Baldor Motor Basics — Part 10
How to Select Motors for Hazardous Locations

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A continuing series of articles, courtesy of the Baldor Electric Co., dedicated primarily to motor basics; e.g. — how to specify them; how to operate them; how — and when — to repair or replace them, and considerably more.

Failure to specify the proper motor for use in a hazardous location can have serious consequences — lost production, extensive property damage, and even loss of human life. Selection of the proper motor requires an understanding of Underwriters Laboratories' (UL) and National Electrical Code (NEC) class, group and division designations and the T code letters.

In some plant engineering departments there may be only a vague understanding of the selection criteria of motors for hazardous locations. In some cases the specifier passes the buck to another party in the hope that someone — perhaps the motor manufacturer — will fill in the missing specification data. In other cases, the same type of motor that had been used in the plant previously is specified, with the hope that this approach will certainly handle any situation. But this approach can greatly increase the cost of the project, and, in some cases, result in a motor inadequate for the application.

Hazardous locations are operating environments in which explosive or ignitable vapors or dust is present, or is likely to become present. Special motors are required to ensure that any internal fault in the motor will not ignite the vapor or dust. Requirements for electrical installations in hazardous locations are covered in Articles 500, 501, 502, 503, 510, 511, 513, 514, 515, and 516 of the *National Electrical Code*.

A relatively new Article 505 makes an abrupt change in traditional hazardous location requirements and brings the NEC closer to the somewhat less stringent European code requirements by classifying areas into three separate zones, i. e. — 0, 1 and 2. This section tends to involve wiring practices and components, rather than motors, so it will not be included in the discussion to follow.

At the present time, Article 505 sets forth some principles, but it will be some time before equipment suppliers will have products available to match the new requirements. We can also expect the "inertia of habit" to slow the change to the somewhat relaxed zone requirements. Perhaps the changes will be used first by multinational companies where engineers are more familiar with the zone system and matching hardware.

The term "explosion-proof" is often erroneously thought to apply to any hazardous-location motor.

Explosion-proof motors, however, are only those approved for Class I locations; that is, where potentially explosive gases or vapors are present. A Class I unit is constructed to contain an explosion within itself without rupturing. After the initial pressure buildup on ignition, the hot gas is forced to cool by passing through long, tight passageways (flame paths) before escaping from the motor. The temperature of gas escaping from the motor will then be below the minimum ignition temperature (MIT) of the gases of vapors in the atmosphere surrounding the motor.

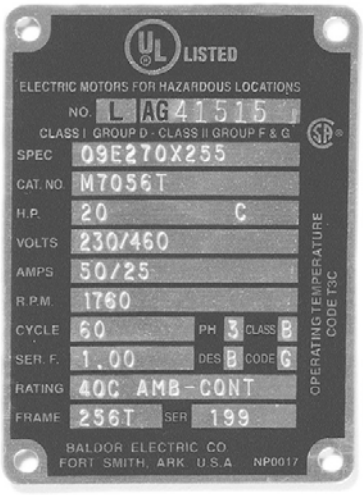

Figure 1 An Underwriters Laboratory (UL) nameplate is used on all motors approved for use in Division 1 hazardous locations. In addition to the normal motor data such as horsepower, speed, voltage, amperage, NEMA code letter, etc. it also shows the specific class(es) and group(s) for which the motor is approved. In the example shown the motor is approved for Class I Group D and Class II Groups F and G. The T code is also indicated.

Meaning of Motor "Class" Designations

Every motor approved for hazardous locations carries an Underwriters Laboratories (UL) nameplate that indicates the motor is approved for hazardous locations (see illustration). This nameplate identifies the motor as having been designed for operation in Class I or Class II locations' some motors may be approved for *both* Class I and II locations.

Basically, the class identifies the physical characteristics of the hazardous materials present at the location where the motor will be used. Class I covers gases, vapors, or liquids that are explosive or else pose a threat as ignitable mixtures. A familiar example of a Class I material is gasoline. It is explosive as a vapor and ignitable as a liquid. Some of the most common Class I substances are listed in Table 1.

Class II covers dusts — specifically, dust in amounts sufficient to create explosive mixtures, and dusts that are electrically conductive. A prime example of a hazardous dust is wheat flour. As a compact mass, flour burns or smolders; but when it is finely distributed in air, it is highly explosive. Also included in Class II are electrically conductive metallic and nonmetallic dusts, such as powdered aluminum and magnesium, and pulverized coal. Aluminum and magnesium dusts can burn violently even when not suspended in air; but when airborne, they are explosive. Some common Class II substances are listed in Table 2.

