COMPARISON OF NATIONAL REQUIREMENTS FOR ELECTRICAL APPARATUS FOR USE IN HAZARDOUS ATMOSPHERES

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SYNOPSIS

International standardisation of the methods of protecting equipment for use in hazardous gas or vapour atmospheres is becoming increasingly important. The paper gives a comparison of the design requirements of various countries for such methods as flameproofness and intrinsic safety, and also describes methods standardised internationally which are not at present used in this country. A short summary of methods of marking and of classification of gas hazards is also given.

Introduction

In recent years there has been a considerable expansion in the scale of operations in the chemical and petrochemical industries. This has necessitated a corresponding increase in the use of electrical equipment for power, lighting, control, and so on, and as much of this has to operate in areas where flammable gas concentrations can occur suitable methods of minimising the potential explosion hazards have had to be adopted. This is not a new problem, of course, and protective methods such as flameproof enclosure of the equipment have been in use for many years, but modern needs call for a more flexible approach to the problem.

A similar situation exists overseas and in some countries alternative methods have been developed. Increased economic and political pressures, the international character of large companies, and other factors are now combining to make international standardisation of vital importance in this field. The extent to which this can be achieved and the time needed to implement it will depend on the degree to which present National Standards diverge and it is therefore necessary to compare such Standards for different countries. At the same time this will also indicate what is at present acceptable in these countries.

Recognised Methods of Protection

There are in existence at present at least nine different methods of protection against the danger of ignition of gases by electrical apparatus, namely flameproof enclosure, intrinsic safety, pressurisation, oil immersion, increased-safety, sand-filling, hermetic-sealing, encapsulation, and the use of flame-traps. In addition, there is the range of apparatus, known in this country as Division 2 apparatus, which is intended for use where the risk is rather less than that for which the more stringent methods of protection are required. These methods are not all used or even accepted in some countries but are listed to give an indication of the variety of methods now needing consideration. Seven of the methods have been recognised internationally in the sense that the International Electrotechnical Commission (I.E.C.) has set up committees to deal with them but so far International Recommendations have only been produced for two of these, flameproof enclosure and pressurisation, although Recommendations on the oil-immersion, sand-filling and increased-safety methods are in advanced stages of preparation and the committee dealing with intrinsic-safety is very active.

It is therefore proposed to deal with each of these methods in turn and to consider the differing attitudes to them of individual countries, as expressed in National Standards and International Recommendations, although it is obviously only possible to deal with the individual requirements in general terms and not in great detail in this short review. Some emphasis is placed on the requirements of the German VDE regulations, as many countries accept these, or, as in the U.S.S.R., have similar rules.

Flameproof enclosures

As is well-known, the two principal requirements of a flameproof enclosure are that it will withstand the mechanical effects of an internal explosion and at the same time prevent the transmission of the explosion to the outside atmosphere. These two requirements are therefore covered in all standards for flameproof enclosures. However, the actual details vary from country to country. In most European countries, fixed test pressures are specified, depending on the gases concerned and on the volume of the enclosures, whereas in this country the actual explosion pressure is measured and this is increased by a factor of 1·5 for strength tests.

In practice, the resulting test pressures for a large proportion of equipment are similar whichever method is used. In the U.S.A., however, a safety factor of four is applied to the explosion pressure for test purposes but as this is applied as a type test and not as a routine test as in this country, and since a much higher proportion of enclosures made in the USA are cast instead of fabricated, this is said to be not uneconomic in comparison with European methods.

With regard to joint dimensions, there is again a relatively small difference between the permitted gaps for comparable joint breadths in British and European requirements, but a large difference compared with the U.S.A. where values between 0·0015 in. and 0·003 in. are generally required. This necessitates very fine machining or grinding and one imagines that maintenance of these gaps might present a problem. In most countries other than Britain a maximum degree of surface roughness of flanges is specified.

