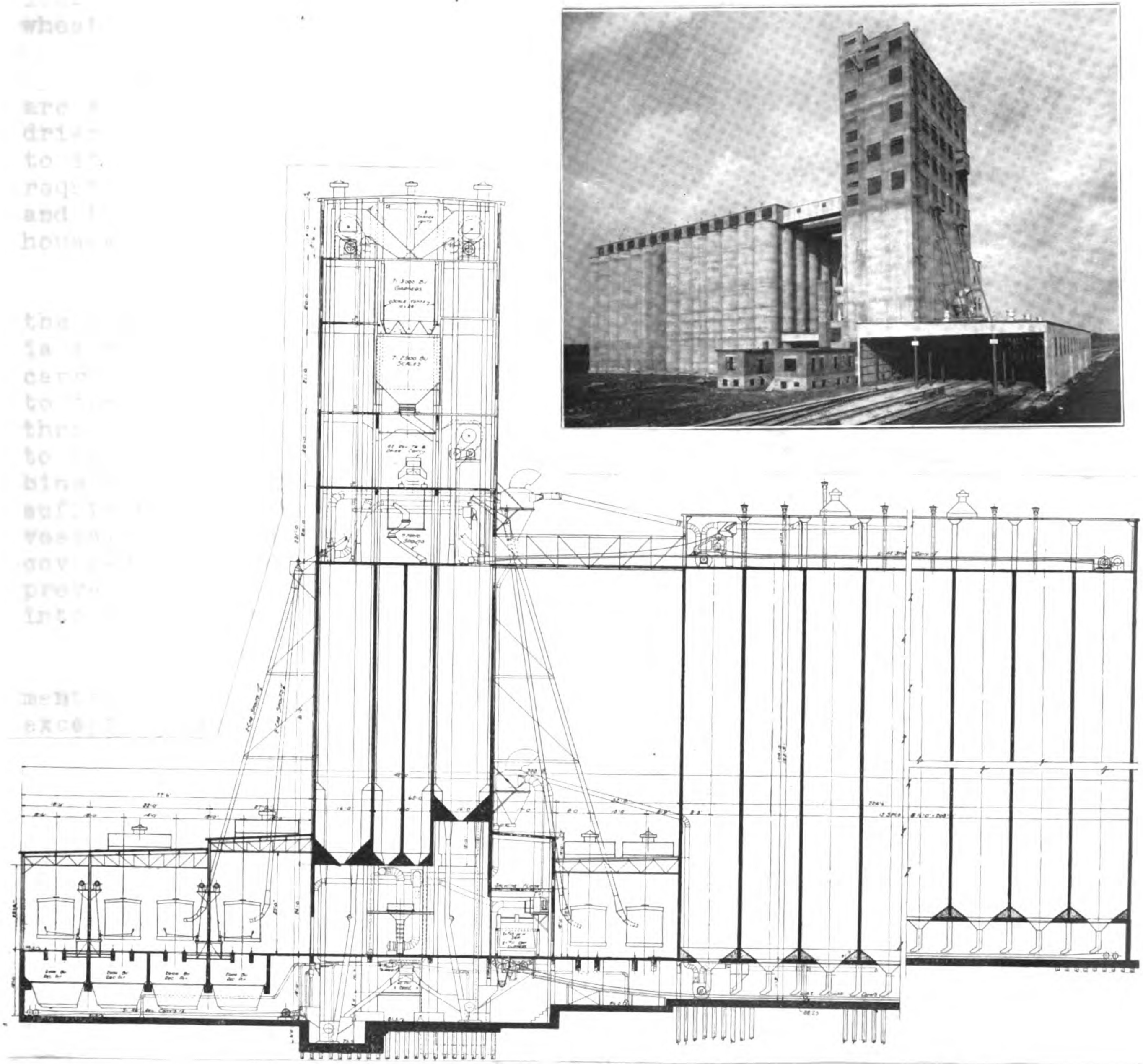


Figure No. 2.
A Modern Terminal Grain Elevator

The view in the upper right shows the car shed, the work house, the grain storage tanks, and several auxiliary buildings.

The drawing below is a transverse cross-sectional view of the same elevator which is explanatory of the interior construction and the placing of equipment.

where the grain is cleaned before being sent to the bins or tanks. Such cleaners or separators are practically always located in the work house. The work house may also contain wheat washers, oat clippers, and other machines.

4. The drier house, although not all terminal elevators are equipped with facilities for drying grain. Usually the drier house is either detached from the work house or attached to it with standard fire cut-offs. Where driers are used it requires a furnace or boiler for supplying hot air or steam and these are usually located in separate cut-off boiler houses.

5. The storage section, made up of tanks or bins, where the grain is stored. Over the top of such tanks or bins there is a gallery or "texas" in which are located conveyors which carry the grain from the distributing floor of the work house to the bins or tanks. Below the tank is a floor or tunnels through which belt conveyors travel, the purpose of which is to carry the grain discharged from the bottom of the tanks or bins back into the work house where it is elevated to a height sufficient for spouting or conveying directly into cars or vessels. In the more modern elevators, the bins or tanks are covered, thus separating one tank from the next as well as preventing to some extent the issue of dust from the tanks up into the gallery.

6. The shop, laboratory, office and change room departments, which are usually detached from the main elevator, except in some of the older elevators where they may be attached or even within the main elevator building in which case they are usually cut-off from the hazardous dusty sections.

Note: In some types of elevator construction, the functions of the work house are combined in a superstructure built above the tanks or bins with the elevator legs, stairways, etc., extending upward from the basement or first floor in spaces between tanks or bins.

Of the above divisions, those which can without question be placed in the hazardous class are, divisions 3, 4 and 5, with no exceptions. Division 1, the car shed, in part, at least, might be questioned. Usually car sheds are of semi-open construction permitting of free air circulation, thus eliminating to a large extent the possibility of dust explosion. However, electrical equipment in car sheds is frequently placed in such a location that considerable dust will collect on it. This is especially true of motors which are often placed on decks or in pits where maintenance work is difficult. Where this is done, Class II equipment should be used. The locations under the floor or track level of the car shed, such as tunnels or unloading pits should be definitely classed as Class II locations.

Marine legs, division 2, are often tightly constructed of concrete and, therefore, the dust explosion hazard is as serious as in the main work house. In the majority of cases, marine legs should be classed as hazardous locations and the electrical equipment installed to suit. Boiler houses, power houses, transformer and switch houses should not be classed as hazardous locations.

As in the case of the newer country elevators, the tendency in the more modern terminal elevators is toward individual motor drives for machinery and the isolation of motor controllers with provisions for remote control through push button stations. Elsewhere in this volume will be found illustrations of several typical installations.

The dust condition in terminal elevators is more serious than in either the country elevator or the mill elevator, due to the large amount of grain handled and the speed at which the various operations are carried on. The amount of dust in suspension and accumulated depends to a large extent on the nature of construction and arrangement, the type, if any, of the dust collection system, and the character of housekeeping and maintenance. However, even in the best of elevators, conditions at times are of an extremely hazardous nature.

Mill Elevators

By mill elevators are meant those located at flour, feed or rice mills, malting plants, breweries, linseed oil plants, or other points where grain storage is needed. The functions are identical with those of country and terminal elevators, namely, those of receiving, cleaning and storage of grain. Facilities for washing and drying grain are sometimes included. There is usually more cleaning equipment in the mill elevator than in those previously discussed in order that the grain may be more completely prepared for milling.

In the smaller milling plants, the grain elevator may be very similar to the country elevator, but in the large modern merchant milling plants, the grain storage facilities represent what are practically terminal elevators, large capacity being needed to insure sufficient grain to maintain uniformity of product.

Further discussion of mill elevators is not needed as that included under the sections on country and terminal elevators will, with the understanding that the hazards are practically identical, give the engineer sufficient data as to what type of electrical installation is required.

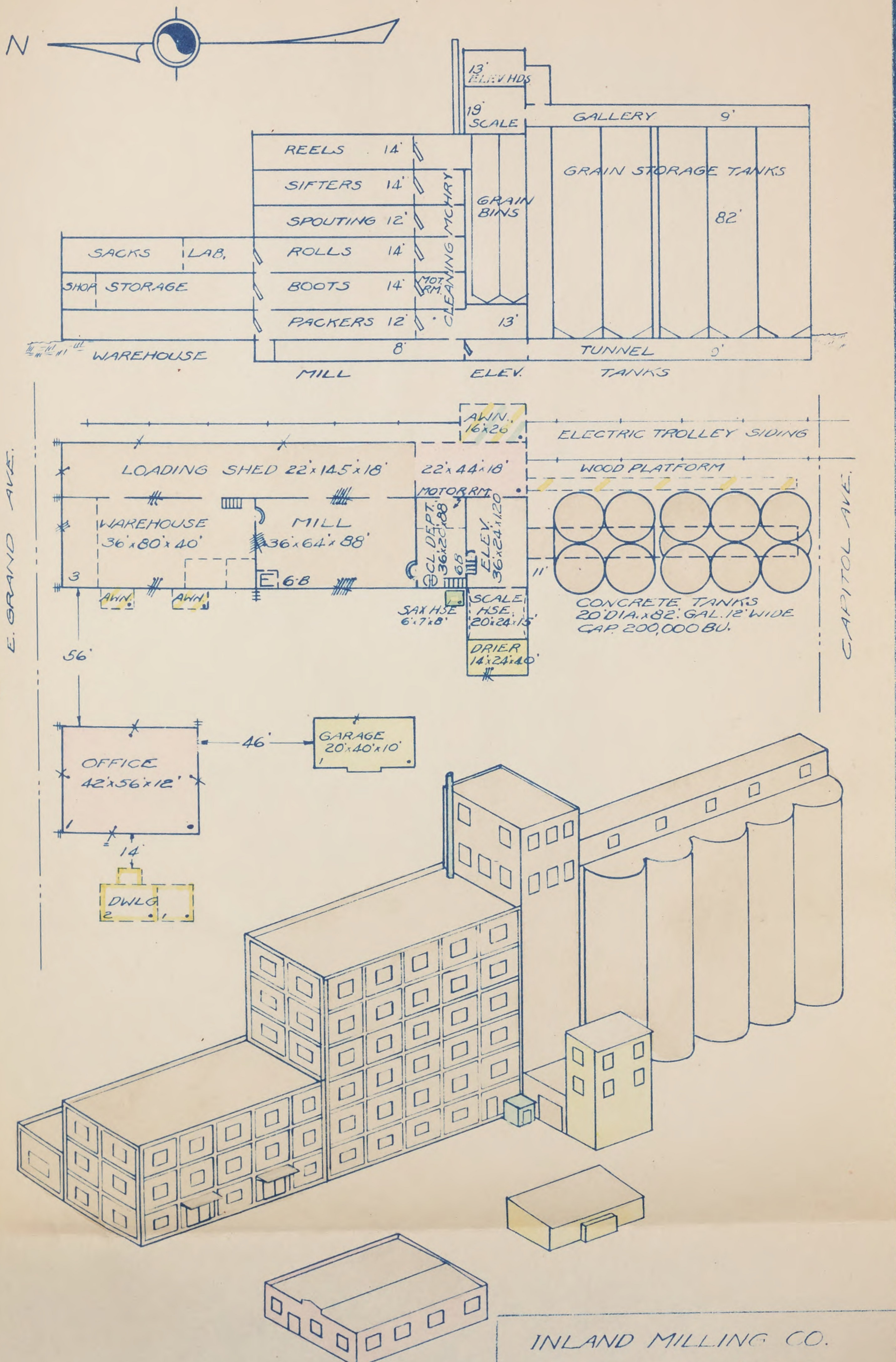
FLOUR MILLS

The milling of wheat, rye, or corn is a process of gradual reduction and separation which is accomplished by a group of machines operating coincidently and almost always driven by a single power unit. In brief, the process is as follows:

When the wheat comes from the elevator it has, as previously related, been cleaned to remove chaff, dirt, dust and other foreign materials. However, before being milled, further cleaning is necessary and this is done either in the mill proper or in a division known as the cleaning or "smuts" department cut off from the milling division. The wheat is spouted into the boot of an elevator leg, is elevated, usually weighed, and passes over a magnetic separator to remove any iron or steel which might be present and then over a cleaner or separator similar to those used in an elevator. The grain is now sent through a scourer which removes the tiny hair, present in the end of the grain berry, and remaining dust by a type of abrasive and brushing action. Foreign seeds and grain are removed by disc type separators and this leaves the grain ready for tempering preparatory to milling. Tempering is done in bins or steel tanks and consists of adding a certain small amount of water to the grain and permitting it to remain in the tempering tanks for a period of from twelve to twenty four hours and sometimes longer depending on the type of grain. The tempering bins or tanks may be located in the cleaning department or in the mill division proper.

The grain now passes into the milling process proper. The first step is the breaking of the grain which is done in a roller mill equipped with corrugated rolls. The broken or slightly crushed grain, as it is discharged below the rolls, is elevated by means of cup belt elevators and discharged into spouts connected with a sifter or bolter which removes the flour resulting from the initial crushing and sends the balance or "tailings" back to another roller mill for further grinding. This procedure is repeated a number of times. The result of this process of gradual reduction and separation is the production of several grades of flour, bran and middlings which are spouted into their respective bins. The exact process or "flow" of a flour mill is too involved to detail here, but it is hoped that the brief explanation given will be sufficient for our needs.

The packing of the finished products into sacks or barrels is done either in the mill building proper or in a separate packing building. If the latter, the flour is carried by means of special conveyors or spouts into bins or tanks located directly over the packers. When the products are packed into sacks or barrels, auger type packers are used, but when placed in cartons, special automatic packers are



INLAND MILLING CO.
DES MOINES, IOWA
MUTUAL FIRE PREVENTION BUREAU
ENGINEERING SERVICE DEPT.
CHICAGO ILL
DATE 3-10-32
SCALE 1" = 50'
PRINT NO.

Figure No. 3.
This drawing shows the various divisions of a flour mill including the warehouse and grain elevator.

found which form the carton and fill, weigh, close and wrap them ready to be placed in shipping cases.

There are many refinements in the milling process such as bleaching, purifying and rebolting, which, while important to the miller, need not be mentioned here. Figure number 3 gives a map, cross section and an isometric drawing of a modern flour mill, indicating the divisions and general arrangement.

The following summarizes the divisions into which a flour mill may be divided and briefly states the operations conducted in each:

1. The office with which is sometimes combined a laboratory and retail sales room.

2. The elevator or grain receiving and storage department where grain is received and stored. In the larger mills, this division approaches in size and equipment a terminal grain elevator.

3. The cleaning department where the grain is cleaned by removal of chaff, dust, etc., sometimes washed and dried, and scoured. In some mills, this department is divided from milling department proper by definite fire walls, but in others it is in the same fire division.

4. The mill proper where the grain is ground in roller mills, bolted or sifted, purified and rebolted. The products from this department are flour of various grades and the offal consisting of bran, middlings, etc. From this department, the products go to packing bins located in the same building or sometimes (in larger mills) located in a separate packing building.

5. The warehouse and shipping departments where the sacked flour and other products are stored and held for shipment.

6. The shop and similar departments.

Of the above divisions, in general, divisions 1, 5, and 6 are not considered in the hazardous class unless they are so much a part of a unit building including the main milling operations that no definite separation may be assumed. Divisions 2, 3 and 4 should be regarded as Class II locations. Division 2 may be subdivided as has already been done under terminal and country elevators, although in the case of the smaller mills, this division is really often a part of the unit mill building. In the case of division 4, it is usually found that the major portion of the milling machinery is driven by a single motor as the relation of one machine to

the next is coincidental. In most cases, this motor is located in a separate power house or motor room which, if of suitable construction, places the motor outside of the hazardous area. Motor control equipment is then located in the motor room. In the case of auxiliary motors in section 4, these should be approved for Class II locations. The same remarks can also apply to section 3 as here, to at least a large extent, the machines also operate together as a unit.

The divisions suggested above are based on average conditions and hold for the majority of cases. In some instances, however, we find that housekeeping is far above average and that adequate dust control and collection systems have been installed which greatly reduce the dust explosion hazard as well as the hazard of electrical fires due to accumulation of dust on or in apparatus or wiring. But what is the condition today may not necessarily be true tomorrow, for some fault might develop in the dust control system for instance, which would cause the dust condition in the risk to be especially bad and should an electrical fault develop at the same time, a serious dust explosion or fire might result.

Most of the floors of such a modern flour mill, that is, of the main mill building, are clean and the atmosphere is remarkably free from suspended dust so long as the mill is operating properly. But let a choke-up or a serious leak develop in the spouts or elevator legs and we find that a considerable amount of flour dust is thrown into suspension in the air. Should a motor burn out, an electric light break, or a short circuit occur at the time when this dust is in suspension, the chances of a dust explosion are good. But the point is, that in order for this explosion to occur, a number of conditions must prevail concurrently. The chances of a motor burnout at just that time, for instance, may not be one in a thousand, but the chances of sparks from a commutator or slip ring coming at that time are good. Hence, the definite rule 3204e (N. E. C. Article 32) which provides for enclosing such parts of motors. Note that rule 3204f permits open squirrel cage motors except where it is impracticable to keep them clean.

It should be kept in mind that in flour mills we are dealing first with grain, which, no matter how many times it is cleaned, will shed a highly explosive dust when spouted or otherwise handled, and second, with a finely divided starchy material known as flour which is also highly explosive when in suspension in air. The many explosions which have occurred in flour mills are sufficient to warn us of the hazards with which we are concerned and the precautions which must be taken to avoid these explosions and fires.

FEED MILLS

The process of preparing feeds for livestock and poultry is generally a combination of grinding and mixing operations, although some feed mills confine their activities solely to grinding or to mixing. In any event, however, the process is usually attended by the handling of quantities of grain, and therefore, the dust hazard is present to a greater or lesser degree.

Feed mills offer a wide variety of sizes and types of arrangement ranging from the small custom feed mill to the large commercial feed mill producing a complete variety of feeds. It is, therefore, difficult to attempt to describe the processes involved and the arrangement of buildings or divisions. However, the average feed mill may be assumed to consist of the following divisions:

1. The office with which is sometimes combined a retail sales room.

2. The elevator or grain receiving and storage department where grain or other feed constituents are received and stored in bulk.

3. The grinding, mixing and packing department.

4. The warehouse or warehouses used for the storage and handling of sacked products or sacked feed constituents.

5. The shop, laboratory, and change room departments.

In general, divisions 1, 4 and 5 are not to be considered as hazardous locations for in these departments we rarely find dust conditions such as to be dangerous either from the standpoint of dust in suspension so as to introduce the dust explosion hazard, or from the hazard of collection of dust on or in motors or other electrical equipment so as to prevent normal radiation of heat.

There then remain divisions 2 and 3 which should be classed as Class II locations, and the electrical equipment required to be installed accordingly.

In the small feed mill, the operations are similar to those of the average feed mill except that they are on a smaller scale. Also, the various divisions detailed in the foregoing may, in many cases, be contained under a single roof with no attempt at providing fire cutoffs. It is, therefore, necessary in such cases to place the entire building in the Class II classification.

In the large commercial feed mill, the operations are usually entirely given over to the grinding and mixing of feeds in large quantities intended for shipment in wholesale quantities by truck or rail. The values involved are generally high and, consequently, the probability of heavy damage from explosion or fire is correspondingly great. In this type of mill, the same departments as in the average feed mill usually exist, but some divisions, especially divisions 3 and 4 may be further subdivided to provide separate departments for mixing and grinding, and often, still further subdivision of both of these is found as pertaining to the mixing of dry feeds and molasses feeds as well as to grinding of the different feed ingredients. In some plants, for instance, an entirely separate building is employed to house the cotton seed cake grinding operations. This, however, does not affect the classification and all such departments included under 3 and 4 must be placed in the hazardous class. Figure number 4 is a reproduction of a photograph taken of a large eastern commercial feed mill.

In the large commercial feed mills, the grain receiving and storage department, as in division 2, approach in construction and equipment that of a terminal elevator.

In feed mills it is the exception rather than the rule to find group drives for machinery. Individual motor drive is used because of the fact that each grinder, for instance, is independent of the operations of a mixer and so on through the plant. It is not uncommon to find as many as 100 motors in the larger commercial feed mills.

So far as the hazards of dust are concerned, they are not far different from those existing in flour mills and grain elevators. It is usually more difficult to maintain a feed mill in a clean and neat order owing to the more open nature of operations, so feed mills are generally considered more hazardous from the dust explosion standpoint than flour mills. The matters of selection and installation of electric power and lighting equipment for feed mills are of prime importance to provide the necessary safeguards against ignition of dust.

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So far as the hazards of dust are concerned, they are not far different from those existing in flour mills and grain elevators. It is usually more difficult to maintain a feed mill in a clean and neat order owing to the more open nature of operations, so feed mills are generally considered more hazardous from the dust explosion standpoint than flour mills. The matters of selection and installation of electric power and lighting equipment for feed mills are of prime importance to provide the necessary safeguards against ignition of dust.

CEREAL MILLS

Cereal mills may, in general, be considered to be in approximately the same class as feed mills with regard to the dust hazard. This applies especially to those producing rolled oats, for records reveal a number of disastrous dust explosions in such plants. In the better type of cereal plants, such as those producing corn flakes and other breakfast foods, the standard of housekeeping is usually of a high grade and, therefore, the dust explosion hazard, as affected by the nature of the electrical installation is not as serious as in others. However, all cereal mills must have facilities for receiving grain. Hence, the grain receiving department or elevator must be considered in the same class as any other elevator. The other departments of a cereal plant are subject to individual study and judgment.

Figure No. 4.
A Large Commercial Feed Mill.

The buildings in the background are the feed mill and elevator divisions. The warehouses are shown in the foreground.

STARCH FACTORIES

The larger part of the starch made in this country is a product of corn. Due to the carbonaceous nature and finely divided character of powdered starch, it has been found to be extremely explosive. Several disastrous explosions have occurred in starch plants within late years and, unfortunately, in most of them, a number of lives were lost.

The manufacture of corn starch first involves means for receiving and cleaning the shelled corn. For these purposes the starch factory buildings include a grain elevator similar to those previously discussed. In the larger starch factories this elevator is practically in the terminal class and it should be so regarded.

When the shelled corn has been thoroughly cleaned in the elevator, it is conveyed or spouted to the main starch plant where it is placed in steeping tanks containing water, where it is permitted to remain for from thirty to forty hours. From this point to the point where the starch is kiln dried, the process is of a wet nature and, therefore, the dust explosion hazards are not present, and these divisions of the process need not be discussed here. By the time the starch reaches the kiln drying operation, the hull, the steepwater or soluble protein matter, the germ from which corn oil is made, and the gluten have been removed, leaving starch, the main product, which constitutes about 65 per cent of the original shelled corn. The starch is placed in drying kilns in screened trays on wagons and after drying about twenty-four hours, the starch is passed through a milling process similar to that of a flour mill whereby the starch is reduced to the size required by the particular purpose for which it is to be used.

Edible starch is given further washing and milling to remove impurities, while laundry starch is partly cooked with steam to increase the solubility, then pressed, broken up and passed through reels. After these operations, the starch is packed in barrels, bags, or cartons as desired.

Dextrine is made by treating dry starch with a small amount of hydrochloride or nitric acid, and roasting until the starch is partially cooked or dextrinized. Dextrine is used for making glue, gum, leather dressing, cloth and carpet sizing, and foods.

Corn syrup is made from wet starch from the filters and the process is non-hazardous from our viewpoint. Therefore, it will not be discussed. As a by-product in the manufacture of the syrup, corn sugar is produced, but under ordinary conditions the process is not hazardous so far as application of Article 32 is concerned.

Of the various divisions of a starch factory, the elevator should be given the same treatment as given under "Terminal Grain Elevators," that is, regarded for the most part as a Class II location. The sections of the main starch plant beginning at and including the dry kiln room through the packing department, should likewise be considered as Class II locations except for offices, laboratories, or similar rooms, cut off from the hazardous area so as to be free from starch dust, and the warehouse used solely for the storage of finished starch in barrels, sacks or cartons. It is likely that the larger part of the dextrine department should also be considered as Class II locations owing to the fact that dry starch and dextrine are handled. The gluten feed department is somewhat similar in nature to a feed mill and, therefore, requires consideration as recommended under the section "Feed Mills."

RICE MILLS

In the process of preparing rice for the domestic market, a certain amount of combustible dust is liberated, making it necessary to regard certain parts of rice mills as Class II locations.

Rice mills, as found in Louisiana and Texas, receive the rough rice in sacks from the rice warehouses located throughout the rice growing sections. In the rough form, the rice grain is covered by a thin skin known as bran and this by a tough hard shell or hull. The milling processes consist of thoroughly cleaning the rough rice or "paddy", then hulling, removing the bran, polishing and grading and finally packing in sacks or cartons. As in the case of flour and feed mills, facilities must be provid d for the storage of rough rice. In the usual rice mill we, therefore, find extensive warehouses for the storage of this rice in sacks. These warehouses commonly adjoin an elevator similar in nature to the grain elevators previously discussed, and in these are located machinery for cleaning and handling the rough rice in bulk, previous to its being conveyed or spouted to the main mill building proper for processing. In handling rice in the elevator, considerable dust is usually released, and inasmuch as rice dust forms explosive mixtures with air, the elevator should be considered as a Class II location as qualified by the analysis given under "Grain Elevators." The warehouses used for the storage of sacked rice are usually cut off from the elevator and, therefore, need not be considered as Class II locations.

In the processes of hulling, separating, pearling, polishing and grading carried on in the rice mill proper, there is considerable combustible dust liberated, in fact, while no grinding is actually done in the ordinary rice mill, the rice milling building is subject to the same comments as made under "Flour Mills", and the building is regarded as a Class II location. Where rice flour is produced, the process is similar to that used in the milling of wheat flour and is, therefore, to be similarly considered in establishing the application of Article 32. After the finished rice comes from the milling process, it is sent to the packing department in sacks or cartons. This is usually done in a separate building attached to, but cut off from the mill building and commonly forms a part of the warehouse used for the storage of the finished sacked or package rice. The packing department and warehouses should not be considered as hazardous locations.

VEGETABLE OIL INDUSTRY

Vegetable oils, such as cotton seed, linseed, soy bean and others of this class, are not regarded as flammable volatile liquids due to the fact that their flash points are relatively high, ranging from 470 to 590 degrees Fahrenheit. However, there are certain hazards attending their production and refining which require that they be discussed briefly. It is recognized that these vegetable oils are hazardous from the standpoint of contributing to spontaneous ignition, but that hazard does not immediately concern us.

Cotton Seed Oil Mills

In the manufacture of cotton seed oil, the cotton seed is received directly from the cotton gins as removed from the seed cotton by the ginning process. In this form the seeds contain much foreign material such as dirt, bolls and twigs, and the seeds have clinging to them considerable lint. Upon arrival at the oil mill, the seeds are stored in the seed house from whence they are passed through revolving reels or screens to remove the foreign material. The next step is the delinting process by which means the lint is removed from the seeds. This is done by means of machines similar to cotton gins. The seeds then enter the hulling machines while the cotton linters are baled for shipment. After hulling, the seeds are crushed, cooked and finally pressed to remove the oil, which is then refined by filtering. The cotton seed cake remaining from the pressing process is broken up or sold whole to be used in the manufacture of live stock feeds. From our point of view, the hazards connected with a cotton seed oil mill are those resulting from the presence of cotton lint. The delinting room is commonly found to have considerable loose,easily ignitable lint hanging to machinery and building members, and ignition of this lint would cause a serious flash fire. The delinting department should be regarded as a Class III location. The baling room, cleaning department, and seed house are also hazardous locations because of the presence of lint, and all should be regarded as Class III locations.

Soy Bean Oil Mills

In plants used for the manufacture of soy bean oil, the hazards are not particalarly great from our standpoint unless the solvent extraction method of separating or refining the oil is used. If this method is used, the extraction or refining rooms become Class I locations as do the rooms containing the

pumps used to handle the flammable solvents used in the process. Attention is called to the section entitled "Extraction Processes" under "Chemical Works." The soy beans as received at the mill are handled and stored in a manner similar to that used in connection with flour mills, that is, in elevators, This section of the plant then, is subject to the comments under "Grain Elevators."

Linseed Oil Mills

The process of producing linseed oil is quite similar to that used for soy bean oil, and the same comments apply. The flax seed is received in bulk and handled and stored in grain elevators identical with those used in connection with flour mills.

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WOODWORKING FACTORIES

In this class are included a large number of industries producing lumber or articles manufactured from lumber such as saw mills, piano factories, furniture and cabinet works, box factories, wagon and auto truck building plants, wicker, veneer and woodenware works, agricultural implement factories and numerous others. In many of our industries, woodworking is an important operation in the manufacture of articles requiring other processes such as the working of metal, upholstering and paint and varnish finishing and, therefore, we may have a combination of different types of hazards present in a plant normally classed as a woodworker.

Considering for the moment only the immediate hazards of the woodworking industry as such, we find we are concerned with one which involves the production of a great amount of waste in the form of wood shavings, saw dust and finely divided wood dust. The modern woodworker is equipped with adequate blower systems which remove this waste practically as fast as it is produced and, therefore, the amount of waste accumulated about the various machines is at a minimum. However, there is still usually a certain amount of waste which accumulates about machines to such an extent as to collect in objectionable quantities in open motors, in switch boxes and on resistors and lamps. Such waste, especially when in the form of fine dust or as loose shavings, may readily be ignited by sparks or arcs from electrical apparatus and wiring.

In the newer types of wood working machinery, we find that individual motor drive has been adopted to a very large extent, the motor and its controller being mounted directly on the machine or built into it as an integral part. Unfortunately, this practice often places the motor at a point where it is subjected to considerable dust and many motor burn-outs and resulting fires are traced to breakdown of windings caused by these dust accumulations. However, there now seems to be a trend toward the use of the enclosed types of motors for use with woodworking machinery a course which is highly commended. In the older woodworking plants, it is common to see motors mounted on platforms suspended from ceilings in which position they are likely to gather considerable fine dust, and as they are relatively inaccessible due to their location, probably do not receive as frequent cleaning as is warranted. In many cases, therefore, the engineer is justified in requiring that motors be of the enclosed type. This point is definitely covered in the rules for Class III locations, in which class woodworkers fall.

The nature of the waste in woodworking plants is such as to render dust explosions an improbable occurence, with the exception of the shavings and dust vaults, in which it is common to find a cloud of fine wood dust in suspension. These

vaults should be regarded as Class II locations. However, flash fires may easily occur in the main plant, especially in the neighborhood of sanding machines where a very fine dust is liberated. A certain quantity of this dust passes off into the air in spite of dust collector systems, and finally comes to rest on beams and other horizontal surfaces in a thin film through which fire may pass with considerable rapidity. Therefore, in woodworking plants, precautions should be taken to prevent ignition.

In the application of the rules for Class III locations to woodworkers, it is necessary to consider as Class III locations, only those areas surrounding machines which produce waste in quantities. The general joining, fitting and assembling departments as usually found, may be regarded as sufficiently safeguarded by the use of reasonable care in locating motors and in enclosing switches, fuses and motor controllers.

Where painting and varnishing are done on any considerable scale, the departments where this process is carried on should be cut off from the balance of the plant and considered as Class I locations. This department is then subject to the discussion given under "Finishing Processes".

Upholstering is often an important process in woodworking establishments, especially in those manufacturing furniture, automobile bodies and caskets. This process usually involves the use of large quantities of readily ignitable fibers and in plants of appreciable size include the storage and picking of such fibers. The hazards involved are similar to those discussed under "The Cotton Industry" to which reference should be made. The upholstery departments are usually in separate divisions and these should be considered as Class III locations.

A comparatively new industry is that concerned with the manufacture of wood flour which is used as the basis for wood fillers and other purposes. In the preparation of this product, wood is reduced to a very fine powder in pulverizing mills and is attended by the release of considerable fine dust. Although the writer has never had the opportunity of visiting a plant of this type, the N.F.P.A. Committee on Dust Explosion Hazards has seen fit to draw standards for the construction and arrangement of wood flour plants in which adherence to the rules for Class II locations is prescribed with respect to the installation of electrical apparatus and wiring.

INDUSTRIES AND PROCESSES IN GENERAL

To this point we have discussed in a rather complete manner, a number of industries and processes in which the rules of Article 32 apply more or less generally. There are, however, numerous other industries or processes to which the rules of Article 32 should be applied, probably to a small part of the plant or to a portion of a process or operation. In the following a few of these will be mentioned merely indicating the probable application of the rules of article 32.

Ammunition and Explosives

The manufacture of these materials is in the hands of thoroughly reliable firms who take upon themselves the responsibility for safeguarding life and property. Hence, discussing recommendations for electrical construction in factories manufacturing these materials would be of questionable value. In general, motors and their control apparatus are placed outside the hazardous area, and lighting is by the indirect method with the lights placed in a non hazardous area.

Automobile Factories

The chief hazards from our viewpoint are woodworking, painting, varnishing and upholstering, all of which have been discussed under their respective headings.

Candy and Chocolate Factories

Only the sections used for the pulverizing of cocoa and sugar should be placed in the hazardous class. Cocoa and sugar dusts are explosive and, therefore, the rooms where these are produced should be considered as Class II locations.

Clothing Factories

In the cutting of cloth considerable waste and lint are often produced and reasonable means should be taken to prevent its ignition. The rules for Class III locations should be followed as far as they apply.

Coal Pulverizing and Handling

Coal dust is extremely explosive and this should be kept in mind when considering electrical installations in power houses or other locations where coal is pulverized. In

general, the coal pulverizing departments are regarded as Class II locations. In the handling of bulk coal in coal elevators, coal pockets and bunkers, similar consideration to the rules for Class II locations should be given.

Combustible Fibers other than Cotton

In general, the same comment applies as given under "The Cotton Industry." Bagging factories and upholstery works should be considered as Class III locations. Warehouses used for the storage of fibers such as jute, tow, hemp, etc., are included as Class IV locations.

Electric Appliance Manufacturing

Finishing process hazards are predominant from our viewpoint. Also hazards attached to the use of flammable volatile solvents for thinning insulating varnishes applied by dipping and baking. Reference should be made to section on "Finishing Proceses."

Garages

Inasmuch as electrical rules for garages are contained in Article 33 of the National Electrical Code, discussion of them is not within the province of this thesis.

Hat Manufacturing

In the manufacture of straw hats, the practice of using pyroxylin lacquer for sizing and varnishing is becoming very common. Generally, this is required to be done in a cut off room which, with the drying room, should be regarded as a Class I location. The hazards are similar to those discussed under "Finishing Process."

Mattress Factories

These are usually regarded as a poor fire insurance risks due to the presence of quantities of loose combustible fibers. In general the sections devoted to the storage of the fiber, the picker rooms, and the mattress filling department should be regarded as Class III locations.

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Metal Working Processes

Outside of the hazards associated with the painting or varnishing of finished products, the hazards of metal working processes are light. A notable exception is that present when dipping processes involving flammable solvents are used for the removal of cutting oil and grease preparatory to heat treatment or plating or for rust proofing purposes. The hazards of such dipping processes are equivalent to those of ordinary naphtha thinned varnish dip processes. Attention is called to the section headed "Finishing Processes."

Oil Clothing Factories

In one step in the process of manufacturing oil clothing, the garment is painted with a naphtha thinned varnish. General rules usually require this to be done in cut off rooms which should be regarded as Class I locations. This also applies to the dry room connected with this step of the process.

Paper Industry

The manufacture of paper must be regarded in the light of a process producing an easily ignitable material. The modern paper factories producing newsprint and similar papers from wood pulp are usually well ordered and all waste is promptly removed and reworked. In paper factories producing special cut papers, there is likely to be considerable waste and cuttings, and in such plants extra precautions should be taken to prevent ignition. It is probable that reasonable application of the rules for Class III locations will be sufficient. In the production of certain papers or paper products, such as boxes and cartons, varnishes are used. Such processes should, in general, be subjected to the comments made under "Finishing Processes." Also see section on "Fabric and Paper Coating Plants."

Printing Industry

In this industry, we are concerned chiefly with the use of flammable liquids in the mixing of inks and cleaning of type and presses. Usually, the amounts of such liquids used for the latter are comparatively small and require only reasonable care to prevent ignition of vapors. However, in some types of inks, especially those used for "Rotogravure" processes, naphtha is used for thinning, in fact some rotogravure inks are composed of one part ink to three parts naphtha. In printing establishments where such inks are used, it is apparent that rigid precautions should be taken, possibly to the extent of enforcing all provision of the rules for Class

I locations, especially if the presses are located in small, poorly ventilated rooms. Another hazard found in some types of printing establishments is that of accumulation of waste paper and trimmings which justifies the enforcement of the rules for Class III locations in some instances.

Soap Manufacturing

In the manufacture of some types of soaps naphtha is added to the extent of about 5%. The naphtha is added when saponification is completed and is mixed with the soap at a low temperature. Necessarily, the manufacture of such soap entails the storage and pumping of naphtha and requires the application of the rules for Class I locations to the pump houses and the rooms where the naphtha is mixed with the soap. In toilet soaps, of the transparent variety, alcohol is used for the purpose of dissolving the soap and permitting the impurities to settle, whereupon the alcohol is distilled off. Obviously, the rooms or sections where these processes are carried on should be regarded as Class I locations. Liquid soap is made by dissolving a hard soap, usually made from cocoanut oil, in warm alcohol to which potash and essences are added. It is likely that the flammable vapors of alcohol will be present where this process is carried on and, therefore, the rooms or section involved should be considered as Class I locations. It has been discovered that soap dust is explosive and for this reason due consideration should be given to the application of the rules for Class II locations to the soap pulverizing rooms.

Sugar Refineries

The manufacture and refining of sugar is largely a wet process and, therefore, there are no unusual hazards present from our viewpoint. However, when sugar is pulverized, the dust explosion hazard is present as sugar dust is quite explosive. The rules for Class II locations should be enforced in the pulverizing rooms or department.

Woolen Industry

As wool fiber is not readily ignitable and burns very slowly, we are not concerned with the woolen industry generally. However, in many types of woolen fabrics some cotton is used which may place certain sections of what are normally woolen mills in the hazardous class. When this is found to be the fact, the comments made in the section entitled "The Cotton Industry" apply.

P A R T III

THE RULES OF ARTICLE 32

Containing a complete
discussion of the rules
of Article 32 with re-
ference to their intent
and application; illust-
rated to indicate apparatus
available and methods of
installation.

THE RULES OF ARTICLE 32

INTRODUCTORY

Having disposed of the question of classification by means of the foregoing discussion, it is now in order to discuss the individual rules of Article 32 as applied to each of the four classes into which the various types of hazardous materials have been placed. Such discussion should be of value inasmuch as many engineers and inspectors have requested interpretations regarding the application of some of the rules to definite installations and advice concerning the suitability of certain apparatus for use in a given hazardous location. This might seem to indicate weakness in the wording of the rules, but before reaching the conclusion that the rules should be more explicit, it should be remembered that an attempt has been made in Article 32 to outline the requirements for safe electrical construction for a host of various types of industries and conditions. To mention in the rules every conceivable condition which might arise would result in an article far too lengthy for the practical uses of the engineer or inspector. In fact, it would be a volume in itself. Necessarily then, the rules were required to be more or less general with respect to detailed application, and yet specific enough in principle to be capable of enforcement.

In this section of the thesis it is proposed to discuss each rule individually. First, by stating the intent of the rule and the reasons for its inclusion; second, by suggesting possible forms of electrical construction to comply with the rules; and third, by illustrating the application of the rule with photographs or drawings of available apparatus or actual installations. Included also is a brief outline of the standards of the Underwriters' Laboratories and their test methods as pertaining to the construction and required performance of electrical apparatus such as motors, controllers, fittings, and switches, intended for use in hazardous locations. To eliminate possible confusion, each of the four classes into which Article 32 is divided will be considered separately, and to render unnecessary reference to a copy of the National Electrical Code, each rule will be quoted in full.

GENERAL

Under the heading of "General" there appears a rule (Rule 3202a) which applies to all of the four classes and which states: "The requirements of this Article shall be considered additional and amendatory to those prescribed in Articles 1 to 19 inclusive of this Code." This rule is inserted for the purpose of calling attention to the fact that the

rules of Article 32 are not complete in themselves as covering all phases of an electrical installation, but are merely supplementary rules to provide the necessary guidance for installations in locations more hazardous than those ordinarily found.

CLASS I LOCATIONS

The first rule (Rule 3202a) of this section states: "In locations judged to be as described for Class I in paragraph b of section 3201, the following provisions shall be observed." This was inserted in order to make clear that the rules of section 3203 are to be applied when the engineer or inspector judges the conditions present to be as described in the definition of what should be considered as Class I location, -- in brief, where flammable gases, vapors, or highly flammable substances are present.

In several of the rules of this Class the term "explosion-resisting" occurs. A few words in explanation of this term at this point will make toward a better understanding of the rules. It has been found that it is practically impossible to make joints in conduit or fittings, the cases of controllers, and the enclosures of motors such as to be vapor or gas-tight. The alternate heating and cooling of the air within the enclosures results in an unbalancing of pressures to such an extent that the vapor or gas is forced through even the most minute openings. This phenomena is usually referred to as "breathing". Assuming, therefore, that the vapor or gas will enter the conduit and other parts of the enclosing system, it can be expected that the mixture of vapor or gas and air will explode when an arc occurs within the enclosure if the mixture is within the flammable limits of the vapor or gas involved. With this in mind, it is apparent that conduit joints and fittings, motor and controller cases, and other enclosures must be so designed as to prevent the emission of flame or hot gases, as well as to withstand the pressures developed within the enclosing system. The tests of the Underwriters' Laboratories, as will be pointed out later, are made on this basis.

