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INTRODUCTION

The following is an attempt to explain in reasonably simply terms the criteria that should be taken into consideration when making a decision on the selection and application of electric motors in "hazardous" locations.

It is not intended, and should certainly not be interpreted, as a definitive or all embracing thesis on the subject. Hopefully, however, it will prove to be of assistance to those who, while having no reason or inclination to become involved with the scientific and engineering concepts and principles of explosion prevention or containment, do by virtue of their work, purchase or use motors destined for this type of application.

HAZARDOUS AREAS

Hazardous "areas" are defined b the nature, presence and physical characteristics of the potentially flammable or explosive material.

There are two "classes", 1 and 2, and three "zones" (formerly know as "divisions"), 0, 1 and 2.

Class 1 indicated that the hazardous material in question is a gas (or vapour). Every flammable gas has its own particular ignition temperature and its own degree of volatility or explosiveness. These characteristics are covered later under "Temperature Classifications" and "Gas Groups" respectively.

Class 2 indicates that the hazardous material is a dust (or fine fibre). Almost any dust, under certain conditions, can represent a potentially explosive situation, even if the dust particles are of a substance that is normally considered to be non-combustible. The main factors that contribute to an explosive dust-air mixture are the dust particle size, the conductivity of the material and the concentration of the dust in the air (grams per cubic metre).

Zone 0 indicates that the flammable substance may be present continuously during the normal operation of the equipment. Rotating or switching electrical equipment is not permitted in such areas and zone 0 is therefore not relevant to equipment driven by electric motors.

Zone 1 indicates that the flammable gas or dust laden air may be present in the vicinity of the equipment concerned for short periods of time during normal operation.

Zone 2 indicates that the flammable material will not be present during the normal operation of the equipment and that if it is present, it would be so for only a short period of time (eg. due to a leaking valve or some other malfunction of nearby equipment).

It can be seen form the above that the four basic conditions relevant to our topis are:

Class 1 Zone 1

Class 1 Zone 2

Class 2 Zone 1

Class 2 Zone 2

Note: Classes and Zones are often expressed in Roman Numerals, ie Class I and Zone II.

TEMPERATURE CLASSIFICATIONS

An obvious and very important consideration when installing equipment in a Hazardous location is the ignition temperature of the flammable material, ie the lowest temperature at which the gas or dust-air mixture can spontaneously ignite.

Rather than allocate a multitude of different temperature limitations with which equipment must comply, these limitations are grouped into six temperature "Classifications" as follows:

T1-450 deg C	T4-135 deg C
T2-300 deg C	T5-100 deg C
T3-200 deg C	T6- 85 deg C*

*There are only two known gases which require a T6 Classification, Carbon Disulphide and Ethyl Nitrate.

To illustrate with an example, if a particular gas has a flash-point of 185 deg C, it would be given a Temperature Classification of T4, and any equipment operating in an area which may be subject to the presence of this gas would have to comply with this requirement. That is to say, any equipment or component that could come into contact with the gas (sometimes including internal parts such as windings in a motor) must have a maximum temperature under normal operating conditions - and sometimes under "abnormal" conditions - of 135 deg C and must carry the appropriate "T4" nameplate.

GAS GROUPS (ALSO KNOWN AS EQUIPMENT OR APPARATUS GROUPS)

This designation relates to the volatility or explosiveness of the flammable material; in other words, given that the ignition temperature has been exceeded or a spark or flame has occurred, the violence of the resulting explosion.

All commonly encountered flammable gases have been allocated a Gas Group, and these range from Gas Group I (methane or "firedamp" in mining) through IIa and IIb to IIc, which is Hydrogen (the most volatile).

RISK MINIMISATION METHODS

Australian Standards identify five basic different methods of minimising the possibility of plant machinery contributing to a significant industrial mishap in flammable hazardous areas. Of these, four are relevant to rotating electrical machinery (including, of course, A.C. induction motors) and, including two sub-categories, making six in total.

(I) Complete encapsulation of all windings, terminals and switching componentry to ensure no "open-air" short-circuits or arcing.

(II) Hermetically sealed motors that are, before sealing, purged with an inert gas to ensure the exclusion of oxygen form the enclosure, thus eliminating the support of any combustion within the enclosure.

(III) Continuously pressurised motors from an outside inert gas supply which maintains an internal pressure in excess of the outside atmospheric pressure which in turn ensures a continuous flow of (inert) gas from inside the motor to the surrounding air thus preventing the ingress of any flammable gases from the outside to the motor windings of terminations.