The biggest difference between British requirements for safe gap dimensions and, say, the German VDE regulations or the

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U.S.S.R. requirements, is that the former specifies gaps for two flange breadths, ½ in. or 1 in. irrespective of enclosure volume, whereas the latter permit smaller breadths with corresponding values of gap for different ranges of volume. Although this undoubtedly gives greater flexibility in design, and enables the size of some smaller enclosures to be reduced significantly, it could lead to difficulties for the user. For example, in the VDE regulations four different values of permitted gap are associated with four ranges of enclosure volume and five values of joint breadth. It could therefore be extremely difficult for the user to check that gaps remained below the permitted values. Although there is a genuine need for this kind of flexibility, and a similarly complex system is being adopted by the I.E.C., there would appear to be some scope for compromise in this direction.

There are a number of other features in which the British Standard 229 differs from other Standards. Direct entry of cables into flameproof enclosures is permitted in some countries although others follow the same practice as in this country and do not permit this. In many countries where the use of Increased Safety apparatus is recognised, and in particular in Germany, the terminal boxes of flameproof equipment are normally of Increased Safety construction as it is thought that the risk of terminal box faults is thereby diminished. Oil-filled flameproof equipment is also not normally permitted, and the oil-immersion method of protection is used instead.

One respect in which there is general agreement in European Standards is that light alloy enclosures are either not permitted or are only permitted under certain limited conditions such as with certain limits of composition or for use only where impact is unlikely.

Equipment for use in Group IV hazards such as hydrogen is not yet covered by B.S.229, although its use in this country is allowed if it can be shown to be suitable. Elsewhere, requirements have been in existence for many years and much equipment, particularly of the smaller types is in use in, for example, Germany and the U.S.A.

Finally, some mention must be made of the external surface temperature limitations imposed on flameproof equipment in many European countries. B.S.229 gives a warning on the dangers of thermal ignition and B.S.889 gives temperature limits for lighting fittings for use in various gases and vapours but this is done much more systematically in these other countries and all equipment must be marked to show in which gas ignition temperature class it may be used.

Intrinsically safe apparatus

The second of the two main methods of protection used in this country is the intrinsically-safe design of apparatus in which any sparking, whether normal or arising as the result of faults, is incapable of igniting the gas or vapour in which it may be used. It is almost the only method which is recognised in the majority of countries as suitable for use in situations where there may be continuous or nearly-continuous hazard although for this use it is advisable only to use equipment that can be shown to have an inherently large safety margin.

The principal differences that arise from one country to another in this field stem either from differences in the methods employed for testing the safety of the equipment or from differences in installation requirements, particularly with respect to earthing. As far as the latter is concerned in Germany, for example, earthing of intrinsically safe equipment in the hazardous area is considered to introduce an additional hazard due to possible fault currents in the earth loops and is not usually accepted.

Lack of agreement on methods of testing has, however, been the greatest obstacle to international standardisation. Although experience of intrinsically safe apparatus in this country has been very satisfactory other countries have in recent years developed different test equipment which is in some cases more sensitive than the standard British test equipment. The levels of current, voltage, *etc.* that are considered safe in these countries are therefore lower than in this country and as a result, a proportion of the equipment that would be considered satisfactory in this country would fail to satisfy other countries, particularly those using the German test equipment. The main reason for this greater sensitivity is that the German apparatus uses cadmium as one of the sparking electrodes and materials of this kind are known to produce very incendive sparks. However, cadmium or zinc plating is becoming very common in electronic equipment and it therefore reasonable to assume that sparking to such a material may take place and should be taken into account. International consideration of this problem is in progress, and taken together with consideration of the type and number of faults to be taken into account in assessing the safety of the equipment, this may lead to a more uniform standard of safety in this field.

Methods of construction, which are the main factors determining the incidence of faults in intrinsically safe equipment, are specified in some detail in some overseas standards in contrast to the general Standard (B.S.1259) in this country, but the principles are much the same in all countries and compliance with the features set out in the Examination Schedules of the Factory Inspectorate of the Ministry of Labour would usually provide an adequate basis for design.

Although not strictly-speaking intrinsically safe, types of apparatus known as non-incendive are being accepted in the U.S.A. and Canada. This is equipment which is incapable of causing ignition under normal operating conditions and therefore includes suitably designed non-sparking equipment and sparking equipment which is intrinsically safe as far as normal sparking is concerned. Such apparatus is used in N. America in Division 2 areas where there is only a low probability of the presence of flammable gas.