Service Equipment, Panelboards and Switchboards

Rule 3203b provides: "Service entrance equipment, and all panelboards and switchboards shall not be installed."

It was felt that there was no good reason for installing this equipment within the hazardous area inasmuch as provisions could always be made for locating service equipment, panelboards and switchboards outside of the hazardous area. The rule is based on a premise which is used throughout Article 32, namely, that of eliminating as much electrical equipment from the hazardous area as possible, consistent with sound economics, and providing that more serious hazards, whether of an electrical or general nature, are not introduced by such elimination. While it may be possible to design and build explosion resisting service and distributing equipment, the cost would undoubtedly be excessive, especially for installa-

tions of any considerable size. Furthermore, the replacement of fuses which might often be necessary during working hours would entail opening the enclosing cases, a procedure which is distinctly undesirable.

In an industrial plant such as an oil refinery where the major portion is classed as a hazardous area, the service equipment, panelboards and switchboards are best located in a separate building outside of the hazardous area or one so built and located that explosive vapors will not be present within it. Very often such a building can be utilized for containing automatic motor controllers as well as the service and distribution equipment, thus serving a dual purpose.

In other instances where only a small part of the area is classed as hazardous the service equipment can usually readily be placed in an adjoining room or building in which the hazardous conditions are not present. As an illustration, in a rubber factory where the churn room may represent the only hazardous location, the service equipment could be placed in the calender room, boiler room, or other similarly non-hazardous location, and yet be convenient with respect to the churn room.

Type of Wiring

The Code requirements for wiring in Class I locations are contained in Rule 3203c as follows: "Rigid conduit with vapor-tight joints and fittings shall be employed as the type of wiring. Where it is necessary to employ flexible connections, as at motor terminals, an approved flexible fitting of the explosion resisting type may be used. At points where conduit terminates, such as at motor terminal boxes, switch boxes and similar places, provision shall be made for sealing off the conduit by use of a suitable insulating compound to prevent the passage of gases or vapors through the conduit system."

It is imperative that the type of wiring employed in Class I locations be of the safest type available. Rigid conduit seemed to be the only type which could be regarded as answering this specification for the reason that, unlike various types of wiring, it provides, (1) effective protection against mechanical injury to the conductors, (2) a low resistance equipment grounding circuit, (3) reasonable protection against possible arcs burning through the conduit wall, (4) explosion-resisting threaded joints or couplings, and (5) a type of wiring not unreasonably expensive. Other types of wiring such as armored cable, non-metallic sheathed cable, and open knob and tube wiring are not considered suitable for use in Class I locations for obvious reasons. Electrical metallic tubing or thin-walled conduit, as it is

sometimes called, is a comparatively new wiring material and although having many good qualities has not yet been considered satisfactory for hazardous locations. Its construction is such as to necessitate the use of threadless fittings with which there might be difficulty in making joints and connections permanently explosion-resisting.

It will be noted that the rule requires that joints be vapor-tight. It has been found that it is impracticable to make joints vapor tight, due to the "breathing effect." However, it has been established by test that the joints in successive lengths of conduit using threaded couplings are explosion-resisting provided that at least five threads of each length of conduit engage those in the coupling. From our standpoint approval based on the joints being explosion-resisting rather than vapor-tight is warranted. As a matter of fact, the next edition of the Code will so amend the rule.

What has been stated in the preceding paragraph with regard to the requirement for vapor-tight points also applies to the various types of conduit fittings. Complete lines of explosion resisting conduit fittings have been developed and are readily obtainable. Many of these have been approved for Class I locations by the Underwriters' Laboratories which have developed standards for the design and test of such fittings. These are equipped with threaded hubs rather than the usual "knock-out" openings and the covers are of the screw type, both provided with at least five engaging threads. Figure number 5 illustrates a group of approved fittings for various uses in Class I locations. The method of testing fittings is very similar to that employed in testing Class I motors to which section reference should be made.

Because of the fact that in many applications, it is necessary to provide a flexible connection at the terminals of a motor to permit shifting the motor on its base to take up looseness in belts, it was found necessary to make a concession and permit a flexible fitting at the motor terminals. In some instances it is necessary to provide some flexibility at motor terminals to prevent breakage of the conduit or objectionable loosening of conduit connections.where excessive vibration exists. It will be noted that the rule requires that this fitting be approved, and while approved fittings for this purpose are not yet available, it is expected that one will receive approval shortly. This particular type consists of a flexible metal tube made up of closed convolutions of special design and the whole covered with a wire braid. Screw connections are fitted to either end for attachment to the rigid conduit fitting and the motor terminal box. To obtain approval it is, of course, required that this

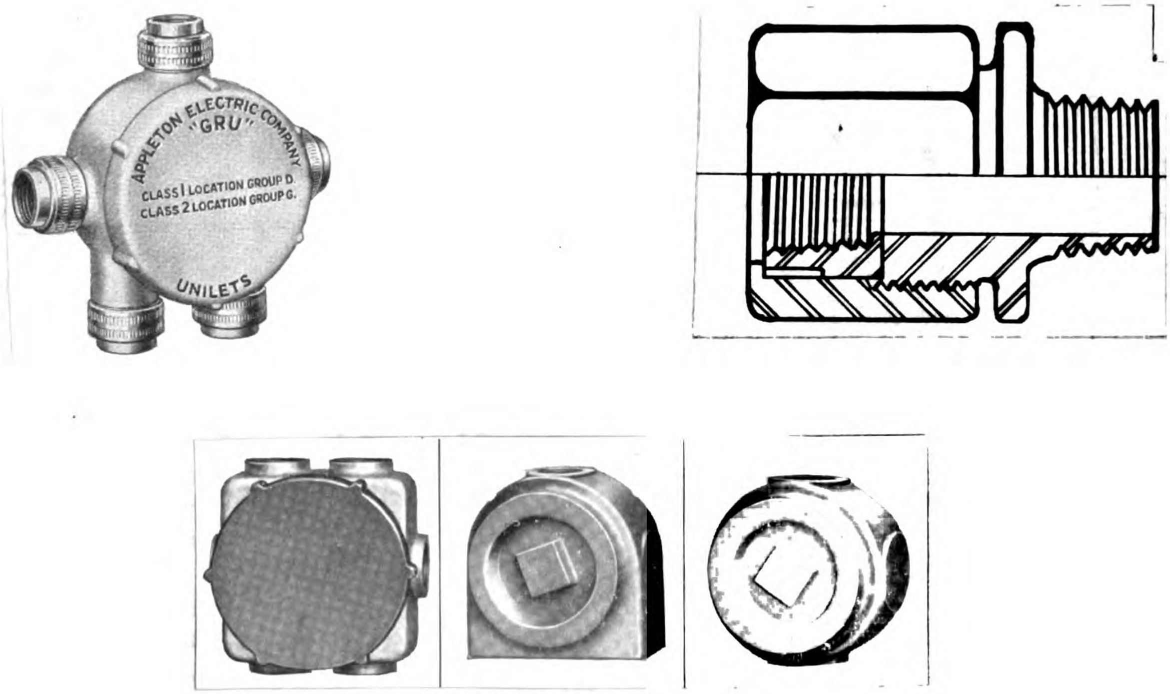
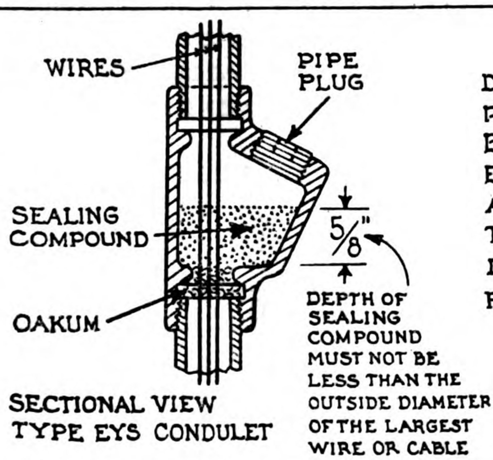


Figure No. 5.
Group of Explosion-Resisting
Fittings for Class I Locations

TYPE EYS SEALING CONDULET



TYPE EYS SEALING CONDULETS WERE DESIGNED TO FACILITATE SEALING OF A RIGID CONDUIT SYSTEM AS REQUIRED BY RULE 3203-C OF THE 1931 NATIONAL ELECTRICAL CODE WHICH READS IN PART AS FOLLOWS;- AT POINTS WHERE CONDUIT TERMINATES, SUCH AS AT MOTOR TERMINAL BOXES, SWITCH BOXES AND SIMILAR PLACES, PROVISION SHALL BE MADE FOR SEALING OFF THE CONDUIT BY THE USE OF A SUITABLE INSULATING COMPOUND TO PREVENT THE PASSAGE OF GASES OR VAPORS THROUGH THE CONDUIT SYSTEM.

Figure No. 6.
A Type of Sealing Fitting
Designed to Prevent Travel
of Vapors or Gases Through
Conduit Systems

fitting be explosion-resisting. The use of such flexible fittings should be avoided whenever possible but there are times when the exigencies of the case require their use and only then should they be permitted.

The provision for sealing-off conduit runs at motor terminal boxes, switch boxes and similar places was inserted in the rule for two reasons. Recognizing that the conduit system, controller cases, motors, and other enclosures are not vapor-tight, the "breathing action" would cause the vapors or gases, mixed with air, to enter the enclosing system where the mixture might be ignited by an arc from a motor controller, a spark from a motor or from an arc in the wiring. As the first consideration, it is desirable to limit the amount of vapor or gas present in an enclosing system subject to a single source of ignition by sealing off the conduit at the points mentioned and so break it up into a series of individual enclosures. This is especially important at motor controllers, switches, and commutator type motors where sources of ignition are present in normal operation, but should be done at all fittings, outlet boxes and other points as well, whether containing normally arcing or sparking parts or not. The second consideration involves the tendency of gases and vapors to diffuse. Assuming the presence of an explosive mixture in the conduit it would be most undesirable that this mixture be permitted to flow through the conduit to a point beyond the hazardous area to a service switch for instance, which being in a non-hazardous area would be permitted to be of the ordinary enclosed type. It is reasonable to believe that under some conditions a sufficient amount of an explosive mixture of vapor or gas and air would accumulate in this service switch to cause an explosion when the switch was operated. The switch box not being designed to withstand such explosion pressures would most likely burst, causing injury or fire.

Some manufacturers have so designed their Class I fittings, controller cases and other equipment to effect sealing by providing small wells into which the melted compound can be poured after the conductors are in place. There are available specially designed sealing fittings which are intended to be used at controller cases and similar points to provide easy facilities for sealing. One of these will be found illustrated in figure number 6. There are also suitable insulating compounds on the market, some of which are specially compounded to resist the solvent action of certain vapors and gases and which will not soften or crack in use.

Fuses and Circuit Breakers

The text of the rule (Rule 3203d) governing the use of fuses and circuit breakers is as follows: "Fuses shall not be installed unless mounted within explosion-resisting enclosures. Circuit breakers, if used, shall be of a type approved for use in explosive atmospheres."

It is contemplated that fuses and circuit breakers generally will be located outside of the hazardous area as discussed under "Service Equipment, Panelboards and Switchboards." However, there are instances where it may be desired to install them for single branch circuit protection or for motor overload protection in locations within the hazardous area. Obviously, it would not be desirable to depend on ordinary pressed steel cases for enclosing such devices in a hazardous area and therefore, explosion-resisting enclosures are specified for fuses and specially approved types for circuit breakers.

At this writing, there are no assemblies of fuses mounted in explosion-resisting enclosures approved by the Underwriters' Laboratories. It is probable that when such an assembly is submitted for approval that it will be as a complete device consisting of a cut-out block mounted in an explosion-resisting case having sufficient strength to withstand the pressures generated by explosions of vapor or gas and air within the case as well as those resulting when the fuses are called upon to open on heavy ground or short circuit conditions.

It is generally recommended that when it is necessary to use a form of circuit protection within hazardous areas, that circuit breakers be used in lieu of fuses. Circuit breakers are arranged so as to be self-resetting or so as to be capable of being reset without opening their enclosures, whereas in the case of fuses, the enclosures must be opened when renewals are made. The latter is a decidedly unsafe practice.

There are available a variety of circuit breakers which have been approved for hazardous locations. The demand for such devices has been confined to a large extent to those of comparatively small capacity, that is, up to about 50 amperes. The units now available employ the small circuit breakers incorporating a thermal trip of the types represented by the Westinghouse "Sentinel." These circuit breakers are enclosed in explosion-resisting boxes fitted with threaded hub conduit connections and a screw type cover to permit inspection and repair. In Figure No. 7 are reproductions of drawings of two types of circuit breakers now available. Figure No. 8 illustrates two hypothetical installations making use of circuit breakers and other apparatus. These are externally operable and may be used as a switch for the control of small motors, lights or other devices in lieu of a switch if desired.

The operating lever extends through a hub on the enclosure so arranged that the emission of flame or heated gases at that point is prevented. The testing of devices of this character follows somewhat the same plan as outlined for motors for Class I locations.

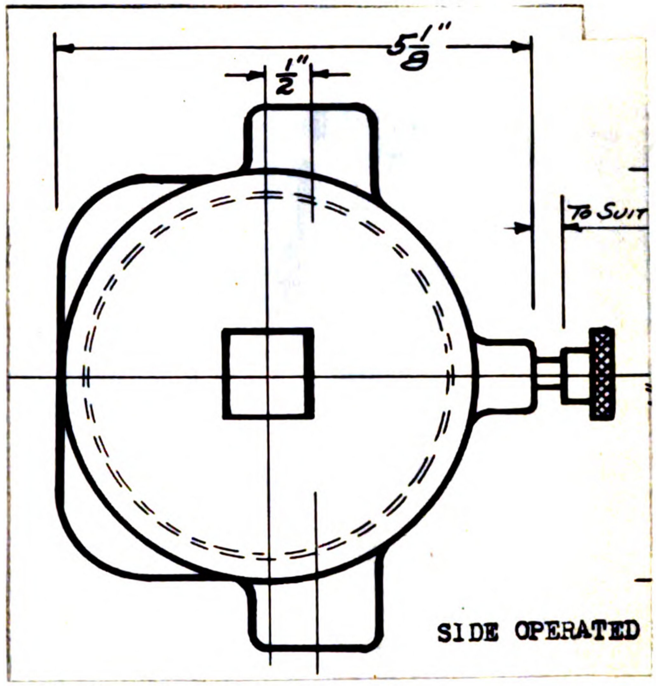


Figure No. 7.
Two Types of Explosion-Resisting
Circuit Breakers.

These devices consist of thermal type circuit breaker units enclosed in explosion-resisting fittings and arranged for manual operation. These may be used for branch circuit operation or as control switches for lighting circuits or small motors.

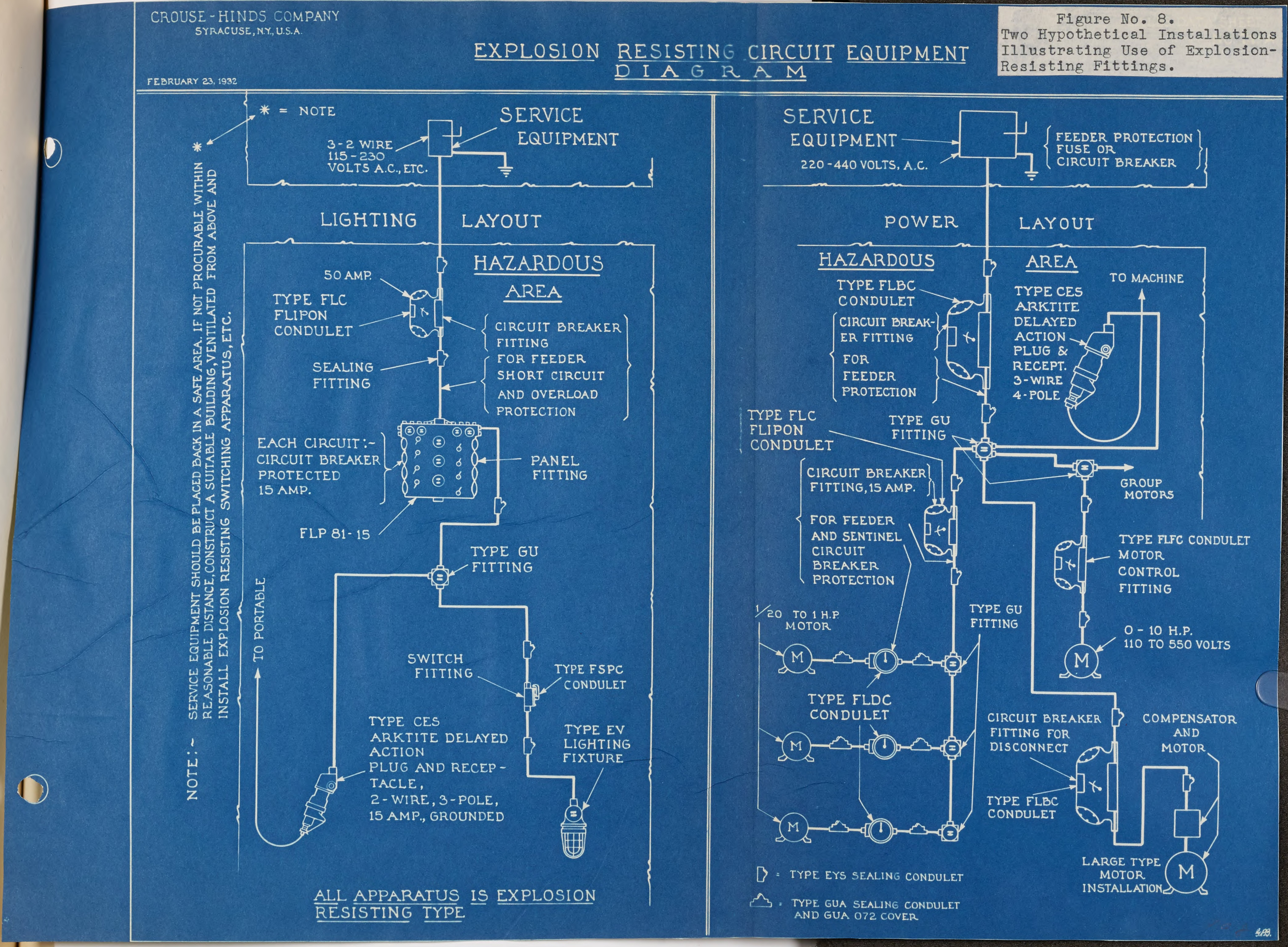


Figure No. 8.
Two Hypothetical Installations Illustrating Use of Explosion-Resisting Fittings.

Motors

Rule 3203e requires that "Motors shall be of the types approved for use in explosive atmospheres."

From our point of view there are two types of motors; first, those which have sparking or arcing parts, which includes the usual single phase commutator motors, direct current motors, wound rotor slip ring motors and some polyphase self starting motors which employ open centrifugal switches or similar devices; and second, squirrel cage induction motors. Although motors of the first type are more hazardous than those of the second, when operating in a hazardous atmosphere, it was deemed necessary to require that all motors be of types approved for operation under the particular conditions to which they will be exposed. The word "approved" as defined in Article I means, briefly, "acceptable to the authority enforcing this Code." In reality, as accepted in practice, the definition is extended to imply, so far as equipment is concerned, test, approval and subsequent listing by the Underwriters' Laboratories, as individual inspection authorities, rarely possessing the necessary apparatus, are not in position to make the required tests.

A motor, to be considered safe for operation in Class I locations must necessarily be so designed that whether in normal operation or in case of a fault, such as a burn out, it will not cause ignition of the hazardous material outside of the motor. It is recognized that an open squirrel cage induction motor normally having no arcing or sparking parts would be safe if positive assurance were had that it would operate as intended at all times. However, it is a known fact that such motors develop faults which produce arcs and sometimes complete burnout in spite of the best of maintenance and protection, and so even such a motor cannot be considered safe in Class I locations.

In order to regulate the production of motors intended for Class I locations the Underwriters' Laboratories assisted by the Industry Conference of the motor manufacturers have developed standards for the design and performance of a special type of motor. It was found by test that the ordinary types of enclosed motors were not suitable for several reasons. The Underwriters' Laboratories standard covering motors for class I locations is of too great length to repeat in full in this thesis. However, briefly stated, the requirements provide that; (1) the casing or enclosing housing of the motor shall have sufficient mechanical strength (with certain prescribed factors of safety) to withstand successfully the explosion of flammable substances within the casing; (2) the fits at points where joints are made and at the shaft openings shall be of such width and length as to prevent the issue of flame or

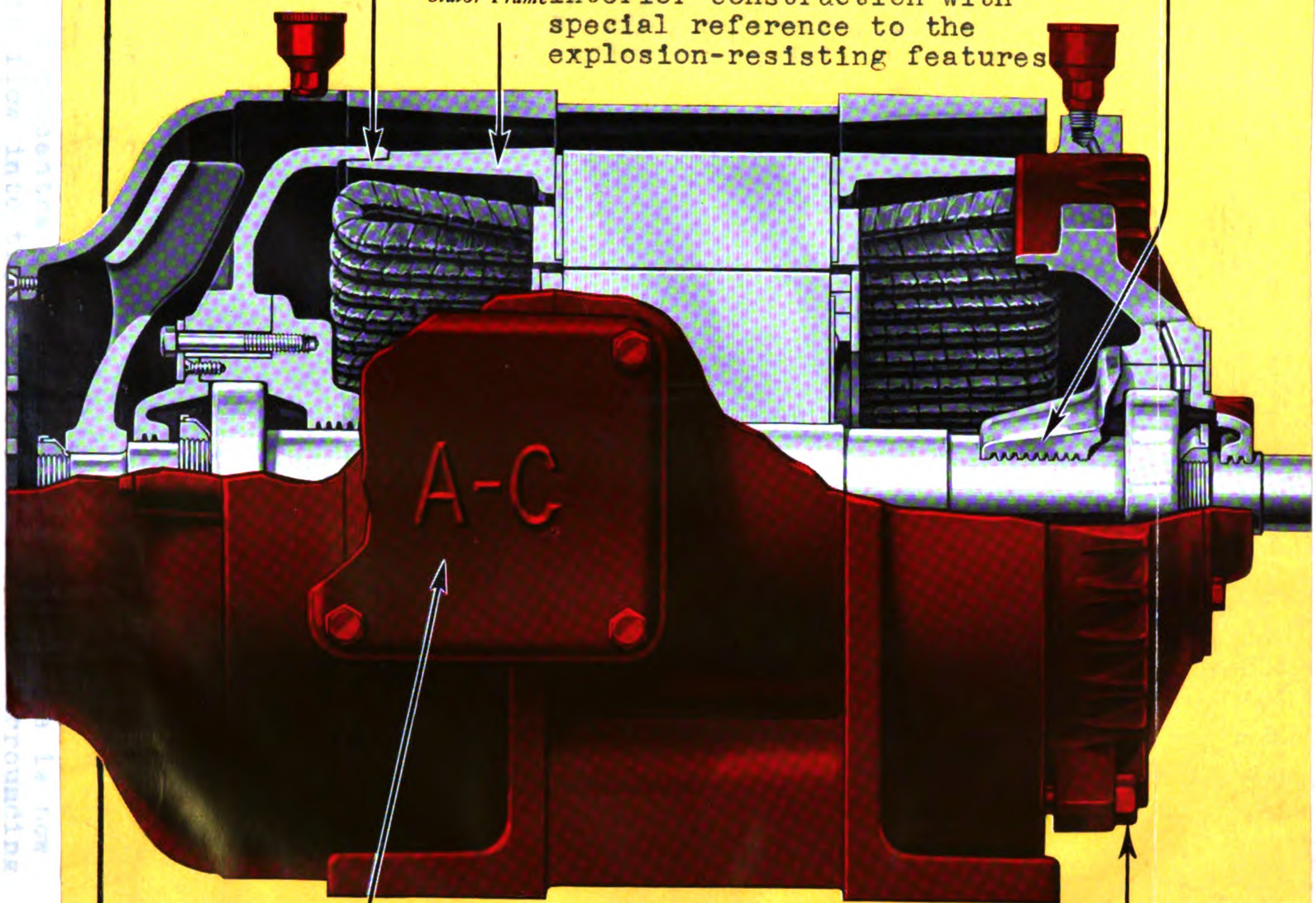
heated gases or vapors produced by such explosions to the atmosphere surrounding the motor; (3) the motor assembly shall have sufficient heat capacity to prevent the motor casing reaching a temperature which would ignite the surrounding hazardous substances even in event of burn-out of the motor windings; (4) the terminal leads or conductors be securely held and tightly fitted where they pass into the motor case. (Note: This is usually accomplished by use of a sealing compound); (5) a suitable terminal box be provided for motors larger than one horse power and a terminal box or provisions for direct conduit connection for fractional horsepower motors; (6) each motor be marked with a name plate giving, in addition to the information generally included, data as to the class and group for which the motor has been approved.

As in the case of conduit joints and fittings, a motor to comply with the above requirements need not be vapor tight, in fact, none of them may be so described, but they may be termed explosion-resisting which is all that is required to provide safety. The standards of the Underwriters' Laboratories for Class I motors recognize three general types of enclosed motors as candidates for approval for Class I locations; (1) the totally enclosed; (2) the enclosed-fan-ventilated; and (3) the enclosed-pipe-ventilated. Of the Class I motors above the fractional horsepower size so far approved, all are of the enclosed-fan-ventilated type. This is probably due to the fact that this type is the most economical to build to answer the requirements of the standards and also the easiest to install. The totally enclosed type requires much additional capacity to secure rated output and, therefore, results in a very bulky machine. For instance, what would normally be a 15 horse power open motor may have a rating of only 7½ horse power when it is made over into the totally enclosed type. The pipe-ventilated type, while practical for some applications, offers objections in the way of necessitating pipes, the installation of which is not always convenient. Figures 9 and 10 illustrate a sectional and an assembled view respectively of typical enclosed-fan-ventilated motors which have been approved for Class I Group D locations. Figure 11 is a reproduction of a label by which motors approved for hazardous locations may be identified.

As was pointed out earlier in this thesis, the different gases and vapors possess varying characteristics as to flammability and explosion pressures. For economic reasons, due consideration was given to these facts in the testing and listing of motors for hazardous locations. As a matter of fact, the Underwriters' Laboratories for their purposes have subdivided Class I locations as follows:

Figure No. 9.
A Motor Approved for
Class I Locations.

This cut-away view shows
interior construction with
special reference to the
explosion-resisting features



Class I, Group A - Atmospheres containing acetylene.

Class I, Group B - Atmospheres containing hydrogen.

Class I, Group C - Atmospheres containing ethyl ether vapor.

Class I, Group D - Atmospheres containing the vapors of gasoline, common petroleum, ethyl alcohol, methyl alcohol, acetone and lacquer solvents.

These hazardous vapors and gases are arranged in the order of their degree of hazard, so equipment designed for the more hazardous conditions can be used for the lesser. As an example, a Class I Group C motor which is approved for use in an atmosphere of ethyl ether vapor may be used in a group D location, where gasoline vapor or others of the group are present. However, a Group D motor is not approved for use in a Group C, ethyl ether vapor atmosphere. This holds true in like manner for the other groups into which Class I is divided, and as will be pointed out later, applies similarly in principle to motors approves for Class II locations. The group classification of a particular approved motor will be found on the motor name plate.

The tests to which Class I motors are subjected in the Laboratories are of an interesting nature. It is required by the Standard that the motors be subjected to a series of tests in the presence of specific gas or vapor-air mixtures over the range of flammable or explosive concentrations so as to cover (1) the maximum pressure effects of the gas or vapor-air mixture and (2) the maximum propogation effects of the gas or vapor-air mixture. These tests are conducted upon the motor with the shaft bearings machined to clearances representing maximum wear under service conditions.

The tests are conducted by placing the motor in a test chamber provided with gas inlet and outlet connections to the pipes carrying the explosive mixture. The motor casing is then tapped with threaded holes for connection to the inlet and outlet pipes carrying the explosive vapor or gas-air mixture and is also tapped with threaded openings for attachment of the explosion pressure recording device and a spark plug for ignition. Suitable auxiliary equipment is provided to prepare and maintain the vapor or gas-air mixture in accordance with predetermined concentrations. The explosive mixture is now permitted to flow into the motor casing and the surrounding test chamber until all of the original air has been displaced, whereupon samples for analysis are taken from within the motor casing, the test chamber and from the supply line. The mixture within the motor casing is then ignited either by the spark

Figure No. 10.
A Motor Approved for
Class I Locations.

This view shows end where cooling air is discharged. The outer shell directs the blast of air from the fan over the surface of the enclosed inner casing.

Figure No. 11.
Label of
Underwriters' Laboratories.

A label of this type appears on approved motors which permits ready identification.

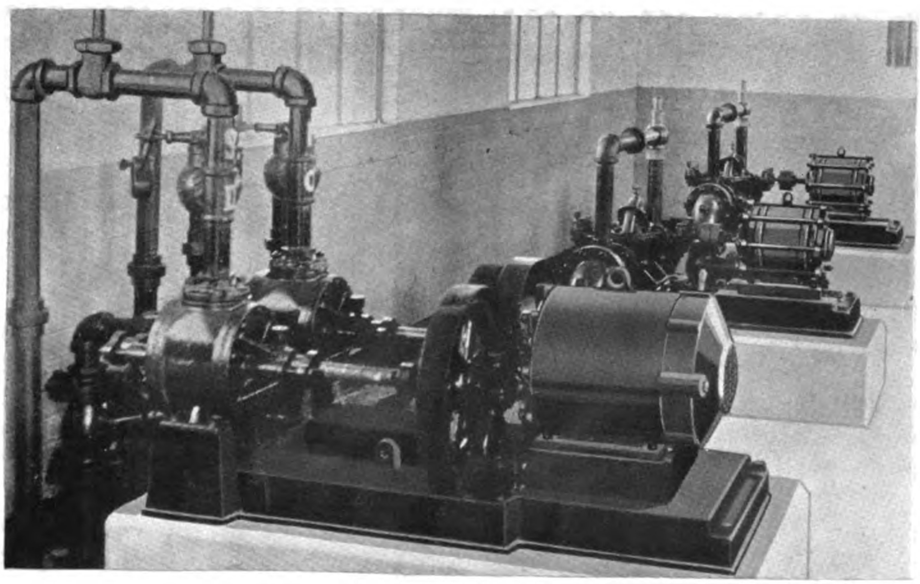


Figure No. 12.
Explosion-Resisting Motors
in a Petroleum Refinery.

This view shows part of a loading rack pump house where explosion-resisting motors are direct connected to loading pumps.

plug or by sparks from the motor. Failure of the mixture in the test chamber to ignite and explode when the mixture within the motor casing was fired shows that flame did not propagate from the interior of the motor casing to the surrounding explosive atmosphere. A series of sixty or more such tests are conducted, both with the motor in operation and at rest, and with explosive mixtures over the entire flammable range.

A burnout test is then made to determine the maximum temperature reached by the casing of the motor. In this test the motor windings are actually burned out by "single phasing" or other means. The maximum temperature usually reached in such tests on motors which are otherwise satisfactory is about 500 degrees Fahrenheit, which is well below the ignition temperatures of all common gases and vapors, with the exception of carbon disulphide vapor, and possibly that of hexane. Some solid substances, however, such as pyroxylin, have ignition temperatures as low as 212 degrees Fahrenheit and naturally the usual type of Class I motor will not be safe for operation where pyroxylin dust is present and likely to accumulate on the motor casing.

The development of suitable explosion-resisting motors approved for use in Class I locations has provided types of motors which are permitted to be installed directly within the hazardous area except for those areas where pyroxylin lacquers or their residues might accumulate on the motor or where carbon disulphide vapors may be present. When substances having such low ignition temperature are involved, it is probable that the only alternative is to isolate the motors from these extra-hazardous vapor atmospheres or substances. This is the course taken with regard to the motor installations required for pyroxylin spray booths as will be seen in the discussion on spray booths later in this section.

Attempts at isolating ordinary open motors from hazardous vapor or gas atmospheres have not always proved successful, due to the fact that it is difficult to protect the shaft openings so that entrance of the flammable gases or vapors into the motor compartment will be prevented. The "Loss Record" appearing as the concluding part of this thesis relates several fires and explosions which have occurred as the result of depending on such isolation for safety. Approved Class I motors properly selected with respect to the vapor or gas atmosphere group are to be preferred to attempts at isolation as a general rule. In figures 12 to 21 will be found photographs illustrating typical Class I motor installations. The explanatory notes accompanying these illustrations describe the hazardous conditions involved and the advantages gained by the use of Class I motors in each instance.

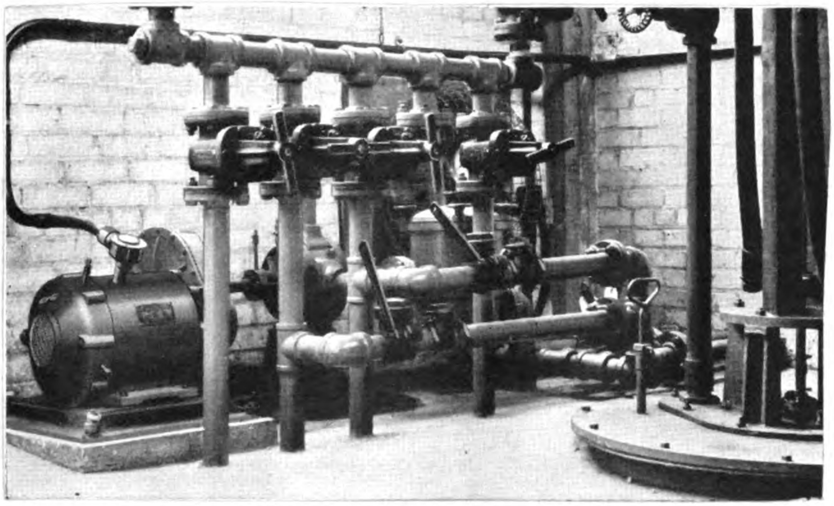


Figure No. 13.
Explosion-Resisting Motor
Driving Pump.

Pump is used for handling naphtha and other volatile solvents. Use of explosion-resisting motor permits its installation directly in pump room.

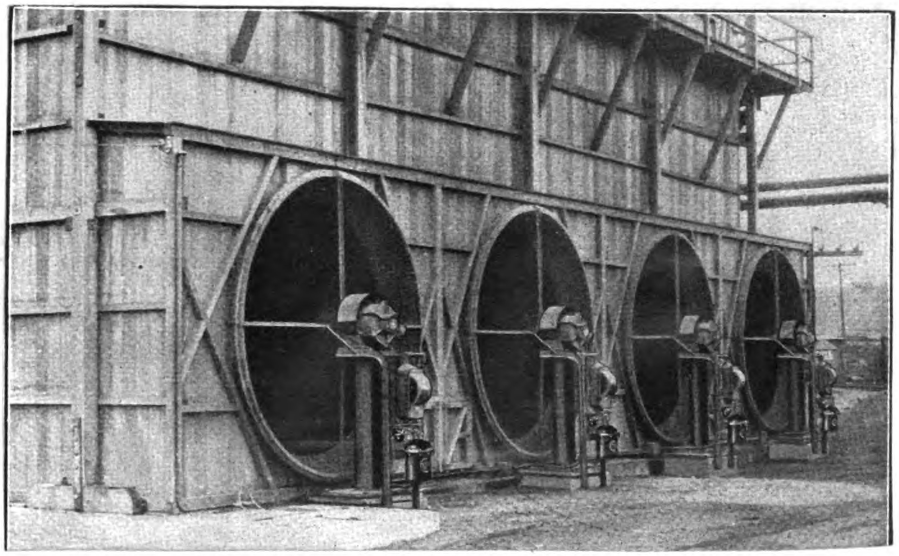


Figure No. 14.
Fan Motor Installation.

This illustration shows use of explosion-resisting motors for driving fans in gasoline recovery plants in large Eastern refineries. Note use of explosion-resisting motor controllers.

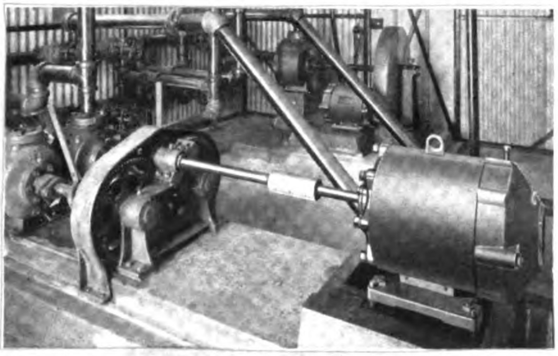


Figure No. 15.
Explosion-Resisting Motor
Installation in Bulk
Gasoline Station.

Use of this type of motor
permits its installation in
same room with the pumps.

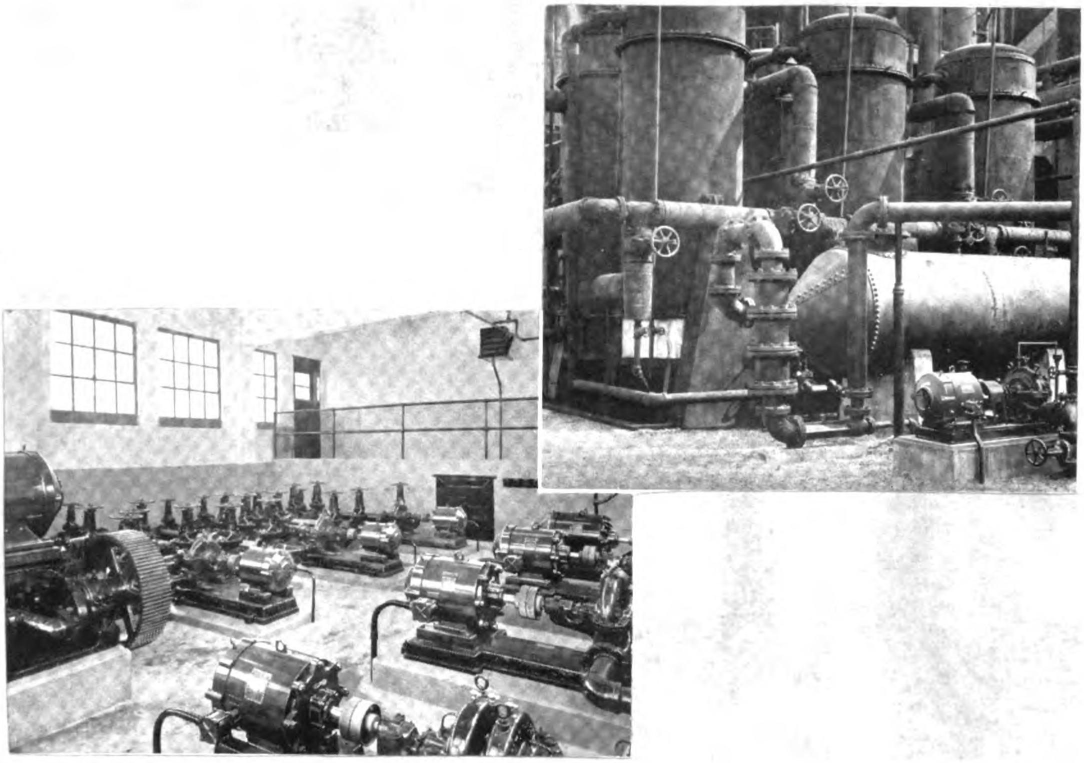
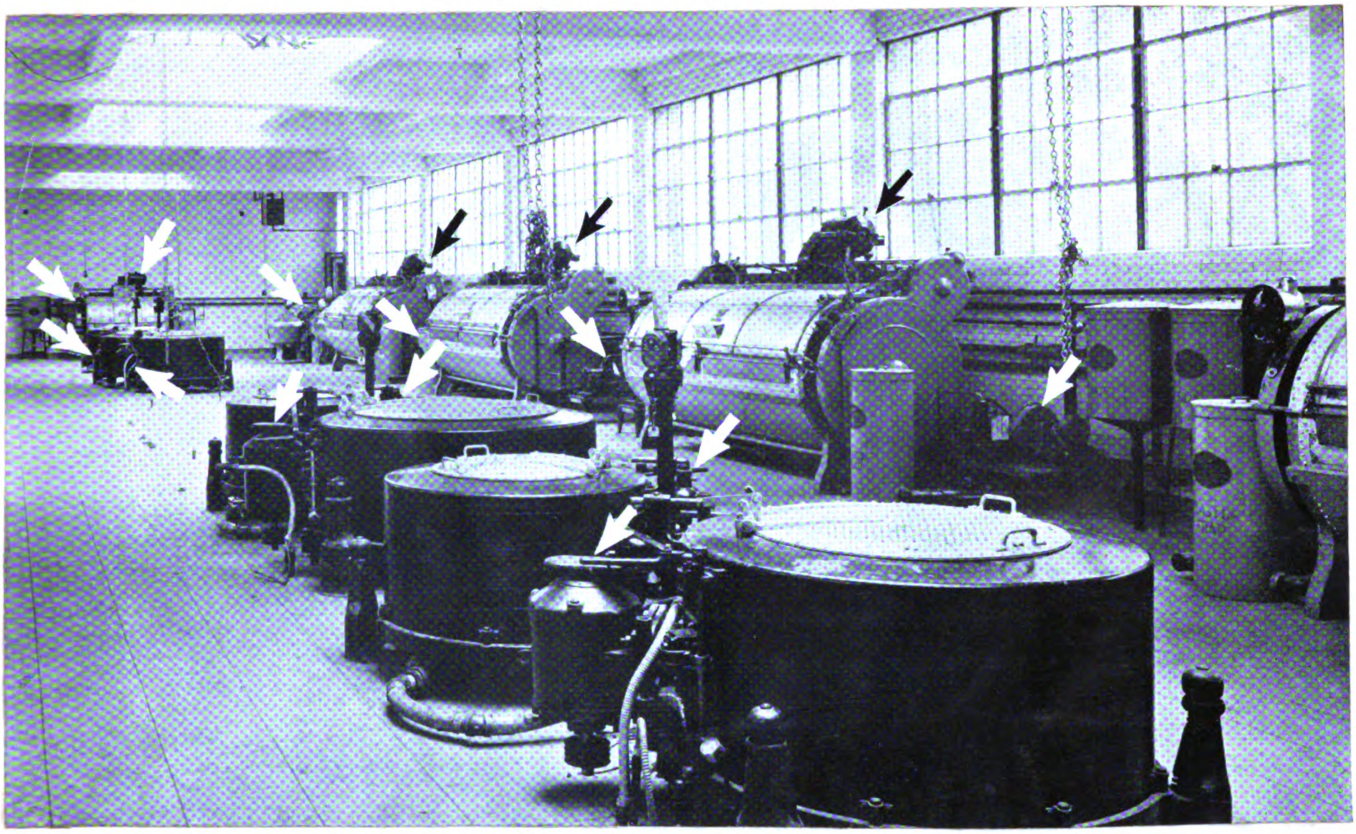


Figure No. 16.
Motor Installation in
Petroleum Refinery.