Table 1 Class 1 substances and atmospheres	
Substance or Atmosphere	**Minimum Ignition Temperature**
Group A	
acetylene	305°C (581°F)
Group B	
butadiene	420°C (788°F)
ethylene oxide	570°C (1058°F)
hydrogen	500°C (932°F)
Group C	
acetaldehyde	175°C (347°F)
cyclopropane	498°C (928°F)
diethyl ether	180°C (356°F)
ethylene	450°C (842°F)
isoprene unsymmetrical dimethyl hydrazine	395°C (743°F)
(UDMH) 1, 1-dimethyl hydrazine)	249°C (480°F)
Group D	
acetone	465°C (869°F)
acrylonitrile	481°C (898°F)
ammonia	651°C (1204°F)
benzene	498°C (928°F)
butane	287°C (550°F)
1-butanol (butyl alcohol)	343°C (650°F)
2-butanol (secondary butyl alcohol)	405°C (761°F)
n-butyl acetate	425°C (797°F)
isobutyl acetate	421°C (790°F)
ethane	472°C (882°F)
ethanol (ethyl alcohol)	363°C (685°F)
ethyl acetate	426°C (800°F)
ethylene dichloride	413°C (775°F)
gasoline	280°C (536°F)
heptane	204°C (399°F)
hexane	225°C (437°F)
methane (natural gas)	537°C (999°F)
methanol (methyl alcohol)	464°C (867°F)
3-methyl-1-butanol (isoamyl alcohol)	350°C (662°F)
methyl ethyl ketone	404°C (759°F)
methyl isobutyl ketone	448°C (840°F)
2-methyl-l-propanol (isobutyl alcohol)	415°C (780°F)
2-methyl-2-propanol (tertiary butyl alcohol)	478°C (892°F)
octane	206°C (403°F)
petroleum naphtha	288°C (550°F)
1-pentanol (amyl alcohol)	300°C (572°F)
propane	450°C (842°F)
1-propanol (propyl alcohol)	412°C (775°F)
2-propanol (isopropyl alcohol)	399°C (750°F)
propylene	455°C (851°F)
styrene	490°C (914°F)
vinyl acetate	402°C (756°F)
vinyl Chloride	472°C (882°F)
p-xylene	528°C (984°F)

Class III locations do not normally require hazardous-location motors. Specifying a hazardous location motor for Class III locations is a common error. Section 503-6 of the NEC permits a totally enclosed fan-cooled or non-ventilated motor to be used in Class III locations. A totally enclosed motor can be purchased at lower cost than a motor approved for hazardous locations. NEC Section 503-6 also allows the use of an open drip-proof motor in Class III locations, if the inspection authority is satisfied that proper housekeeping will be maintained. Class III locations are those where easily ignitable fibers and "flyings" are likely to be present. Such substances are commonly encountered in the textile, woodworking, and plastics industries. Class III materials are not normally airborne, because they are fairly heavy and settle rapidly. They are, however, quite flammable, and, therefore, create a potentially hazardous condition when near electrical equipment. Common Class III substances are listed in Table 3.

Meaning of "group" designations. Within Class I and Class II, Group designations are assigned to various combustible substances on the basis of their behavior after ignition. Group designations A through G are arranged in descending order according to the stringency of motor design requirements; Group A requirements would require the longest flame paths and tightest fits. Groups A through D fall within Class I, and Groups E, F, and G fall within Class II. Class III materials are not broken down by group.

Gasoline and acetylene provide an illustration of the group concept. Both are Class I substances. Acetylene is designated as a Group A substance, gasoline falls within Group D. MIT of automotive gasoline is 280°C (536°F), slightly below the 305°C (581°F) MIT of acetylene. An acetylene explosion, however, is more intense than a gasoline explosion, so acetylene is grouped well above gasoline.

Table 3 Class 3 substances (no groups assigned)	
Ignitable Fibers or Flyings	
Rayon	Cotton
Sawdust	Sisal
Henequen	Istle
Jute	Hemp
Tow	Cocoa fiber
Oakum	Baled waste kapok
Spanish moss	Excelsior
(and other materials of similar nature)	

Table 2 Class II substances		
Group	**General definitions**	**Examples**
E	Metallic dusts	Dusts of aluminum, magnesium, their commercial alloys and other metals of similarly hazardous characteristics
F	Electrically conducting non-metallic dusts	Coal dust Pulverized coal Pulverized coke Pulverized charcoal Carbon black and similar substances
G	Electrically non- conducting dusts	Grain dusts Grain product dusts Pulverized sugar Pulverized starch Dried powdered potato Pulverized cocoa Pulverized spices Dried egg and milk powder Wood flour Oilmeal from beans and seeds Dried hay and other products producing combustible dust when dried or handled and other similar substances

It is a common misconception that Class I transcends Class II and that a Class I motor will automatically satisfy any Class II requirement. But, a Class I motor is designed primarily to confine the effects of an internal motor explosion. Design is based on the assumption that, over a period of time, normal heating and cooling will cause the motor to breathe the surrounding atmosphere, and the atmosphere within the motor will, eventually, become the same as that of the operating environment. A subsequent internal fault can, therefore, cause an explosion within the motor.