Apparatus for use in Division two areas

The classification of hazardous areas into Divisions according to the degree of risk that flammable gases may be present is an idea which, although only recently generally recognised and introduced into Code of Practice C.P.1003, has been in use in certain large organisations in this country and in some overseas countries, notably the U.S.A. and the Netherlands, for a number of years. However, it is still not recognised in most other countries in an explicit way, although most recognise that there are variations in environmental conditions which can be considered in deciding on the type of equipment necessary. Areas classified in Division 0 are those in which a flammable concentration of gas may be expected to occur continuously or nearly continuously, Division 1 areas are those where such a concentration may be expected to occur from time to time and Division 2 areas are those where this can only occur in the event of very abnormal occurences such as plant failure.

Where this concept is accepted, the principle adopted in selecting equipment for Division 2 areas is that if the equipment is incapable of causing an ignition in normal operation and is sufficiently well designed that faults are not likely the risk of the simultaneous occurrence of a plant fault to produce the gas hazard and an equipment fault to produce the ignition source is very small. Division 2 equipment must therefore be normally non-sparking, must not normally reach a temperature sufficient to cause thermal ignition, and must be so designed that the risk of sparking due to faulty connections, inadequate insulation or mechanical damage is minimised. In general, a temperature limit of 200°C is applied as this is safe for the great majority of gases and vapours.

As yet there are no British Standards for this equipment, but a B.S. Guide should shortly be available and Standards for lighting fittings and motors are being prepared. The requirements for lighting fittings are in the form of various permitted combinations of enclosures with a restriction on breathing and/or special lampholders arranged with contacts enclosed in a small flameproof enclosure so that loosening of the lamp will not produce open sparking. With regard to breathing restriction, this is similar to the U.S. requirements for vapour-proof fittings in Division 2 areas. The enclosed-break lampholder is basically the same as that used in Germany for Increased Safety apparatus, but as indicated in the next section, its use in Germany is not confined to Division 2 areas or their equivalent.

It is of course accepted that equipment such as intrinsically safe equipment, which is suitable for a Division 1 area with a particular gas hazard is also suitable for a Division 2 area with the same gas. This then leads to the U.S. compromise of " non-incendive " apparatus in which normally sparking parts are made " intrinsically-safe " in the limited sense that faults elsewhere in the equipment are not considered.

Increased safety apparatus

Increased safety apparatus is basically a German concept but is also used widely in other parts of both Western and Eastern Europe. It is also used to a very limited extent in this country for particular types of equipment such as batteries where other forms of protection are impractical.

The name " Increased Safety " is a translation of the German description " erhöhte Sicherheit." The abbreviation used in Germany for marking this type of equipment is " e " and because in the early international discussions on this subject the term " increased " was thought to give a misleading indication of relative merit compared with other types of equipment, " Type e " has come to be used as an alternative description.

Increased Safety equipment is designed on the same basic principles as are used for Division 2 apparatus, namely freedom from sparking and from excessive temperatures. However, as it is used in areas which would be classified in this country as Division 1, the design requirements are laid down in much greater detail than is necessary for Division 2 equipment. Both in Germany and in Russia, for example, clearances and creepage distances for various grades of insulation are specified, and these are larger than would be required for normal industrial equipment. Temperature limits for insulation are also reduced below the values normally accepted, and great care is taken to prevent over-heating of motors, *etc.*, in the event of stalling. All motors are labelled with a time, t_E, which is the time taken for the temperatures of the windings to reach the maximum permissible temperature if the motor stalls after reaching its normal running temperature (see Fig. 1.) This time is usually required to be greater than 5 s and the user must supply protective equipment which will operate within this time in order to prevent over-heating. Obviously, repeated stopping and starting could still cause the temperature limit to be exceeded and for this reason motors of this type are not used for this type of duty.

It has already been mentioned that terminal boxes of flameproof equipment are usually of Increased Safety construction. Similarly sparking parts, such as small switches or even contactors, are often housed in small ceramic flameproof enclosures with connections terminated on the outside of the enclosure by Increased Safety type of terminals. Such combinations of various methods of protection make the arrangements very flexible.