View in upper right shows explosion-resisting
motor driving caustic soda pump for scrubbing
condensed gasoline.

Lower view shows group of motors approved
for Class I locations direct-connected to
gasoline pumps. Explosive vapors occur in
this pump house due to the flammable volatile
liquids, hence need for explosion-resisting
equipment.



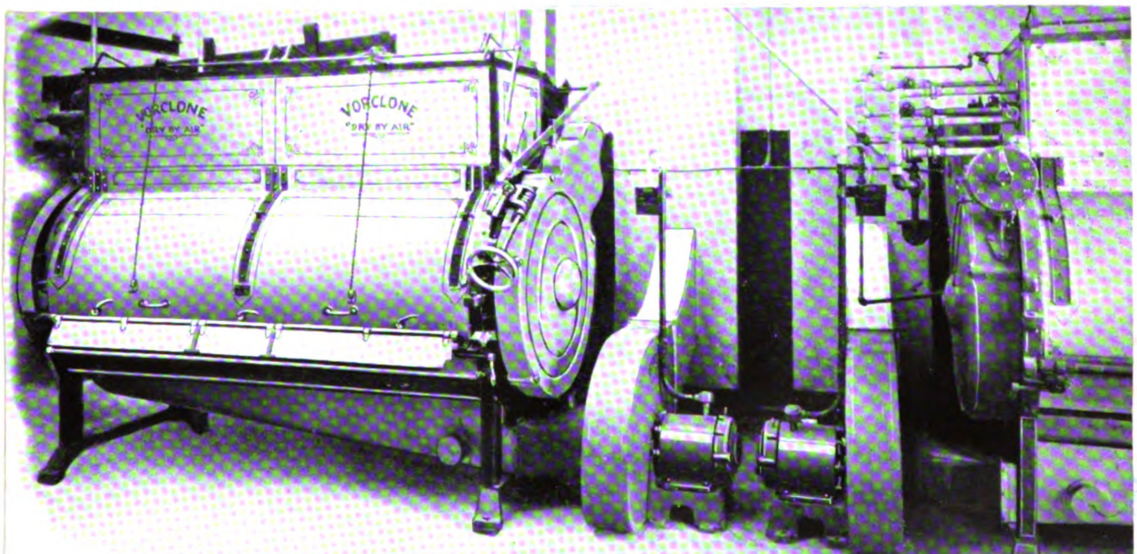


Figure No. 17.
A Modern Dry Cleaning Establishment.

The upper illustration is of a dry cleaning room showing washers along wall and extractors in foreground all individually driven by motors approved for Class I locations.

The lower installation illustrates one of a row of tumbler driers each with its individual explosion-resisting motor.

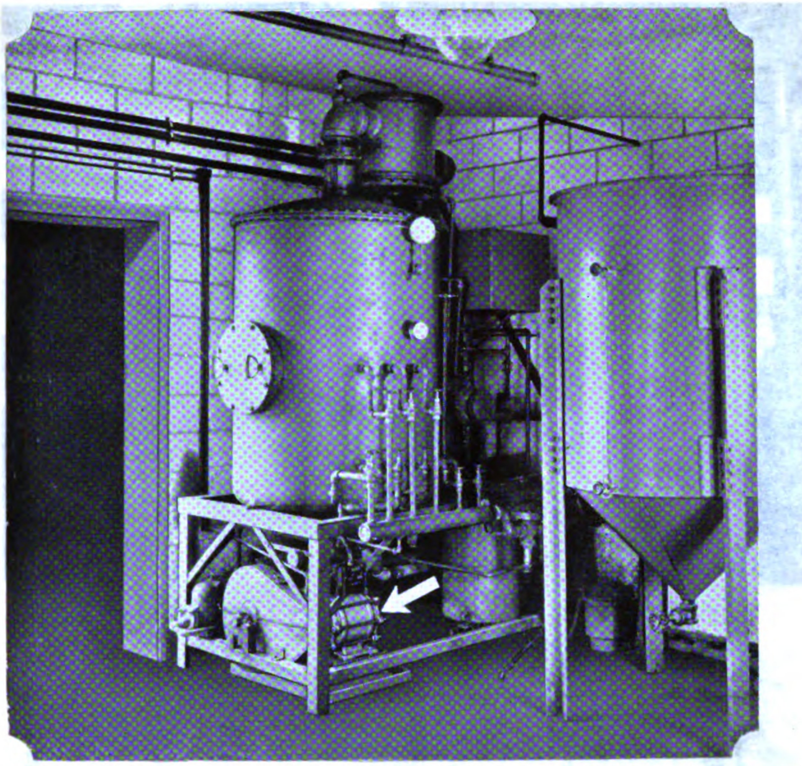


Figure No. 18.
Solvent Recovery Still.

The arrow points to the Class I motor employed to drive the pump.

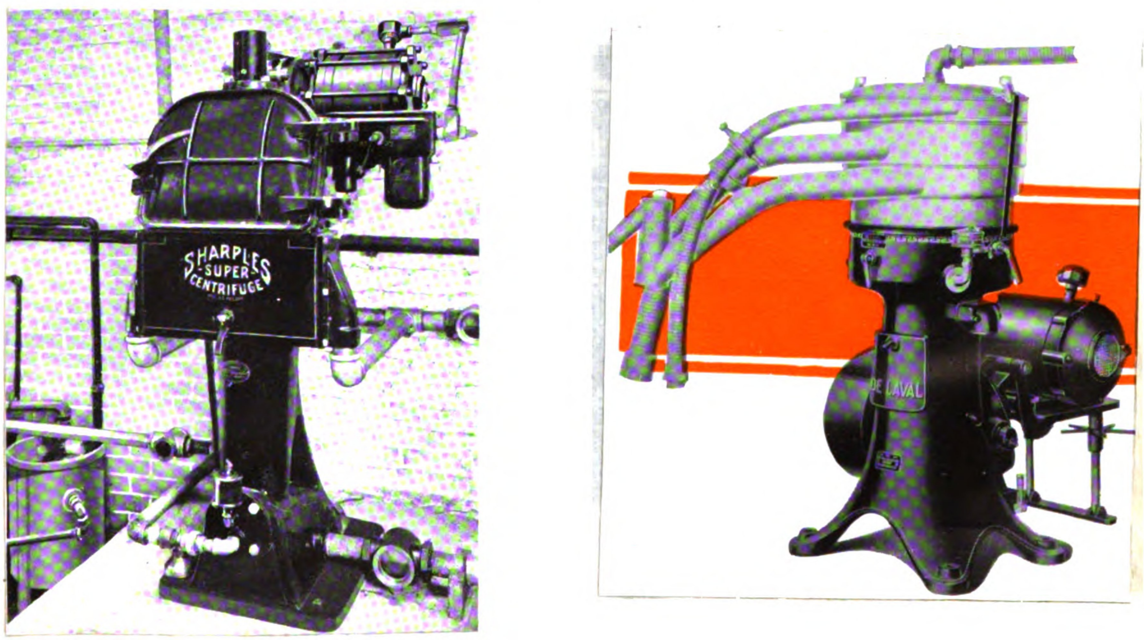


Figure No. 19.
Two Types of Solvent Purifiers.

Note explosion-resisting motors used to provide individual drives for these machines.

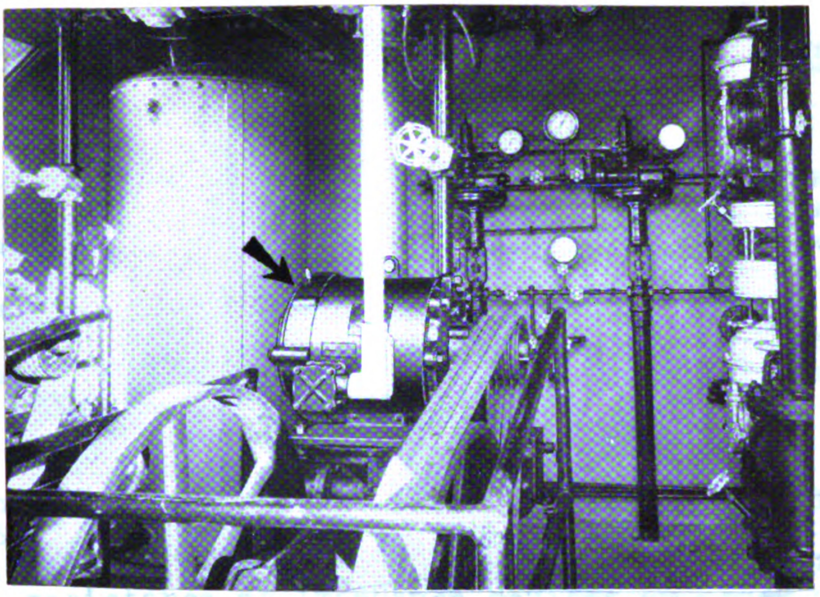


Figure No. 20.
Compressed Gas Plant.

Explosion-resisting motor installation in "bottled" gas plant. Such plants handle gases of a highly explosive nature, hence the precaution taken in the type of motor selected.

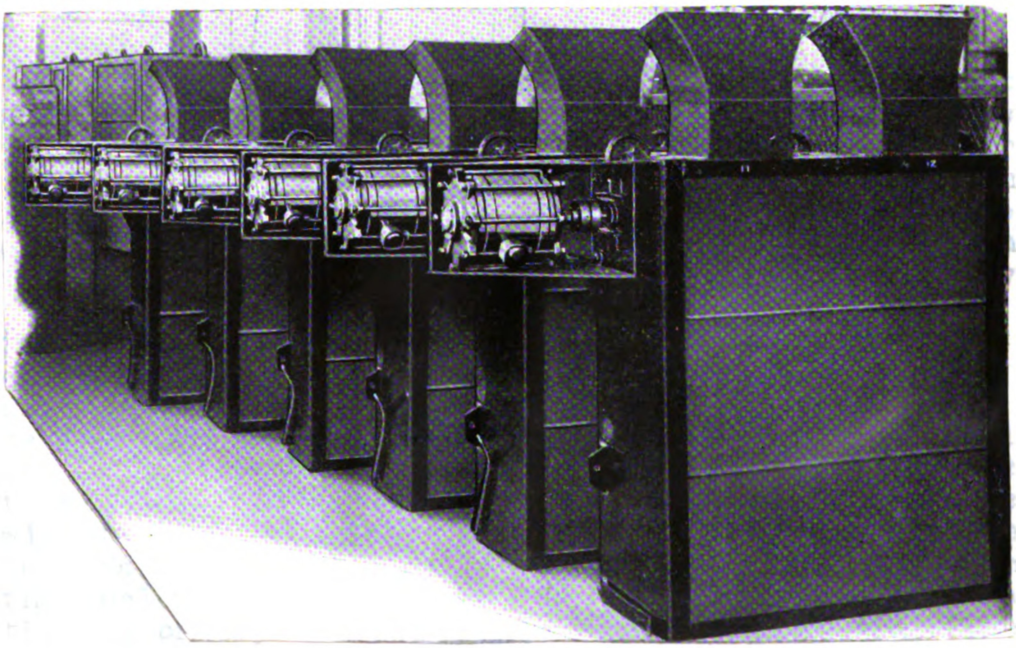


Figure No. 21.
Application of Class I Motors to Unit Heaters.

These unit heaters are intended for installation in lacquer plants or others where flammable vapors are present.

Motor Controllers, Switches, Resistance Devices And Similar Apparatus

It is obvious that it would be unsafe to permit motor controllers, switches, resistance devices and similar apparatus, which, in their normal operation create arcs, sparks or high temperatures, in the hazardous areas with which we are concerned unless such apparatus were so designed and built as to comply with certain requirements regarding type of enclosure, capability of the enclosure to withstand internal explosion pressures, and ability of the enclosure to prevent emission of flame in event of internal explosion.

The rules for Class I locations cover this situation in Rule 3203 which states: "Motor controllers, thermal cutouts, switches, relays, the switches and contactors of autotransformer starters, resistance or impedance devices or other devices or apparatus which, in their normal operation, tend to create arcs, or high temperatures, shall not be installed unless such devices are of a type approved for use in explosive atmospheres." Following this rule is a fine print note as follows: "It is recommended that motor controllers be of the remote control type with the main contactors located at a point where the hazardous conditions of this class do not prevail, auxiliary control push buttons or switches of a type approved for use in explosive atmospheres may then be placed in the most convenient locations."

As in the case of motors, approval of the apparatus and devices mentioned or implied by this rule usually involves compliance with the standards of the Underwriters' Laboratories for the design and test performance of such apparatus and devices for the particular atmosphere group in which they are intended to be used. Definite standards for construction and test methods have been set up for industrial control devices for Class I locations. These standards are of too great length to repeat in full here, but it should be mentioned that two types of control devices are recognized, viz: (1) those in which contact is made and broken in air (air break) and (2) those in which contact is made and broken under oil (oil break). Briefly, the standard for air break control devices specifies that the enclosures be of substantial construction and capable of withstanding certain internal pressure, (with certain prescribed factors of safety), depending on the size and shape of the enclosure, its free internal volume and on the nature of the gas or vapor-air mixture. Joints in the enclosure are limited to certain maximum widths with respect to the length of the joints and definite requirements are provided with regard to the nature of the shaft openings for re-setting or operating mechanisms. Such joints and openings are required to be of the metal to metal type, gaskets not being permitted.

The standard further states that provision for conduit connections with threaded joints shall be made and that the temperature of the exterior of the enclosure, assuming an ambient temperature of 40 degrees Centrigrade, shall not exceed safe temperatures for the gas or vapor-air mixtures under consideration, which, for the various groups, are specified as follows:

Group	Mixture	Temperature Deg. Cent.
A	Acetylene	(None given)
B	Hydrogen	(None given)
C	Ether	180
D	Gasoline	280

The tests made by the Laboratories on air break control devices for Class I locations are practically identical with those made on motors, with the special provision that the devices shall be energized at rated potential and with all current carrying parts at maximum temperatures as based on full rated load operating conditions. A series of fifty or more such tests is made, covering the entire flammable range of the vapor or gas for use in which the device is intended. As with tests on motors, failure of the mixture in the test box to be ignited and explode when the mixture within the device enclosure was fired shows that flames did not propogate from the interior of the device under test to the surrounding atmosphere. Thus, the two principal points of the standard are established and the approval of the device is given or it is rejected. These tests are, of course, additional to those made by the Laboratories on industrial control equipment generally.

In oil break control devices, it is required by the standard to have all electrical connections, joints, terminals, or arcing parts below the normal oil level. The enclosures are required to be of substantial construction and shall be so designed as to avoid any possibility of sparks being produced above the oil level. Visible oil level indicators must be provided to indicate minimum, normal and maximum oil levels, and it is required that all connections, terminals, and arcing parts be immersed to a depth of at least six inches below normal oil level. The exterior temperature requirements are identical with those for air break devices.

In testing oilbreak control devices the enclosure is filled to two inches below normal level with oil specified by the manufacturers of the device. It is then tested by introducing the particular gas or vapor-air mixture into the enclosure above the oil and subjecting the controller to a series of operation tests conducted at rated potential and at full rated load. Necessarily, to pass these tests success-

Figure No. 22.
Explosion-Resisting
Switches Approved for
Use as Auxiliaries
for Motor Controllers.

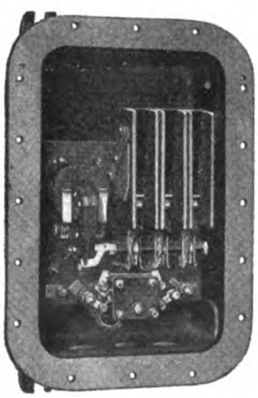


Figure No. 23.
Group of Motor
Controllers Approved
for Class I Locations.

These are of the air-break type. Note width of flange of switch case in illustration to left.

fully no ignition of the flammable gas or vapor-air mixture should occur.

Although the rule specifies that thermal cutouts, relays and similar spark producing devices be of the type approved for use in explosive atmospheres, they are usually an integral part of a motor controller and, therefore, are approved with the controller as an assembled device.

Resistance and impedance devices are not commonly found in Class I locations, but, if used, are required to comply with the above standards for control devices. At the time of this writing no resistance or impedance devices have been submitted to the laboratories for approval for Class I locations. It is probable that where such devices are needed, they might better be isolated from the hazardous area.

Switches other than those used as motor control devices are also required to be explosion resisting and are tested in a manner similar to that used for control devices.

Where automatic controllers are employed, it is necessary that the auxiliary control push buttons or switches, if in the hazardous area be of the type approved for Class I locations of the particular group of gases or vapors involved.

The manufacturers of motor control equipment have placed on the market complete lines of motor controllers and auxiliary control push buttons or switches for Class I, Group D locations. They are made in both the oilbreak and air break types and arranged for either manual or automatic operation. In figures 22 to 24 inclusive are illustrated several representative types of motor controllers, with their auxiliary push buttons and switches, which have been approved for Class I locations.

The fine print note following this rule should receive special mention. In many cases it is convenient to isolate the principal control equipment from the hazardous area in a manner similar to that suggested under "Service Equipment, Panel Boards and Switchboards." This course should be followed whenever possible as isolation of controllers always results in a safer installation than is the case when controllers are placed within the hazardous area, even if the latter controllers are of the types approved for such hazardous locations.

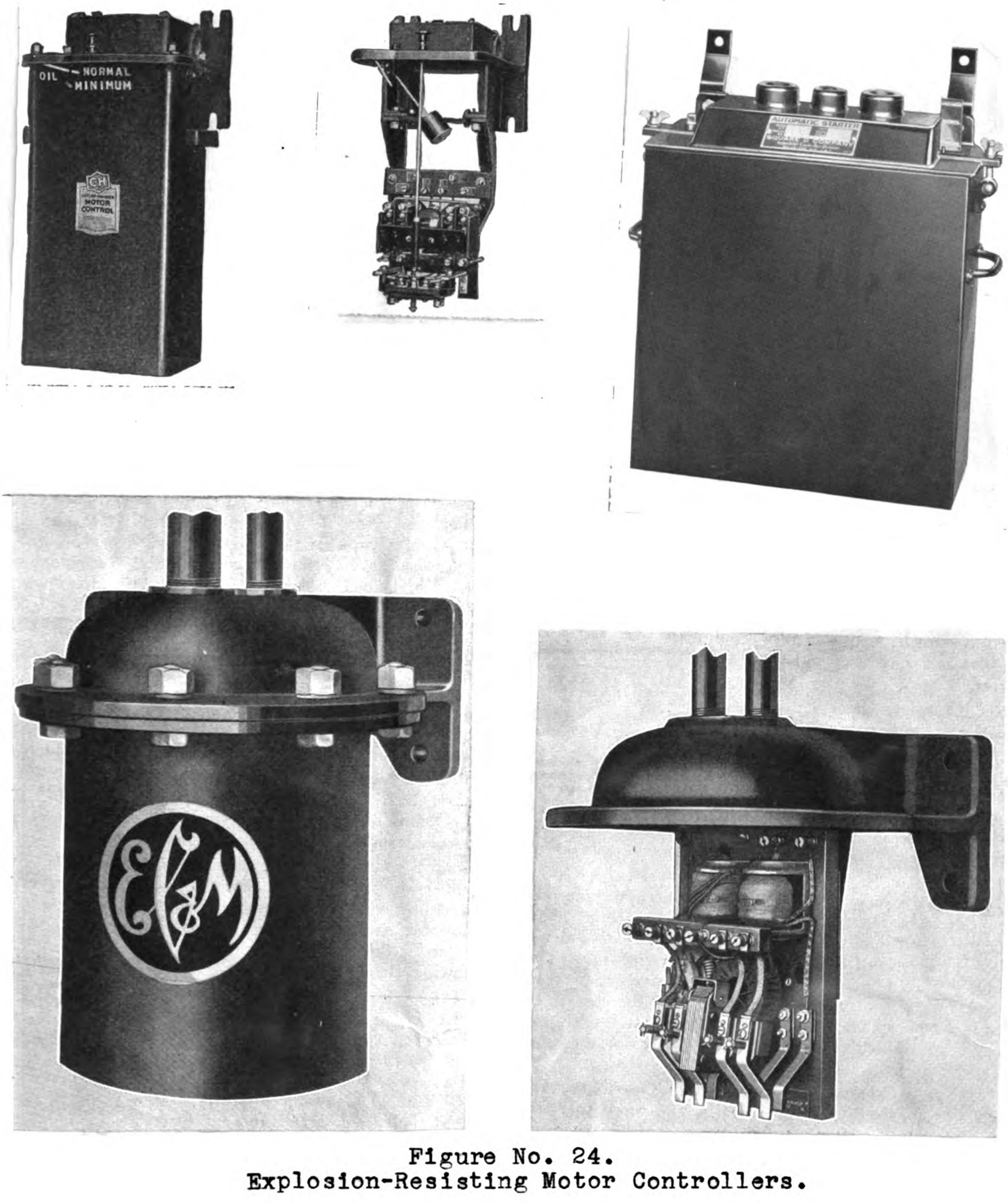


Figure No. 24.
Explosion-Resisting Motor Controllers.

The controllers illustrated are of the oil break type. The interior construction is illustrated in the views showing the oil tanks removed.

Heating Appliances

Permitting the installation of heating appliances in hazardous areas without definite control as to what type of heating appliance would be used, would result in the introduction of serious hazards. The temperatures reached by heating appliances are often far above the apparent ignition temperatures of the various gases and vapors in the atmospheres of which they may be installed and so would furnish an excellent source of ignition to cause an explosion.

To control such a situation, the following rule (3203g) was inserted: "Electric heating appliances shall not be used unless they are of a type approved for the particular location or type of material in or with which they are used." This rule again contemplates approval of such heating appliances by the Underwriters' Laboratories in practically all cases.

So far as the writer is aware, no heating appliances have yet been submitted to the laboratories for examination and test and there apparently has been no demand on the Laboratories for a standard to guide manufacturers as to what would be required in order to secure approval of a heating appliance for Class I locations.

It is not likely that there will be any extensive use of electrical heating appliances in hazardous locations except for very special uses, such as sterilizers for use in hospital operating rooms where the sterilizer may be in an ether or ethylene air atmosphere. Another possible exception are the specially designed heaters used in connection with spray painting. Undoubtedly the development of suitable and safe appliances for these purposes will require much study and experimental work.

Switches for Lighting Circuits

Rule 3203k states that: "Switches controlling lighting circuits shall not be installed unless of a type approved for use in explosive atmospheres."

This rule requires little comment as the situation is similar to that discussed under "Motor Controllers, etc." Such switches are subjected to tests similar to those used for air break motor controllers and are required to have the same qualities with regard to non-emmission of flame and maximum temperature of the housing.

It will be seen that the rule implies the possibility of locating the switches outside of the hazardous area. This is done in many cases, especially when the hazardous area is

represented by a single room or cut-off section of an establishment of considerable extent. As an example, the switches for controlling the light circuits of a dry cleaning room may be placed just outside of this room, and then such switches may be of the ordinary type, providing, of course, that the room in which they are located is not also a hazardous location.

In event of lighting installations of considerable size, a possible solution is to extend each circuit to a point well outside of the hazardous area, fuse each circuit separately and control the entire group of circuits by a single magnetic contactor type switch actuated by means of an explosion-resisting auxiliary push button or switch located within the hazardous area. Such control would be both convenient and safe.

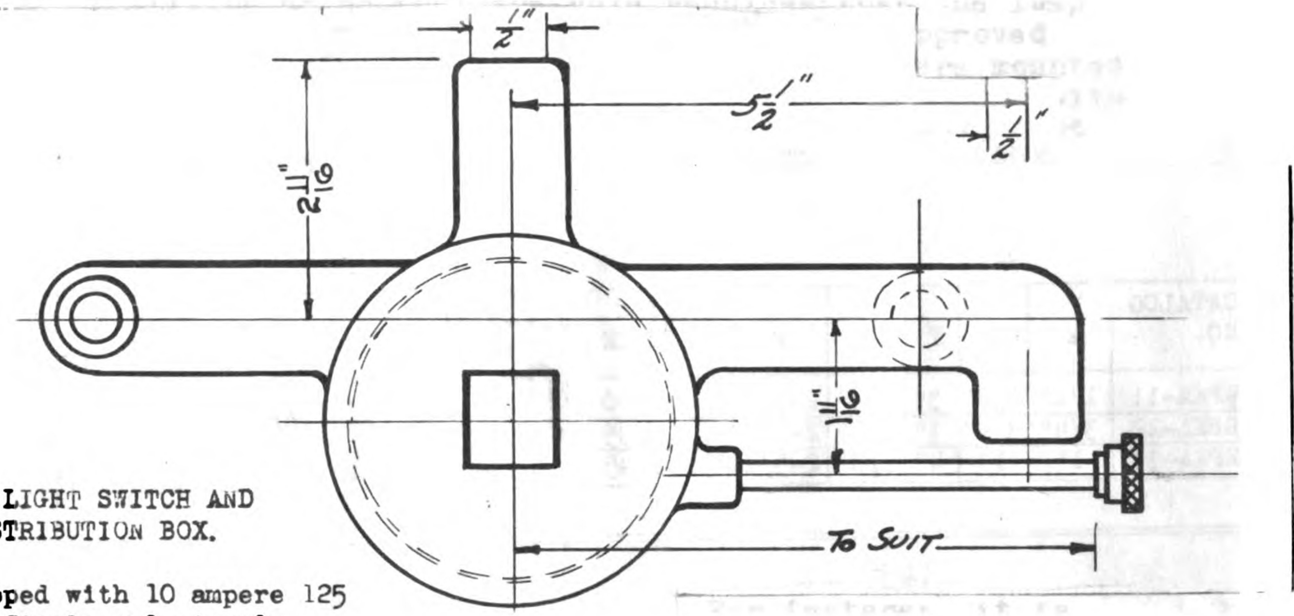
Suitable explosion-resisting switches for lighting circuits have been developed and are available. In figure 25 are illustrated two types for use in Class I, Group D, locations. The switching mechanisms of these switches are housed in explosion-resisting cases having the operating shafts extending through long-path, small-clearance bearings or sleeves which successfully prevent the emission of flame to the outside should an explosion occur within the housing.

The circuit breaker assemblies mentioned under "Fuses and Circuit Breakers," are also suitable for use in Class I locations for controlling lighting circuits.

Lamps in Fixed Positions

In rule 32031 it is required that: "Lamps in fixed positions shall be enclosed in a manner approved for explosive atmospheres and shall be properly protected by substantial metal guards or other approved means where exposed to breakage. Lamps shall not be of the pendant type unless supported ridigly by conduit hangers. Where rubber covered wire is used, it shall have insulation not less than 3/64th inch thick."

The proper guarding of lamps is of extreme importance as the breakage of a lamp results in an intense flash or arc and is usually accompanied by the falling of incandescent metal, either of which may accomplish ignition of hazardous substances. Also the temperatures reached by some parts of an electric lamp, especially one of high wattage, is often in excess of the apparent ignition temperatures of certain vapors and gases. By providing such lamps with enclosing globes or with specially designed fixtures with heavy glass lenses, the maximum temperature of exposed parts is considerably reduced. The enclosing globe or fixture assists to some extent the purpose of the required guard, as it is found that the strength of the globe or fixture is sufficient to



PUMP LIGHT SWITCH AND DISTRIBUTION BOX.

Equipped with 10 ampere 125 volt Single pole toggle switch operated by rod extending thru the pump housing.

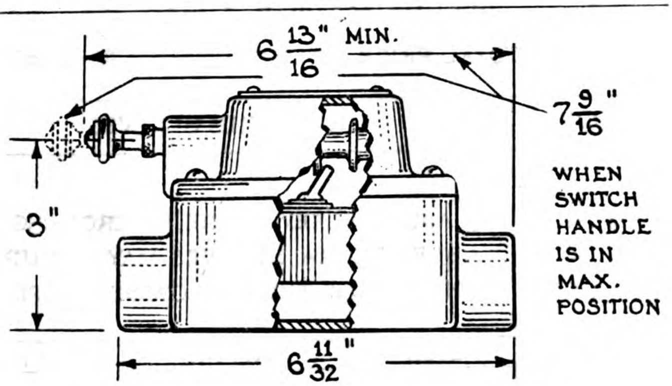


Figure No. 25.
Types of Lighting Circuit Switches.

The upper switch is especially designed for gasoline pump dome lights.

withstand a considerable shock or blow and thus serve to help protect the lamp from breakage.

It will be noted that the rule requires that the lamp shall be protected by substantial guards or other approved means where exposed to breakage. Thus, lamps which are mounted at or near the ceiling may not be required to be provided with guards, due to their position. It should also be pointed out that a possible substitute for metal guards might be heavy glass lenses properly fitted to a lighting fixture. Lighting units of such design are available and, undoubtedly, are sufficiently rugged to withstand any shock or blows which might be reasonably expected. Probably lighting units of such types will be found suitable for the operating rooms of hospitals.

In order that the temperature of enclosing fixtures be reduced, it is to be recommended that the installation of a few high wattage lamps in a hazardous area be avoided in favor of a large number of lower wattage lamps to obtain the same intensity of illumination. Another procedure which should be followed is that of using oversize enclosing fixtures in order to provide increased radiating surface. For instance, it is advisable to employ a 100 watt size fixture to accomodate none larger than a 60 watt lamp. The temperatures reached by certain parts of so-called vapor proof fixtures are excessively high when the higher wattage lamps are used. Attention is called to the drawing accompanying the section on spray booth lighting (Figure 27) which gives some definite information on this matter.

The Underwriters' Laboratories have developed a tentative standard for the design and testing of lighting fixtures for Class I hazardous locations. This standard, in brief, provides that, (1) the enclosure shall be of sufficient strength to withstand the pressures developed by vapor or gas-air explosions occurring within it, (2) the glass of which the globe or lens is made shall be free from internal strain and of sufficient thickness to resist breakage by internal explosions, (3) the joints of the enclosure shall be of the metal to metal type and of certain width and length specifications and (4) that protection in the form of guards shall be provided unless the fixture design itself adequately protects the globe or lens against breakage. Several other specifications are included regarding provisions for connection and sealing-in of conductors. The temperature requirements are identical with those mentioned under "Motor Controllers, etc.," this referring to both the internal and external temperatures. The internal temperature limitation is necessary in order to prevent the repeated ignition and possible explosion of mixtures within the fixture and which is possible when such mixtures can enter and accumulate.

Again the "breathing action" is involved in a manner similar to that which has been discussed previously.

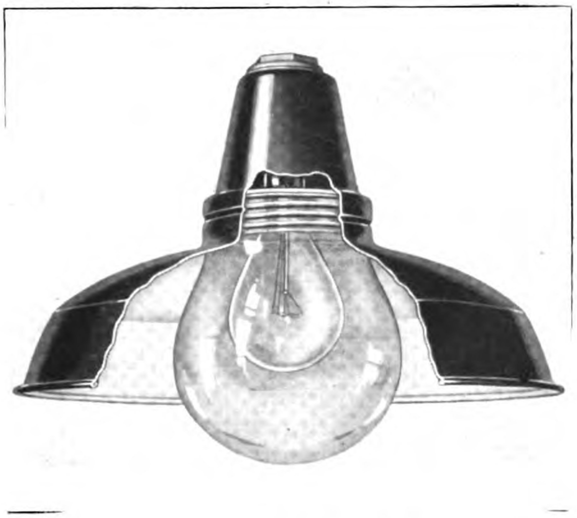
The tests to which such fixtures are subjected are similar to those made on motors for Class I locations so far as the explosion tests are concerned. Gas or vapor air mixtures are introduced within the globe or fixture and fired, and if flame does not pass out of the fixture to ignite the mixture in the test box, it is assumed to be explosion resisting. A series of fifty or more such tests are made. Temperatures, both internal and external are also determined when a lamp of the maximum wattage for which the fixture is designed is in place and operating at rated voltage. Vibration tests to determine the security of assembly of the fixture complete the tests.

To date no lighting fixtures have been approved as complying with this standard, although one manufacturer has just recently developed a fixture which he believes will be approved.

As a temporary substitute for lighting fixtures especially approved for Class I locations, inspection authorities have been accepting fixtures of the so called vapor-proof type, a group of which are illustrated in figure 26.

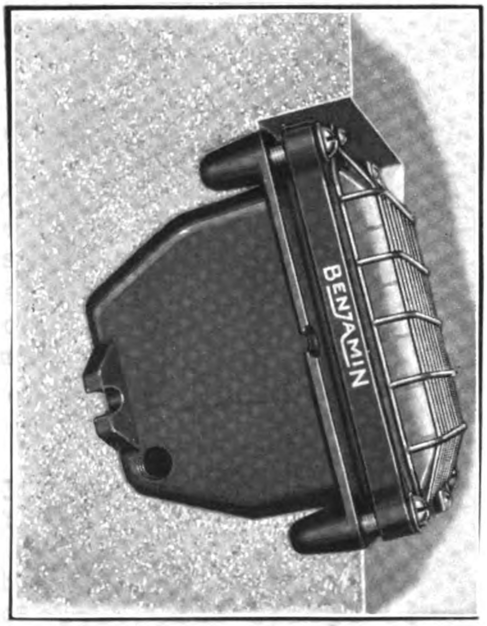
It will be seen from the rule that ordinary flexible cord pendant supports for lamps are not permitted. This is for the reason that such pendants are readily subject to injury, to undue wear by coming into contact with vibrating objects, and because such injury or wear may cause exposed arcs or sparks. There remain then two alternatives, the first, use of rigid conduit hangers and the second, attaching the fixtures direct to the circuit conduit.

The final sentence of the rules requires the insulation of conductors used for wiring fixtures to be 3/64 inch thick when rubber covered wire is used. This was inserted as a precaution against break-down and injury.



The above units are suitable
where not exposed to breakage.

Fixed lighting unit
equipped with guard
and vapor-proof globe.



Unit designed for use
in automobile greasing
pits.

Figure No. 26.
Group of Vapor-Proof Lighting Fixtures.

These should be regarded as temporary
substitutes pending development of light-
ing fixtures especially approved for
Class I Locations.

Electrical Equipment in Spray Booths

Owing to the low temperatures at which pyroxylin varnish residues decompose and ignite (ignition at temperatures of 212 degrees Fahreheit and possibly lower) it was found necessary to provide definite rules for the exclusion of electrical equipment in spray booths. Rule 3203j, which relates to this states: "No motor, lamps, or lighting fixtures of any type shall be located within spray booths, in ventilating ducts connected therewith nor in any location where there is a possibility of the spray lodging upon them." This is followed by a fine print note as follows: "Motors in spray painting establishments that are located outside of the paint spray booths and ventilating ducts and are judged by the authority enforcing this code to be outside of the hazardous area may be of any standard totally-enclosed type or of the open induction type having no brushes, make-and-break contacts, collectors or other arcing or sparking parts."

Closely associated with the foregoing is rule 3203k which provides that: "The auxiliaries of mercury-vapor lamps shall be offset at least ten feet from spray booth working face."

It should first be pointed out that the above rules apply to all spray booths and not only those in which pyroxylin varnish sprays are used. One can never be certain that a booth used in connection with ordinary oil varnish spraying operations will not be changed to accomodate pyroxylin varnish spraying without notice. Furthermore, even with the less hazardous oil varnish sprays it is found that objectionable coatings of varnish are formed on any motors, and lighting fixtures with which it comes in contact, often in such quantities as to prevent normal radiation of heat from such motors and fixtures. Hence, the desirability of rule 3203j.

With regard to pyroxylin sprays, it should be repeated that with them a combination of hazardous materials is involved, first, the pyroxylin itself; second, the solvent such as amyl acetate; and third, a thinner, such as acetone or alcohol. In the application of such pyroxylin sprays we not only have to deal with the explosive vapors of the solvents and thinners, but also with a fine highly flammable dust or residue placed in suspension in the air within the booth and ventilating ducts. Quantities of this residue accumulate in the booth and in the ducts in spite of the ventilating system, and if motors or lighting fixtures are located in these places it is a foregone conclusion that considerable residue will collect on them. The normal heat of a motor or lamp is sufficient to cause decomposition and ignition of this residue and this often results in a

flash fire or literally an explosion.

The Underwriters' Laboratories conducted a series of tests about four years ago to determine whether or not so-called vapor proof lighting fixtures could be safely installed directly within spray booths in which pyroxylin sprays were employed. The answer provided by these tests was an emphatic "No", for it was found that ignition of the pyroxylin dust was obtained at various points on the fixture and globe when pyroxylin varnish was sprayed directly at them. Flaming ignition occurred at a frequency of one trial out of five, in some cases ignition occurring at the moment the spray came in contact with the surface and in others a few moments later. In the tests not producing actual ignition it was found that the residue was decomposed with the evolution of the characteristic explosive vapors or fumes. By means of thermocouples the temperaturesof various points on the globes and fixture were determined. These ranged from 293 degrees Fahrenheit on the neck of the fixture to 471 degrees Fahrenheit on the surface of the globe.

The tests also included an investigation of the temperatures of various parts of a mercury vapor lamp and of the resistance coils of its auxiliary. The spray test using pyroxylin varnish was also made on this lamp and on the auxiliary. Ignition occurred at the upper end of the lamp where the temperature was found to be 453 degrees Fahrenheit and also on the main resistance coils of the auxiliary where a temperature of 738 degrees Fahrenheit was recorded. The latter is sufficient explanation of the reason why mercury vapor lamp auxiliaries are required to be placed at a distance of at least ten feet from the working faces of spray booths and the entire test is offered in support of the rule prohibiting the installation of lamps and lighting fixtures within spray booths. Obviously, this also excludes portable lamp units for use in spray booths.

While no actual tests have been conducted to determine the possibility of ignition of pyroxylin varnishes by motors, it is a safe assumption that if ignition is obtained on an enclosed lamp with a temperature of 471 degrees Fahrenheit that igntion would certainly occur in event of burnout of a Class I motor during which it is known to reach a temperature of 500 degrees Fahrenheit. Hence, the exclusion of motors of any type from spray booths or ventilating ducts connected with them.

The tests referred to above are reported in some detail in an article by Mr. A. H. Nuckolls, Chemical Engineer of the Underwriters' Laboratories, which appeared in "Laboratories' Data" issue of March, 1928. The article contains some valuable and interesting data. Through the courtesy of Mr. Nuckolls it is possible to reproduce a graphic record of the results of the tests. This will be found in Figure 27.