A Class II motor, however, is designed to maintain the motor's surface temperature at a level such that Class II materials in the motor operating environment will not be heated to their MIT. If the operating environment contains both Class I and Class II substances, a dual-rated Class I/Class II motor must be specified.

Another common misconception is that because the Classes and Groups exist — then there should be suitable products (motors or other equipment) to operate in the defined environment. As it turns out, Classes and Groups are used for all types of equipment including enclosures, light fixtures, heating elements, operator devices, etc. But just because there is a definition it doesn't mean that a matching product is available. In the case of motors this is especially true for Class I Groups A and B. Apparently the market for motors to operate in these environments is so limited — and the designs so difficult — that most manufacturers do not make them.

The most common hazardous location motors are made for Class I Group D and Class II Groups F and G. Several manufacturers can build motors for Groups C and E but they are normally made on a special order basis.

Meaning of "division." Hazardous locations are further broken down into Division 1 and Division 2. The distinctions are defined in detail in Article 500 of the NEC. Simply stated, a Division 1 location is one in which ignitable substances are likely to be present continuously or intermittently in the course of normal operations. In a Division 2 location, ignitable materials are handled or stored in a manner that allows the combustible substance to escape in the event of spill, accident, or equipment failure.

For a complete list of Class I materials refer to NFPA 325 — "Guide to Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids."

Division distinctions are concerned primarily with installation procedures required by the NEC. Class I and Class II motors for hazardous locations have no Division designation on the UL label. All Class I and Class II motors are designed to meet Division 1 requirements and are, therefore, suitable for installation in both Division 1 and Division 2 locations.

Hazardous-location motor T codes. All motors manufactured after February 1975 carry a T code designation (Table 4). The T code identifies the maximum absolute motor surface temperature that will be developed under all conditions of operation, including overload up to and including motor burnout. The T code designation of the motor must be correlated with the Minimum Ignition Temperature (MIT) of the substances in the motor's operating environment.

The presence of acetone or gasoline, for example, will affect motor selection. Acetone and gasoline are both Class I, Group D materials. Acetone has an MIT of 465°C (869°F) (Table IV) indicates that a motor with a T1 rating (450°C maximum surface temperature) would be acceptable for operation in an acetone environment.

Gasoline, however, has an MIT of 280°C (536°F). For operation in an environment containing gasoline, no less than a T2A motor, designed to develop a surface temperature no greater than 280°C, should be specified (Table 4). Although T codes and ignition temperatures are conservatively assigned and are based on "worst case" testing procedures, an extra margin of safety should be provided by specifying a T2B or higher T rated motor, designed to develop a maximum surface temperature of 260°C (500°F).

Meeting some of the lower temperature T Code requirements necessitates the use of automatic thermal overload devices (fractional horsepower motors) or normally closed (NC) winding thermostats in larger (integral horsepower) motors.

Winding thermostats are control devices with relatively low current capacity. They have to be connected to the motor's magnetic starter to cause it to interrupt power to the motor when the internal temperature gets too high. Failure to make the required "CONTROL CIRCUIT" connection will negate the motor nameplate T Code rating.

In a motor designed for Division 1 use, the winding thermostats are mounted inside the frame's flame path. On Division 2 motors, such a construction is not used, so thermostats and any other accessory must be intrinsically safe as discussed in IEEE 303. "Recommended practice for Auxiliary Devices for Rotating Electrical Machines in Class I, Division 2 and Zone 2 locations".

Use with inverter power supply. Unlike standard motors which can readily be used with Adjustable Speed Drives, motors used in Division 1 and 2 locations need specific certification and marking indicating suitability for the specific class and group, speed range and constant or variable torque. Most manufacturers have a specific family of Inverter Duty Explosion Proof motors suitable for Division 1 or 2 locations. Standard motors that are suitable for Division 2 use may be

Table 4 T codes and their associated temperatures

T Number	Maximum motor surface temperature	
	°C	°F
T1	450	842
T2	300	572
T2A	280	536
T2B	260	500
T2C	230	446
T2D	215	419
T3	200	392
T3A	180	356
T3B	165	329
T3C	160	320
T4	135	275
T4A	120	248
T5	100	212
T6	85	185

name plated with their speed capabilities. Intrinsically Sate Auxiliary devices must be used.

Additional sources of information. In addition to the NEC, three other publications of the National Fire Protection Association (NFPA) (*NFPA publications can be obtained from National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.*) will be helpful in selecting the proper motor. NFPA publication 325, mentioned previously, covers the properties of hazardous liquids, gases, and volatile solids, and provides a more comprehensive listing of hazardous substances than does Table 1. NFPA 497 —"Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas" will help classify installations and areas. NFPA 499 — "Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas" covers Class II substances. Each publication provides MIT's for the substances covered in the respective publications.

The field service representative of the plant's insurance underwriter can also provide advice when there is uncertainty as to what type of motor is required for a particular hazardous-location application. **PTE**

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