The biggest problem in assessing the safety of this type of equipment lies in the difficulty of deciding on the probability of faults occurring because of, say, insulation failure. Hence, although some of the equipment now used in Division 2 areas in this country would meet the German requirements for Increased Safety and could be used there in more hazardous areas, this type of protection is not at present accepted here for use in Division 1 areas. Nevertheless international recommendations are in an advanced stage of preparation, and if this method of protection is thus recognised, economic penalties might have to be paid if it is not used in these areas in this country. Only experience would show whether the added risk, if any, justified such exclusion.

Other methods of protection

For some applications methods of protection other than those outlined above are used. The most usual alternative in this country is pressurisation or purging with air or inert gas, using intrinsically safe interlocks, and pressure switches for protection against pressure failure or during start-up. Such systems are acceptable in most countries and in some a warning signal is regarded as a sufficient indication of pressure failure. There are also I.E.C. Recommendations for this method of protection. The main variation in the requirements of different countries is in the minimum value of the pressure differential that is accepted. This varies from 0·1 in. water guage up to 6 in. water gauge, the recommended I.E.C. value being 5 mm.

Other methods for which I.E.C. Recommendations are being prepared are oil-immersion and sand-filling, and the former is a method quite widely accepted in Europe. It is also an accepted method in the U.S.A. As with pressurisation, the principle variation in the requirements is in the depth of oil which it is specified must cover live conductors. In the U.S.A. the minimum is 6 in. for Division 1 areas but only 10 mm in Germany and the U.S.S.R. The proposed I.E.C. minimum is 5 cm. In each case, the actual level required for safety must be verified by test, but the adequacy of some of these tests has been questioned in this country. The additional fire hazard is another reason why the method is regarded with some doubt in this country. As already mentioned, the international acceptance of immersion in oil as an adequate safeguard in itself has led to the omission of oil-immersed flameproof equipment from the I.E.C. Recommendations.

Sand-filled equipment is not widely used, although I.E.C. Recommendations are being prepared, and is largely confined

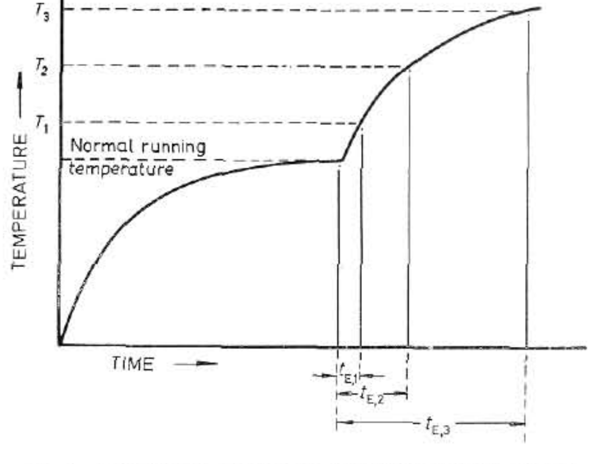

Fig. 1—*Determination of time, t_E, for different classes of gas*

to Eastern European countries and, to some extent, France. It is obviously an extension of the oil-immersion principle but has much more limited applications.

There are other special methods of construction which are not generally applied to the whole range of electrical equipment but which are accepted in most countries if the application is a suitable one. These include hermetic sealing and encapsulation with the object of preventing gas access to the apparatus. Equipment using these methods is usually assessed on its individual merits and is not covered by Standards. Flame-traps are also used for special applications. They are usually employed for pressure relief in the event of an explosion in an enclosure so that it is not necessary to have the strength of enclosure needed for flameproof equipment. The flame-trap may consist of stacks of parallel plates as permitted for mining applications in the VDE regulations (although this method is little used nowadays) or vents filled with corrugated metal strips or porous metal plugs. Great care must be taken to avoid corrosion or clogging by dust and every application has at present to be separately considered.

Marking of Equipment:

International standardisation of marking of electrical equipment for hazardous atmospheres has yet to be achieved. Proposals are under consideration, involving among other items, the possible use of the relevant I.E.C. Recommendation number but it is unlikely that any rapid decision will be reached.

The two systems of marking most likely to be encountered outside this country are the VDE system and the U.S. system. The former is a comprehensive system which details the field of application, the type of protection, the gas explosion class for which the equipment is suitable (if this is necessary as with flameproof equipment) and the temperature class of the gases for which it is suitable. The details are summarised in Table I.