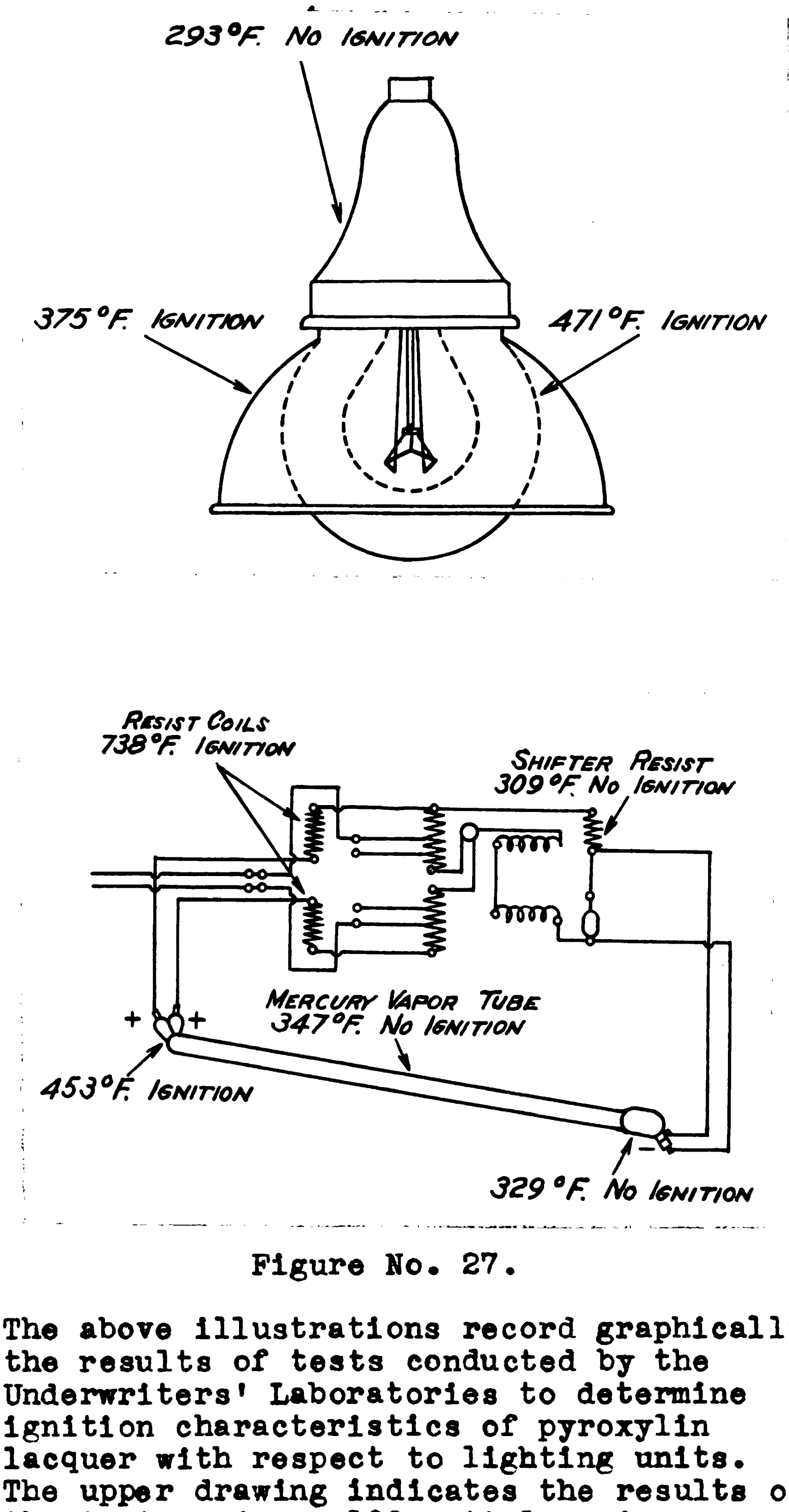


Figure No. 27.

The above illustrations record graphically the results of tests conducted by the Underwriters' Laboratories to determine ignition characteristics of pyroxylin lacquer with respect to lighting units. The upper drawing indicates the results of the tests using a 100 watt lamp in vapor-proof fixture. The lower drawing gives similar data when a mercury vapor lamp and its auxiliaries were used in the tests.

The motors driving the fans for ventilating spray booths, being required to be placed outside of the booths and ventilating ducts, can be located in any of the several places with safety. In ventilating systems using the indirect method, the motors and fans may be placed on the roof or in some other equally non-hazardous place. Where the fan proper is placed directly within the duct the motor driving the fan is located outside of the booth and duct, usually in the rear of the booth where it will not be exposed to the spray. In such locations, it will be noted that the rules permit the use of any standard type enclosed motor or an open induction motor of the non-sparking type. However, where there is any possibility of diffusion of the flammable solvent or thinner vapors to the area where such motors are located, the type approved for Class I locations should be specified. Figure 28 illustrates two methods of spray booth ventilation and shows approved motor installations for them.

Inasmuch as lamps are not permitted directly within spray booths it is necessary to place them outside of the booth in such a manner that sufficient light will be provided so as not to interfere with the quality of the work produced. There are several plans which have been used successfully which will be described briefly.

In a large automobile body factory which the writer visited, the owners had provided openings in the walls of the booths which openings were covered with wire glass. Behind the glass were installed mercury vapor lamps outside of the booth and where they would not be subjected to accumulations of varnish residue. In another plant, high wattage flood lights with reflectors were placed at a distance of about ten feet from the face of the booth and the lights focused on the articles being sprayed. This method is probably the safest of all. In long tunnel type spray booths it is common to find openings at intervals along the length of the booth through which openings light from vapor proof flood lights was directed. This method has found considerable use in railroad coach finishing shops.

For the smaller booths a reasonably safe lighting installation can be provided by placing vapor proof lighting fixtures on special brackets so attached to the top of the booth that the fixtures are fairly well away from the booth. In such installations a baffle is provided to prevent the spray from coming into contact with the fixture.

The practice of placing lighting fixtures in such a position as to project inward from the wall of the booth is to be condemned, as in such a position not only will residue collect on the fixture, but the fixture is subject to mechanical injury. This applies, whether the fixture is of the vapor proof type or not.

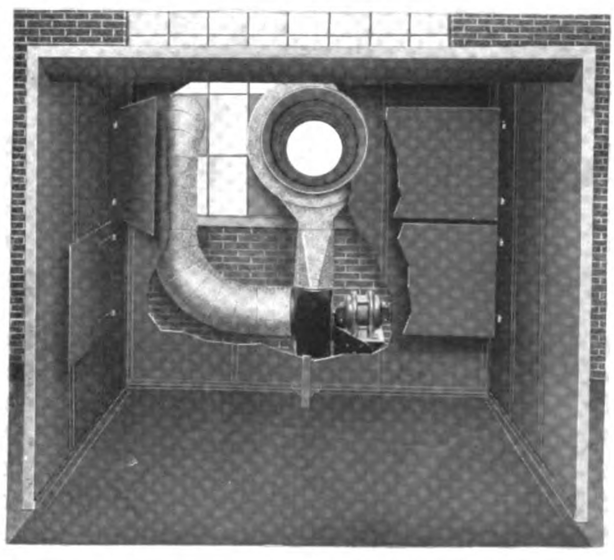


Figure No. 28.
Two Methods of Spray Booth Ventilation.

The upper view illustrates the direct method and procedure of placing motor outside of the booth and duct.

The lower illustration shows application of the indirect type of ventilation. Note that motor driving fan is outside of the booth in a place which permits use of open non-sparking type.

In the illustrations (Figures 29 and 30) will be found representative examples of spray booth lighting of the types mentioned above. There are included in Figure 31 two types of vaporproof floodlights which are suitable for mounting at a distance from the face of the booth or for providing light through openings in the side walls of tunnel type booths.

Portable Lamps

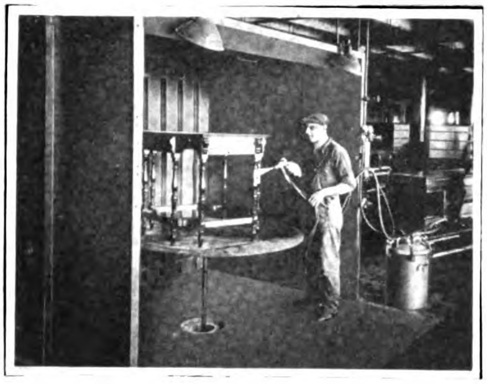
Portable lamps and their cords are without a doubt the most hazardous pieces of equipment used and, as will be seen by referring to the "Loss Record" of this thesis, they have been responsible for many losses which have occurred in Class I locations. Any attempt to produce a portable lamp assembly for use in a Class I location is but a concession to necessity or convenience. However, it must be recognized that such portable lamp assemblies will be used and rather than leaving the matter to the judgment of the individual, rule 32031 was inserted which states: "Sufficient general illumination shall be provided by fixed lighting units to eliminate, so far as possible, the need for portable lamps. When portable lamps are necessary, they shall be enclosed in a manner approved for explosive atmospheres and shall be properly protected by substantial metal or other approved types of guards to prevent breakage. Sockets for portable lamps shall be of the keyless moulded composition type with no exposed metal parts."

The importance of providing sufficient illumination by means of fixed lighting units should be strongly emphasized. In many cases, portable lights would not be needed were the general illumination properly designed originally. Illumination by fixed lighting units should be designed with respect to machines or work benches for by so doing it is probable that the need for portable lamps will be greatly reduced. The Underwriters' Laboratories have not yet developed a standard for design and test of portable lamps specifically, but it is assumed that the standard for lighting fixtures generally will apply to portable lamps. As this standard has already been discussed, nothing further need be said. To the knowledge of the writer no portable lamp assemblies have yet been submitted to the Laboratories for examination and test. However, the practice has been to accept the so-called vapor proof portable lamp assembly for use in Class I locations; again a concession to necessity. Such an assembly is illustrated in Figure 32.

It should be mentioned that there are some places where portable lamps of any type should be prohibited because of the rather high temperatures reached by the surface of the enclosing globe. Such locations may be in factories manufacturing articles from pyroxylin plastic, nitrate film

An improper method.

A better method.



Proper method for lighting small spray booths. Note baffles for protecting lamp unit from spray residue.

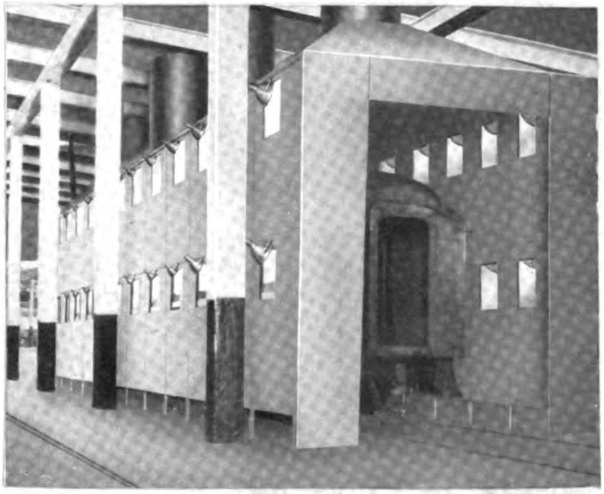


Illustration to left shows tunnel type spray booth of large size for railroad coaches. Note that light is projected through openings in booth walls from vapor-proof flood lights.

Figure No. 29.
Illustrating Various Methods of Spray Booth Lighting.

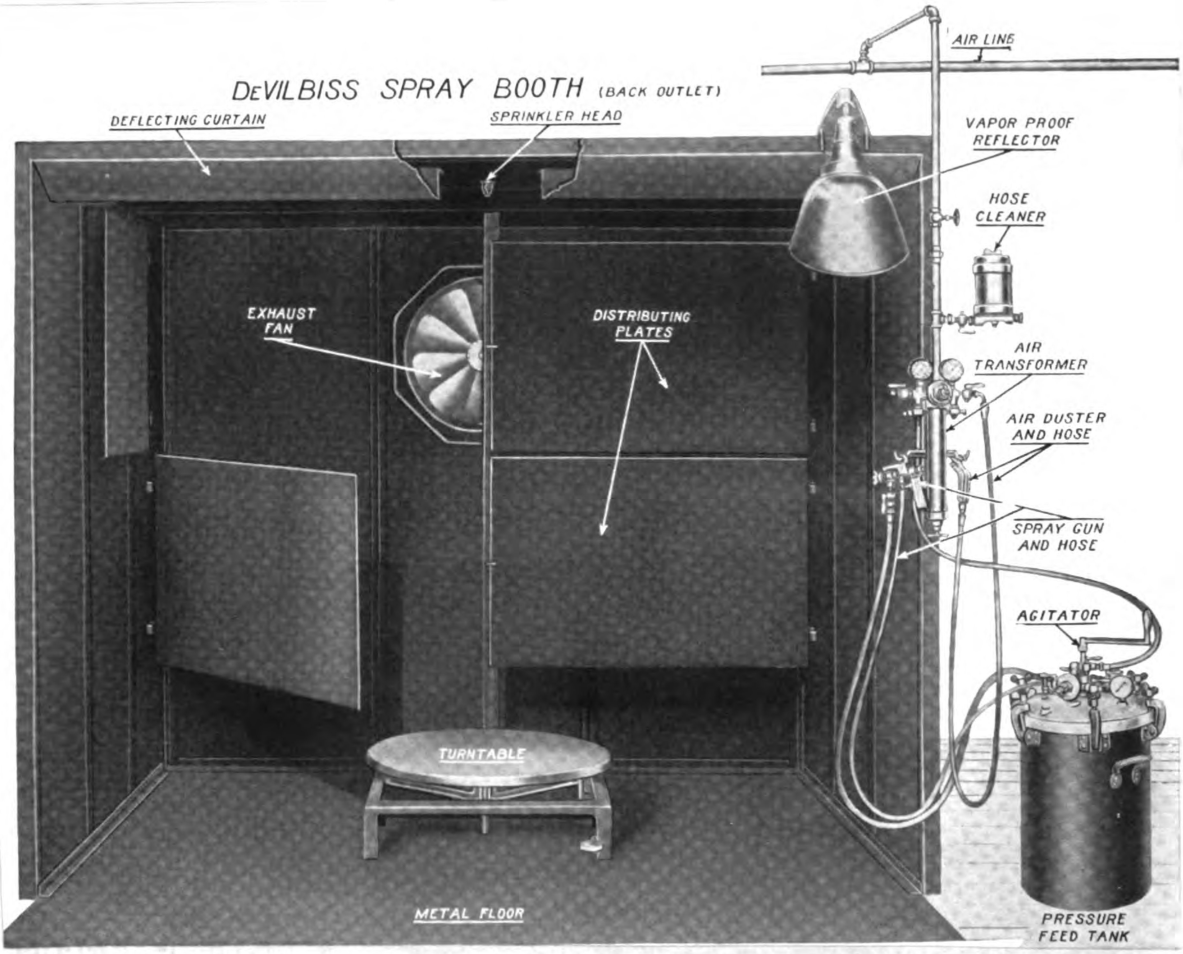


Figure No. 30.
Detailed View of Small Spray Booth.
Note location and protection of
lighting fixture.

Figure No. 31.
Two Types of Vapor-Proof Flood
Lights for Spray Booth Lighting.

Fixtures of this type may be placed at a distance of ten feet from the working face of the booth and the light directed into the booth interior.

storage vaults, sections of establishments where carbon disulphide is used, and others. The materials mentioned have low ignition temperatures and might easily be ignited by the heat from a portable lamp, even though the lamp is enclosed.

It is required that the exposed metal portions of a portable lamp assembly be grounded, but this is specifically cared for in rules 3203m and 3203p, discussion of which will follow. A grounding terminal is usually provided within the lamp assembly to which the grounding conductors may readily be connected.

Portable Cords

Sub-standard portable cords have caused many fires and explosions in Class I locations and are placed in the same category as portable lamps from the point of view of being concessions to necessity. Their use should be avoided whenever possible, but when it is necessary to employ portable cords, they should be of as short a length as practicable to accomplish the purpose desired.

Recognizing the fact that portable cords must be used under some circumstances, guidance as to the types which should be selected is given by rule 3203m which provides that: "When necessary to use portable lamps or other portable current-consuming devices, approved flexible cord designed for hard usage such as Type S or Type PA shall be used. Such a flexible cord shall contain one extra insulated conductor which shall be properly connected to form a grounding connection for metal lamp guards, motor frames, and all other exposed metal portions of such portable lamps and devices."

The Type S cord referred to is a heavy reinforced rubber-jacketed cord which is designed to withstand very rough usage. Of any portable cord, it is probably the most desirable for Class I locations. The type PA cord has a steel armor over the rubber insulation and while having enduring qualities, it is not nearly as flexible as the type S cord which may, under some circumstances, be a point against its use.

It will be noted that an extra conductor is required to provide for grounding of the exposed metal parts of the lamp assembly or other portable device. This extra conductor is connected to the grounding terminal in the lamp assembly or device and also to the grounding connection in the attachment plug, or to the conduit system when portable cords are attached directly to the supply conductors. The metal armor of type PA cord is not to be accepted as a grounding circuit, due to its probable high resistance and the doubtful character of the terminal connections.

Connection of Portable Cords

Rule 3203m provides for attachment of portable cords direct to the supply conductors as follows: "Connections of portable cords direct to supply conductors shall first be made mechanically secure and shall then be soldered and heavily taped. In addition, the cord shall be securely supported so that the probability of a break in the conductors at this point will be minimized. This rule is in recognition of possible installations such as over a long row of work benches where permanent attachment of portable cords is desired. The importance of removing the strain from the connections is to be emphasized. There are fittings on the market which were specially developed to comply with this rule. These are of the type which attach directly to the conduit by threaded joints and provide means for gripping the conductors securely to remove the strain from the connections. Facilities for sealing-off the conduit are also provided. It is not expected that this method of attaching portable cords to the supply conductors will be very generally employed.

The separable connections as provided for by rule 3203o will probably be used in the large majority of cases for connecting portable cords to the supply. This rule states: "Receptacles and attachment plugs, if used, shall be so connected as a part of a unit device with an explosion-proof inter-locking switch that the plug cannot be removed while the switch is in the "on" position or approved devices which seal the arc, made when current is interrupted, by means of an explosion-resisting or vapor-proof enclosure shall be used. Such receptacles and plugs shall be of the polarized type, providing a connection for the grounding wire of the portable cord."

It is admitted that the wording of this rule is rather involved and the exact meaning not clear to one not familiar with the intent. An attempt will be made to clarify this rule for the next edition of the Code.

The intent of the rule is to provide for attachment plugs and receptacles which will not permit an arc to occur in the hazardous atmosphere when the plug is removed from the receptacle. This may be done by two methods as follows:

1. By designing an assembly consisting of a circuit switch and a receptacle which are so interlocked that the plug cannot be inserted in the receptacle unless the switch is in the "off" position, and when once in the receptacle, the plug cannot be removed while the switch is in the "on" position. While the rule now reads "explosion-proof" it is intended that the switch and receptacle assembly be "explosion-resisting" in accordance with the requirements for switches in general.

2. By a specially designed plug and receptacle in which the arc developed when the plug is removed is contained within an explosion-resisting enclosure. This may be accomplished by providing a long sleeve plug fitting closely over the shell of the receptacle with prongs or contacts of such length that the circuit is broken before the plug has travelled a sufficient distance to permit the emission of flame from any explosion which might occur within the chamber made by the plug and receptacle. It will be noted that the plug and receptacles of both types are required to be polarized to eliminate the possibility of the plug being incorrectly inserted. An extra contact is provided to accomodate the grounding conductor.

Devices of both types are available. One complying with the second specifications above will be found illustrated in figure 33.

Grounding

The proper grounding of the non-current carrying metal parts of equipment is very important because of the fact that should an accidental ground occur anywhere in the system within the hazardous area, the service fuses or other circuit protection should open immediately and clear the circuit. With a high resitance grounding circuit, or an installation operating without an equipment ground, it is probable that serious arcing would result, possibly to the extent of burning through the conduit. Rule 3203p provides that: "The exposed non-current carrying metal parts of equipment, such as the frames or metal exteriors of motors, fixed or portable appliances, fixtures, cabinets, cases, and conduit shall be grounded as provided in Article 9 of this Code. The locknut-bushing and the double-locknut type of contact shall not be depended upon for bonding purposes, bonding jumpers or other approved means being required to assure an effective grounding circuit."

It will be noted first, that it is required that equipment grounding be provided in accordance with the rules of Article 9 which is the article of the National Electrical Code dealing with the subject of "Grounding." The second sentence of the rule is intended to provide for a low resistance grounding circuit in that part of the conduit system outside of the hazardous area to the point where the connection is made to the water pipe or grounding electrode. It is not thought safe to rely on locknut and bushing types of contact between conduit and cases as very often excessively high resistance is introduced into the grounding circuit by improperly made or loosened conduit connections at cases or similar points. For this reason the requirement for bonding

jumpers at such points is provided. Inasmuch as positive threaded connections are used at all points within the hazardous area, bonding jumpers are not required, for the threaded connections are sufficient in themselves. Suitable bonding bushings and flexible jumpers are available by which the bonding can be neatly done within the cabinets or cases. Figure 34 illustrates the use of such devices. As an alternative method, exterior bonds employing clamps and jumper conductors are permitted by the rule.

For the grounding of equipment in a Class I location, every effort should be extended to secure a ground connection of low resistance. Preference should always be given to a continuous water piping system as the grounding electrode.

Live Parts

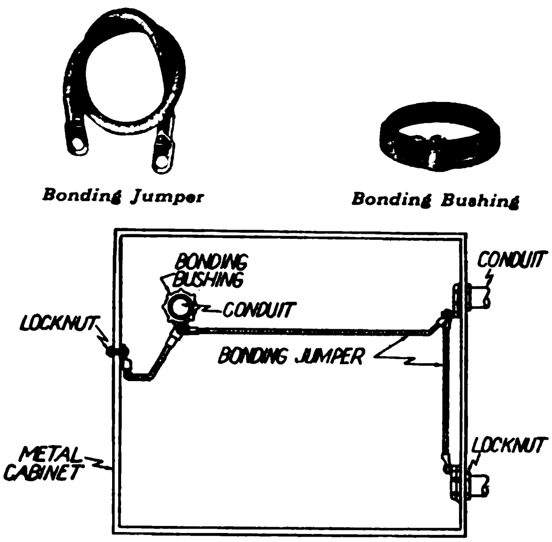
Rule 3203q requires that "There shall be no exposed live parts." This rule requires no comment, as in reality, compliance with all of the preceding rules of the Article automatically fulfills the conditions imposed by this rule.

Gasoline Discharge Devices

The Underwriters' Laboratories have established standards for the design and test performance of motor driven gasoline discharge devices for filling stations. Where formerly the pump itself was examined and tested as an individual device, the new procedure provides for the examination, testing and listing of the entire pump assembly, including the motor, its control switch, and wiring as a complete unit. When a dome light is provided on the top of the device, this also is included in the consideration.

The standards provide requirements which are in thorough conformity with the rules for Article 32, Class I locations. The motor is required to be of the type approved for Class I, Group D locations. The same requirements are made of the motor control switch and dome light and switch, if any. Rigid conduit wiring with explosion resisting joints and fittings are specified.

As the device is usually received at the filling station for installation, the device is completely wired down to the explosion resisting junction fitting located in the base of the pump. The installer runs a circuit from the filling station building to the pump and makes the necessary conduit connection to the junction fitting in the base of the pump and then seals off the conduit at the fitting in the base of the pump with a suitable compound. Attention is called to the discussion on "Filling Stations" appearing under "The Petroleum Industry" of Part II of this thesis.



Showing Interior of Cabinet to Illustrate Use of Bonding Bushings and Jumpers. These devises result in neat and effective bonds

Figure No. 34
This Illustrates Method of Bonding Using Bonding Bushings.

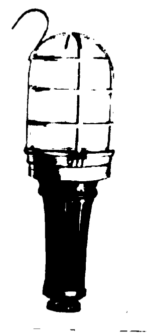


Figure No. 32.
A Vapor-Proof Hand Lamp Assembly with Live Rubber Handle.

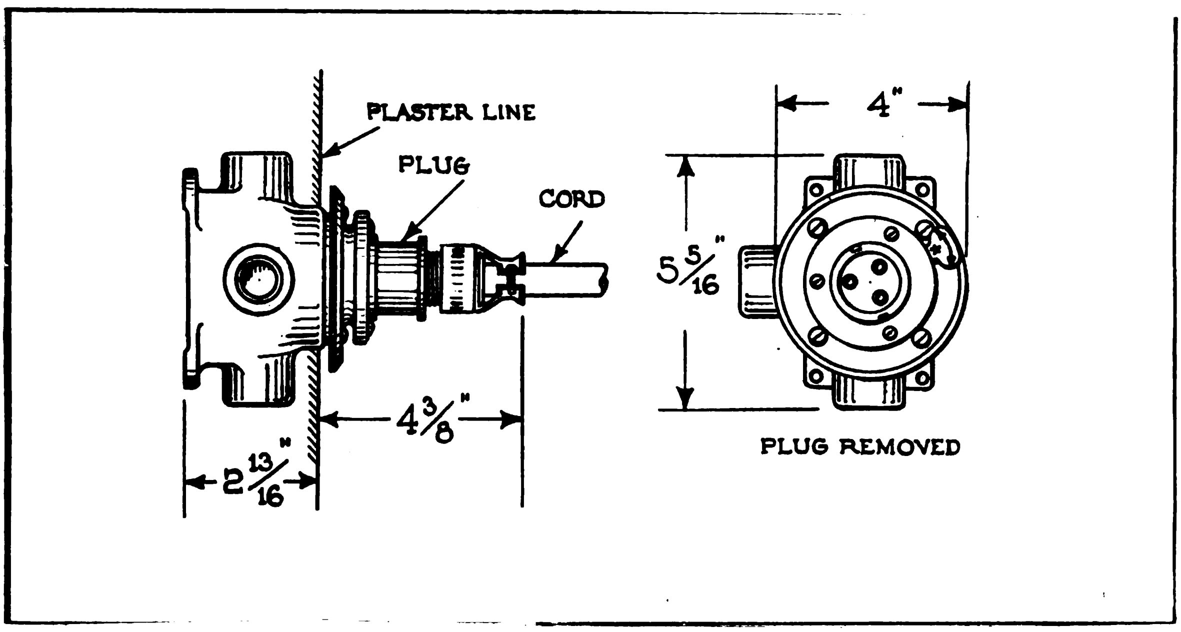


Figure No. 33.
Receptacle and Plug Intended for Use in Class I Locations.

CLASS II LOCATIONS

As the introductory rule of this section, the following appears: "In locations judged to be as described for Class II locations in paragraph c of section 3201, the following provisions shall be observed:" This rule was inserted for the purpose of providing a definite reference back to the definitions for the various classes, where Class II locations are described briefly, as those where combustible dust is present.

Before beginning the discussion of the rules of this class, it should be pointed out that it is practicable to exclude dust from within the enclosure of electrical apparatus. As the discussion of the rules proceeds, it will be noted that they specify dust-tightness in certain instances. This section, then, differs in this respect from that pertaining to Class I locations for which explosion-resisting, rather than vapor or gas-tight, equipment is specified. The term "dust-tight" as applied to enclosures is defined as: "so constructed that dust will not enter the enclosing case."

The intent generally, of the rules for Class II locations is to prescribe types of enclosures for electrical apparatus and wiring which will, first, prevent the occurrence of electrical arcs or sparks in the immediate presence of combustible dust which is likely to be in suspension in the atmosphere; and second, prevent the ignition of combustible dust which may have accumulated in or on motors, lamps, or other electrical devices in such quantities that normal radiation of heat from such devices is prevented.

Due to the presence of combustible dust in the atmosphere in places judged to be Class II locations, it is obviously necessary to take proper precautions to not only enclose sparking or arcing parts of apparatus, but also to design such enclosures that dust will not enter them. Lamps must be protected to guard against their breakage when exposed to mechanical injury and must be enclosed in enclosing globes to prevent ignition of the dust by the heat of the bare lamps. These requirements are satisfied by compliance with the rules which we shall now discuss.

The supposition is sometimes made that because a device is approved for Class I locations, it is automatically approved for Class II locations. This is not necessarily true, in fact, may be decidedly untrue in some cases. Whether or not a Class I device is suitable for installation in a Class II location can be determined only by specific examination and test. Some electrical manufacturers have requested dual listing of the Underwriters' Laboratories for certain pieces of equipment and in some instances such dual listing will be found.

Service Equipment, Panelboards and Switchboards

Service and circuit protection equipment involves switches, fuses, circuit breakers, metering equipment and associated apparatus which in their operation entails the production of arcs and sparks which, if occurring in the immediate presence of an atmosphere of combustible dust, may result in an explosion. Hence, the need for either adequately enclosing such apparatus, or removing it to a location where combustible dust is not present. Rule 3204b provides as follows: "Service entrance equipment, and all panelboards and switchboards shall not be placed in locations of this class, but, if impracticable to locate elsewhere, all live parts shall be enclosed in dust-tight metal cases or cabinets having provisions for external operation only, or shall be located in a separate dust-tight room built of or lined with substantial non-combustible materials and having a self closing door, so constructed and installed as to adequately exclude dust."

In the large majority of instances, especially in new construction, convenient arrangements can be made to place the main service equipment, panelboards and switchboards in some comparatively dust-free location judged to be outside of the hazardous area. This is a procedure much to be preferred over any other. In the larger establishments, such as large capacity flour mills or terminal grain elevators, space for this equipment is ordinarily provided in a power house of non-combustible construction, either attached or detached from the main plant, or oftentimes a special switch house is built for this particular purpose. In the smaller plants, such as the smaller flour and feed mills and country elevators, there will commonly be found an attached building regarded as out of the hazardous area in which the service equipment can be installed. This may be an office, warehouse, or power house, which are usually divisions of such plants.

Where it is not practicable, from an economic or convenience standpoint to provide such an arrangement, and installation within the hazardous area is required, recourse can be taken to the portion of the rule which permits the equipment to be so installed provided it is located in a room of suitable construction. In plants of fire resistive construction, the room should be built completely of non-combustible materials such as concrete, tile or brick, but where the building is of a combustible nature, a room of steel lath and cement plaster on a framework of wood or steel is permitted. Necessarily, there should be no exposed combustible material within the room, which requires that the floor be covered with concrete. Any openings from the room into the main plant should be provided with tight-fitting fire doors so arranged as to be self closing. It is important that the room be sufficiently large to permit of ready entrance by persons for operation and maintenance work. In general, rooms lined with sheet metal, asbestos, or similar fire-retardant materials are not suitable, for they are rarely

found to exclude dust adequately and do not have the necessary qualities to confine fire within the room. In the section entitled "Motors" will be found complete instructions for the construction of a suitable steel lath-cement plaster room.

It is often feasible to provide a room of the above description to contain, not only the service and circuit protection apparatus, but the motor controllers as well, especially when controllers of the remote control type are used. This plan is coming into quite general use and with complete satisfaction.

In the larger elevators and mills it is often found necessary to provide sub-feeder distribution panelboards in certain portions of the plant to obtain a more economical and convenient installation. This can be readily provided for by building rooms of the style previously suggested at or near the load centers, and in them locate the panelboards.

It is not generally required that panelboards located in such rooms be enclosed in cases or cabinets because of the fact that they are regarded to be accessible only to qualified persons. However, if there is a possibility that the room will be accessible to all workmen, it may be advisable, in the interest of safety, to provide the necessary cases or cabinets which when so located may be of the ordinary dust-proof type.

Only when lack of space or possible great inconvenience dictates, should the portion of the rule permitting the use of dust-tight metal enclosures for service equipment, panel-boards and switchboards be resorted to, for as in the case of Class I locations, a hazard of no small degree is introduced when it is found necessary to renew fuses or do other maintenance work at a time when the plant is in operation.

There is available, one type of dust tight metal enclosed panelboard, but so far as the writer is aware, none has yet been approved by the Underwriters' Laboratories. There is also a dust tight fused service switch available and, of course, various types of oil circuit breakers, some of which may answer the specification for dust-tightness, but to the knowledge of the writer, none has been specifically approved for service switch duty in hazardous locations.

Fuses and Circuit Breakers

Rule 3204c provides that: "Fuses shall not be placed in locations described in this class unless enclosed in dust-tight metal cabinets or cases." Circuit breakers shall be of the dust-tight or dust-tight oil immersed type."

found to exclude dust adequately and do not have the necessary qualities to confine fire within the room. In the section entitled "Motors" will be found complete instructions for the construction of a suitable steel lath-cement plaster room.

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Practically the same comment is in order on this rule as was made in the case of "Service Equipment, Panelboards and Switchboards." Every effort should be made to have fuses and circuit breakers placed in rooms of the types suggested, as this procedure is by far the safest.

In installations of the older type and possibly in isolated instances in new construction, it may be found necessary to provide for the installation of fuses in the hazardous area. In such an event, the rule is invoked and such fuses are required to be enclosed in a case so constructed that dust will not enter. It should also be required that certain temperature limits for the enclosing case be prescribed in accordance with the discussion which will appear under "Motors."

It should be noted that circuit breakers are required to be of the dust-tight or dust-tight oil immersed type if installed in the hazardous area, but not in rooms of the type which has been mentioned. Such circuit breakers should be of a type meeting the requirements for "Motor Controllers" generally, which will appear later in this section.

Type of Wiring

The requirements as pertaining to the type of wiring for Class II locations is contained in Rule 3204d which states: "Rigid conduit shall be the wiring method employed. Where it is necessary to employ flexible connections, as at motor terminals, a short length of flexible steel conduit may be used."

As in Class I locations, the type of wiring for Class II locations should be the safest available and for this reason rigid conduit was specified. It offers, (1) effective protection against mechanical injury, (2) a low resistance equipment grounding circuit, (3) reasonable protection against destructive arcs within it, (4) dust-tight joints when threaded couplings are used, and (5) a type of wiring not unreasonably expensive.

It is the understanding that threaded connections are required at couplings, cabinets and eases, no recognition having been given threadless fittings.

The present rule does not indicate whether fittings, such as "ells" or "tees", are required to be of the dust-tight type. It was not the intention at the time when this rule was drawn to require such fittings to be dust-tight as it was not felt that the small amount of dust which would enter such fittings could, by any stretch of the imagination, cause an explosion or do any other damage. To avoid differences in interpretations on this point, the matter will be referred to

the Article 32 Committee who will so amend the rule as to be explicit.

The same may be said with regard to pull boxes, junction boxes and similar enclosures which do not contain, normally, arcing or sparking parts. In general, it has not been the practice to require such boxes to be of the dust-tight type, not to require that conduit connections to such boxes be made through threaded hubs, as it was felt by the majority that the small amount of dust that would enter such boxes could do no damage. It is admitted, however, that the rule is not explicit with regard to the matter, and so proper amendment is in order.

It has been found that in order to render switch cabinets, fuse boxes, controller cases, and other enclosures containing normally arcing or sparking parts permanently dust-tight as required by the rule, it is necessary to specify that the conduit connections to them be of the threaded type, that is, so as not to depend on the locknut and bushing type of attachment. However, with enclosures for normally non-sparking parts such dust-tightness does not appear to be necessary, although opinions vary on this point. It is important, however, that when the locknut-bushing type of attachment for conduit is used that proper bonding be provided around and to such enclosures as will be discussed under "Grounding."

It is often necessary to provide flexibility at motor terminals in order to permit the motor to be shifted on its base for the purpose of tightening the drive belt. A concession has been made to care for this by permitting the use of a short length of flexible steel conduit to enclose the terminal wires. This should be as short as is practicable and usually need not exceed three feet in length. This flexible conduit is required by the general rules of the Code to be attached to the terminal box of the motor and to the rigid conduit by means of clamps or fittings approved for the purpose.

Motors and Generators

There are three rules in the section pertaining to Class II locations which deal with the design, construction and installation of motors and generators. To avoid confusion, these will be quoted and discussed separately. The first rule, (Rule 3204e) relates to motors which might be referred to as of the "sparking type", and states: "Where explosive dusty atmospheres are likely to be present, as in (1) of paragraph c of section 3201, motors or generators having brushes or sliding contacts shall have such contacts enclosed in substantial dust-tight housings or shall be of the totally-enclosed, totally-enclosed-fan-cooled, or totally-enclosed-

pipe-ventilated types or shall be enclosed in separate dust-tight rooms or housings, built of or lined with substantial non-combustible materials, and so constructed as to adequately exclude dust, and properly ventilated from a source of clean air." Following the rule is the fine print notes: "It is recommended that all motors installed in dusty locations be of the totally-enclosed, totally-enclosed-fan-cooled or totally-enclosed-pipe-ventilated types."

The intent of this rule is only to guard against ignition of the explosive mixture of dust and air by sparks or arcs from unenclosed brushes, collectors, centrifugal switches or other so-called sparking parts. Such sparks or arcs may occur to some extent even when the motor or generator is in normal operation, but more serious sparking occurs when the machine is overloaded, is being started, or when faults develop in the windings.

The rule should be interpreted that such guarding is necessary in any Class II location, as it is practically impossible to have accumulations of dust in motors and other equipment without at some time having explosive mixtures of dust present in the atmosphere. The reverse is not always true, however, as will be pointed out later.

The rule suggests several methods for compliance with its provisions. The first, that of enclosing the sparking parts in dust-tight housings, may be conveniently used for the larger slip ring wound rotor motors or for certain types of the centrifugal switch self-starting polyphase motors. Figure 35 illustrates a slip ring would rotor motor having its slip rings enclosed in a dust-tight housing.

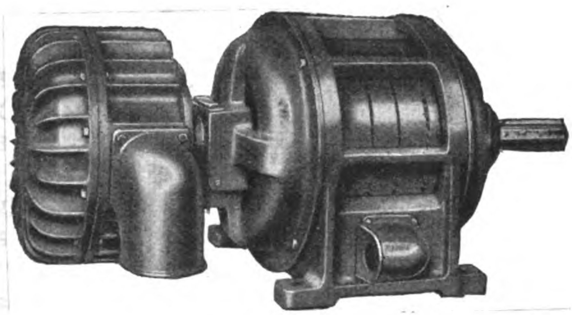


Figure No. 35.
Slip Ring Motor with Enclosed Slip Rings.

In this type of motor, the slip rings are arranged for out-board mounting. Although the hazard of normally sparking parts is removed by such enclosure, the windings of the motor are still exposed to accumulations of dust.

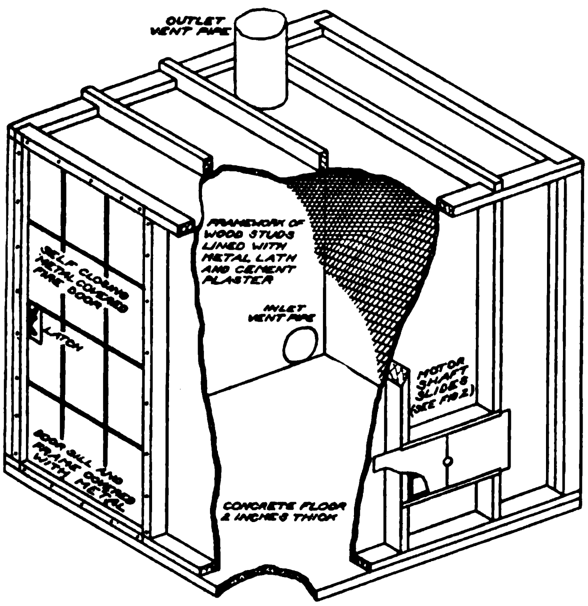
However, for some types of slip ring wound rotor motors it is difficult to provide an enclosure for the slip rings, in which case, it becomes necessary to employ some other method to secure the necessary protection of the sparking parts.

While the enclosed types of slip ring,wound rotor motors are available, it is found that the cost of the larger sizes, such as used for main drives in flour mills, is excessively high and it is usually more economical to locate such motors in a special fire resistive motor room, or in a power house outside of the hazardous area. In either of these latter cases it is permissible to use the standard open motor without enclosures for the slip rings.

The comments in the preceding paragraph also hold true for generators, direct current motors, the smaller slip ring motors, and single phase motors of the commutator or centrifugal switch type, except possibly in the comparatively small capacities when totally-enclosed or totally-enclosed-fan-cooled or pipe-ventilated types of machines may be economically employed, all of which are available.

The construction of a motor room in or in connection with a plant of fire resistive construction should necessarily be of equally fire resistive construction. The walls may be of brick, tile or concrete; the floor and ceiling or roof of concrete or tile; and so built that there will be no unprotected combustible material within the room. Door openings into the main buildings should be protected by tight-fitting approved fire doors so arranged as to be self-closing. The shaft opening should be protected by slides of non-combustible or tin-clad wood construction, fitting tightly around the shaft. The room should be of sufficient size so that a person can readily enter the room to perform the necessary maintenance work.

When the plant is of combustible construction, the same type of motor room as specified in the preceding paragraph may be used, especially if the motor room is outside of the main building. If it is required that the motor room be within the building and in the hazardous area, a lighter form of construction may be necessary, due to the danger of overloading floors. In this case, a motor room built of steel lath and cement plaster on a frame work of wood or steel may be used, the other requirements of the preceding paragraph as to shaft and door protection, being the same. Figure 36 illustrates two types of motor rooms or enclosures which have been found very satisfactory in combustible flour mills, feed mills, and grain elevators. Some details as to construction are given which, will be of assistance. In general, and for motors or generators of from 7½ to 50 horsepower inclusive, the enclosure pictured in the upper illustration may be used, in which case, one having dimensions of six feet by six feet



STANDARD MOTOR ENCLOSURE

Figure 1

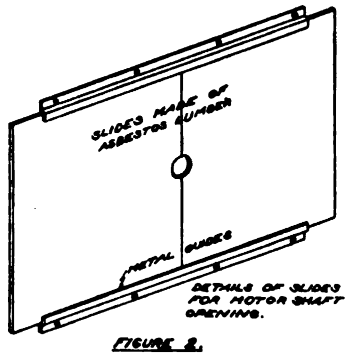


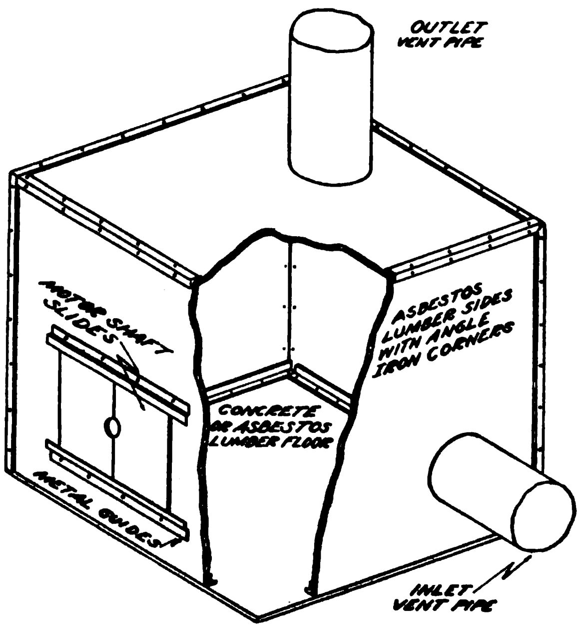
Figure 2

Figure 1 illustrates the standard motor enclosure which should be used for all motors larger than 5 horsepower.