(IV) Minimisation of the risk of ignition of the flammable gases inside the enclosure.

(V) Exclusion of the hazardous material from the area where an ignition is likely to occur.

(VI) Explosion containment - while incorporating most, if not all, of the aspects of the "risk minimisation" motors as per (IV) above, the main safety feature of the type of motor lies in its "enclosure" which is specifically designed to "contain and withstand" an internal explosion. That is to say that, in the (unlikely) event that the flammable gas explodes inside the motor, the "ignited" gas will not be allowed to escape outside the motor enclosure and the enclosure itself will not disintegrate as a result of the internal explosion.

The vast majority of hazardous location applications in Australian industrial situations are filled by motors in the last three categories as listed above, ie:
"risk-minimisation", "exclusion" and "explosion containment" motors.

What follows will deal only with these three hazardous location motor categories.

EXPLOSION RISK MINIMISATION MOTORS. (EX 'n' AND EX 'e')

(A) EX 'n' (Non-Sparking) Motors:

These are basically standard TEFC motors but with certain modifications carried out to ensure the following compliance with the relevant Australian Standards:

(I) Strict control over air gap between stator and rotor to minimise the possibility of contact ("poling") between stationary and rotating parts.

(II) Compatible materials used in cooling fan and fan cowl combinations to ensure no sparking occurs between the two resulting from electrostatic build-up.

(III) Adequate clearance and creepage distance between terminals in the terminal box.

(IV) Control over internal and external surface temperature under normal "running" conditions as required by the relevant Temperature Classifications of the job in hand.

Generally speaking, EX 'n' motors available in Australia are rated at T2 or T4 Temperature Classifications and, since the concept of this style of motor does not involve containment of an internal explosion, all EX 'n' motors are suitable for use where the hazardous material is a gas group IIc (Hydrogen). EX 'n' motors are suitable for Class 1 Zone 2 applications only.

(B) EX 'e' (Increased safety) Motors.

All the design criteria mentioned above in reference to EX 'n' motors are equally applicable to EX 'e', and, in terms of the concept involved, and EX 'e' motor could fairly be described as a

The major additional requirements for EX 'e' status is that the internal surface temperature limitations must be adhered to, not only under "running' conditions but under starting and stalled torque conditions. For this reason the Ia/In ratio (starting current over nominal or full load current) and the te time (time in seconds that it takes under locked rotor/stalled torque condition to reach the maximum permissible temperature at any point - normally on the rotor - when starting from the normal steady-state running temperature) must both be shown on the nameplate of the motor. The control gear for an EX 'e' motor must incorporate approved relays to de-energise the motor if the te time is exceeded, or if the starting current and/or starting duration are abnormally high.

As a general rule, EX 'e' motors are not, nowadays, approved for use with variable-voltage-variable-frequency speed control devices because of the uncertainty regarding the heating effect within the motor due to the non-perfect sine-wave produced by the VSD and the unusual demands made on the motor particularly at low speeds.

Rather than design a completely new range of motors to meet the requirements of EX 'e' standards, motor suppliers upgrade their standard TEFC machines and, where necessary, derate the nominal power output to a point where internal surface temperatures comply with the T2, T3 or T4 limits. As a result, particularly in the larger sizes, the kW ratings of EX 'e' motors may vary from the standard or "preferred" ratings for a particular frame size.

EX 'e' motors are approved for use in Class 1 Zone 1 areas except in mining applications where the motors are to be underground or where they are above ground but in the air-stream of an exhaust fan expelling air from below the surface. (In these instances EX 'd' is called for). EX 'e' motors are occasionally called for in Class 1 Zone 2 areas but this is up to the user's discretion and would be mainly to allow the user the flexibility to shift plant in the future to other areas of the site which may have Zone 1 classification.

HAZARD EXCLUSION MOTORS (DIP).

In one sense these are comparable to EX 'n' motors in that the safety requirements as described above for EX 'n' to reduce the risk of sparking are similarly required for DIP applications. As the name implies, however, DIP motors are designed for use in areas where the "hazard" is dust rather than gas, and while it is not practical to prevent the ingress of a gas into the body of a motor (of the type under discussion), measures can be taken to prevent the ingress of small particles and, in this respect, the two concepts vary significantly.