Thus equipment marked with the Symbols Ex d3n G4 would indicate that it was equipment for non-mining use, of flameproof construction suitable for all gases except those in temperature class G5, *i.e.* all except carbon disulphide or other gases and vapours of low ignition temperatures.

TABLE I.—*Summary of Symbols used for Marking Electrical Equipment for Hazardous Atmospheres in Germany*

Symbol for equipment for use in mining:	Sch
Symbol for equipment for use in other industries:	Ex
Symbol for method of protection:	
Flamproof enclosure	d
Intrinsically safe	i
Increased safety	e (+ time, t_E, when applicable)
Pressurised	f
Oil immersed	o
Plate (flametrap) protected	p
Special methods	s
Explosion classes for flameproof enclosures:	
Gases corresponding approximately to Group II (B.S.229)	1
Gases corresponding approximately to Group III (B.S.229)	2
Hydrogen	3a
Carbon disulphide	3b
Acetylene	3c
All gases of class 3	3n
Temperature Classes:	
Suitable for gases with ignition temperatures >450°C	G1
Suitable for gases with ignition temperatures 300°C—450°C	G2
Suitable for gases with ignition temperatures 200°C—300°C	G3
135°C—200°C	G4
100°C—135°C	G5

In the U.S.A., in addition to a Division 1 or Division 2 classification of the degrees of risk in particular areas, hazards are divided into three Classes. Class I hazards are flammable gas and vapour hazards, Class II is applicable where combustible dusts are present and Class III locations are those where ignitable fibres, *etc.* are found. Gases and vapours are classified into four groups. Group A contains acetylene only and Group B atmospheres containing hydrogen including mixtures such as water gas. Group C is for ethyl ether, ethylene and cyclo-propane while Group D includes most of the usual industrial solvents and petroleum hydrocarbons, natural gas and so on. There is therefore a slightly different grouping to that used in this country. In addition to these markings, some indication of surface temperature is usually given where this is necessary, as for example on lighting fittings on which a maximum lamp wattage may be given for different gas Groups, because surface-temperatures are not permitted to exceed 80% of the ignition temperature of the gas or vapour concerned.

Many European countries use the German system of marking, but in some, *e.g.* France, flameproof gas groups are almost the same as in this country.

In most cases, therefore, it is possible to discover the intended use of equipment from the name-plate marking.

Concluding Remarks

It is obviously impossible in a short paper to give any detailed indication of the differences which exist between equipment and practices in different countries. The outline which has been given above is an attempt to describe the main features of these so as to help users when selecting or using equipment of foreign manufacture, but there are many facets of the problem which it has been impossible to include. The system in use in this country has proved satisfactory in the past but may require some modifications to maintain adequate flexibility to meet changing needs. Practice overseas may indicate some ways in which such changes could be made, and improved standards of safety as well as great benefits to both users and manufacturers can be derived by pressing forward as quickly as possible with international standardisation in matters affecting safety.

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DISCUSSION

Mr. Z. W. ROGOWSKI said that he knew that sand was recommended for use in flame traps in Russia. He thought its use was restricted probably because it was difficult to ensure that it stayed in place and remained dry.

Mr. T. J. DYE said that, on page 56 of the paper the statement was made that " Direct entry of cables into flameproof enclosures is permitted in some countries, although others follow the same practice as in this country and do not permit this". He asked Riddlestone to amplify this because he himself had been instrumental in having some apparatus installed using pvc single-wire armoured cables which, if he had interpreted the statement correctly, was illegal.

On the question of division of areas, would it be correct to assume that the normal TEFC squirrel-cage motor, which was non-spark producing, could be classified for use in this area?

Mr. RIDDLESTONE said that the term " direct entry " might cause confusion. It was used in this particular field to indicate that cables were taken directly into the body of the equipment and not into a separate terminal chamber. In the U.K., on flameproof equipment all in-coming cables had to go into a flameproof terminal chamber which was separate from the main enclosure. In some countries such as the U.S.A. this was not necessary and cables could be wired directly into the main enclosure.

Mr. DYE asked what was the position about starters or normal push button stations.

Mr. RIDDLESTONE said that according to the regulations in this country, the cables had still to go into separate flameproof terminal chambers, however small the equipment, and even when this meant that the overall size was considerably increased.