Figure 2 illustrates the construction of the asbestos lumber slides which should fit tightly around the motor shaft and yet permit moving motor on its rails for adjusting the belt.

Figure 3 illustrates an enclosure for motors of 5 horsepower and smaller and for motors so located that space is limited.

See typewritten specifications for size of enclosure and ventilating space recommended.



ENCLOSURE FOR SMALL MOTORS

Figure 3

Figure No. 36.
Suggested Methods for
Construction of Motor and
Controller Rooms.

MOTOR ENCLOSURE SPECIFICATIONS

MUTUAL FIRE PREVENTION BUREAU
ENGINEERING SERVICE DEPT.

CHICAGO, ILL. DATE 3/1/28
SCALE______ PRINT No. 1208

by six and one half feet high has been found satisfactory. For small motors up to seven and one half horsepower, where space is restricted, the enclosure shown in the lower illustration, having dimensions of a three foot cube, may be employed. Sheet metal or asbestos lined frame motor rooms should not be recommended.

The ventilation of motor rooms or enclosures is important, as without adequate ventilating facilities overheating of the motor may result and defeat, to a large extent, the purpose of the enclosure. When a motor room is a separate structure, sufficient ventilation can usually be secured by means of window openings or louvres in an outside wall, but when the motor room or enclosure is within the building, it is necessary to extend inlet and outlet vent pipes to the outside of the building to a source of clean air. To secure the needed ventilation there must be provided a certain difference in level between the upper end of the outlet pipe and the lower end of the outlet pipe, this depending on the size of motors, the diameter of the vent pipes and other factors. For motors larger than 25 horsepower, when enclosed in the 6' x 6' x 6½' enclosure, it is usually necessary to employ an exhaust fan in the outlet pipe to insure sufficient flow of ventilating air.

The construction of sheet metal housings for motors should be discouraged as such attempts at protection are seldom of any value, due to difficulties encountered in making them dust-tight, and in providing the needed ventilation. In many instances, such housings are worse than none at all. Figure 37 illustrates the use of such housings on the two motors of an attrition mill. It is only in exceptional cases that housings of this type are successful. Usually dangerous heating of the motor occurs, or the operator, falsely believing that he possesses dust-tight housings for his motors, neglects to open the housings for inspection of the interior. This often results in the burning out of the motors sometimes with disastrous results because of the failure of ordinary sheet metal to retard spread of fire.

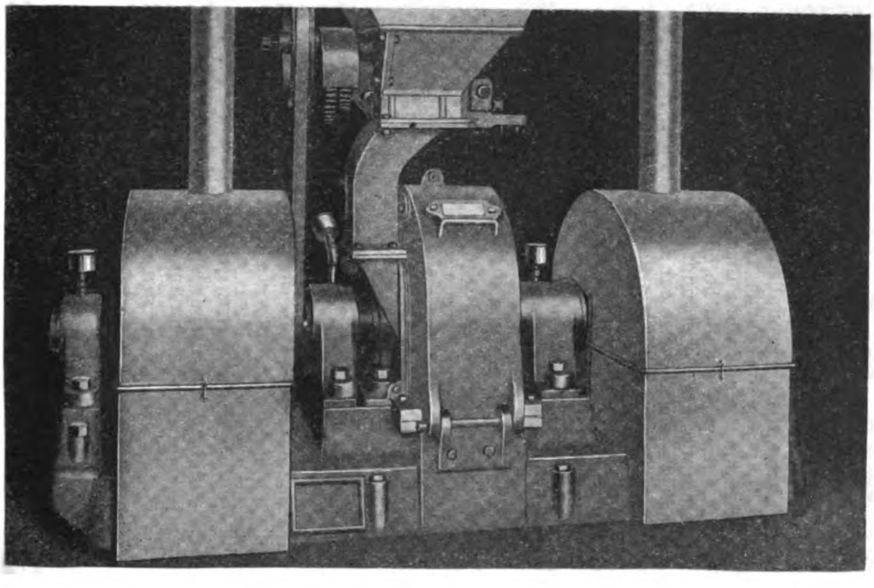


Figure No. 37.
Illustrating Attempts to Protect Open Type Motors From Dust.

When motor rooms are provided, it is often convenient to locate service equipment, switchboards, and controllers in it, thus making a safe and satisfactory arrangement.

The fine print note following rule 3204e recommends the use of the totally enclosed types of motors in all dusty locations whether or not conditions are such as to require the application of rule 3204f. The enclosed types of motors are much to be desired throughout the hazardous area, even though the motor be of the squirrel cage type without sparking parts. As a matter of fact, various fire insurance underwriters have recognized the value of such procedure by granting liberal credits in the fire insurance rates applying when this is done.

In rule 3204f, there appears the following: "Where it is impracticable to prevent combustible dust from collecting in dangerous quantities on or in motors as in (2) of paragraph c of section 3201, all motors shall be of the totally-enclosed, totally-enclosed-fan-cooled, or enclosed-pipe-ventilated types, or shall be enclosed in separate dust-tight rooms or housings built of or lined with substantial non-combustible materials and so constructed as to adequately exclude dust, and properly ventilated from a source of clean air." Following this rule, this fine print note is found; "The above conditions often exist in sugar, cocoa, and coal pulverizing rooms, cupolas, head-houses, basements and other points in grain elevators, flour mills and feed mills, where grains are spouted, and in similar locations. Where the installation and maintenance are such that the hazardous conditions do not exist, the foregoing requirements are not called for and are waived."

The intent of this rule is to provide protection for motors which are located in areas where they are likely to be exposed to combustible dust in such quantities as to seriously interfere with the radiation of heat. It is clear that when combustible dust accumulates in the ventilating ducts or on the windings of a motor that it is impossible for the motor to radiate heat as intended by the designer. The overheating thus caused, eventually results in the breakdown of the windings of the motor with accompanying arcs or sometimes by ignition of the dust in and about the motor. Very often the condition is aggravated by spillage of oil by careless attendants or leakage from defective bearings. This oil mixed with the dust not only causes the dust accumulations in the motor to build up rapidly, but destroys the insulation of the windings in a comparatively short time.

By referring back to the discussion appearing on pages 17 to 19 inclusive and 24 to 26 inclusive, of this thesis, it will be clear that there are several factors which have bearing on the question as to what motors should be required to be guarded against dust accumulations in the manner pre-

scribed by the rule now under discussion. The location of the motor with respect to accessibility in an important factor, for there is a natural tendency to neglect a motor which is more or less out of reach. The character of the operation or process in the vicinity of the motor is also an important consideration. An attempt is made in the fine print note following rule 3204f to suggest the general nature of the processes or operations which are likely to produce excessive quantities of dust.

However, each type of process in the industries producing combustible dust must be considered separately and only after considerable experience will the engineer be in a position to judge beforehand where dust in excessive quantities will be likely to occur.

Attention is called to the discussion beginning on page 75 of this thesis in which will be found recommendations as to the treatment of motor installations in grain elevators, flour mills and feed mills.

While it is admitted that ordinary open type squirrel cage motors may be operated with comparative safety in some parts of plants which involve the production of combustible dust, it should always be kept in mind that for all locations in such plants, the enclosing of motors or the use of the enclosed types of motors is always to be preferred. This removed the need for considering such factors as housekeeping, efficiency of dust collection systems and general maintenance.

From an economic standpoint, the enclosed motor is also favored, for even in the cleanest location in a grain handling risk an open motor is bound to collect considerable dust which can be removed only by means of compressed air or by disassembling the motor and thoroughly cleaning it. Necessarily such maintenance work entails considerable expense, all of which can be avoided by employing the enclosed types of motors.

It is seen that the provisions of rule 3204f, with regard to the protection of motors from dust accumulations, is similar to that in rule 3204e except that the latter rule permits the enclosing of the sparking parts only as one means of compliance, whereas rule 3204f requires the enclosing of the entire motor. The distinction between the two rules is that in rule 3204e it is contemplated that dust will be present in the atmosphere of the location in explosive quantities, but not necessarily so as to cause accumulations of the dust in motors so as to prevent normal radiation. Thus, the condition considered in rule 3204e can be present without that outlined in rule 3204f. However, the conditions considered in rule 3204f almost always involve those of rule 3204e also.

There are now on the market a wide variety of the various types of enclosed motors, and are available in all standard sizes up to 150 horsepower. All motor manufacturers of any importance have developed complete lines of such motors to answer the demands of not only those industries coming under the Class II designation, but others of the non-hazardous classes as well. In figures 38 to 41 will be found illustrated several of the various types from which can be obtained a good idea as to their construction and operation. Several photographs are included showing application of enclosed motors to grain elevators. These will be found in figures 42 to 47.

Although there are three general types of enclosed motors available, viz; the totally enclosed, the totally-enclosed-pipe-ventilated and the totally-enclosed-fan-ventilated; the totally-enclosed-fan-ventilated has had by far the widest application, at least in capacities up to 50 horsepower. The advantages of this type are represented chiefly by the facts that vent pipes are not required, that the weight is but little more than that of the open motor of like size, and that the mounting dimensions are in most cases identical with those of the open motor of the same size. The totally enclosed non-ventilated motor is out of the question, except in sizes of two horsepower or less because of its great size and weight, in comparison to its output. The totally enclosed-pipe-ventilated type is often objectionable, due to the necessity for providing vent pipes which is not always convenient where space is limited. However, in the larger sizes (50 HP and larger) the pipe ventilated type is often used for economic reasons.

The Underwriters' Laboratories have developed standards for the construction and test performance of enclosed motors intended for use in Class II locations. These standards are available in printed form and, therefore, will not be repeated here, except to mention briefly the general considerations involved. As was the case with motors intended for installation in Class I locations, it was found that various dusts possessed varying degrees of hazard and, therefore, rather than grouping all motors for Class II locations together, a division was made with respect to the type of dust. These divisions are as follows:

Group	Mixture
E	Metal Dust
F	Coal or Carbon Black Dust
G	Grain Dust

The construction requirements of the Standards recognize enclosed motors of all of the three types which have been discussed and prescribed that they shall be enclosed in a casing of substantial dust-tight construction. Metal-to-metal

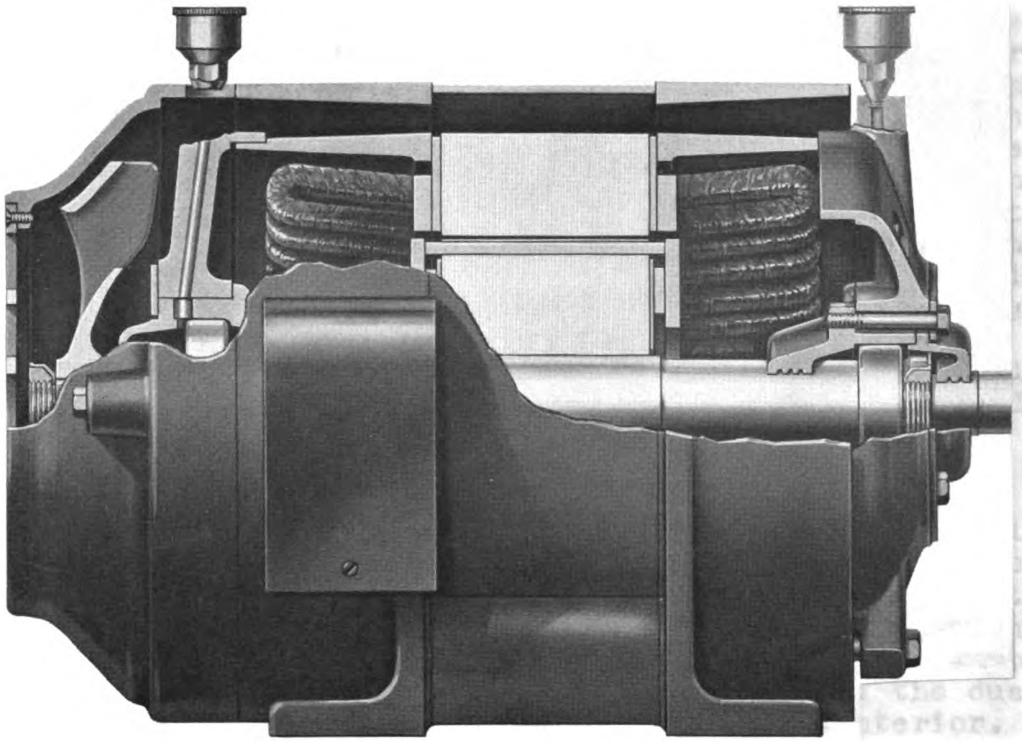


Figure No. 38.
Cut-Away View Showing Interior
Construction of Totally-Enclosed-
Fan-Ventilated Motor.

Note that windings and rotor are completely sealed against the entrance of dust. Also note external fan for forcing cooling air between inner and outer casings.

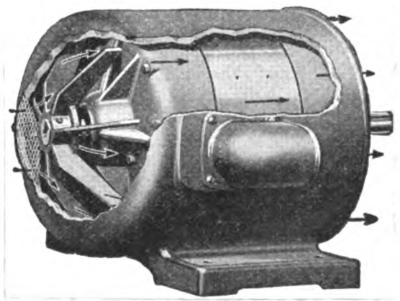
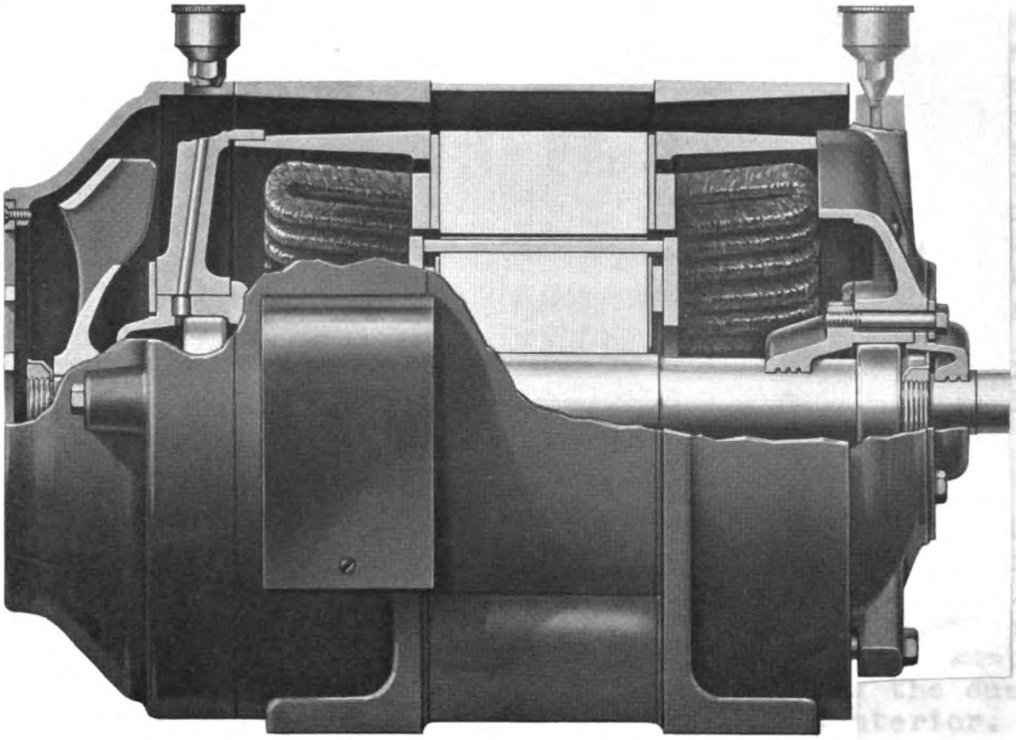


Figure No. 39.
Sectional View of Totally-Enclosed-
Fan-Ventilated Motor to Show Path of
Cooling Air.



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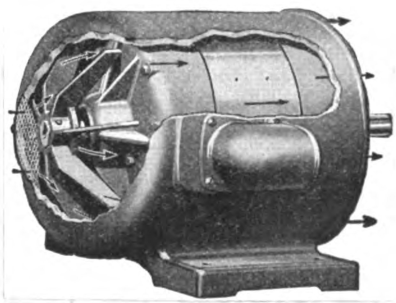


Figure No. 39.
Sectional View of Totally-Enclosed-
Fan-Ventilated Motor to Show Path of
Cooling Air.

joints with a metal-to-metal surface of at least 3/16 of an inch in width when assembled, are required. Gaskets are not permitted except on those parts subject to removal for inspection and maintenance. The shaft openings are required to have a length of path of not less than 1/2 inch for a maximum radial clearance of .005 inches. For greater lengths of path larger clearances are permitted, complete information on which is contained in the standard. The terminal leads are required to be securely held and tightly fitted where they pass into the casing. This is accomplished by sealing the conductors by means of a suitable insulating compound. A terminal box, arranged for conduit connection is also required, and finally the motor is required to be marked with a label on which is stated the Class and dust group for which the motor is intended.

In testing a motor submitted for approval for Class II locations, it is placed in a special test chamber of sufficient size to prevent other than normal heating of the motor. This chamber is about six feet by six feet by five feet high, the bottom of which is hoppered. Means are provided for causing continuous circulation of dust, which dust is held in suspension in the chamber by means of a blower fan directing the dust through nozzles placed at various points in the interior. The motor shaft extends through a protected opening in a wall of the chamber and is caused to drive a generator which permits testing the motor under actual load conditions. Tests are made under both continuous and intermittent operation. In the latter test, the motor is permitted to operate fully loaded until normal temperature rise has been attained and is then allowed to cool to ambient temperature when the test is repeated. The purpose here is to determine the possible influence of the "breathing" action in causing dust to be forced into the motor casing. These tests are continued for a period of time sufficient to determine the dust-tightness of the motor under these conditions. Naturally, if dust enters the motor casing which surrounds the working parts, the motor is not dust-tight and is not eligible for approval. Figure No. 53 illustrates the test chamber and auxiliary apparatus used in the Underwriters' Laboratories for testing Class II motors.

A further test is now made for the purpose of determining whether the temperature attained by the motor casing, when operating fully loaded and when blanketed with dust is sufficiently high to cause ignition of the dust. This temperature is measured by the thermocouples placed on the casing, and the dust is examined for evidence of charring and ignition. Temperatures produced on burn-out of the windings of the motor are also determined. The ignition temperature of Group G dusts, (grain dusts, etc.), is taken at 500 degrees Fahrenheit.

Practically all of the important motor manufacturers have been successful in obtaining approval of their motors

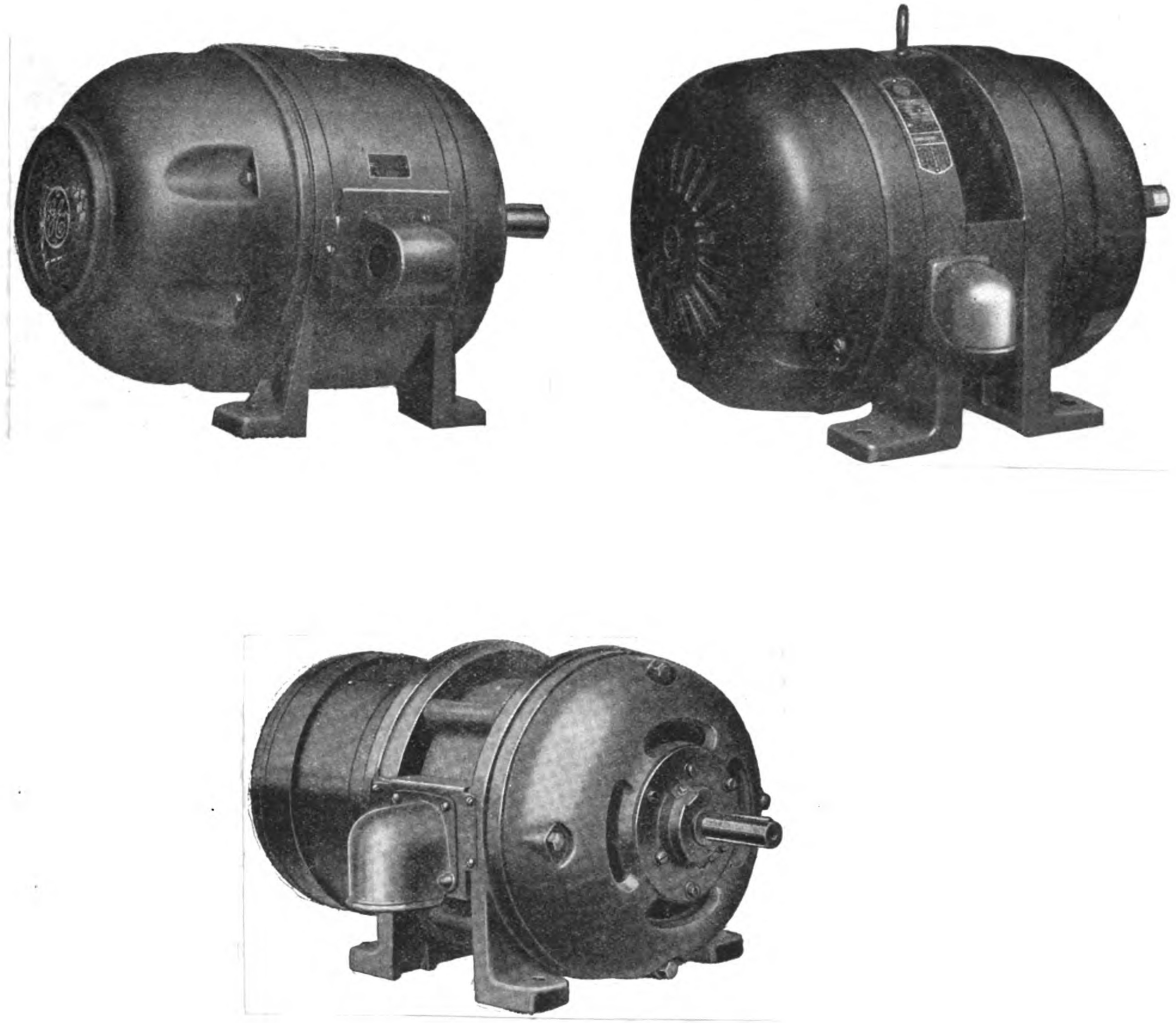


Figure No. 40.
Group of Totally-Enclosed
Fan-Ventilated Motors.

The upper illustrations are of squirrel cage motors while the lower is of a single phase motor.

for Class II, Group G locations. All of those so far approved are of the totally-enclosed-fan-ventilated type, and so far as the writer can learn, none has been submitted for approval for Group E and Group F dusts.

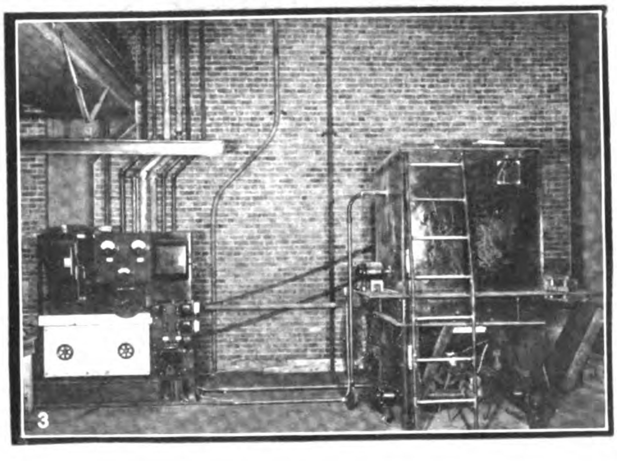
When motors are enclosed in motor rooms which require vent pipes, or when motors are of the totally-enclosed-pipe-ventilated type, it is very important that the vent pipes be properly installed. This is provided for in Rule 3204g which states: "When motors of the enclosed-pipe-ventilated type are used, or when motors are enclosed in rooms or housings, the vent pipes shall extend to the outside of the building to a source of clean air. The vent pipes shall be of metal, substantially constructed and with each section attached to the next by riveting, welding, or other approved methods. When motors are intended to be moved on their bases, a slip or universal joint, tight enough to prevent the entrance of dust shall be provided in the vent pipes. The outer ends of vent pipes shall be suitably screened to prevent the entrance of animals or birds."

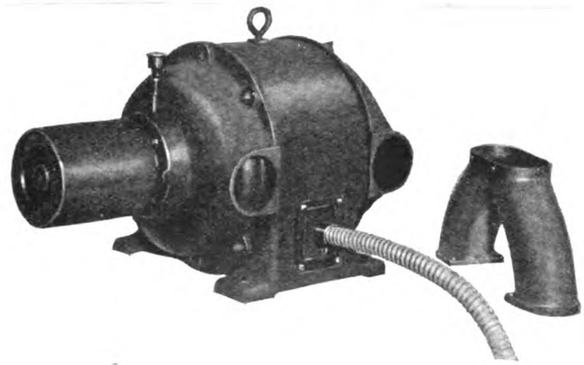
It is not thought that this rule needs much special comment. It should be mentioned, however, that both the inlet and outlet vent pipes are required to be extended to the outside of the building. It is sometimes found that only the inlet vent pipe is so extended, but this is likely to cause accumulations of dust within the motor or room, due to the possible reversal of direction of flow of air when the motor is not in operation. The screening of both pipes at their outer ends is also important lest birds or rodents build nests in the pipes, and so cause obstructions to the flow of air.

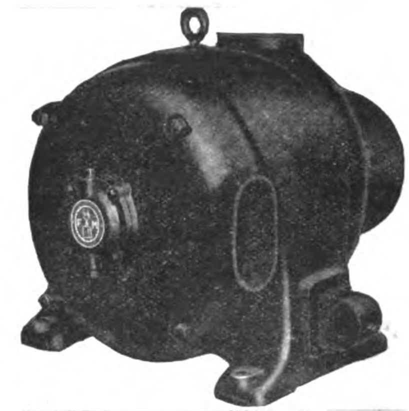
The size of vent pipes and required pressure head should be calculated for each installation in order to prevent overheating of the motor. This is especially true when the motor is enclosed in a comparatively small room and long lengths of vent piping are needed to reach the outside of the building.

A number of typical motor installations in the dusty industries will be found illustrated in Figures No. 42 to 47, inclusive.

Figure No. 53.
Test Chamber and Auxiliary Apparatus Used by Underwriters' Laboratories for testing Class II Motors.







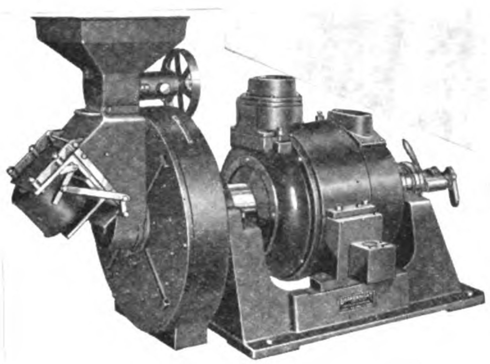
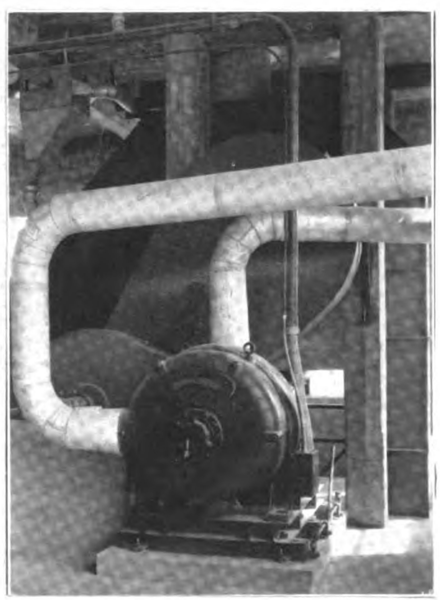


Figure No. 41
Group of Totally-Enclosed-Pipe-Ventilated Motors.

The illustration to the left shows a motor of this type direct-connected to a feed grinder.

Figure No. 42.

The photograph to the right illustrates actual installation of a totally-enclosed-pipe-ventilated motor in a grain elevator.



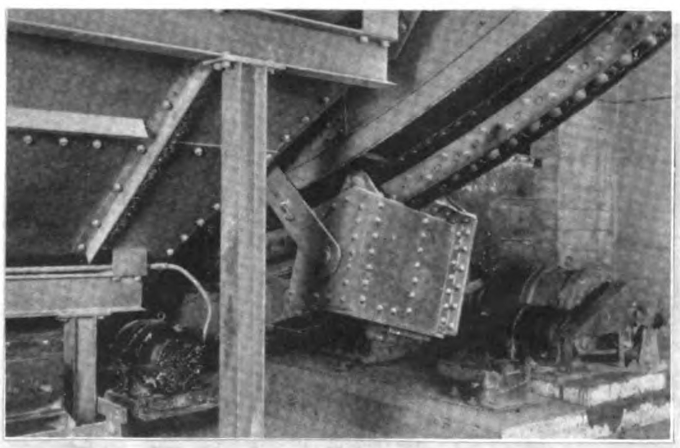


Figure No. 43.
These Photographs Illustrate Application
of Totally-Enclosed-Fan-Ventilated Motors
to Grain Elevators.

The upper photograph is taken in the cupola of a country elevator and shows motor driving elevator leg. The lower illustrates motors driving car dumpers located under the car dumping shed.

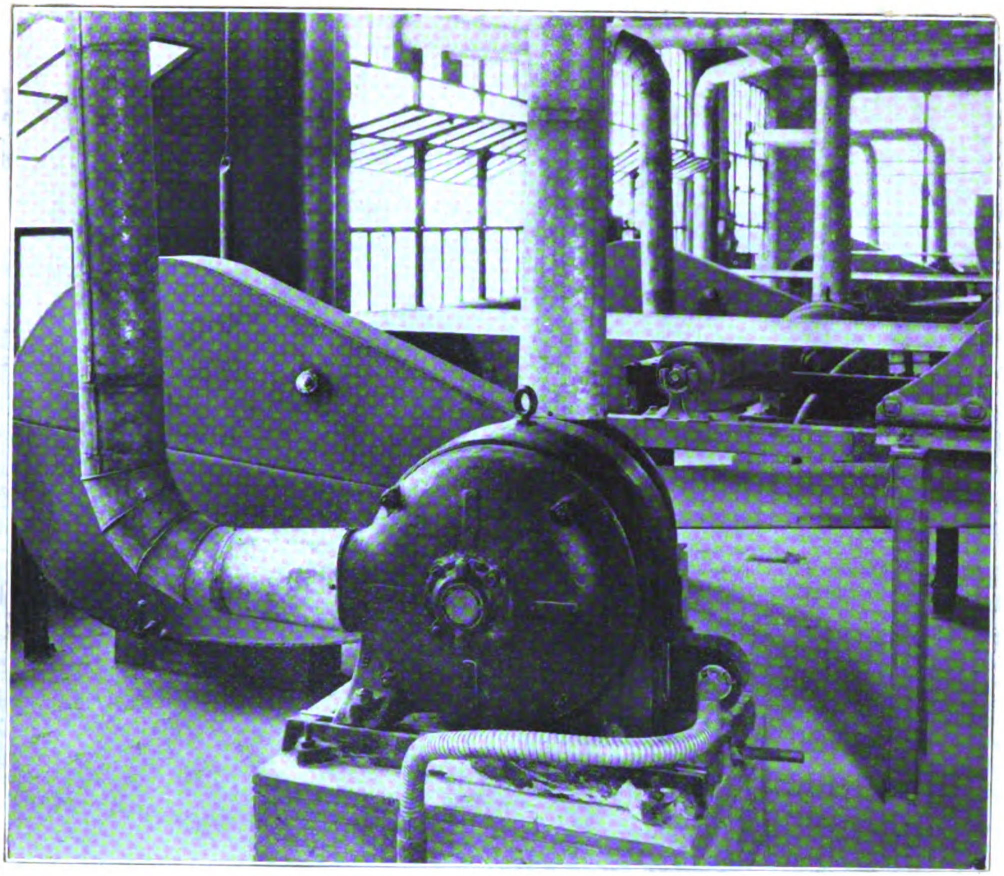


Figure No. 44.
Totally-Enclosed-Pipe-Ventilated
Motors Driving Belt Conveyors in
Bin Floor of Large Terminal Elevator.

Figure No. 45.
Totally-Enclosed-Fan Ventilated
Motor Employed to Drive Receiving
Belt under Car Shed.

Figure No. 46.
Totally-Enclosed-
Fan-Ventilated
Motor Driving
Air Compressor
in a Country
Elevator.

Figure No. 47.
Totally-Enclosed-
Fan-Ventilated
Motor Driving Grain
Separator in First
Floor of a Country
Elevator.

Motor Controllers, Switches, Resistance Devices and Similar Apparatus

Rule 3204h requires that: "Motor controllers, thermal cutouts, switches, relays, the switches and contactors of auto-transformer starters, resistance or impedance devices, or other devices or apparatus which, in their normal operation, tend to create arcs, sparks, or high temperatures, shall not be installed in these locations unless such devices or apparatus are enclosed in dust tight cases or cabinets or are of the dust-tight or dust-tight-oil-immersed type, and so designed that the device may be operated without opening the cabinet or case." A fine print note follows the main rule which states: "It is recommended that motor control devices be of the remote control type, with the main contactors located in separate rooms or compartments, built of non-combustible materials so constructed as to exclude dust. The remote control push buttons or switches of the oil immersed or dust-tight type may then be placed in the most convenient locations."

It will be seen that this rule is practically identical with that which covers the same subject for Class I locations except that it is provided that the enclosures be dust-tight, rather than explosion-resisting. Because of the similarity of principles involved, it is not necessary to include detailed discussion of the provisions of the rule at this point. It should be obvious that the purpose of the rule is, (1) to prevent the occurrence of arcs, sparks or high temperatures in the immediate presence of combustible dust and so cause ignition and probable explosions and, (2) to prevent accumulations of dust on or in the apparatus mentioned or implied by the rule so as to introduce the possibility of ignition of such dust through overheating. These purposes are accomplished by requiring that (1) the apparatus be enclosed in dust-tight cases with certain limitations as to maximum temperatures attained by such cases or (2) that the apparatus be isolated from the immediate hazardous area by installing such apparatus in a non-combustible room.

The second procedure is recommended as being the safest in all instances and should always receive first consideration. The various possibilities of this method have already been discussed under "Service Equipment, Panelboards, and Switchboards" of this section to which reference should be made. It has also been suggested, under "Motors" that it is often feasible to install remote type motor controllers or even those of the manually operated type in the motor rooms, thus isolating all electric power equipment from the hazardous area, excepting the auxiliary control switches which may be located at convenient points throughout the hazardous area to provide means for regular and emergency operation. It will be noted that such auxiliary switches are required to be of the

dust-tight or dust-tight-oil-immersed type.

When it is not practicable or economical to thus isolate controllers and other similar equipment, and it becomes necessary to install all or some of them directly in the hazardous area, the precautions mentioned in the main body of rule 3204i are required to be enforced, that is, such controllers or other devices or apparatus which, in their normal operation, tend to create arcs, sparks, or high temperatures are required to be enclosed in dust-tight cases or cabinet, or to be of the dust-tight or dust-tight-oil-immersed type. An outstanding application of the principle of isolation of control apparatus is shown in figure 48.

A large variety of motor controllers complying with the specification of dust-tightness has been developed and are available. Many of these are of types approved and listed by the Underwriters' Laboratories, which organization has developed standards for the design and test performance of such equipment.

The Underwriters' Laboratories' Standard recognize both air-break and oil immersed control equipment, but both are required to be enclosed in substantial dust-tight enclosures or cases. Joints, if of the metal-to-metal type which, when assembled, are required to have a contact surface at least 3/16 inches in width. Such joints are to be preferred to those which employ gaskets which, while permitted, are sometimes capable of being easily removed. The standard prohibits the use of rubber for gasket material because of its liklihood of becoming cracked and otherwise defective in aging. If gaskets are used, they must be mechanically attached, not glued, to the case body or cover. Shaft openings for operating or reset mechanisms are required to have a length of path not less than 1/2 inch with a maximum clearance of .005 inch. For greater clearances, longer paths are specified.

The standard further prescribes that the exterior observable temperature of the case or enclosure based on a 40 degree Centigrade ambient shall not exceed the safe temperatures for the dust-air mixtures under consideration. For grain dust this temperature is assumed to be 500 degrees Fahrenheit.

The tests made on controllers and such apparatus are almost identical with those used for the testing of motors intended for Class II locations. The controller is placed in the test chamber and exposed to the dust-air atmosphere while operating at full rated load. Temperatures on the exterior of the enclosing case are measured just as with motors. A special additional test is made when oil break controllers are under consideration. This consists of subjecting the device to a series of operation tests under full load, during which samples are withdrawn from above the oil level to determine

Figure No. 48.
A View of the Interior of a Fire Resistive Controller Room in a Large Terminal Elevator.

On the switchboard shown are mounted automatic controllers for several synchronous motors which drive elevator legs. To the right of the photograph are shown the steel cabinets containing branch circuit fuses.

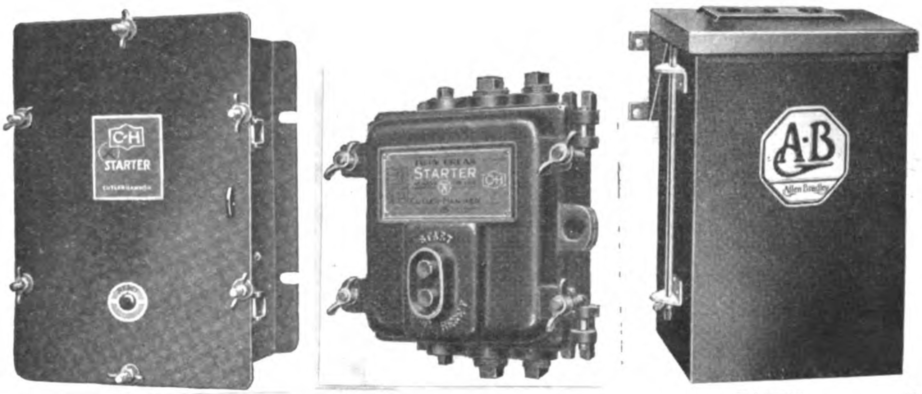


Figure No. 49.
Group of Magnetic Type Motor Controllers Approved for Class II Locations.

whether or not a dangerous amount of hazardous gas or vapor has been produced. Thus, the tests determine whether the device is dust-tight or whether the maximum temperature of the case is sufficiently low to prevent ignition of dust which may have accumulated on it.

Resistance or impedance devices, relays, thermal cutouts and similar apparatus are usually not installed in the hazardous areas unless they are integral parts of a controller. Resistors used in conjunction with the controllers for slip ring wound rotor motors should be located in the motor room or control room, but when such rooms are not provided, such resistors must be enclosed in dust-tight cases. It may be found necessary to ventilate such cases to the outside to prevent excessive temperature rise, especially if the resistors are used for other than intermittent duty.

The accompanying illustrations (Figures 49 to 52 inclusive) show several types of motor controllers suitable for use in Class II locations.

Electric Heating Appliances

It is not contemplated that electric heating appliances will be installed in Class II locations. However, rule 3204i provides for their installation by specifying special approval. The rule states: "Electric heating appliances shall not be used unless of a type approved for installation in dusty atmospheres."

The temperatures reached by electric heaters of any type are usually above the ignition temperatures of any combustible dusts likely to be generally encountered. A possible exception is the electric immersion type radiator heater which employs an enclosed heating unit extended into the header of a radiator filled with water. Such heaters have been used, but not with entire success. No heaters especially approved for dusty locations have yet appeared.

The rule does not imply forced exclusion of "Strip" type or other electric heaters from cut-off dust-free locations, such as the weighmasters' and foremens' offices often found in grain elevators, even though these are in the elevator building proper.

Lamps in Fixed Positions

Rule 3204j provides that: "Lamps in fixed positions shall be enclosed in approved dust-tight globes, and where exposed to mechanical injury, shall be protected by substantial guards. Heavy fixtures used as pendants shall be

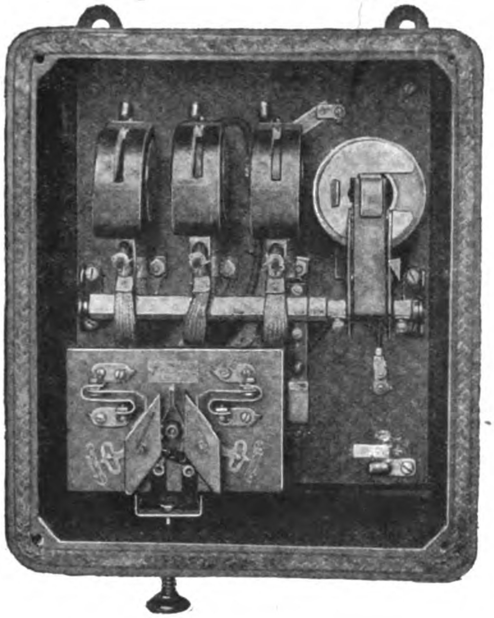


Figure No. 51.
Dust-Tight Auxiliary
Switch for Use in
Connection with Magnetic
Type Controllers.

Figure No. 50.
Magnetic Type Motor Controllers
for Class II Locations Shown
with Cover Removed.