In Class 1 (gaseous) hazardous areas, the relevant standards pay little attention to the IP enclosure ratings (more on this later) but in Class 2 (dust) hazardous areas, an integral aspect of the explosion risk minimisation concept is to stipulate that the first digit of the IP rating number (which indicates the degree of protection against the ingress of solid particles) should be "6". This means, in effect, that the enclosure is to be "dust tight".

In theory, the second digit of the IP number (which indicates the degree of protection against the ingress of water) is not relevant to DIP motors, but in practice it is not possible to ensure a "6" rating for dust without simultaneously achieving at least a "5" rating for water. Therefore any DIP motor would have a protection rating of at least IP65.

DIP motors are suitable for Class 2 Zone 1 and Class 2 Zone 2 areas.

EXPLOSION CONTAINMENT MOTORS - EX 'd' FLAMEPROOF.

Of the type of motors under consideration for Class 1 areas, EX 'd' motors are inherently the safest in that they are specially designed and manufactured to cater for the possibility that an internal explosion does occur despite precautions having been taken to minimise this possibility. Most of the normal "non-sparking" safeguards, as described above on EX 'n' motors are, of course, included in EX 'd' motors but, as mentioned earlier, the predominant safety aspect of an EX 'd' motor is in the design and construction of its "enclosure" or frame, and, for this reason, the interior of the motor is not subject to temperature limitations.

The frame of an EX 'd' motor is significantly heavier and stronger than equivalent TEFC motors and must be proven to be capable of withstanding internal explosions of a designated force.

The mating surfaces of the individual components such as body and endshield, endshield and bearing cap, bearing cap and bearing and/or shaft, terminal box and cover must be of a sufficiently tight fit and of sufficient width to ensure that, in the event of an internal explosion, the ignited and expanding gas will be expelled through these "flamepaths" at such velocity that they will be extinguished before they reach the outside environment, thus avoiding a potential "conflagration".

Unlike EX 'n', EX 'e' and DIP motors, EX 'd' cannot be based on suitably modified TEFC motors and are also significantly more expensive. But in therms of safety they are in a class of their own. There is only one situation in which EX 'n' and EX 'e' motors have an advantage and that is where the hazardous gas is in the group IIc (to all intents and purposes hydrogen). Hydrogen explodes with such violence that it is not economically viable to produce an electric motor strong enough to withstand its force. EX 'd' motors are therefore limited to use in gas groups IIb and below. Group IIc gases require EX 'e' or EX

With the exception of Gas Groups IIc, EX ‘d’ are approved for use in Class 1 Zone 1 areas including mining applications. They would also normally be used in lieu of EX ‘n’ or EX ‘e’ motors where T5 or T6 classification is called for, as this would be more economical than using larger derated motors to comply with internal temperature limitations.

THE “HIERARCHY” OF CLASSIFICATIONS.

It should be apparent from the above that, within a given “Class”, a motor approved for a given risk level is more than suitable (and acceptable) for use in any lower risk level application.

A motor designated “T4”, for instance, is automatically more than appropriate for T1, T2 and T3 classifications. A motor approved for use in Gas Group IIc areas can be used in the lower Gas Groups IIb, IIa and I (except in mining). Naturally a motor acceptable for Zone 1 locations may freely be used in Zone 2 areas.

This “hierarchy” is not applicable when comparing Class 1 to Class 2 or vice versa.

ENCLOSURE PROTECTION (IP RATINGS).

As mentioned above, the IP rating is central to the suitability of a motor for DIP applications (in as much as the principle of preventing the ingress of dust into the enclosure is virtually synonymous with the concept of dust-exclusion for Class 2 situations).

The relationship between IP rating and the suitability of a motor for the environmental conditions in Class 1 applications, however, is by no means as rigorous or obvious.

The Australian standard governing EX ‘n’ motors, for instance, stipulates only that the body of the motor should be rated not less than IP40 and the terminal box (which can open directly into the motor enclosure) not less than IP54. In theory IP rating is not critical to the design and construction even of the EX ‘d’ flameproof motor, but in practical terms it would not be possible to construct a flameproof enclosure with the required close tolerances in the flamepaths without at least achieving IP54, and most EX ‘d’ motors are actually IP55, 56 or even 66 as standard.