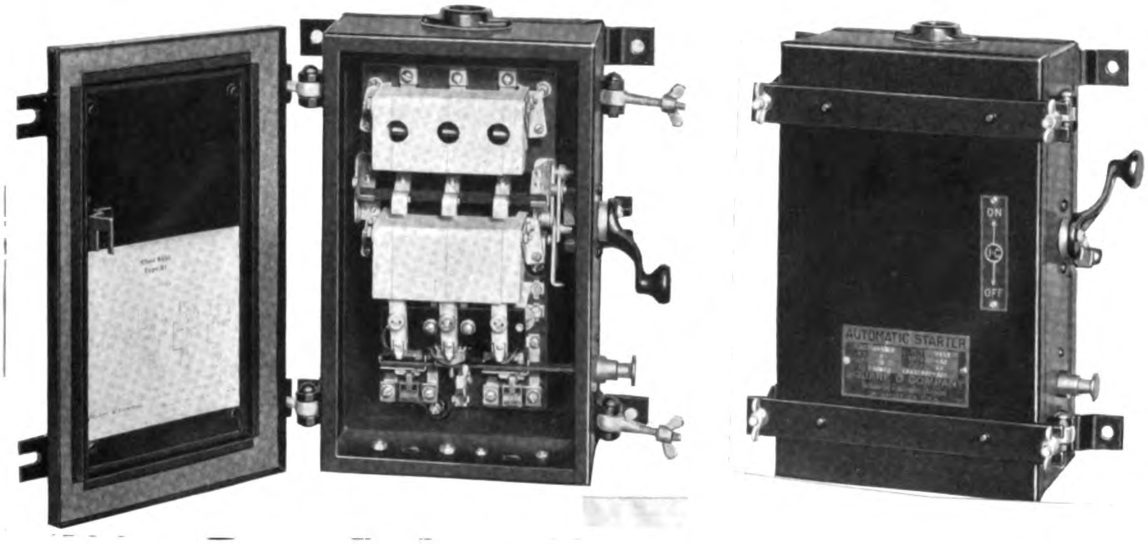


Figure No. 52.
Open and Closed Views of Automatic
Starter Approved for Class II Locations
in Which is Incorporated a Disconnect
Switch.

supported by conduit hangers or chains to prevent strain on the wires. Where rubber covered wire is used, it shall have insulation not less than 3/64 inch thick. Sockets and receptacles shall be of the keyless type, and unless individual switches are provided, shall be located at least 7½ feet above the floor, or shall be otherwise so located or guarded that the lamps cannot readily be backed out by hand." This is followed by a fine print note which states: "When light is required for the interior of bins, hoppers, elevators, conveyors and similar equipment or construction, it is recommended that such light shall, whenever practicable, be supplied by means of lamps, enclosed in dust-tight globes properly protected against mechanical injury, and mounted flush in the walls or floors of the equipment or construction. No wiring or fixtures should be permitted inside of bins, hoppers, elevators or conveyors."

It is important that every precaution be taken to prevent ignition of suspended dust or dust which accumulates on lamps, by providing enclosing globes for lamps in all dusty locations, and in addition, guards, where lamps are so located as to be exposed to mechanical injury.

The use of unguarded lamps in dusty locations has resulted in many fires and explosions, for when such lamps are broken while lighted an intense flash follows accompanied by the emission of incandescent metal.

An equally important matter associated with the hazards of the unenclosed lamp is the fact that when combustible dust accumulates on the bare lamp a heat insulating effect is produced. The heat generated by the lamp is confined by the blanket of dust until the temperature of the dust immediately in contact with the lamp builds up sufficiently to cause charring and finally ignition. This can and does occur even with lamps as small as the 60 watt gas-filled type, the clean surface temperatures of which do not exceed 252 degrees Fahrenheit.

In an investigation made by the writer, it was found that ignition of a small cone of wheat dust on a bare 60 watt inside frosted incandescent lamp occurred in seven minutes, starting at the room temperature of 74 degrees Fahrenheit. The temperature recorded by a thermometer placed on the surface of the lamp under the dust cone was 502 degrees Fahrenheit when ignition was observed. A similar test was made using the same lamp, but enclosed in a standard vapor proof fixture and it was found after continuing the test for 7½ hours that the maximum temperature reached by the surface of the enclosing globe was 324 degrees Fahrenheit. In this test, ignition did not occur and the dust immediately in contact with the globe showed only a very slight discoloration. The tests made involved several other types of lamps,

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Figure No. 54.
Two Types of Guarded Lighting Units Suitable for Installation in Dusty Locations.

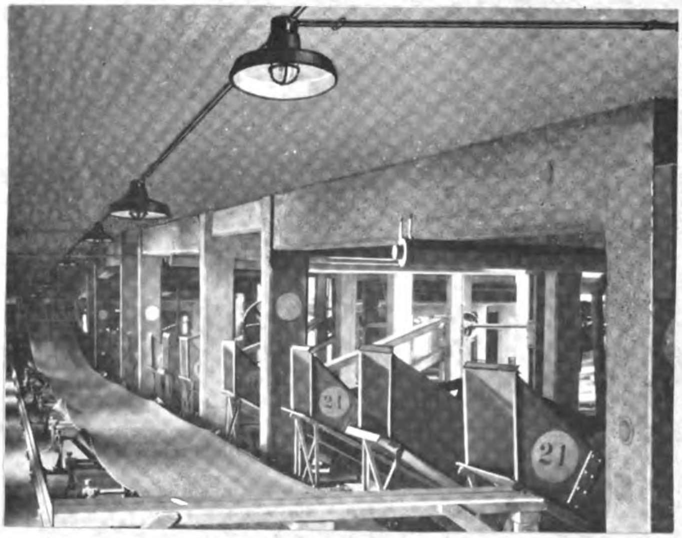

Figure No. 55.
Showing an Approved Lighting Installation in Conveyor Gallery of a Large Terminal Elevator.

including the 100 watt gas filled, 50 watt mill type, and 16 candle power, carbon filament lamps, and the results, while interesting, would be too lengthy to detail here. The data given above should be sufficiently convincing so that the importance of providing enclosing fixtures for lamps in dusty locations can be appreciated. As a matter of fact many fires are caused by the dust accumulated on bare lamps being ignited and falling into additional dust in the vicinity. The "Loss Record" included in this thesis reports several such occurrences.

The Underwriters' Laboratories have drawn standards for the design and test performance of lighting fixtures intended for use in Class II locations. These are comparative to those which have been described for Class I locations except that for Class II fixtures they are required to be dust-tight and the maximum exterior temperature below certain prescribed values, depending on the dust group for which approval is desired. For the grain dust group (Group G) this maximum temperature is 500 degrees Fahrenheit and these maximum temperatures are required not to be exceeded, either when the fixture is clear or blanketed with dust. The tests are made in a manner similar to those used in testing Class II motors with due recognition of the "breathing" effect.

To the knowledge of the writer no fixtures have yet been approved for Class II locations but as a temporary measure, authorities are permitting the use of standard vapor-proof fixtures, several of which are illustrated in Figures 26 and 54. A typical lighting installation in the conveyor gallery of a grain elevator is shown in figure 55.

It will be noted that the rule requires that heavy fixtures be adequately supported by conduit hanger or chains in order that dependence on ordinary pendant cords for such support be eliminated. Key sockets and receptacles are also ruled out, due to the possible ignition of dust by arcs or sparks from the operation of these devices.

The fine print note is intended to recommend means for elimination of the need for using portable lights in bins, hoppers and similar spaces. The method suggested in this note has been used to a considerable extent in starch factories, but has not yet been adopted for grain elevators due to the fact that the bins are usually so deep and the dust so dense that lights placed in the upper part of the bin are ineffective.

Portable Lamps

The importance of designing illumination for Class II locations in such a manner that the need for portable lamps will be eliminated should be strongly emphasized. Portable lamps are distinct hazards no matter how well made or how carefully used.

It seems almost impossible to so build a portable lamp fixture as to render it sufficiently resistant to breakage, especially when accidentally dropped from any appreciable height. Also when an enclosed portable lamp is buried in dust or grain with the lamp burning ignition of the dust or grain will occur if left for a sufficient length of time. In tests

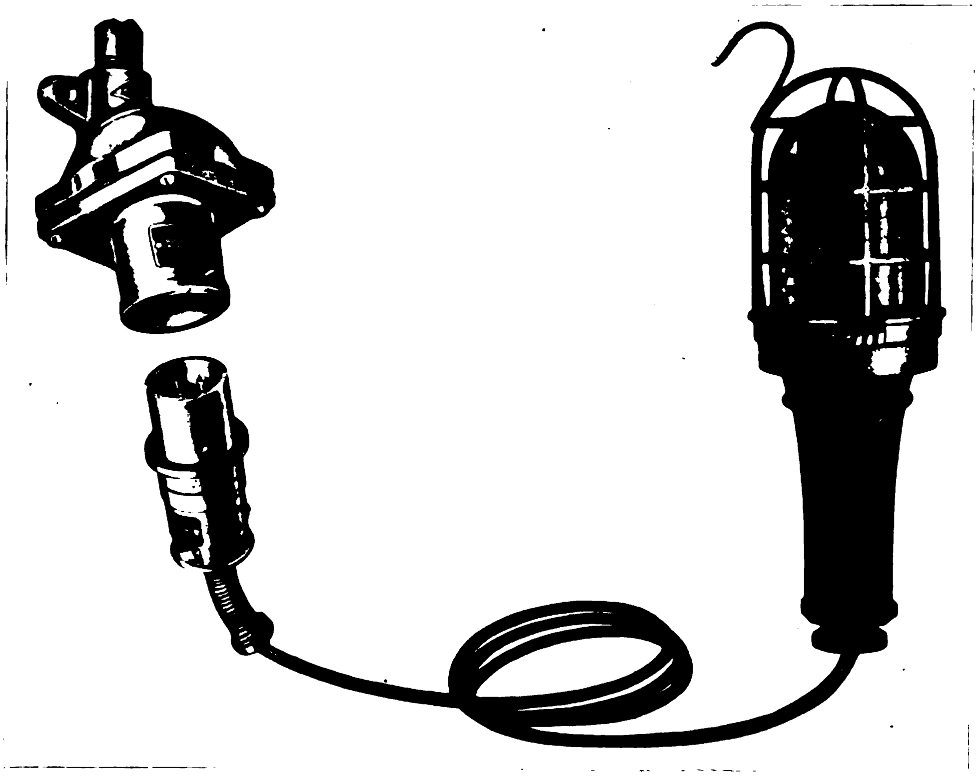

Figure 56
Portable Lamp Assembly and
Plug and Receptacle for
Class II Locations

made by the writer, it was found that a 60 watt gas filled incandescent lamp enclosed in a unit such as illustrated in figure 56 and buried in a box of wheat dust, that ignition of the dust was obtained after 2½ hours operation at a temperature of 506 degrees Fahrenheit. It is granted that the enclosed unit is safer from this point of view than a base lamp, for in a similar test with a bare 60 watt gas filled lamp buried in dust, ignition occurred in eleven minutes. But the hazard is present whether the lamp is used bare or enclosed, due to the possibility of the lamp being buried and forgotten.

Appreciating that portable lamps will be used even though authorities go to the extent of drawing rules prohibiting their use, the rule providing for their design is more or less a concession.

Rule 3204k treats the subject of portable lamps as follows: "Sufficient general illumination shall be provided by fixed lighting units to eliminate so far as possible the need for portable lamps. When portable lamps are necessary they shall be enclosed in dust-tight globes properly protected by substantial metal or other approved types of guards to prevent breakage. Sockets for portable lamps shall be of the moulded composition or metal jacketed porcelain, keyless type."

The standards of the Underwriters' Laboratories for Class II lighting fixtures also apply to portable lamps. However, none have yet been listed by the laboratories for especial use in Class II locations. There are available several types of portable lamp assemblies classed as vapor proof, which are probably also, at least in most instances, sufficiently dust-tight to be permitted. A representative type is found illustrated in figure number 56. This particular unit has a live rubber handle, a dust tight globe, and an aluminum guard and designed so as to not subject the connections of the cord to the socket to strain.

Portable Cords

Rule 3204l states: "When necessary to use portable lamps, or other portable current consuming devices, approved flexible cord designed for hard usage such as Type S or Type PA shall be used. Such a flexible cord shall contain one extra insulated conductor which shall be properly connected to form a grounding connection for metal lamp guards, motor frames, and all other exposed metal portions of such portable lamps and devices." It will be noted that the wording of this rule is identical with the parallel rule for Class I locations (Rule 3203m) and, therefore, the same comment will apply. As in Class I locations, substandard or defective portable cords have caused many fires in mills, elevators, and similar establishments included under Class II locations. The importance of selection of the proper types is to be emphasized.

Connection of Portable Cords

The methods used to connect portable cords to supply conductors through separable connections are of importance. It would be extremely undesirable to employ a plug and receptacle of such a design as to permit the occurrence of

an arc or spark in the immediate presence of an explosive dust-air mixture. Rule 3204m provides adequate precautions against this possibility as follows: "Receptacles and attachment plugs, if used, shall be so connected, as a part of a unit device with a dust-tight interlocking switch that the plug cannot be removed while the switch is in the "on" position or approved devices which seal the arc, made when current is interrupted, by means of an explosion-proof or vapor-proof enclosure shall be used. Such receptacles and plugs shall be of the polarized type providing a connection for the grounding wire of the portable cord. "It will be noted that the rule, although written to provide precautions for a dusty atmosphere specifies that the arc or sparks be confined within an explosion-proof or vapor-proof enclosure. A better wording would be had were the requirement worded so as to specify dust-tight enclosures and undoubtedly this change will be made in the next edition of the Code.

Except for the fact that our considerations in this rule are based on prevention of exposed arcs or sparks in a dusty atmosphere rather than a gas or vapor-air atmosphere, discussion of this rule would be identical with that of the parallel rule, (Rule 3203o) which appears under the rules for Class I locations. For this reason the discussion is not repeated here.

In figure 56 will be found an illustration of a suitable type of receptacle and attachment plug for class II locations. Others of this type are also available, as well as those included as a unit device employing an interlocked switch.

The manner of connecting portable cords direct to supply conductors is treated in rule 3204n as follows: "Connections of portable cords direct to supply conductors shall first be made mechanically secure and shall then be soldered and heavily taped. In addition, the cord shall be securely supported so that the probability of a break in the conductors at this point will be minimized."

Such a manner of connecting portable cords is not used to any great extent in Class II locations, the separable type of connection being used almost entirely. The rule is identical with rule 3203n as applied on the same subject to Class I locations, and the comments to be made are the same.

Grounding

The rule treating this subject (Rule 3204o) states: "The exposed non-current carrying metal parts of equipment, such as the frames or metal exteriors of motors, fixed or portable appliances, lighting fixtures, cabinets, cases,

and conduit, shall be grounded as provided in Article 9 of this Code. The locknut bushing and double-locknut type of contact shall not be depended upon for bonding purposes, bonding jumpers with proper fittings or other approved means being required to assure an effective grounding circuit."

It will be seen that this rule is identical with Rule 3204p covering the same subject under the rules for Class 1 locations. On the whole, the same comment as previously given applies at this point and so will not be repeated. It should be pointed out, however, that whenever pull boxes, junction boxes, and similar enclosures are used which are not definitely required to have threaded type conduit connections, they should be bonded, either by use of the grounding bushings illustrated in figure 34 or by suitable clamps and bonding jumpers connected to the conduit runs and boxes on the exterior. It is recommended that this system of bonding be extended to electrical wiring throughout the premises. It is also recommended that a copper bonding jumper be provided to shunt the flexible steel conduit at motor terminals which such flexible connections are used.

Live Parts

It would be undesirable to permit any exposed live parts and, therefore, rule 3204p was inserted to care for the matter. This rule states: "There shall be no exposed live parts." As a matter of fact, however, compliance with the remaining rules for Class II locations automatically results in no live parts being exposed to contact.

CLASS III LOCATIONS

It is not the intention to discuss the rules for Class III locations in detail because of their similarity to the rules for Class II locations which have been discussed in considerable detail. It may be desirable, however, to point out the distinction between the two classes. In Class II locations, it will be recalled, we were concerned with the probability of sparks or arcs from electrical equipment igniting an explosive mixture of dust and air, as well as the probability of sufficient dust accumulating on or in such equipment as to prevent proper radiation of heat and so cause ignition either directly or indirectly through burnout of a motor resulting from dust accumulations. In Class III locations explosive mixtures are not present in the atmosphere, but there is likely to be present a quantity of easily ignitable lint or other light material on machines and building surfaces which, if ignited, would result in the rapid spread of flames through the area where the material is present. In some instances, especially in the delinting rooms of cotton seed oil mills, the picker rooms of cotton mills and in some woodworking plants, the problem represented by objectionable accumulations of lint, sawdust and such materials in or on electrical apparatus, especially in the windings of open type motors, becomes a serious consideration.

Therefore, in the rules for Class III locations it will be found that provisions are made to (1) prevent ignition of lint and similar substances by arcs, sparks or high temperatures, and (2) prevent accumulation of such substances on or in electrical wiring and apparatus in sufficient quantities to be hazardous from the standpoint of preventing the proper radiation of heat.

From the discussion which has previously appeared under "Classification" with particular reference to Class III locations, it will be understood that the rules must be applied with judgment owing to the wide range of conditions which are likely to be encountered. Some guidance is also given in the section "Classification as to Industries and Processes", especially those parts entitled "The Cotton Industry" and "Woodworkers".

In the following the rules for Class III locations will be stated, but discussion will be confined to only those rules about the application of which questions may arise.

The first rule of the section (Rule 3205a) states that: "In locations judged to be as described for Class III locations in paragraph d of section 3201 the following provisions shall apply:" This rule is for the purpose of referring the user to the definitions of various classes.

Service Equipment, Panelboards and Switchboards

Rule 3205b: "Service entrance equipment and all switchboards and panelboards shall not be placed in locations of this class, but if impracticable to locate them elsewhere, all live parts shall be enclosed in dust-tight metal cases or cabinets with provision for external operation only, or shall be located in separate dust-tight rooms built of or lined with substantial non-combustible materials and with self-closing doors, so constructed and installed as to adequately exclude flyings or lint."

This requirement is identical with that prescribed for Class II locations and needs little comment. In most instances it is possible to place such equipment outside of the hazardous area, but where this cannot be done, the other provisions of the rule are invoked. Reference should be made to page 144 of this thesis where the details of the rule are explained. It will be noted that the term "dust-tight" is used, although the material involved in Class III locations is usually of a linty nature. It was felt that owing to the uncertain degree of fineness of the lint or light material, that dust-tightness should be specified. In other words, where such equipment is required to be installed within the hazardous area, that apparatus approved for Class II locations may be used.

Fuses and Circuit Breakers

Rule 3205c: "All fuses shall be enclosed in dust tight metal cases or cabinets. Circuit breakers shall be of the dust-tight oil-immersed type, or shall be enclosed in dust-tight metal cases." Comment appearing under the same subject in discussion of the rules of Class II applies.

Type of Wiring

Rule 3205d: "Rigid conduit shall be the wiring method employed. Where it is necessary to employ flexible connections, as at motor terminals, a short length of flexible conduit may be used."

Here again it was felt necessary to prescribe the safest available type of wiring inasmuch as we are dealing with locations where every precaution should be taken to prevent ignition. With regard to fittings, boxes, and similar enclosures not containing normally sparking or arcing parts, the discussion under the subject for Class II locations applies.

Motors and Generators

Rule 3205e: "Where it is impracticable to prevent lint and flyings from collecting in dangerous quantities on or in motors, as in cotton gins or the seed cleaning and linter rooms of cotton seed oil mills, all motors shall be of the totally-enclosed, totally-enclosed-fan-cooled or totally-enclosed-pipe-ventilated types, or shall be enclosed in separate dust-tight rooms or housings built of or lined with substantial, non-combustible materials so constructed as to adequately exclude lint or flyings and be properly ventilated from a source of clean air. Elsewhere, if motors or generators having brushing or sliding contacts are used, they shall:

"1. Be of the totally-enclosed, totally-enclosed fan-cooled, or enclosed-pipe-ventilated types, or

"2. Be enclosed in separate rooms or housings as specified above, or

"3. Have brushes or sliding contacts enclosed in substantial tight metal housings, or

"4. Have upper half of brush or sliding contact end of motor enclosed by a wire screen or perforated metal cover and lower half enclosed by solid metal covers. No dimension of any opening in the wire screen or perforated metal cover shall exceed .05 inch, regardless of the shape of the opening and of the material used."

It will be noted that this rule provides not only for the prevention of ignition of lint or other light materials by arcs or sparks from the brushes or sliding contacts of motors and generators, but also for the prevention of accumulations of lint or "flyings" in the windings of open motors of any type whether having brushes or other sliding contacts or not.

In addition to motors in cotton gins, and the seed cleaning and linter rooms of cotton seed oil mills, it is often found that the motors in some woodworking establishments become fouled with excessive sawdust, turnings and similar light material. In such cases it is decidedly advantageous to adopt one of the enclosed types of motors, not only from the standpoint of fire prevention, but also as a money saving measure.

In figure 57 there appears a photograph which illustrates an attempt at motor protection. It will be noted from

the photograph that no provision has been made for ventilation of the motor and unless the motor is much larger than actually needed, or is operated only intermittently, it is certain that overheating and ultimate breakdown of the windings will result. A much safer procedure would have been to have adopted the enclosed-fan-ventilated motor for this duty and location.

Where the amount of lint or light material present is not sufficient to cause it to collect in dangerous quantities in motors, but prevention of ignition is still important, there are four methods suggested in the rule to provide the necessary safeguards. Of these, the last(numbered 4)is the least desirable owing to the liklihood of the screens which are mentioned becoming clogged with lint or dust and impairing the flow of cooling air through the motor.

Undoubtedly, the best method is that of providing motors of the totally-enclosed or totally-enclosed-fan-cooled type.

The dangers associated with the operation of open motors in places where considerable lint is present has been recognized for some time, as evidenced by the development of the textile motor some years ago and, the recommendations of the Associated Factory Mutual Insurance Companies advocating the protection of motors against lint accumulations.

Reference should be made to the discussion of the rules for Class II locations with reference to "Motors and Generators" beginning on page 147 of this thesis, much of which also applies to Class II locations.

The use of Class II motors for those parts of Class III locations where excessive lint may be present is permitted and recommended.

Rule 3205f: "When motors of the enclosed pipe-ventilating type are used, or when motors are enclosed in rooms or housings, the vent pipes shall extend to the outside of the building to a source of clean air. The vent pipes shall be of metal, substantially constructed and with each attached to the next by riveting, welding, or other approved methods. When motors are intended to be moved on their bases, a slip or universal joint tight enough to prevent the entrance of dust shall be provided in the vent pipes. The outer ends of vent pipes shall be suitably screened to prevent the entrance of animals or birds."

This rule is identical with that which appears on the same subject under the discussion of Class II rules and needs no additional comment.

Motor Controllers, Switches, Relays and Thermal Cutouts.

Rule 3205g: "Motor controllers, thermal cutouts, switches, relays, the switches and contactors of autotransformer starters, or other devices or apparatus which in their normal operation tend to create arcs or sparks shall not be installed unless such devices or apparatus are enclosed in dust-tight metal cases or cabinets, or are of the dust-tight-oil-immersed type, and are so designed that they may be operated without opening the cabinet or case."

In the matter of motor controllers the plan of selecting controllers of the automatic remote control type immediately suggests itself and it is probable that this plan can be made use of very generally. When this plan is followed, it is then necessary to place only the auxiliary push button or switches in the hazardous area. The method of locating the controllers and such equipment in specially built controller rooms is also recommended so that lint and light material will not collect in or about such equipment.

For extreme cases when it is necessary to place controllers and such equipment directly in a location where considerable lint or light material is present, the apparatus shall be of the dust-tight design. Apparatus approved for Class II locations will be permitted and is recommended.

Rheostats and Resistance Devices

Rule 3205h: "Rheostats, resistance boxes, or other resistance devices, shall be enclosed in non-combustible cases, so constructed as to adequately exclude flyings or lint."

It would be decidedly unsafe to permit open resistors or other resistance devices in places where lint or other light combustible material is present. Hence, this rule which prescribes the necessary enclosing of resistors in non-combustible cases or enclosures. It is not required that this case be dust-tight, it will be noted, but it should be sufficiently tight to prevent the material from entering. In many instances a switch enclosure can be built of compressed asbestos lumber or similar non-combustible material.

When such resistors are employed in conjunction with motor controllers and a control room is provided, or the controllers are isolated from the hazardous area, the resistors should be mounted in the control room or near the isolated controllers.

Electric Heating Appliances

Rule 3205i: "Electric heating appliances shall not be used unless of a type approved for installation in locations where combustible flyings or lint are present."

This rule is identical with the parallel rule appearing in the discussion of the rules for Class II locations except that it is specified that the appliances be approved for locations where combustible flyings or lint are present.

Heating appliances with exposed heating units are necessarily not to be permitted in the hazardous areas.

Lamps in Fixed Positions

Rule 3205j: "Where there is a possibility of flyings or lint collecting about lamps in fixed positions, such lamps shall be enclosed in globes of the dust-tight type, and when exposed to mechanical injury, shall be protected by substantial metal or other approved types of guards to prevent breakage. Heavy fixtures, used as pendants, shall be supported by conduit hangers or chains to prevent strain on the wires. Where rubber covered wire is used, it shall have insulation not less than 3/64 inch thick. Sockets and receptacles shall be of the keyless type and, unless individual switches are provided, shall be located at least 7½ feet above the floor, or shall be otherwise so located or guarded that the lamps cannot readily be backed out by hand."

Where a considerable amount of lint or finely divided light material is present in the atmosphere of picker rooms, delinting rooms, and in some locations in woodworkers it may be possible that a blanketing effect of the same nature as discussed under Class II locations will occur to cause ignition of the lint or light material. Such instances are rather infrequent and the portion of the rule requiring the use of enclosing globes need not be applied except in extreme cases. It is important, however, that lamps be guarded, as provided by the rule, when they are exposed to injury, for the breakage of a lamp may cause immediate ignition of lint.

Portable Lamps

Rule 3205k: "Sufficient general illumination shall be provided by fixed lighting units to eliminate, so far as possible, the need for portable lamps. When portable lamps are necessary, they shall be enclosed in dust-tight globes properly protected by substantial metal or other approved types of guards to prevent breakage. Sockets for portable lamps shall be of the keyless moulded composition type with no exposed metal parts."

While portable lamps in Class III locations may not create as severe a hazard as when such lamps are used in gas, vapor or dust and air atmospheres, it is still important that they be of the proper type. Breakage of a portable lamp in the presence of lint would be likely to cause a flash fire, so it is necessary that the lamp be equipped with an enclosing globe and a substantial guard.

It will be noted that the rule is identical with that appearing in the rules for Class II locations. The portable lamp units suggested in the latter are suitable for use in Class III locations.

Portable Cords

Rule 32051: "When necessary to use portable lamps, or other portable current-consuming devices, approved flexible cord designed for hard usage such as Type S or Type PA shall be used. Such a flexible cord shall contain one extra conductor, which shall be properly connected to form a grounding connection for metal lamp guards, motor frames, and all exposed metal portions of such portable lamps and devices."

This rule is identical with that on the same subject in the rules for Class II locations and the same comments apply.

Connections of Portable Cords

Rule 3205m: "Connections of portable cords direct to supply conductors shall first be made mechanically secure and shall then be soldered and heavily taped. In addition, the cord shall be securely supported so that the probability of a break in the conductors at this point will be minimized."

This is the only rule which appears in this section providing for the connection of portable cords to supply conductors and is identical with that appearing in the discussion of the rules for Class II locations. The same comment as previously made applies.

Owing to the absence of any other rules on the subject of connection of portable cords to supply conductors in this section, permission is automatically given to employ any approved separable attachment plug and receptacle. It is recognized that the use of an exposed device for this purpose would introduce considerable hazard if opened under load in the presence of quantities of lint. For this reason Article 32 Committee has now under consideration a new rule to care for this matter. It is probable that the requirements will be somewhat similar to those for Class II locations on this point.

Grounding

Rule 3205n: "The exposed non-current carrying metal parts of equipment such as the frames or metal exteriors of motors, fixed or portable appliances, lighting fixtures, cabinets, cases, and conduit shall be grounded as provided in Article 9 of this code. The locknut-bushing and double-locknut type of contact shall not be depended upon for bonding purposes, bonding jumpers with proper fittings or other approved means being required to assure an effective grounding circuit."

This is identical with the rule on Grounding which appears in the discussion of the rules for Class II locations. No additional comment is needed.

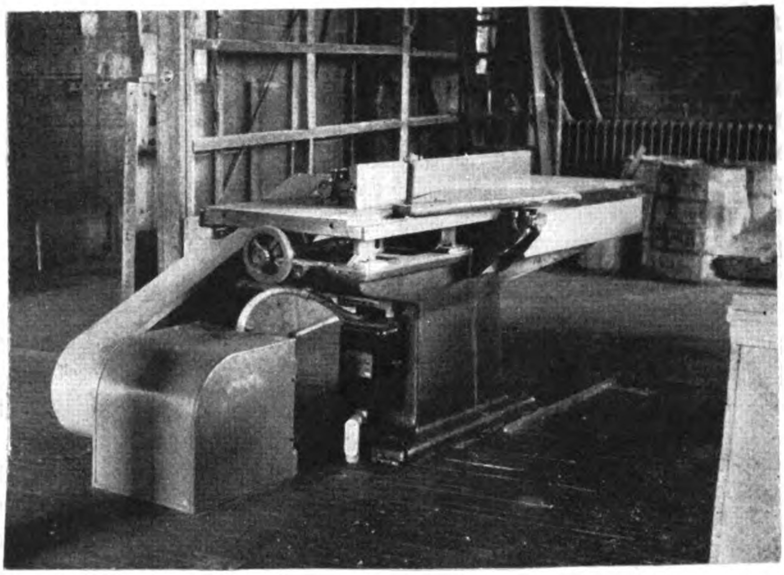

Figure 57
Illustrating Attempt to Protect an Open Motor in a Woodworking Establishment by Use of Sheet Metal Housings. Such Methods May Result in Overheating and Burning Out of the Motor.

CLASS IV LOCATIONS

As has been previously discussed under "Classification", the hazards in Class IV locations are similar to those of Class III locations in that both are involved with easily ignitable combustible fibers. However, where Class III locations are concerned with manufacturing plants where combustible fibers or lint are produced or used, Class IV locations are concerned only with warehouses and storage facilities for these combustible fibers. In most respects the rules for Class IV locations are more rigid than those for Class III, for the reason that the warehouses involved are of large area and the property values usually very high. Consequently, a fire once started spreads with great rapidity due to the easily ignitable nature of the fibers.

The rules for Class IV locations are designed to prevent, so far as possible, ignition of the fibers from arcs, sparks or high temperatures resulting either during normal operation or when faults occur. The hazard represented by accumulations of excessive quantities of lint on or in apparatus, such as motors, is not usually present, except possibly in warehouses where compresses are used. However, it will be seen that rules prescribe enclosed motors, protection of resistance devices, dust-tight enclosures for or isolation of motor controllers, proper placement and enclosing of lighting fixtures and certain requirements with regard to cranes and battery charging equipment. All of these requirements are made for the purpose of safeguarding all possible sources of ignition.

Due to the similarity of the rules for Class IV locations to those of the other Classes previously discussed, detailed comment on many of them is not needed.

Rule 3206a: "In locations judged to be as described for Class IV locations in paragraph e of Section 3201, the following provisions are to be observed:"

This is an introductory rule which refers back to the section containing the definitions of the various classes.

<u>Service Equipment, Switchboards and Panelboards</u>

Rule 3206b: "Service entrance equipment and all switchboards and panelboards shall not be placed in locations of this class, but, if impracticable to locate them elsewhere, all live parts shall be enclosed in dust-tight metal cases or cabinets with provision for external operation only, or shall be located in separate dust-tight rooms built of or lined with substantial non-combustible materials and with self-closing doors, so constructed and installed as to adequately exclude flyings or lint."

This rule is identical with that which appears in the rules for Class II and Class III locations. In the modern large terminal warehouses the service equipment and switchboards are usually placed in a switch house especially provided for the purpose. In the older warehouses a separate room built as specified by the rule may be conveniently provided, either outside of or within the warehouse. Reference should be made to the discussion on the same subject in the treatment of the rules for Class II locations.

When it is impracticable to isolate this equipment as provided for by the rule, it is, of course, necessary to permit its installation in the hazardous area, but only if the equipment is enclosed in dust-tight metal cases or cabinets.

Fuses and Circuit Breakers

Rule 3206c: "Fuses and circuit breakers shall preferably not be installed in storage rooms, but if impracticable to locate them elsewhere, all live parts shall be enclosed in dust-tight metal cases or cabinets or shall be located in separate dust-tight rooms built in accordance with the provisions of paragraph b of this section."

The same comment as made on service equipment applies to fuses and circuit breakers. In most cases it is practicable to isolate or enclose them in non-combustible rooms, but when conditions are such that this cannot be done, they may be located within the warehouse on condition that they are enclosed within dust-tight cases or cabinets.

Type of Wiring

Rule 3206d: "Rigid Conduit shall be the wiring method employed. Where it is necessary to employ flexible connections, as at motor terminals, a short length of flexible steel conduit may be used."

> "It is recommended that pilot lights be installed on the outside of storage rooms to indicate when the current in the rooms is "on" or "off."

Note that rigid conduit is specified as in the other classes of this article and for the same reason.

The recommendation for the installation of pilot lights outside of storage rooms applies to the more modern terminal cotton warehouses which are often found divided into a number of separate compartments, each cut off from the next by fire walls and cutoff from the working alley on aisle by fire

walls with openings protected by fire doors. Under these conditions, greater safety is obtained when all light or power circuits supplying each compartment or room are disconnected. Hence, the need of pilot lights for warning attendants.

Motors and Generators

Rule 3206e: "Motors and generators shall be of the totally-enclosed, totally enclosed-fan-cooled, or enclosed pipe ventilated types, or shall be enclosed in separate dust-tight rooms or housings built of or lined with substantial non-combustible materials and so constructed as to adequately exclude flyings or lint and properly ventilated from a source of clean air."

The requirements in this rule are identical with those in rule 3204f for Class II locations and the discussion included under this rule applies here. However, the reason for such a rule applying to fiber warehouses is not because of accumulations of lint in the motor, but to protect against ignition of fibers in event of burnout of a motor. It is felt that the expense attached to the use of enclosed motors, or the enclosing of open motors in non-combustible rooms is warranted, due to the high property values which are affected by possible fires.

Rule 3206f "When motors of the enclosed-pipe-ventilating type are used, or when motors are enclosed in rooms or housings, the vent pipes shall extend to the outside of the building to a source of clean air. The vent pipes shall be of metal, substantially constructed and with each section attached to the next by riveting, welding, or other approved methods. When motors are intended to be moved on their bases, a slip or universal joint tight enough to prevent the entrance of dust shall be provided in the vent pipes. The outer ends of vent pipes shall be suitably screened to prevent the entrance of animals or birds."

No comment is needed on this rule. Reference should be made to the discussion of the parallel rule appearing under Class II locations.

Resistance Devices

Rule 3206g: "Resistance devices, unless installed in rooms such as described in paragraph b of this section shall be enclosed in especially approved metal cases of dust-tight design. These shall be so constructed that ignition of lint or flyings by direct contact with the enclosing case, whether in normal operation or in case of accident, is avoided."

It has been found that great care must be taken to guard resistance devices to prevent ignition of baled fiber or loose lint by direct contact with resistance devices or their ordinary enclosing cases. As usually interpreted in the field, it is required that the ordinary enclosed resistance device be enclosed in a somewhat larger outer case in order to permit dissipation of heat generated during normal operation or in case of burnout, without resulting in unduly excessive surface temperatures on the outer enclosing case.

Obviously, the safest procedure is to install such resistance devices in a room such as described in Rule 3206b.

Motor Controllers, Switches, Relays and Thermal Cutouts

Rule 3206h: "Motor controllers, thermal cut-outs, switches, relays, switches and contactors of auto-transformer starters, impedance devices, or other devices or apparatus used in connection with the control of power or other circuits shall not be installed in these locations unless such devices or apparatus are enclosed in dust-tight cases or cabinets, and so designed that the device may be operated without opening the cabinet or case.

> "It is recommended that motor control devices be of the remote control type with the main contactors located in separate rooms or compartments built of or lined with substantial non-combustible materials so constructed as to exclude flyings or lint. The remote control push buttons or switches of the oil-immersed or dust-tight type may then be placed in the most convenient locations."

The provisions of this rule are similar to those for Class II locations on the same subject. In general, controllers and similar devices are required to be of the type approved for Class II locations unless located in rooms of the type mentioned in the note following the main rule.

Electric Heating Appliances

Rule 3206i: "Electric heating appliances shall not be used unless of type approved for installation in locations where combustible flyings or lint are present."

It is obvious that electric heating appliances should not be permitted in combustible fiber warehouses where they may cause ignition of baled cotton or other fibers, or lint.

It is probable that the usual radiant or strip type heaters will be permitted in offices, shops or similar locations in which lint is not present.

Lamps In Fixed Positions

Rule 3206j: "Sufficient general illumination shall be provided by fixed lighting units to eliminate so far as possible, the need for portable lamps. Lamps shall not be installed where they are likely to be injured when bales are being tiered or handled. Lighting fixtures shall be wired with not less than No. 14 wire, and the fixture wiring shall be enclosed in rigid conduit or the equivalent in thickness. Lamps may be in receptacles attached directly to the outlet box covers. Lamps and their sockets shall be so enclosed that in the event of a burn-out of the lamp or socket no spark or hot metal can escape from the enclosure."

It should be noted that very rigid precautions are taken to prevent the ignition of baled fiber or "flyings" by the breakage of lamps or faults in their fixtures or wiring. Breakage of lamps by careless handling of baled cotton or other fibers has been a common cause of fire. The wording of the rule is such that both its intent and application are clear.

Portable Lamp

Rule 3206k: "When portable lamps are necessary they shall be enclosed in dust-tight globes properly protected by substantial metal or other approved types of guards to prevent breakage. Sockets for portable lamps shall be of the moulded composition or metal-jacketed porcelain, keyless type."

As in the other types of hazardous locations, portable lamps in fiber warehouses are regarded as a severe hazard. Hence, the provisions of the rule specifying the types described for Class I and Class II locations. Here again should be emphasized the need for so designing general illumination by fixed units that portable lamps will not be necessary.

Portable Cords

Rule 3206l: "When necessary to use portable lamps, or other portable current consuming devices, approved flexible cord designed for hard usage such as type S or type PA shall be used. Such a flexible cord shall contain one extra

insulated conductor which shall be properly connected to form a grounding connection for metal lamp guards, motor frames, and all other exposed metal portions of such portable lamps and devices."

Here again, the safest available types of cord are specified. The provision for an extra conductor for grounding purposes is made as in the rules for the other classes of Article 32.

It will be noted that no requirements are made as to the method to be used in connecting portable cords to supply conductors. This omission has been criticized and undoubtedly a rule will be added to care for this point. It is probable that a rule similar to that for Class II locations 3204m will be adopted.

Electric Cranes

Rule 3206m: "Electric cranes operating over combustible fibers shall not be operated on a system with a grounded conductor. Feeders for electric cranes shall be provided with a recording ground detector, and protected by a relay which will automatically open the feeder circuit breaker in the event of the insulation of the system falling below 1000 ohms. Bare conductors for cranes operating in rooms used for the storage of combustible fibers shall be protected by suitable barriers so arranged as to prevent any escape of sparks or hot particles, and the moving current collectors shall be so designed as to minimize sparking at sliding contacts.

> "It is recommended that where the distance of travel permits, current to the crane be supplied through Type S or PA portable conductors equipped with approved type of reel or take-up device."

In the more modern terminal fiber warehouses, electric cranes are coming into use for handling baled fibers. As usually employed, the crane travels on rails over the loading dock or platform and can be shunted into the various compartments on shunt rails in order to remove bales from the compartment or deliver them. The crane motors are supplied from bare conductors from which current is obtained through "shoes" sliding on the conductors. Necessarily every precaution is required to be taken to prevent sparks or arcs produced by imperfect contact on the bare supply conductor igniting accumulated lint or heated particles falling to the cotton below and causing ignition.

The writer had occasion to inspect a terminal cotton warehouse in which a crane installation made in accordance

with the rule under discussion was in operation and, from all he could learn, it has given entire satisfaction. It will be noted that the system supplying current to the crane is required to be of the ungrounded type. Compliance with this requirement, together with that providing for the use of an automatic recording ground detector, enables the operator to detect any accidental grounds which may occur.

For small crane installations, the type of crane motor current supply mentioned in the recommendation can be employed to good advantage.

Storage Battery Charging Equipment

Rule 3206n: "Storage battery charging equipment shall be ofapproved type located in separate rooms built of or lined with substantial non-combustible materials so constructed as to adequately exclude flyings or lint, and shall be well ventilated. Electric trucks shall be charged only in such rooms."

Inasmuch as the operation of storage battery charging equipment involves the frequent production of arcs or sparks, the requirement for its installation in a separate non-combustible room is warranted. Necessarily also, the charging of electric trucks should be confined to such a room.

Grounding

Rule 3206o: "The exposed non-current carrying metal parts of equipment, such as frames or metal exteriors of motors, fixed or portable appliances, lighting fixtures, cabinets, cases and conduit, shall be grounded as provided in Article 9 of this Code. The locknut-bushing and double-locknut type of contact shall not be depended upon for bonding purposes, bonding jumpers with proper fittings or other approved means being required to assure an effective grounding circuit. The wheels of electric trucks shall be provided with rubber tires or made of non-conducting material."

This rule, both in application and intent is identical with those appearing in the other sections of this Article and, therefore, needs no special comment. It should be noted that wheels of electric trucks are required tobe provided with rubber tires. Electric trucks for use in cotton warehouses are usually made subject to special approval by the inspection authority involved.

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P A R T IV

LOSS RECORD

Containing a number of typical reports of fires and accidents from electrical causes in establishments in which hazardous processes or materials were involved.

LOSS RECORD

TYPICAL FIRE AND ACCIDENT REPORTS INVOLVING HAZARDOUS MATERIALS AND PROCESSES

In the following will be found a number of abbreviated reports of fires and accidents which have occurred in the hazardous industries through electrical causes. These have been included to illustrate and emphasize the need for the types of electrical installations prescribed by Article 32.

It should be pointed out that, because of the nature of the hazardous materials, it is frequently difficult to determine even the approximate causes of fires and explosions which occur in plants where they are present. Very often eye witnesses are killed or are so badly injured that little can be learned of the causes or conditions which brought about the explosion or fire. Furthermore, in the more serious accidents, all material evidence is generally destroyed, with the result that the fire or explosion is classed as from unknown cause.

It will be noted that the actual property losses in many of the reports given involve comparatively small sums of money. This is not to be taken as an indication that such is usually the case. As a matter of fact it is the exception rather than the rule, but it is usually only in the case of these smaller losses that we are able to determine the cause with any degree of accuracy.

In these reports, details as to available fire protection and methods of extinguishment have largely been omitted as we are not immediately concerned with this angle of the case. Our problem is one solely of prevention of ignition of hazardous materials from electrical causes.

Acknowledgment should be made to several persons and agencies who obliged by furnishing many of these reports. The office of the National Fire Protection Association, through the kindness of Messrs. Moulton and Walker, contributed a large volume of the reports involving finishing processes. Free reference was also made to loss reports which have appeared in various issues of the "Quarterly"of the N. F. P. A., and in the Associated Factory Mutual "Record." Messrs. Forsyth, Stewart, Adkins, Smith, Daniel, Wise, Wellman and other members of the International Association of Electrical Inspectors also contributed valuable reports. For fire and explosion reports involving the grain and flour industry, the loss records of the Mutual Fire Prevention Bureau were made use of to a considerable extent. The actual names of the plants involved in these reports are deleted for obvious reasons.

FINISHING PROCESSES

SPRAY PAINTING

Automobile Body Factory, Grand Rapids, Michigan, February 11th, 1926.

A workman was engaged in cleaning out a vent connected to a tunnel type spray booth after operations for the day had ceased. He was standing on a ladder and partly entering the duct, using an unguarded electric light on an extension cord of unknown character. The lamp was broken and a smouldering fire occurred which was quickly followed by a flash and explosion. The flash spread rapidly into connected tunnels and vents, but the prompt operation of automatic sprinklers held the fire loss to the nominal amount of $1,800.00. However, the employee was fatally burned and his assistant suffered serious burns.

Automobile Body Plant, Detroit, Michigan, September 9th, 1926.

An automobile body was being conveyed through a tunnel type spray booth where it was being painted. One door of the body was accidently left open and this struck a protruding vapor proof lighting fixture inside the booth and tore it from its supports. A short circuit followed and the flash caused ignition of the spray vapor and residue in the booth. The fire was extinguished by sprinklers with negligible damage.

Automobile Body Plant, Detroit, Michigan, April 23rd, 1927.

The fire or explosion originated on the third floor of a five story building where lacquer spraying was done. It was due to the ignition of pyroxylin dust or residue by a spark from or the overheating of a mercury vapor lamp over a spray booth. The first explosion was enough to shake the pyroxylin dust into suspension in the air and this, together with the gases formed by the decomposition of residue resulted in a second explosion of great violence. Several workmen were killed outright by the blasts and others died later of their burns. In all, twenty three lives were lost. Property loss was $2,000,000.00.

Automobile Body Plant, Detroit, Michigan, March 19th, 1929.

A worker entered the vent duct of a spray booth with an unguarded portable lamp in his hands which was strictly against orders. The light bulb was broken and ignited by pyroxylin dust in the booth and vents. The workman was fatally burned before he could escape from the booth. Property loss $400.00.

Furniture Factory, Lenoir, North Carolina, November 30th, 1926.

A spray gun was being cleaned in close proximity to unprotected electric lights. The bulb at the booth entrance was broken and there

was an immediate flash of the flammable vapors throughout the second floor. The fire developed sufficient heat to ignite the spray materials stored near the booths and the lacquer residue accumulated on the floor near booth. One man was burned to death and eight were injured. Property loss $260,000.00.

Airplane Wing Factory, Englewood, Colorado, April 20th, 1928.

The fire occurred in a building used for the assembling and treatment of airplane wings. Lacquer was applied by spraying and also by brush from an open fifteen gallon can. Lacquer spraying of plane cowls and metal parts was done in the basement. Neither in the first floor nor in the basement were booths provided for the spraying operation and no artificial ventilation existed except that by motor driven fan in an outside wall. There was a mild explosion coupled with a dull roar followed by two more severe explosions which filled the building with flame, blew the doors closed and piled debris against them in such a manner that those who got out escaped only with difficulty. The first explosion appeared to be from ignition of the lacquer vapors and the explosion that followed from the ignition of the deposit or residue which was to be found throughout the room. The investigators state that just before the first explosion, one of the surviving employees had seen a spark from the fan motor. Eleven deaths and seventeen injured is the toll taken by this accident. The building and contents were totally destroyed with a loss of about $25,000.00. Incidently, the coroner's jury declared the owners guilty of criminal negligence and of "involuntary manslaughter" on hearing the testimony.

Automobile Plant, Detroit, Michigan, February 12th, 1931.

The rumble seat of a car being painted closed down on an extension cord, cutting it in two. This resulted in a short circuit which caused a fire. Loss negligible.

Automobile Factory, Chester, Pa., September 21st, 1911.

The process involved in this fire was the spraying of truck parts with grease dissolved in naphtha to prevent rusting during shipment to foreign countries. This was carried out in a spray booth through which the parts travelled on a conveyor. The spray nozzles were supplied with the grease mixture by pumping from a 750 gallon open tank located beneath the floor of the booth. Early in the morning of the day of the fire employees filled the tank with the thinned grease mixture and operated the pump a few minutes to make sure the nozzles were clear, but did not start the ventilating fans. Naphtha vapors accumulated and two hours later when the foreman pressed the switch button located just outside the booth to start the tank agitator pump, there was a flash in and around the booth. It seems apparent that the flammable vapors were ignited by an electric spark from the switch. The contents of the tank caught fire immediately and the flames spread rapidly. A large portion of the plant was destroyed.

Spray Paint Shop, New York City, Date not available.

An ordinary direct current desk fan was mounted in the rear of a paint spray booth to force vapors out of doors. The windings of the motor broke down and the arc ignited the waste spray in the hood. The fire spread causing a loss of $22,626.18.

Automobile Paint Shop, Dallas, Texas, July 6th, 1928.

It is thought that a short circuit in electric wiring to an exhaust fan caused this fire which resulted in a property loss of $8,724.00.

Auto Body Factory, Detroit, Michigan, April 26th, 1926.

A short circuit in the electric switch terminal of an old style mercury lamp in a spray booth ignited pyroxylin dust on the switch box. Loss was confined to $500.00 damage.

Auto Body Factory, Detroit, Michigan, September 21st, 1926.

The fire started in a pyroxylin spray booth and was probably caused by an electric spark from a mercurial arc lamp or its connections which ignited pyroxylin waste. The loss was small.

Auto Body Factory, Mifflinburg, Pa., October 4th, 1926.

An employee was using gasoline to clean paint from the inside of the spray booth. A spark from an open light socket caused a spark which ignited gasoline fumes. The fire was extinguished without property loss.

Casket Factory, Pittsburg, Pa., November 20th, 1924.

Lacquer solvent fumes in a spray booth were ignited by a spark from a ventilating fan motor located in the path of the fumes. The loss was $2,679.00.

Furniture Factory, North Bennington, Vermont, January 5th, 1924.

A spark from a motor in a spray booth ignited varnish spray inside of the booth. The loss was $4,500.00.

Furniture Factory, St. Louis, Missouri, September 24th, 1924.

Sparks due to short circuit in a fan motor ignited vapor from the spray guns. The loss was small.

Furniture Factory, Martinsville, Virginia, February 12th, 1925.

In lifting a bucket of varnish an employee accidently struck and broke an electric light bulb close to the spraying cabinet which ignited varnish fumes in and around the cabinet. The loss was $14,454.00.

<u>Furniture Factory</u>, Pulaski, N. Y., December 30th, 1926.

An employee threw an open electric switch while holding a spray gun and the gasoline with which he had washed his hands was ignited by the spark. He dropped the gun on the floor where varnish residue was ignited. The loss was $9,208.00.

<u>Furniture Factory</u>, Los Angeles, California, April 23rd, 1927.

A spark from a fan motor ignited vapors in a spray booth causing a flash fire with loss of $4,618.00.

<u>Furniture Factory</u>, Savannah, Ga., April 25th, 1927.

The fire started in a spray booth and was due to a spark from the motor of a ventilating fan. The loss was $52,268.00.

<u>Furniture Factory</u>, Bassett, Virginia, February 23rd, 1925.

The fire started at a spraying machine when a spark from a motor ignited the vapor. The loss was $300,000.00.

<u>Furniture Factory</u>, McGraw, New York, June 4th, 1926.

The fire was due to a hot bearing on a motor located in the exhaust vent of a lacquer spray booth. This ignited the lacquer vapor around the motor. The loss was $6,800.00.

<u>Furniture Factory</u>, Montoursville, Pa., June 12th, 1926.

Fire was caused by a spark due to a short circuit at a motor under an all metal spray hood. The loss was large.

<u>Furniture Factory</u>, Atlanta, Georgia, June 13th, 1926.

The fire started at a motor in a shellac spraying booth which had not been cleaned for some time. The trouble was due to the motor being "gummed up" and arcing from a short circuit. The loss was $13,966.00.

<u>Furniture Factory</u>, Boston, Massachusetts, August 18th, 1926.

An electric light bulb in a spray booth was accidently broken. This ignited the flammable vapors. The loss was $197,000.00.

<u>Tannery</u>, Peabody, Massachusetts, December 24th, 1926.

Butyl acetate vapor and lacquer in a spray booth were ignited by a hot bearing on the booth fan motor. The loss was $367.00.

<u>Metal Worker</u>, New York City, July 25th, 1924.

A spark from an electric motor ignited lacquer residue on the inside of a spray hood. The loss was moderate.

Metal Worker, Keene, New Hampshire, August 14th, 1924.

A surge had occurred in the power supply and when the current was turned on after repairs had been made the wiring to the spray gun equipment heated or short circuited. This ignited the lacquer residue on the equipment. Fire followed with a loss of $3,100.00.

Metal Worker, Binghamton, New York, June, 1926.

A small loss occurred when sparks from an electric motor, used to revolve a table on which parts to be sprayed were laid, ignited lacquer residue.

Furniture Factory, Thomasville, North Carolina, May 19th, 1927.

Vapors which had accumulated in the spray booth were ignited by a short circuit in an electric heater at the booth. Loss of $17,203.00 resulted.

Furniture Factory, Shelbyville, Indiana, July 19th, 1927.

A spark from an electric switch ignited some lacquer which had just been spilled. Fire flashed into the booth badly burning the operator. A large loss followed.

Furniture Factory, Philadelphia, Pa., March 8th, 1928.

The fire started at a varnish spray booth due to a short circuit in a small electric heater or connections used to adjacent to the booth. The loss was small.

Furniture Factory, New York City, June 21st, 1929.

A fire caused by the ignition of varnish in a spray booth from a short circuit in an extension cord did considerable damage.

Metal Worker, New York City, December 1st, 1927.

A fire started in a spray booth when an electric light was broken igniting fumes from lacquer and drawing the flame into the vent duct. The loss was small.

Metal Worker, Buffalo, New York, October 8th, 1928.

The fire was due to the practice of spraying pyroxylin lacquer and varnish in the open without spray hoods. Residues collected not only on the various construction and finish features, but also on the motor switch, and were ignited when employees opened the switch. The flash was almost instantly followed by burning of residue on nearby walls, ceiling, floors and equipment. The loss was moderate.

Metal Worker, New Brighton, Pa., May 30th, 1929.

The case of the fan motor for the fan in a spray booth was removed to clean the commutator shortly after lacquer spraying had been done. Fumes were ignited when the motor was started for inspection after being cleaned. The loss was small.

Metal Worker, Binghamton, New York, August 1926.

A small loss followed when a flash fire occurred in a spray booth. It is believed that the source of ignition was furnished by a spark from the booth fan motor.

Metal Worker, St. Johns, Quebec, December 7th, 1926.

While an employee was changing an electric light in a spray booth an arc resulted, igniting varnish on the walls of the booth. The loss was $700,00.

Metal Worker, Detroit, Michigan, December 16th, 1926.

Sparks from a motor ignited fumes from lacquer in a spray booth. The fire which resulted caused a damage of $1,085.00.

Metal Worker, Brooklyn, New York, June 29th, 1927.

A short circuit in sub-standard wiring to a light and a motor in a spray booth ignited the highly flammable lacquer. The loss was small.

Metal Worker, New York City, June 21st, 1929.

The fire occurred in the lacquer spray hood when a short circuit of electric wiring ignited lacquer on the sides of the hood. Moderate loss occurred when the fire spread to other spray hoods.

Metal Worker, Cambridge, Massachusetts, December 7th, 1929.

Fire was discovered during the night in the rear of a spray booth and was due to an overheated motor which had been started by mistake. The loss was small.

Metal Bed Factory, Boston, Massachusetts, August 30th, 1926.

Paint and lacquer in a spray booth were ignited by a short circuit in a fan motor. The loss was small.

Automobile Factory, Flint, Michigan, July 30th, 1924.

The fire was due to a short circuit in a fan motor inside a spray booth which ignited the lacquer residue in the exhaust vents. The loss was small.

Automobile Factory, Philadelphia, Pa., October 19th, 1925.

While an employee was spraying some metal parts he broke an electric light bulb in the spray booth. Vapors from the paint caught fire and a loss of $300.00 resulted.

Automobile Factory, Flint, Michigan, May 21st, 1925.

An ordinary incandescent light was being used in a spray booth. The lamp became coated with lacquer which decomposed and was ignited by the heat of the lamp. A flash fire followed causing a loss of $300.00.

Automobile Factory, Norwood, Ohio, June 3rd, 1925.

A small can partly filled with lacquer was in a spray booth and a small motor driven pump was used for supplying the spray gun. When an employee raised the cover on the can, fire flashed due to either static sparks or sparks from the motor. The loss was small.

Automobile Factory, Arabi, La., August 13th, 1926.

An employee was cleaning a spray booth and accidently dropped an extension light, the globe of which broke and caused pyroxylin lacquer to ginite. The loss was $168.00.

Electric Appliance Factory, New York City, September 2nd, 1926.

The fire originated under a lacquer spray booth and was caused by a spark from an electric motor. The loss was small.

Electric Appliance Factory, New York City, October 6th, 1926.

The fire was caused by the breaking of an electric light bulb over a lacquer spray hood. The loss was small.

Electric Appliance Factory, Milwaukee, Wisconsin, June 2nd, 1928.

A spark from a fan motor ignited lacquer in a spray booth which resulted in a fire with small loss.

Electric Appliance Factory, New York City, November 7th, 1928.

A spark from a motor started a fire in a small lacquer spray hood. The loss was small.

Electric Appliance Factory, Chicago, Illinois, March 30th, 1929.

A short circuit in electric wires on a spray machine ignited spray material. The resulting fire caused a loss of $33,920.00.

Automobile Factory, Detroit, Michigan, March 1st, 1927.

The fire started inside the "coil box" of a mercury arc lamp which was attached to the side of the spray booth. A short circuit occurred in the "coil box" - the arc igniting dust on the wire and the fire spread to the lacquer residue on the top of and inside the spray booth. The loss was small.

Electric Appliance Factory, New York City, October 24th, 1925.

Fire originated in a lacquer spray hood as the result of a spark from a switch used to control the fan motor. The loss was small.

Electric Appliance Factory, Syracuse, New York, April 2nd, 1926.

Fire in a lacquer spray booth was caused by trouble with the electric fan motor located directly in the exhaust pipe. The loss was small.

Electric Appliance Factory, Hamilton, Ontario, August 28th, 1926.

The fire was caused by the breaking of an electric light bulb hanging in a spray booth. The loss was $200.00.

Display Tray Factory, Providence, Rhode Island, October 26th, 1928.

Jewelers display trays were being finished by spray process in a spray room when the lacquer solvent vapors were ignited by sparks from a ventilating fan motor. The loss was small.

Piano Factory, St. Therese, Quebec, May 19th, 1929.

A spark occurred when the motor drive exhaust fans were started, igniting vapors rising from a pail of lacquer suspended nearby. About twelve employees were injured and heavy property damage occurred.

Metal Worker, Cuyahoga Heights, Ohio, December 17th, 1927.

An employee accidently broke a lighted portable electric light bulb at one of the spray booths. The heated filament was struck by the spray and a violent flash immediately occurred which spread the fire rapidly. The loss was $30,000.00.

Radio Equipment Factory, New York City, August 7th, 1925.

Fire occurred in a lacquer spray hood from a short circuit in electric light wiring inside of the hood. Loss was small.

Furniture Factory, Oakland, California, June 15th, 1928.

The fire was caused by the accidental transmission of high potential to motor circuits which caused the exhaust fan motor inside spray booth to flash. The residue on the sides of the booth ignited and fire spread to wood trusses and roof. The loss was $18,000.00.

Radio Equipment Factory, Boston, Massachusetts, November 18th, 1926.

An electric spark from a motor ignited volatile fumes from pyroxylin spraying. The loss was $240.00.

Radio Equipment Factory, Brooklyn, New York, March 2nd, 1929.

The fire was caused by a short circuit in an electric light socket causing a spark which ignited spray mixture and loose lacquers on the sides of the spray booth. The fire was confined to the coating of residue inside of the booth.

Woodworking plant, McGraw, New York, June 20th, 1927.

The fire occurred when an employee turned on a switch mounted on a frame partition to start the lacquer spraying process. A spark from the switch ignited lacquer residue on the partition and the fire spread rapidly. The loss was $2,000.00.

Woodworking Plant, Sales, Massachusetts, August 11th, 1924.

The fire started near an enamel spray booth due to sparks from an electric fan switch. The loss was $390.00.

Automobile Body Plant, Detroit, Michigan, March 19th, 1929.

The fire occurred when a gas filled lamp on an extension cord in use by cleanup man broke and caused a flash which ignited lacquer residue and dust in booth. The clothing of both cleaners caught fire and one was so badly burned that he died later. The property loss was $400.00.

Metal Partition Manufacturing Plant, Elkhart, Indiana, November 20th, 1929.

Lacquer residue and dust in a spray booth were ignited from a broken incendescent lamp used to illuminate the spray booth while it was being cleaned. The loss was $63.00.

Silver plated Ware Mfg., Plant, Taunton, Mass., June 21st, 1923.

A spark from a motor located inside of a spray booth ignited lacquer fumes and caused a flash fire. Lacquer on the sides of the booth ignited and the fire spread to a dip tank. Loss $3,000.00.

Automobile Truck Assembling Plant, Detroit, Michigan, June 20th, 1919.

The blowing of a fuse in the circuit to a ventilating fan motor in the paint spraying section ignited the flammable vapors and the fire quickly spread along the paint soaked walls. Loss $106,000.00.

E. J. Hauserman Company, Cleveland, Ohio, About 1928.

An unprotected electric light bulb was broken while pyroxylin was being sprayed in a booth. The flash ignited the spray and caused the explosion of three barrels of lacquer which s cattered the flaming liquid over the entire plant, resulting in considerable loss.

Furniture Factory, Ionia, Michigan, About 1928.

A fire originating in the spraying room swept the third floor of the furniture factory. The blaze was caused by a short circuit in electric wiring. Timely work in removing several barrels of lacquer liquids stored on the third floor was thought to have lessened the probable loss considerably.

Manufacturing Plant, Detroit, Michigan, December 16th, 1926.

A spark from a fan motor ignited lacquer vapors in a spray booth. Spray booths, electric wiring and ceilings were damaged to the extent of $1,085.00.

Sewing Machine Factory, St. Johns, Quebec, December 7th, 1926.

As an operator screwed ah electric light bulb into a socket in a varnich spray booth igniting varnish residue on the booth walls. The fire burned the cotton rope supporting a five gallon varnish container, spilling the varnish, which ignited when it fell. The loss was estimated at from $700.00 to $800.00.

Metal Worker, Cleveland, Ohio, October 6th, 1927.

A spark from a motor ignited lacquer residue in the duct to a spray booth in which metal cabinets were being finished. The loss from the fire and water damage was from $3,000.00 to $5,000.00.

DIP TANKS AND DRYING OVENS

Metal Worker, New York City, Date not available.

An electrically operated crane was used to dip bundles of metal parts into a dip tank. An electrical fault in the crane motor permitted molten metal to drop into the tank and ignite the paint in it. The resulting fire caused a loss of $11,654.50.

Automobile Factory, Racine, Wisconsin, October 8th, 1929.

Fire in pull box due to short circuit. Pull box was mounted on the side of an oven used to dry fenders and frames coming from dip tanks.

Automobile Manufacturing Plant, Detroit, Michigan, August 3rd, 1919.

An employee dipping a fender in a naphtha bath hit an insulated wire causing an arc. An explosion occurred and the resulting fire caused a loss of $40,000.00.

Wood Worker, Kansas City, Kansas, November 13th, 1928.

The fire originated in the painting department of a factory producing wagon and truck bodies. A workman accidently struck an unprotected electric light with a scoop board, breaking the light and igniting naphtha vapors from adjacent open dip tanks. The flash fire which resulted spread rapidly and soon involved the entire building. Loss was $22,000.00.

Electrical Manufacturing Plant, East Pittsburg, Pa., April 23rd, 1927.

Workmen were handling small steel plates during repair work when one of the plates came in contact with a bare spot on an electric light wire, producing a spark which fell into and ignited varnish in a dip tank. The loss was $256.00.

GASES

Liquid Petroleum Gas Station, Madison, Wisconsin, December 12th, 1931.

A motor driven pump was being used to pump liquid gas from a tank car into underground tanks. The building housing the pump was divided into two parts by means of a metal partition, with the pump in one compartment and the motor and its control apparatus in the other. An attempt had been made to make this partition vapor proof, but apparently it was not, as consequences proved. The motor was of the open squirrel cage type and the controller an ordinary magnetic switch in non-explosion resisting case. Some difficulty had been experienced with the pump and it was shut down and cleaned. The pump was again started but did not seem to operate properly so the attendant made some adjustments, and while doing so an explosion occurred in the compartment housing the motor and controller. Flames passed through the partition, seriously burning the operator and another employee. It was found the cover of the controller case and also that of the power service switch were blown open. It was apparent that the explosive mixture of liquid gas and air was ignited and exploded.

FLAMMABLE LIQUIDS - GENERAL

Bleachery, Pawtucket, Rhode Island, August 12th, 1924.

Two pails of benzol had been added to the warm water in a washing machine when an explosion occurred due to ignition of the benzol vapors by a spark from an electric motor. An employee operating the machine was fatally burned. Property loss was small - $100.00

An interesting record of fires of previous electrical origin occurring in buildings in metropolitan New York City, where flammable vapors were present, is given in the following:

Year	Number of Fires	Location	Amount of Loss
1918	6		$88,409.49
1919	4		40,726.96
1920	5		33,402.94
1921	7		59,694.63
1922	5		600.00
1923	6		1,210.00
1924	16		8,850.00
1925	21		10,155.00
1927	11	Spray Booths	37,000.00
"	12	Hat Cleaners	835.00
"	3	Garages	70.00
"	3	Alcohol Fumes	700.00
1928	8	Spray Hood	3,400.00
"	21	Varnish Remover	8,996.00
"	14	Hat Cleaner	4,226.00
"	2	Garages	225.00
"	5	Alcohol Fumes	3,751.00
1929	9	Spray Booths	18,696.00
"	20	Hat Cleaner	2,280.00
"	8	Varnish Remover	1,851.00
"	3	Alcohol Fumes	10,648.23
"	1	Paint	2,000.00
1930	10	Spray Booths	8,986.00
"	12	Varnish Remover	3,028.00
"	14	Hat Cleaner	6,118.97
			$380,360.25

Previous to 1927 the record does not indicate the type of plant or occupancy involved.

Metal Working Plant, Turtle Creek, Pa., July 2nd, 1927.

Varnish and benzine stored in buried tanks were handled by means of pumps located in an underground pump house nearby. The engineer entered the pump house to start the varnish pump and it is presumed that he turned on the electric light switch just before passing down the stairway. Immediately an explosion occurred, caused, no doubt, by a spark at the switch igniting an explosive mixture of the flammable vapors and air. The engineer managed to escape, but he was so badly injured that he died a short time after reaching the hospital.

Radio Tube Factory, Salem Massachusetts, Date not available.

A young woman tipped over a can of alcohol on a machine at which she was working and the liquid spilled on the sleeve of her dress. When she stopped her machine a spark from the switch ignited the alcohol soaked sleeve. The girl ran about the room causing the fire to spread and inflict severe burns over almost her entire body which caused her death.

Paper Products Factory, Monroe, Michigan, About 1929.

Fire is said to have originated in the grinding room and as the flames spread, a series of explosions involving tanks of alcohol, benzine, glycerine and other explosive liquids wrecked the plant and spread the blaze in all directions. The loss was reported to be $40,000.00.

Printing Establishment, Milwaukee, Wisconsin, August 27th, 1931.

The rolls of a five color press were being cleaned with gasoline when a spark from the "inch switch" ignited the gasoline vapors. The loss was confined to the press, engraved plates, and driving connections for an amount in excess of $1,500.00.

PYROXYLIN PLASTIC INDUSTRY

Motion Picture Film Laboratory, Fort Lee, N. J., February 7th, 1925.

A short circuit ignited exposed film in the joining room. The fire was followed by an explosion of gases caused by rapid decomposition which lifted the building from its foundations and forced out one wall. Twenty employees and firemen were injured, two of whom died from their injuries. Property loss was $1,000,000.00.

Drafting Supply Factory, St. Louis, Mo., September 25th, 1928.

Plant was engaged in the manufacture of tee squares and triangles from wood and celluloid stock. A defective lamp socket ignited scrap celluloid on the floor causing a fire which did considerable damage to the building and contents.

Box Toe Company, Lynn, Massachusetts, November 8th, 1928.

The plant was used for the manufacture of pyroxylin-impregnated cotton flannel from which box toes for cheaper grades of shoes are cut. They also mix box toe softener and make an adhesive similar to rubber cement for the use of shoe manufacturers. All processes involved the use of flammable solvents. Pyroxylin plastic scrap was dissolved in ethyl acetate and denatured alcohol in mechanically agitated churns, and cotton flannel was then impregnated with this mixture, applied by drawing the flannel strips through an open tank of the mixture. A wooden knife then removed the excess and the flannel was festooned over steam coils on an open dry rack. The adhesive was made from gum mixed with benzol in mechanically agitated mixers. The box toe softener is a mixture of diacetone and denatured alcohol and was sold to the trade in five and ten gallon cans. While some attempt had been made to have the electrical equipment conform to the standard for hazardous occupancies, it was reported that there were several ordinary snap switches, a motor starting box, three small A. C. motors on the ceiling, and several small window fan motors, none of which were of the vapor proof type. It is also reported that there was at least one electric light not enclosed in a vapor proof globe. The fire which occurred in the North end of the building was followed by several explosions of terrific force. The cause could not be definitely ascertained, as of the fifteen male employees, thirteen were killed and seven other perons living in adjoining dwellings died from burns. The property loss to the plant was $15,000.00.

Hospital, Boston, Massachusetts, April 25th, 1923.

A fire occurred in the X-ray film room in the basement, caused, it is said, by the ignition of the film by the heat of an unprotected electric light bulb which accidently came in contact with the film.

Clothing Factory, Toronto, Ontario, March 13th, 1927.

An unprotected electric light had been permitted to lay lighted in a tray of celluloid buttons. The celluloid started to decompose and presently the vapors were ignited. The fumes prevented firemen from entering which greatly increased the extent of the loss. The damage was estimated at from $10,000.00 to $20,000.00.

Advertising Novelty Factory, Newark, New Jersey, April 27th, 1927.

Celluloid advertising novelties were stored in open crates in a vault. Smoke was discovered coming from the vault and investigation indicated that the celluloid had begun to decompose either spontaneously or from heat from an incandescent drop light,which had then burst into flame. Only about three quarters of the celluloid was consumed, but the remainder was badly discolored. The smoke left a brownish deposit throughout the upper floors of the building necessitating repolishing some of the goods.Loss was $8,500.00.

COATING PLANTS

Shade Cloth Factory, Oswego, New York, November 2nd, 1923.

A drum of benzine was spilled at the bottom of an elevator shaft. This was ignited it is reported, by an electric spark. Three lives were lost, but the fire was extinguished with no property loss.

Waterproof Canvas Manufacturing Plant, Poughkeepsie, New York, March 14th, 1921.

The fire was caused by a short circuit due to worn insulation of an electric light extension cord, igniting fumes near the impregnating machine. There was no explosion, but the fire caused a loss of $1,358.00.

Leather Finisher Works, Boston, Massachusetts, January 5th, 1929.

The fire occurred in the mixing room of the plant where a mixture was being prepared from alcohol, lacquer, thinner and other ingredients. The mixing was done in three tanks, each of which had a capacity of 250 gallons. During the process the liquid in these tanks was ignited by a spark from a loose connection on the mixer motor. The operation of automatic sprinklers confined the fire somewhat, yet the loss was considerable due to the highly flammable contents of the building.

CLEANING AND DYEING

Hat Cleaning Establishment, Washington, D. C., November 16th, 1928.

An explosion occurred when gasoline vapor was ignited by a spark from an electric motor in a bootblack shop while a hat was being blocked and cleaned. Three of the ten persons who were in the shop at the time were more or less burned and damage amounting to $1,000.00 was done to the building and contents.

Dry Cleaning Plant, Harvey, North Dakota, March 19th, 1928.

A spark from an electric switch ignited gasoline vapor and caused an explosion in a small detached cleaning room. The loss was $850.00.

CHEMICAL INDUSTRY

Industrial Plant, Detroit, Michigan, January 4th, 1931.

A damaged extension cord in the vicinity of wooden vats used for storage of alcohol short circuited and ignited the alcohol vapors. The loss was small.

Alcohol Manufacturing Plant, New Orleans, La., August 31st, 1928.

Two men were engaged in filling 50 gallon drums with denatured alcohol in a warehouse when an explosion occurred. The fire spread rapidly from the point of origin and the buildings involved were completely enveloped in flames by the time the first fire companies arrived. Several additional explosions occurred in quick succession. A fireman was killed by an exploding drum which was thrown about 100 feet into the air. Several firemen were also overcome by the intense heat. The exact cause of the explosion could not be determined but was apparently due to the ignition of alcohol vapor. Investigators stated that the most probable causewas ignition of the vapors by an electric spark from defective wiring or short circuiting of a storage battery used in connection with a weighing device. Total loss to buildings and equipment was approximately $220,000.00.

Chemical Laboratory, Ossining, New York, November 27th, 1929.

A short circuit in an electric cord ignited a pail of powdered paraffin which was the base of a secret waterproofing compound being made. The woman chemist lost her life when her clothing was ignited.

Alcohol Still Plant, Cadillac, Michigan, December 12th, 1907.

A fire occurred when an employee started to look for a leak in one of the alcohol stills. He used an extension light which was protected by a wire guard, but had no vapor proof globe. Alcohol vapor escaping from the still ignited. The fire spread rapidly causing total destruction of the buildings for a loss of $48,000.00.

Alcohol Plant, Binghamton, New York, January 26th, 1917.

An employee removed the manhole cover from an alcohol still while it was in operation in order to investigate the interior of the still. He used an incandescent lamp on an extension cord which was provided with a wire guard. During his investigation he thrust the lamp inside of the still, but in so doing he struck the side of the still and alcohol vapors ignited and blew through the manhole, seriously burning the employee. A ball of fire is reported to have passed up through a hoist opening, the trap of which was blown off and the monitor ignited. The property loss was slight.

Chemical Plant, Niagara Falls, New York, January 6th, 1921.

Toluol was being chlorinated in ten gallon glass carboys in the presence of heat and light which was furnished by a high wattage nitrogen filled incandescent lamp. It is believed that the lamp broke and ignited the vapors. The fire spread with great rapidity and the building was a total loss.

Alcohol Manufacturing Plant, New Orleans, La., August 31st, 1928.

Two men were engaged in filling 50 gallon drums with denatured alcohol in a warehouse when an explosion occurred. The fire spread rapidly from the point of origin and the buildings involved were completely enveloped in flames by the time the first fire companies arrived. Several additional explosions occurred in quick succession. A fireman was killed by an exploding drum which was thrown about 100 feet into the air. Several firemen were also overcome by the intense heat. The exact cause of the explosion could not be determined but was apparently due to the ignition of alcohol vapor. Investigators stated that the most probable causewas ignition of the vapors by an electric spark from defective wiring or short circuiting of a storage battery used in connection with a weighing device. Total loss to buildings and equipment was approximately $220,000.00.

Chemical Laboratory, Ossining, New York, November 27th, 1929.

A short circuit in an electric cord ignited a pail of powdered paraffin which was the base of a secret waterproofing compound being made. The woman chemist lost her life when her clothing was ignited.

Alcohol Still Plant, Cadillac, Michigan, December 12th, 1907.

A fire occurred when an employee started to look for a leak in one of the alcohol stills. He used an extension light which was protected by a wire guard, but had no vapor proof globe. Alcohol vapor escaping from the still ignited. The fire spread rapidly causing total destruction of the buildings for a loss of $48,000.00.

Alcohol Plant, Binghamton, New York, January 26th, 1917.

An employee removed the manhole cover from an alcohol still while it was in operation in order to investigate the interior of the still. He used an incandescent lamp on an extension cord which was provided with a wire guard. During his investigation he thrust the lamp inside of the still, but in so doing he struck the side of the still and alcohol vapors ignited and blew through the manhole, seriously burning the employee. A ball of fire is reported to have passed up through a hoist opening, the trap of which was blown off and the monitor ignited. The property loss was slight.

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Chemical Laboratories, Chicago, Illinois, August 8th, 1921.

A leak occurred in the rotary drier used for extracting water from alcohol. Before the power could be shut off an explosion occurred, killing two men and seriously injuring four others. The explosion was due to a spark from or an arc in an electric motor at the dryer, igniting fumes of alcohol escaping from the dryer. The automatic sprinkler operated and held fire loss to a small amount.

Chemical Works, Chicago, Illinois, June 30th, 1922.

Fire occurred when a spark from an electric motor ignited alcohol vapors in a still room. There was no explosion and the automatic sprinklers held the fire in check. The property loss was small.

Coal Tar Dye Stuffs Factory, Buffalo, New York, September 25th, 1923.

A tank used in a process involving the recovery of benzol leaked and was accidently filled during the night. The benzol leaked through a hole to the first floor where it was ignited at a motor starting switch. The fire flashed to the tank of the second floor and upwards through the stair openings to the third floor. The loss was held to moderate proportions by automatic sprinklers.

Chemical Plant, Belleville, New Jersey, September 6th, 1930.

Fire was caused by the ignition of gasoline fumes by an electric motor used in pumping a solution of phosphorous oxy-chloride phenol and gasoline from the mixing tank to the crystalizing vat. Fire occurred when an employee started the electric motor which caused the ignition of the gasoline fumes. The fire was held in check by sprinklers. The loss was $2,700.00.

Chemical Works, Everett, Massachusetts, September 8th, 1930.

Fire started at a lacquer filter press machine and was due to either a faulty electric light globe or the breaking of a globe. The fire was extinguished by sprinklers and an automatic carbon dioxide system. The loss was $267.00.

Coal Tar Dye Stuff Factory, Buffalo, New York, January 7th, 1924.

Naphthalene which dropped from the floor above was ignited by a heated electrical connection to inductor coils for heating an autoclave. A flash took place which ignited the woodwork which was saturated with naphthalene. Automatic sprinklers held the loss to small proportions.

Chemical Works, Perth, Amboy, New Jersey, February 12th, 1926.

Alcohol was being pumped through a rubber hose which either broke or became disconnected. The room was filled with alcohol vapor.

A spark from the electric pump motor ignited the vapors and an explosion occurred in which one life was lost. The property loss was considerable.

Chemical Works, Shawinigan, Quebec, February 13th, 1929.

Employees were cleaning a steel churn used for mixing ethyl acetate. A flash fire occurred when an electric extension light was lowered into the manhole of the churn. Two employees were burned when the fire flashed from the manhole. Sprinklers checked the fire.

Stove Polish Manufacturing Plant, Buffalo, New York, April 16th, 1924.

Fire occurred when an electric drop cord short circuited against a steel tank in the room where stove polish was being manufactured. A spark from the short circuit ignited naphtha fumes in the room. The main portion of the East end of the one story frame building was destroyed by the fire which followed.

PAINT AND VARNISH FACTORIES

Paint Factory, Racine, Wisconsin, 1931.

A tank in which dyes were mixed had been drained preparatory to being cleaned. An employee dropped a non-standard extension cord into the tank. It is reported that the cord was defective and short circuited, igniting the vapors in the tank and the fire spread to adjoining tanks causing considerable damage.

Paint and Varnish Works, Reading Pa., August 28th, 1929.

Fire occurred in a paint mixing room where tanks were located. There were eleven 225 gallon tanks located on a turn table on which was also located an electric light on a drop cord which was used to examine the tanks occasionally. This light was apparently unguarded and it is thought that it broke directly over a tank and ignited vapors. An employee who was present did not see the bulb break, but heard glass falling and saw flames shoot from the tank immediately afterward. The loss was $110,000.00.

Varnish Remover Factory, Newark, New Jersey, October 27th, 1924.

The mixing room was one story with desk floor on one side, containing several 250 gallon tanks of alcohol and acetone, two benzol and one all alcohol. These liquids were pumped from the drums to the tanks and thence drawn to mixing kettles beneath in order to see the gauge glasses on the tanks from the floor below, an electric light provided with a wire guard but no vapor proof globe was hung near the gauge glasses. While filling the tank with acetone, more or less vapor was given off which ignited either from the electric light bulb or a short circuit in the wire, and a flash fire resulted. The fire was extinguished with some difficulty. The loss was $262.00.

Varnish Works, Cleveland, Ohio, June 30th, 1926.

This fire was caused by the breaking of a connection between an extension cord and a socket near a point where cans were being filled with varnish remover. The spark which resulted ignited the flammable vapors. The fire was held to small proportions by automatic sprinklers.

Paint Factory, Frankford, Pa., August 22nd, 1924.

Fumes from paint mixing and grinding process collected at the ceiling around an electric motor and were apparently ignited by a spark from the motor. Fire extended to the second floor through an open hoist causing a loss of $10,000.00.

Shellac Varnish Factory, Brooklyn, New York, October 11th, 1924.

Fire occurred in a building in which spirit shellac was manufactured and barreled. After closing down, an employee was cleaning the interior of a small wooden varnish tank. To obtain light he was using an electric extension light which in some way became broken, causing the fumes within to ignite and loose varnish in the tank also ignited. Fortunately, the employee was able to escape from the tank uninjured. The fire was held to small proportions by the operation of automatic sprinklers.

Varnish Works, Pittsburg, Pa., January 15th, 1919.

A tar composition for roofing paint was being thinned down in two steam heated metal tanks. The process was nearly completed when an electric light globe located directly over and about five feet above one of the tanks was accidently broken, and the resulting spark was sufficient to ignite the naphtha fumes present. A flash occurred immediately, but the operation of automatic sprinklers confined the loss to small proportions.

Shellac and Paint Factory, New York City, N. Y., February 1st, 1923.

A flash fire occurred in a large wooden shellac mixing vat. In the vat were large metal paddles run by an induction motor with knife switches in the room. Considerable dust was created when shellac was poured into the vat, and alcohol was then added to be mixed with the shellac. This process was not cut off from the remainder of the room and there was not even a cover for the vat. Alcohol fumes were ignited either by a spark from the motor or from a starting switch. The loss was confined to the contents of the vat.

PETROLEUM INDUSTRY

REFINERIES.

Oil Refinery, Fort Worth, Texas, April 9th, 1927.

An employee attending a motor driven pump used to pump gasoline from a tank car into storage tanks, discovered that the pump was leaking. As he opened the switch which was located in the pump room, the arc ignited the gasoline vapors and resulted in an explosion which destroyed the building and severely burned the operator.

Gasoline Tank, Shreveport, Louisiana, February 25th, 1928.

Two men were assigned to clean out an all steel gasoline tank. While at work, one of them dropped a portable extension lamp which was unprotected, on the floor of the tank. The spark which resulted ignited the gasoline vapors in the tank, causing an explosion which blew the men from the tank, badly damaged the tank itself and ignited the oil refuse outside the tank. The fire spread to another tank and nearby buildings. The men were but slightly injured, but the property loss was $97,500.00.

Gravity Filter Building, Warren, Pa., December 12th, 1922.