Nevertheless, complications can arise in the supply of hazardous location motors if they are to also comply with a customer specification which calls for an IP rating higher than that of the suppliers standard for that particular type of motor. The approval certificates issued by the Standards Association for all hazardous location motors include reference to the IP rating of the motors (taken from the motor that was originally submitted for approval). The motor supplier is not able to vary specificational aspects of the motor that represent part of their approval without either making application for a supplementary certificate (which can be a lengthy process) or voiding their approval.

[In the case of EX ‘d’ flameproof motors, it is quite conceivable that changing the IP rating (in either direction) could have a detrimental effect on the rigidly controlled flamepaths and it is therefore clear that adherence to the stipulated IP rating on the approval certificate is important in a practical sense. On the other hand, it is difficult to imagine how increasing the IP rating of an EX ‘n’, EX ‘e’, or DIP motor could have any damaging effect on the inherent safety of the motor, but no reputable motor supplier would risk losing their approval for hazardous location motors simply to comply with the specification.]

FOREIGN STANDARDS.

It is not uncommon to encounter specifications calling for compliance with and/or certification to European, American, Japanese or other standards. It is important that the purchaser/user understand the following aspects of this situation:

A/ If the specification itself is of foreign origin or is based on a foreign specification and the motors are for use within Australia, it is more than likely that the requirement for compliance with non-Australian hazardous location standards is, in fact, incorrect, and should be queried.

B/ Some standards, in particular American, use different terminology, are based on different principles and do not accept the concept of "explosion risk minimisation" techniques. In some instances there is no direct correlation between local and foreign requirements and it is therefore difficult, if not impossible, to claim compliance with the requirements of the foreign specification.

C/ A motor supplier may quite legitimately claim "compliance" with a foreign (or any other) specification or standard but this is not to say that they have "approval". There is a large difference and the potential purchaser would be wise to clarify the situation if in doubt.

D/ In most instances, especially if the motors are for local operation, if compliance with or certification to the required standard is not possible, then certification to local standards will ultimately be accepted as an alternative.

E/ While it is naturally in the interest of the motor supplier to be as helpful as possible, the onus of interpreting the requirements of foreign standards should not be laid on the supplier. This is both dangerous and unfair, and the responsibility for expressing the requirements in terms of Australian standards, concepts and terminology must ultimately lie with the user or his appointed consulting engineer or representative.

AUSTRALIAN STANDARDS.

For more comprehensive, detailed and authoritative information, reference should be made to the following standards:

AS 2381	Electrical equipment for explosive atmospheres - selection, installation and maintenance. Part 1 (General Requirement), 2 (EX 'd'), 6 (EX 'e').
AS 2236	Dust-excluding ignition-proof (DIP) enclosures.
AS 2338*	EX 'n' (now superseded by AS 2380 Part 9).
AS 2380	Electrical equipment for explosive atmospheres-explosion protection techniques. Parts 1 (general requirements), 2 (EX 'd'), 6 (EX'e') and 9 (EX 'n').
AS 2430	Classification of hazardous areas. Parts 1 (Explosive gases), 2 (Combustible dusts), 3 (Specific occupancies).
AS 2460*	EX 'd' (now superseded by AS 2380 Part 2)
SAA HB 13	Electrical equipment for hazardous areas.

AS 1939 Degrees of protection provided by enclosures for electrical equipment (IP ratings).

AS 3000 SAA Wiring Rules.

* Most, if not all, EX 'n' and EX 'd' motors currently available would carry approval certificates in accordance with the old standards AS 2238 and AS 2460 respectively. AS 2380 parts 2 and 9 were introduced only at the end of 1991.

<u>SUMMARY</u>

The whole question of utilising electrical equipment that is inherently capable of producing high temperature and sparks in locations where such an occurrence has the potential to cause a calamitous explosion is inevitably complex and full of grey areas and compromises. Ultimately it comes down to what is considered an acceptable level of risk.

In response to this complex, clouded issue, a set of highly defined, black and white rules and regulations have been drawn up which, if imperfect, are probably as fair and logical as could be expected, within the context of normal design and manufacturing processes in the electrical industry today.

Perhaps because of the "grey" nature of the problem and the "black and white" nature of the solution, there is widespread confusion and misunderstanding of the situation in the electrical industry itself and in the wider circle of equipment manufacturers and, in some instances, end-users.

It is hoped that the foregoing may have served to at least reduce (rather than increase) this level of confusion amongst those who have taken the time to read it. Perhaps, more importantly, it may prompt questions that will ultimately improve the safety of the equipment in question or make it easier or cheaper to achieve the existing level of safety.