Defective electric light wiring is thought to have been responsible for a flash fire which occurred at an open barrel capacity tank containing light filtered motor oil. The fire spread to the contents of sixteen other tanks located in the building and to the roof of the filter house and adjoining boiler house. The loss was $43,000.00.

BULK GASOLINE DISTRIBUTING STATIONS.

Flying Field, Madison, Wisconsin, September 6th, 1931.

A motor driven pump, used to pump gasoline from tank cars to storage tanks, was located in a concrete pit near the railroad tanks. The pit was divided into two parts, with the pump in one compartment and the motor and its control switch in the other. The motor is reported to have been of the approved explosion resisting type, but the switch was of the ordinary type in a non-explosion resisting case. The unloading had been completed and the attendant had gone into the pit to stop the motor. When the switch was opened there was an explosion. Apparently there were sufficient gasoline vapors in the motor compartment to form an explosive mixture in spite of the tile partition which divided the pit. The attendant was seriously burned about the hands, face, arms and neck.

Bulk Gasoline Sation, Wichita, Kansas, May 11th, 1931.

A motor driven pump was employed to pump gasoline from storage tanks to a tank truck. The motor and its control apparatus were decidedly sub-standard, the motor being of the open brush type and the control switch of the ordinary type. When the switch was opened the arc ignited the accumulated gasoline vapors in the pump house. The building was wrecked and the man in charge dangerously burned. Only good work on the part of the fire department prevented the fire spreading to the adjoining gasoline storage tanks, thus averting a major disaster.

Bulk Gasoline Sation, Berlin, Wisconsin, June 20th, 1925.

The manager had driven his truck into the wagon house for filling direct from a tank car. A motor driven pump controlled by an ordinary knife switch was used for this purpose and these were located in the wagon house. As the switch was closed to start the pump motor, the arc ignited the gasoline vapors which seemed to fill the building and in a moment the entire building was in flames. The manager was badly burned and only his presence of mind saved him from death.

Bulk Gasoline Station, Plentywood, Montana, About 1922.

An accident similar to the foregoing case occurred when a knife switch was operated to start a motor driving a gasoline pump. The arc ignited accumulated gasoline vapors which resulted in an explosion causing total destruction of the entire station. The attendant, fortunately, escaped without serious injury.

Gasoline Pump House, Linden, New Jersey, Februay 12th, 1929.

The pump operator was preparing to load a long line of tank cars at the loading rack and pressed the button to start the pump. A sudden flash ignited gasoline vapor and enveloped the room. It is thought that a short circuit in the electric pump was responsible for the ignition of the flammable vapor. The loss was estimated at from $50,000.00 to $100,000.00.

Gasoline Pump House, Everett, Massachusetts, April 14th, 1922.

An explosion of gasoline vapors occurred in a space under an air compressor room. It is thought that a spark from defective wiring was responsible for the explosion. The concrete floor was raised about six inches and four reinforced concrete beams were cracked. The fire was confined to the pit, but one man was killed and several injured. The property loss was about $5,000.00.

Bulk Gasoline Sation, Minot, North Dakota, July 3rd, 1928.

Two persons lost their lives and two others were badly burned in a fire following an explosion in the basement of the warehouse of an

oil company. A spark from an electric motor used to operate the pump which pumped gasoline and other petroleum from the tank cars to storage tanks ignited an accumulation of flammable vapors. The property loss was $23,820.00.

<u>Bulk Gasoline Station</u>, Wilmington, Ohio, January 26th, 1929.

Gasoline was being pumped from a storage tank to a tank truck. An employee was in the filling house at the time, and it is thought that he opened the switch to stop the operation of the pump. The Electric arc caused by the operation of the switch is thought to have ignited gasoline vapors which filled the building. The operators were fatally burned. All buildings and tanks, together with a nearby bulk gasoline station were destroyed. The property loss was $22,000.00.

<u>Bulk Gasoline Station</u>, Clearwater, Florida, March 1st, 1924.

Gasoline vapor, due to overflowing of a tank, accumulated in the motor room and was ignited by sparks from the electric motor which was not enclosed. The office, motor room and one tank were destroyed by the explosion which followed. The loss was $8,000.00.

<u>Bulk Gasoline Station</u>, Houston, Texas, April 19th, 1927.

Gasoline vapor accumulated and was ignited by a spark from an electric switch which controlled the motor driving a pump which was used to pump gasoline from one tank to another. Several thousand gallons of gasoline and lubricating oil were destroyed together with considerable building property. The total loss was $28,265.00.

<u>Bulk Gasoline Station</u>, Green Bay, Wisconsin, August 22nd, 1929.

A 1,000 gallon loading tank located inside a building was being filled. The pump was left unattended with the result that the tank overflowed. An employee threw the electric switch to shut off the pump and a spark from this switch ignited the vapor and caused a terrific explosion. Three men were killed and four others injured. The property loss was $50,000.00.

<u>Bulk Gasoline Station</u>, Desmet, South Dakota, April 12th, 1930.

An explosion occurred when an employee threw an electric switch in the station. Accumulated vapors were apparently ignited by a spark from the switch. One man died as a result of burns received. The station was totally destroyed.

<u>Bulk Gasoline Station</u>, New Orleans, Louisiana, January 7th, 1932.

An underground tank was being filled with gasoline from a tank car by means of a motor driven pump. The pump was located out in the open, but the driving motor and its control, together with a motor driven air compressor were located in a small pump room. The pump shaft extended through the wall of the pump house. The motor was an open single phase brush type motor of about 2 horse power capacity and the control switch and service equipment were of the ordinary enclosed type. It appears that the tank became filled and overflowed through the vent pipe, spraying the attendant with gasoline. He immediately went into the pump house to open the motor control switch, but as he did so the gasoline vapors were ignited by the arc at the switch contacts and his clothing was set afire. The attendant died from his burns. Considerable damage resulted to the pump house and its equipment as well as to the attached office.

GASOLINE FILLING STATIONS

Gasoline Filling Station, Rock Rapids, Iowa, July 21st, 1930.

One man was killed when gasoline fumes which had accumulated in the basement of the building at a filling station exploded. The vapors were ignited by a spark from the switch of an automatic air pump.

Gasoline Filling Station, Hartford, Conn., August 19th, 1930.

A man was burned to death as the result of an explosion of gasoline vapors which had accumulated in the basement of an office at a filling station. A pipe line from the storage tanks to the filling pumps had developed a leak and gasoline had filtered into the basement. The victim of the fire was using a broom to sweep up the gasoline and it is believed that his broom broke an electric light bulb which ignited the vapors.

Filling Station Building, Pittsburg, Pa., January 23rd, 1920.

An employee in a gasoline filling pit accidently broke an unprotected electric light bulb. The resulting spark ignited gasoline vapor and an explosion followed. The building was destroyed with large loss.

Filling Station, Rock Rapids, Iowa, July 21st, 1930.

One man was killed when gasoline fumes, which had accumulated in the basement of the building at a gasoline filling station, exploded. The explosion was due to the ignition of the fumes by a spark from the switch of an automatic air pump.

The writer has been told of numerous explosions originating in motor driven gasoline pumps, the causes of many of which were attributed to improper wiring at the pumps. In a certain city in Illinois, six such explosions occurred within one year. One explosion resulted in the rupture of the pump assembly, one half being thrown

into the filling station shelter and the other half across a street and into the wall of a church. It is unnecessary to point out the possible results of such an explosion should it occur on a busy corner of a large city.

GARAGES

Garage, Providence, Rhode Island, December 11th, 1930.

Four garage employees were burned, three of them fatally, when an electric light bulb dropped into a pit in which they were working. The light was broken and ignited gasoline on the floor of the pit. The flames spread rapidly, fed by the oil and gasoline on the floor of the garage and before they could reach the door, which was closed, three of them were so badly burned that they died later in the hospital

MISCELLANEOUS

Residence, Boston, Massachusetts, July 17th, 1926.

The residence was being renovated during the process of which painters were using a paint remover. A fire occurred, thought to have been caused by ignition of the vapors by the arc from a switch. One of the painters was trapped in the burning building and suffered death by suffocation.

Building under Construction, Boston, Massachusetts, January 15th, 1927.

A plastic floor covering containing a volatile flammable solvent was being laid, when a spark from a broken electric light bulb ignited the vapors. An explosion followed and one workman was burned so badly that he died. Three others were knocked down by the force of the explosion.

INDUSTRIES PRODUCING COMBUSTIBLE DUST

COUNTRY GRAIN ELEVATORS.

Grain Elevator, Abilene, Kansas, August 12th, 1921.

A motor was enclosed in a poorly constructed non-standard enclosure. Considerable dust had collected in and about the motor. A poorly made connection at the terminals of the motor caused sufficient heat to ignite the dust. Flames passed out through the belt opening in the enclosure to the main plant and did considerable damage. The loss was $167.00.

Grain Elevator, Wessington Springs, South Dakota, October 17th, 1927.

A five horse power squirrel cage motor in the cupola of a grain elevator burned out due to accumulations of dust in the windings and ventilating ducts. The motor was found in flames and the fire was extinguished only after considerable effort. The cupola walls were badly damaged and the motor destroyed. The loss was $143.00.

Grain Elevator, Calamus, Iowa., September 27th, 1921.

A ten horse power single phase commutator type motor was mounted on a platform about 12 feet above the cupola floor of this fire resistive elevator. Circumstances indicated that dust had collected around the commutator and had been ignited by sparks from the brushes. This burning dust fell onto dust on the platform and destroyed the motor. The loss was $456.00.

Grain Elevator, Little River, Kansas, June 13th, 1926.

An unguarded portable electric light was left burning in a dump pit and the pit was filled with grain. This forced the light against a wood partition and a fire resulted. The loss was $15.00.

Grain Elevator, Oberon, North Dakota, May 18th, 1925.

The manager left an unguarded portable electric light burning in a pit. The next morning he found a fire smouldering in the pit which was easily extinguished. The loss was $10.00.

Grain Elevator, Capron, Oklahoma, October 31st, 1921.

An open squirrel cage motor in the cupola burned out from overload or insulation breakdown. The flames spread rapidly and caused the total destruction of the building and contents. The loss was $10,799.00.

Grain Elevator, Park Rapids, Minnesota, January 11th, 1921.

Several days before the fire electricians had replaced the brushes on a motor and in so doing had removed the enclosure from the motor and had not replaced it. Considerable dust accumulated on the motor and a spark from the brushes ignited the dust which fell to the floor igniting dust there. The flames then spread through the cupola but prompt action by employees prevented further damages. The loss was $164.00.

Grain Elevator, Dalton, Missouri, April 22nd, 1930.

A fifteen horse power single phase commutator type motor was enclosed in a sub-standard metal lined enclosure in the cupola of the elevator. A defective brush spring lodged against the rotor causing sparks and finally a fire which was just beginning to burn through

the enclosure when discovered. The fire was extinguished with water but the owners report that had it not been discovered when it was, the elevator would have been a total loss. The loss was $168.00.

Grain Elevator, Kingsley, Kansas, January 6th, 1930.

An open motor located in the cupola had accumulated so much dust that its ventilation was impaired. The motor was discovered in flames and prompt action with an extinguisher held the loss to $50.00. The motor windings were ruined.

Grain Elevator, Morrison, Iowa, January 10th, 1931.

A defective drop cord on a lighting circuit caused this fire according to the investigator's report. The elevator building and contents were a total loss in the amount of $7,016.85.

Grain Elevator, Clear Lake, Iowa, May 2nd, 1931.

An open squirrel cage motor in the cupola burned out during the afternoon, but was discovered and cooled with an extinguisher and the motor disconnected. Apparently dust about the motor was ignited and smouldered for the fire broke out early the following morning causing total destruction of buildings and contents with a loss of $8,637.00.

Grain Elevator, Marshfield, Wisconsin, March 21st, 1929.

A short circuit in undersize open conductor serving two fifteen horse power motors or an attrition mill caused the ignition of a frame wall. The flames followed the wall up to the roof, causing considerable damage. The loss was $1,905.00.

Grain Elevator, Lake Andes, South Dakota, December 1st, 1926.

A seven and one half horse power single phase motor was located in a substandard metal lined wooden room in the cupola. According to the report, the motor failed to start when the controller was thrown in, probably because of defective brush mechanism. When the operator went to the cupola to look for the trouble he discovered fire, and by the time help was summoned the flames had come through the walls of the motor room. Considerable damage to buildings and contents resulted before the fire was extinguished. The loss was $481.00.

Grain Elevator, Palmyra, Missouri, June 13th, 1929.

This fire was caused by the burning out of a twenty horse power open squirrel cage motor probably from dust accumulations in the motor or overloading. The loss was $131.00.

Grain Elevator, Java, South Dakota, April 13th, 1931.

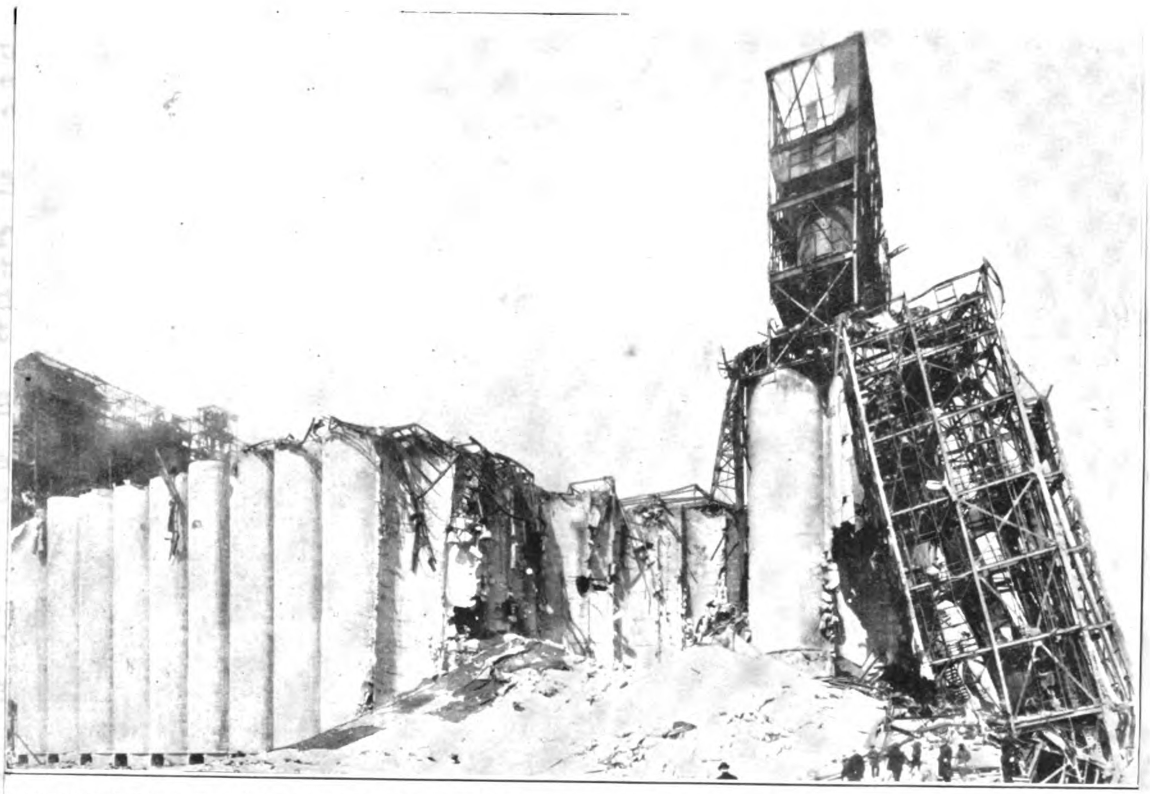
A single phase motor was being started by means of an open resistance type starter. At the same instant a dust explosion occurred damaging the building considerably and seriously butning three men. The loss was about $2,000.00.

Grain Elevator, Burdett, Kansas, 1931.

The odor of smoke was detected in the elevator at closing time, but, although a thorough search was made, no fire was discovered. The next morning the odor was more pronounced and after further search, dust accumulated in a pit was found to be on fire at a point directly under an unprotected electric light. Apparently, dust collected on the light bulb had ignited and dropped to the dust below.

Grain Elevator, Blackwell, Oklahoma, January 8th, 1920.

Two unprotected incandescent lights in the boot pit of the elevator were installed in a horizontal position. Dust which had collected on them became heated to the ignition point, dropped into the dust in the boot pit and caused fire. The flames spread and considerable damage resulted. The loss was $2,874.00.



DUST EXPLOSION IN A LARGE TERMINAL GRAIN ELEVATOR IN THE MIDDLE WEST. ALL THE SIX WORKMEN IN ELEVATOR AT TIME OF EXPLOSION WERE KILLED; PROPERTY DAMAGE OVER $3,000,000

<u>Grain Elevator</u>, Webster City, Iowa, October 27th, 1927.

An open squirrel cage motor was enclosed in a small frame box in cupola. The bearings of the motor were permitted to wear to such an extent that the rotor came in contact with the stator thus damaging the windings. This caused a fire which resulted in a damage loss of $114.00.

<u>Grain Elevator</u>, Belle Plain, Kansas, December 31st, 1926.

A five horse power single phase open type motor located in the cupola burned out, probably from breakdown of insulation. The cupola was practically destroyed before the fire was extinguished. The loss was $246.00.

<u>Grain Elevator</u>, Huntington, Indiana, October 18th, 1926

An open squirrel cage motor located in the cupola had burned out during the afternoon. The motor had been removed for rewinding at which time there was no evidence of fire. However, late that night fire broke out in the cupola, probably from a spark smouldering in accumulated dust, and total destruction resulted. The loss was $21,985.00.

<u>Grain Elevator</u>, Sleepy Eye, Minnesota, January 13th, 1925.

An open type motor in a substandard metal lined enclosure in cupola burned out and burst into flames. The operator summoned the fire department, but frozen hydrants rendered them helpless. The plant burned to the ground for a loss of $44,975.00.

<u>Grain Elevator</u>, Elk Mound, Wisconsin, October 1st, 1925.

A fire was located at a seven and one half horse power single phase motor in the basement and, although the operator thought that it had been extinguished, the fire spread rapidly and resulted in total loss to the building and contents in the amount of $5,089.00.

<u>Grain Elevator</u>, Danville, Kentucky, March 21st, 1928.

The resistance grids used in connection with a wound rotor motor became overheated, igniting nearby combustible equipment and construction. The loss was $187.25.

<u>FLOUR AND FEED MILLS</u>.

<u>Feed Mill</u>, South Bartonville, Illinois, January 1st, 1919.

An electric spark is given as the cause of an explosion and fire in the grinding and mixing plant. The estimated loss was reported as $750,000.00 to buildings and contents.

Feed Mill, Buffalo, New York, November 22nd, 1921.

An employee was using an improperly guarded portable electric light to inspect the interior of an elevator head which was not discharging properly. In some manner the steel buckets of the elevators struck the lamp, crushed the light wire guard and crushed the lamp. An explosion followed. The property loss was but $4,000.00.

Flour Mills, Czegled, Hungary, About twelve years ago,

The breaking of an electric light in a flour bin caused a flour dust explosion. Complete details could not be secured.

Feed Mill, Milwaukee, Wisconsin, Date not available.

A serious explosion of grain dust occurred which, according to the investigation, was caused by the breaking of a portable electric light.

Hogan Mill Feed Company, Kansas City, Missouri, August 22nd, 1930.

A dust explosion resulting from ignition of ground screenings and wheat scourings resulted in the death of two employees and injury to two others with property loss of $75,000.00 - a total loss. The cause was not definitely ascertained although first reports stated that the explosion occurred when a motor starting switch was thrown in.

Flour Mill, Crete, Nebraska, April 16th, 1923.

A two horse power open type motor burned out from unknown cause. The fire spread to surrounding equipment. The loss was $129.00.

Feed Mill, Waverly, New York, May 26th, 1923.

A double disc attrition mill was driven by two ten horse power open squirrel cage motors. An employee smelled smoke and looking up observed the attrition mill in flames and surrounded by smoke. Quick action with chemical extinguishers checked the fire. Both motors were found to have been burned out due, apparently, to overload. The overload relays did not operate. The loss was $180.00.

Flour Mill, Neodesha, Kansas, November 30th, 1921.

Indications point conclusively to a short circuit in substandard electric light wiring as the cause of this fire. The loss was $21,971.00.

Flour Mill, Crookston, Minnesota, July 8th, 1924.

A direct current motor was enclosed in a substandard enclosure which permitted considerable dust to collect in the motor. The motor

burned out or a spark from the brushes ignited the dust in the enclosure and the fire spread causing considerable damage. The loss was $1,211.00.

Flour Mill, Shelbyville, Indiana, January 23rd, 1928.

Defective electric light wiring of the open knob and tube type is reported to have caused this fire. The loss was $969.00.

Feed Mill, Russellville, Kentucky, November 28th, 1927.

All evidence points to improperly installed open power wiring as the cause of this fire which practically completely destroyed the building and cotents. The loss was $8, 696.00.

Feed Mill, Byesville, Ohio, July 13th, 1930.

A short occurred in a run of steel armored cable in the basement of the mill. The original installation light wiring was in rigid conduit, but this armored cable was an extension to the original job. Three holes were found burned through the cable by the arc. The fire burned through the first floor and caused heavy damage to buildings and contents with a loss of $5,407.72.

Feed Mill, Noy, Ohio, May 15th, 1930.

A motor driving a hammer mill burned out and when discovered was in flames. It is reported that the motor was not overloaded and that the overload relays and bearings were in proper order. It is probable that the burnout was caused by breakdown of the insulation due to dust accumulations. The loss was $200.00.

Feed Mill, Hannaford, North Dakota, October 5th, 1931.

A small open squirrel cage motor burned out and set fire to nearby construction and dust in several places. The fires were thought extinguished and the motor replaced. The next day the fire broke out anew and caused practically total destruction of the mill and attached buildings. The loss was $19,580.00.

Flour Mill, Toledo, Ohio, April 5th, 1929.

A defective electric light socket ignited a pile of flour in paper sacks causing considerable damage to flour. The loss was $231.00.

Feed Mill, Huron, South Dakota, May 30th, 1929.

All indications point to this fire as having been caused by an overloaded 40 horse power open squirrel cage motor. The fire brde out while the men were at lunch and was beyond control when discovered. The motor had been "running hot" previous to the fire. The loss was $18,840.00.

<u>Feed</u> <u>Mill</u>, Noble, Illinois, May 29th, 1929.

This fire is reported to have originated at the service switch cabinet of the electric power installation. Trouble had been experienced from the blowing of the transformer primary fuses so it seems probable that there was a short circuit in the cabinet or wiring. The building and contents were a total loss amounting to $13,036.00.

<u>Feed</u> <u>Mill</u>, Springield, Illinois, May 27th, 1927.

A fifteen horse power three phase open type squirrel cage motor was operating "single phase" due to the blowing of a fuse in one of the circuit wires. This caused the motor to heat and finally burst into flames. Prompt action with extinguishers saved the plant from destruction. The loss was $261.00.

<u>Flour</u> <u>Mill</u>, Wichita, Kansas, April 30th, 1929.

A 100 horse ppwer motor located in a standard metal lath and plaster motor room burned from unknown cause. The fire was confined entirely within the motor room, the damage being to belting, motor room vents and similar parts. This demonstrates the value of a standard motor room. The loss was $138.00.

<u>Flour</u> <u>Mill</u>, Yakima, Washington, December 7th, 1926.

A seventy five horse power 2200 volt motor with its control equipment was located in a standard metal lath and plaster enclosure. The fire originated in an oil circuit breaker and intense heat was generated. However, the fire was confined to the interior of the enclosure until the fire department was called and the flames extinguished. The fact that the loss was but $311.00 demonstrates the value of locating electrical equipment in standard rooms.

<u>Flour</u> <u>Mill</u>, Lawrence, Kansas, April 13th, 1930.

The night superintendent lowered a portable light into a metal flour bin. As he did so a dust explosion occurred burning him about the arms and face. The top was blown from the bin and dust was scorched for a distance of 30 feet from it. The resulting fire spread to several separated sections of the plant through screw conveyors and opened nine sprinkler heads in the frame elevator building. The lamp unit which was recovered was found to be of unapproved type consisting of a brass shell socket, a wooden handle, and wire guard. The light bulb was intact after the explosion, so it was apparent that the explosion was caused either by a defective socket or a ground to the metal guard. The loss was about $925.00.

Feed Mill, Liverpool, England, November 24th, 1911.

In this dust explosion thirty nine persons lost their lives and one hundred and one others were injured. According to the reports a drive belt broke and caused a dense cloud of dust to tbe thrown into suspension. This dust, it is reported, was ignited by the blowing of a fuse on a temporary switchboard in the hazardous area.

Feed Mill, Chicago, Illinois, February 3rd, 1929.

The plant manager visited the plant at 11:00 oclock A. M. Sunday morning and found it filled with smoke. The fire department was summoned and located the fire in an elevator boot pit which was filled with ground tankage. Immediately over the pit hung an unprotected incandescent electric light. It is apparent that the fire was started by burning dust falling from the light into the tankage. The loss was $50.00.

TERMINAL GRAIN ELEVATORS.

Grain Elevator, Akron, Ohio, December 2nd, 1913.

An employee was examining the interior of an elevator leg, using a portable light to enable him to see. Details are not clear as to whether or not the lamp caused the explosion. However, the explosion occurred in the elevator leg which was being examined after after the explosion the lamp was found to have been burned out. No lives were lost and the property loss was confined to damaging the leg.

Terminal Grain Elevator, Kansas City, Missouri, Sept. 13th, 1919.

Fourteen men were killed, ten injured and property in the amount of $500,000.00 was destroyed in this explosion. All evidence indicated that it originated in the basement of the elevator near the receiving legs where men were engaged in cleaning. It is suspected that the source of ignition was furnished by defective electrical devices such as substandard extension cords or unprotected electric lights or switches. The exact cause could not be discovered.

MISCELLANEOUS
(Sugar, Starch, Etc.)

Starch Factory, Argo, Illinois, March 12th, 1919.

Two men were seriously injured in an explosion which followed when a portable light lowered into a starch bin was broken. The property loss was not large.

Sugar Refinery, Chicago, Illinois, June 16th, 1920.

An arc from an electric switch which ignited the sugar dust in the air is assigned as the cause of an explosion in the sugar pulverizing section. Fire following caused considerable damage.

Rubber Recovery Plant, Muskegan, Michigan, August 18th, 1920.

In this plant hard rubber scrap was first broken up into small pieces, then pressed between steam heated rollers and finally pulverized. Large quantities of fine dust was produced. An explosion of this dust occurred in which eight men lost their lives and one was seriously injured. Property was damaged to the extent of $25,000.00. All evidence as to the origin of the spark which ignited the dust was destroyed, but one of the sources advanced by the investigation was the breaking of an electric light.

COMBUSTIBLE FIBERS

COTTON MILLS.

Cotton Mill, East Newark, New Jersey, April 28th, 1927.

An operator had thrown a switch to start a motor driving a ring spinning frame when an electric arc occurred blowing off the cover of a fuse box and ignited the operators clothing and the lint and banding on five adjoining frames. The employee died from his burns. Loss $300.00.

Cotton Mill, Lancaster, South Carolina, December 15th, 1926.

A short circuit in an oil switch started a fire which damaged three cards, although it was extinguished by a single automatic sprinkler. Damage was $217.00.

Glove Lining Factory, Fonda, New York, May 28th, 1927.

In the "mule" spinning room the electric lights hung by ordinary suspension cords from the conduit. The cover of an outlet box was accidently detached by a drive belt and the sharp edges of the cover wore the insulation from the cord until a short circuit occurred. This ignited the lint accumulated on the cord and fire dropped to the mule carriage below and to the floor. The total fire and water damage was estimated at from $9,000.00 to $10,000.00, and the use and cocupancy insurance loss at between $2,500.00 and $3,000.00.

Textile Mill, Newton, New Jersey, October 23rd, 28th, 1931.

A weaver suddenly discovered that a fire had started in a Jacquard loom about which there was considerable fine lint. The fire spread rapidly, but the operation of automatic sprinklers checked the fire, though not until loom harbesses, cylinders, warps and cloth had been damaged to the extent of $1,100.00. Five days later a similar

fire occurred, but the damage was held to less than $500.00. The reports state that both of these fires were started by defective electric light cords or by a spark from the electric warps stop-motion.

MATTRESS FACTORIES.

Mattress Factory, Derry, N. H., May 22nd, 1929.

The fire was caused by ignition of loose flammable stock by an arc from an electric motor driving a sewing machine located between two mattress forming machines. Fire flashed rapidly over floor causing the death of an elderly woman. Property loss was $30,000.00.

Bedding Factory, St. Paul, Minnesota, January 17th, 1927.

The greatest single fire loss on record in St. Paul involving a loss of $600,000.00, originated in a bedding factory. While the fire was not of electrical origin, the circumstances emphasize the need for every care in preventing sparks from any cause whatever in or about places where cotton is handled or stored. In this case it is believed that the spark came from a piece of metal passing through the rolls of a carding machine. Suddenly, as the "camel back" of the machine operated, flames burst out on its under side. The flames spread so rapidly from the carding machine to baled cotton in the room that one of the operators of the carding machine who attempted to fight the fire was not able to escape from the building before he was so badly burned that he was forced into hospital confinement for two months, and will probably be partially disabled for the remainder of his life. The building was practically totally destroyed and considerable damage resulted to dwellings in the neighborhood. The raw material in a plant of this type is very flammable, and the type of process is usually such as to coat everything in the plant with fine lint or dust of an easily ignitable nature. The slightest spark, arc or molten metal coming into contact with this material will cause an immediate flash fire more like an explosion in speed of propagation than a fire.

BAG FACTORIES.

Bagging Factory, New Orleans, La., September 2nd, 1929.

This factory was engaged in working over old burlap bags, scrap gunny, etc., into bagging material. This material was run through pickers in the picker room where it was reduced to a fluffy material (jute shoddy), and then conveyed by air to a condenser. Under each condenser was a hopper which discharged the fiber to a belt which carried the fiber to the carding machines. It is reported that an unprotected portable electric light was hung in the hopper under the condenser while some adjustments were being made. It appears that this lamp was in some manner broken and the flash ignited the fiber on the conveyor. The machinery was shut down thereby averting a heavy loss. The damage to the machines was estimated at $3,000.00.

Bag Factory, New Orleans, La., November 9th, 1927.

Several workmen were inside a drier, used for drying sugar sacks, repairing a blower fan. A portable light equipped with a cheap wire guard was accidently dropped. The light was broken by the fall and the resulting flash ignited accumulated lint resulting in a small flash fire within the dryer. The damage was small.

MISCELLANEOUS (Hosiery Mills, etc.)

Hosiery Mill, Philadelphia, Pa., April 8th, 1927.

An employee started a motor driving a fan connected with a hosiery drybox and in so doing an arc at the rheostat ignited greasy lint. The fire spread was but extinguished by workmen. The loss was estimated at from $200.00 to $400.00.

Hosiery Mill, Macon, Georgia, December 17th, 1926.

Sparks from a switch controlling the card room motor ignited accumulated cotton lint clinging to the wall. The fire flashed up through an old elevator tower and into the attic. Automatic sprinklers held the fire in check, but when the fire department responded considerable water was thrown into the building causing heavy water damage. The loss was estimated at from $2,000.00 to $4,000.00.

Carpet Factory, Thompsonville, Conn., February 11th, 1930.

While a repairman was making repairs on a Jacquard loom, he dropped a wrench which broke an unprotected electric light bulb. The hot filament ignited lint and fire flashed over the loom. It was extinguished by prompt action of automatic sprinklers before it spread to other looms. The loss was about $2,250.00.

Telephone Factory, Kearney, New Jersey, January 27th, 1932.

An accumulation of lint on a braiding machine used for making telephone cord was ignited by a spark from a broken wire in an electric "stop-motion" device. The fire flashed over twenty of the braiding machines before being extinguished, resulting in a loss estimated at $3,000.00.

Textile Mill, York, Pa., December 18th, 1931.

An electrician had removed the motor from a Jacquard loom and failed to tape the ends of the circuit conductor. Several days later a workman closed the circuit switch not knowing that the motor had been removed. An arc occurred at the loose ends of the conductors and ignited lint on the loom and the flames spread to the harness

and cards. The fire was extinguished by sprinklers and first aid equipment, but damage resulted to the extent of about $850.00.

Textile Mill, Shamokin, Pa., December 16th, 1931.

A weaver heard falling glass and looking up saw fire in a nearby Jacquard loom. The cause was determined to be from an arc caused by a worn pendant cord coming into contact with a grounded steel beam. The cord had been in contact with the beam and the vibration had caused the cord to be worn until the bare conductors were exposed. The fire was extinguished by sprinklers, but fire and water damage was estimated at between $10,000.00 and $15,000.00.

WAREHOUSES.

Terminal Cotton Warehouse, New Orleans, La., June 5th, 1919.

This fire was caused by the breaking of one of the cast iron collector shoes on an electric crane and short circuiting the collector rail. A slight arc resulted and molton metal fell on a quantity of baled cotton ten feet below, igniting some loose lint. The fire was discovered promptly and the damage confined to five bales of cotton. Two fires of similar type caused by defects originating in the crane current collectors occurred in this same warehouse on March 10th and 16th, 1916. The first resulted in a loss of about $1,000.00 and the second in a loss of about $2,500.00.

PAPER MILLS

Paper Mill, North Chattanooga, Tennessee, February 29th, 1928.

Sparks from a short circuit in a two piece plug connector in a portable cord connected to a portable electric elevator in a paper warehouse ignited loose paper. A fireman was suffocated in fighting the fire. Loss $43,344.00.

Paper Mill, Kalamazoo, Michigan, May 27th, 1931.

Fire originated in a section of the plant where waxed paper was prepared. A spark from a short circuit in an overhead uncovered junction box ignited bales of waste waxed paper. The blaze was held in check by automatic sprinklers and finally extinguished by firemen. The loss was nearly $700.00.

WOODWORKING PLANTS

Woodworkers (Dust Hazard)

Veneer Factory, Rhinelander, Wisconsin, Date not available.

Directly over the center of a long wooden dry box hung a pendant light. The cord rested against a top member of the box in such

fashion that the vibration caused the cord to wear until finally a short circuit occurred and a small flame passed up the cord. An employee attempted to extinguish the fire, but in doing so he stirred into suspension accumulations of wood dust which in turn were ignited. This produced other dust flashes and the entire plant was destroyed. The employee's clothing was burned before he made his escape, an indication of the rapidity with which the flame spread.

This photograph illustrates the effects of an explosion of gasoline vapor in a bulk oil station pump house in Wichita, Kansas. The vapors were ignited by the arc from an ordinary enclosed knife switch used to control an open single phase motor.

This circular was prepared by the writer following a disastrous flour dust explosion. Eight thousand of these were distributed to mills and elevators throughout this country and Canada.

LIGHT BULB CAUSES BLAST IN OMAHA MILL

One Man Fatally Injured When Dust Explosion Wrecks Packing Department of Nebraska Consolidated Mills Co.

OMAHA, NEB.—The packing department of the 1,000-bbl plant of the Nebraska Consolidated Mills Co. in Omaha was wrecked by a dust explosion on Dec. 18, fatally injuring Orval Walker, chief clerk, and entailing a loss of nearly $100,000.

Floyd Woosley, chemist; Miss Oliver Simon and George Buetow, office employees, suffered burns but were not seriously injured. Mr. Woosley was hurled from the building by the blast. Arthur W. Glade, general superintendent, was changing clothes in a dressing room and was blown, trouserless, to the street, but was not severely hurt.

Have You Taken Precautions to Prevent This Happening in ..Your Plant..

?

View to left is from a photograph taken after the explosion and fire.

The portion in ruins was a two story frame iron clad packing department attached to the mill building. Heavy damage also occurred to the mill and its equipment.

Here Is The Story

DURING the early afternoon of December 18, 1931, a terrific explosion followed by fire occurred in the packing department of the Nebraska Consolidated Mills at Omaha, Nebraska. The packing building, a two story frame iron clad structure, was practically totally destroyed and considerable damage was done to the mill and other attached buildings. The accompanying photographs show clearly the effects of the explosion.

One Man Dead and Seven Injured

is the toll taken by this accident. The operator of the packer, referred to on the opposite page, was blown upwards and onto the roof of the adjoining mill building from which the firemen rescued him. His injuries were so serious that he died twelve hours later Several of the injured were buried under the debris.

The view to the right illustrates the effects of the explosion. Note how the roof and walls were completely blown out. Neighbors report that the blast rocked their houses.

That flour dust has explosive qualities approaching that of dynamite cannot be doubted after seeing what flour dust did in this instance.

The Damaged Property Can Be Replaced But Lost Life Never!

What Caused It?

THE operator of a flour packer wished to determine what quantity of flour remained in the steel bin over his packer. He used a portable electric light on an extension cord to enable him to see the interior of the bin. As he lowered the light into the bin the lamp was broken and there followed a terrific explosion, the effects of which are so well illustrated in this circular.

The portable light assembly was found after the explosion and although the rubber cord was burned somewhat by the fire, the socket and a portion of the lamp remained as proof that—

The Lamp Was Not Equipped With a Guard!

HERE ARE THE REMAINS OF THE CORD, SOCKET AND LAMP

Note the fragment of lamp still in the socket and no evidences of a guard ever having been attached. Also note the ordinary key type brass shell socket which is in itself unsafe for use with portable lights in dusty locations. The cord, itself, however, is of the correct type.

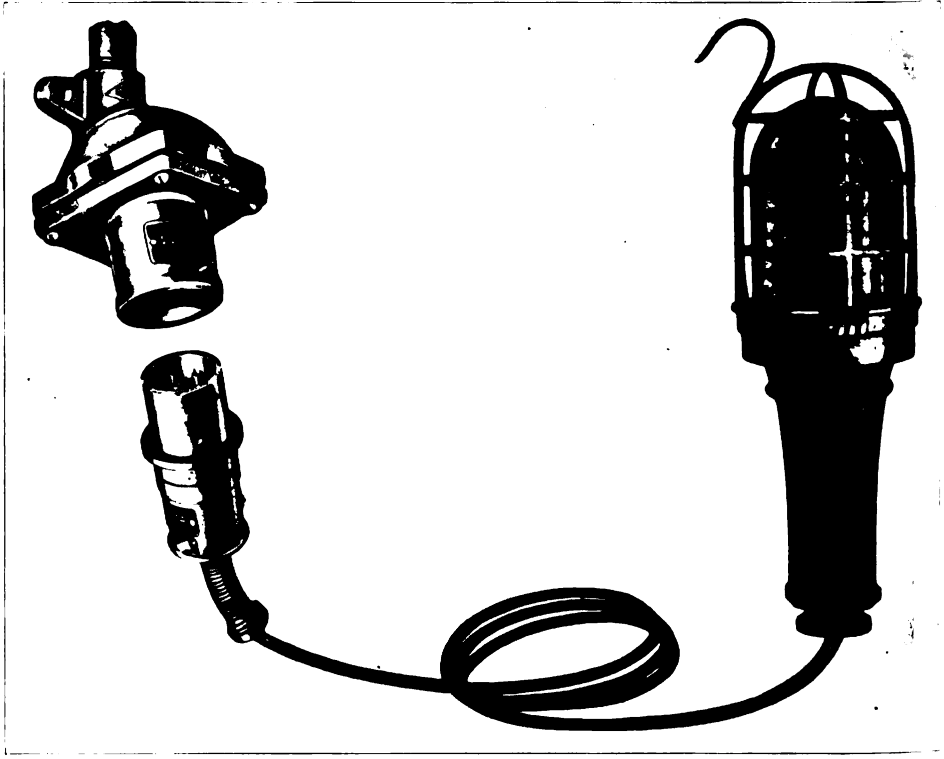
Unguarded Electric Lights in Dusty Locations Are Serious Hazards

The Lessons Taught

FIRST, we are again shown that flour dust in suspension and mixed with air in proper proportions constitutes a perfect setup for a terrific explosion. All that is needed is a tiny flash or spark to ignite the mixture. In this case the flash incidental to the breaking of an electric lamp was sufficient to cause destruction.

Second, this explosion illustrates the absolute necessity of properly guarding all electric lights in dusty locations, but more especially, portable lights. A proper portable light unit consisting of a keyless socket of proper construction, a dust tight globe, and a substantial guard made up into a single assembly should be adopted for all dusty locations. Only heavy rubber jacketed cord, known as Type S, should be used. The various cotton covered cords are distinctly unsafe. An excellent portable unit, cord, attachment plug and receptacle are illustrated below.

To the right is illustrated an excellent type of portable light assembly. Note that the socket, dust tight globe and guard, with handle is made up into a convenient unit. Also note that cord is of the heavy rubber jacketed Type S, rugged and long wearing. The receptacle and plug are well adapted to use in mills and elevators.



Properly Guard the Lights in Your Plant Before it Is Too Late!

For advice or assistance in making your plant lighting safe, write your Mill Mutual insurance office.

THE MILL MUTUALS

Mutual Fire Prevention Bureau

230 East Ohio Street , , , , CHICAGO, ILLINOIS

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Construction and Operation of Pyroxylin Lacquer Manufacturing Plants
Installation of Blower and Exhaust Systems
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Outline for Examination and Test of Explosion-Resisting Electrical Fittings for Use in Hazardous Locations
Standard for Construction and Performance of Power-Operated Discharge Devices
Standard for Electric Motors for Use in Hazardous Gas or Vapor-Air Atmospheres - 30 HP or Less
Report on Propogation of Flame in Pipes and Effectiveness of Arrestors

ROOM USE ONLY