Mr. DYE said it was correct that flameproof push button stations were usually provided.

Mr. RIDDLESTONE said that a problem arose with, for example, junction boxes. These were flameproof enclosures but in fact had direct cable entry. There was now a suggestion that all conduit entering a junction box should be sealed, which was likely to create problems for users if put into effect. In the United States, conduit above a diameter of 2 in. had to be sealed within 18 in. of the entry to the enclosure, and smaller sizes had to be sealed if the equipment contained sparking devices such as switches.

With regard to the query about squirrel-cage motors, they were acceptable for Division 2, although certain additional requirements might have to be specified. Obviously the construction had to be such that loose connections or rubbing between the rotor and stator did not occur but basically, a good quality squirrel-cage motor was satisfactory for Division 2 use.

Mr. K. J. BROWN said that the thread which ran through Riddlestone's paper was that no one country had the monopoly of wisdom on the subject. There were many methods of protection but most, if not all, countries concerned made use of only selection of them. Even those methods which were common in most industrialised countries were differently treated, *e.g.* in flameproof equipment the flame path distances and clearances varied and in intrinsic safety testing there were several type of breakflash apparatus in use and several safety factors were applied.

As a representative of the instrument industry, he asked users not to insist on having British approval for instruments which they specified for their plants. Intrinsic safety certification to B.S.1259 had turned out to be far from the panacea which some had thought it would be. It was virtually impossible for the major international companies to maintain certification in the face of continuing detailed changes to certified equipment, the many possible combinations of modular instruments, and the interconnection of equipment of more than one manufacturer. In many cases the field equipment was flameproof to the standards of the country in which it was designed and reliance on this was a perfectly acceptable alternative.

A word about the legal situation was not out of place. In the experience of his company there was misunderstanding about this. In normal industrial use, such as the chemical plants which were the main interest of most users present at the symposium, the only legal requirement which was of concern to the Factory Inspectorate was a broadly based statement in the Electricity Regulations [Electricity (Factories Act) Special Regulations 1908 and 1944, Regulation 27], to the effect that equipment used in areas where a flammable atmosphere constituted a hazard must be constructed and installed so as to prevent danger arising from the presence of the atmosphere. There was no requirement that only equipment covered by a British certificate be used. This view of the legal position was endorsed by senior staff at the headquarters of the Factory Inspectorate.

Mr. Brown said that he had been impressed by Claydon's paper in which he had described how each possible hazard to safety had been carefully considered and the precautions taken, if any, had depended on the facts thrown up by the investigation. He asked for this reasoned approach to be used in the selection of plant instrumentation.

Mr. RIDDLESTONE said that as far as the system of certification and approval was concerned, the Ministry of Technology was at present trying to set up a new organisation to give the present arrangements greater flexibility. It had been hoped that this would have been functioning by now but there had been a number of delays. It was still hoped that the new organisation would be set up during the coming year and this might give the greater flexibility that Mr. Brown sought. As far as the legal requirements were concerned, these were already very flexible, and the Factory Inspectorate had approved the use of American equipment and certain German equipment in particular circumstances in this country.

Mr. K. C. MYERS said that Riddlestone's paper was a valuable contribution in understanding the differences in national standards. He asked whether Riddlestone had any idea of the time scale for international agreement as this would be a real step forward, but this had been partly covered by a previous answer.

His second question was whether the national arrangements for approval of apparatus was to be brought under one organisation as there were at present three different bodies involved. This was confusing to many users and to manufacturers who wished to submit apparatus for approval.

Concerning apparatus manufactured to B.S.229, he asked whether this Standard took into account the greater incendivity of aluminium which was increasingly used in electrical apparatus for conductors, *i.e.* rotor bars, *etc.*

Mr. RIDDLESTONE said that the time scale for international standards was always difficult to assess. There were two factors to be considered. It was one thing to have an international standard prepared and circulated; it was another to get it actually applied and implemented in a particular country. There had been an international standard for flameproof enclosures in existence for ten years now but equipment manufactured to that standard would, in general, not be acceptable in many countries and certainly not in the advanced industrial countries because it did not cover all the features required, or considered to be required, for safety. Therefore, even when an international standard was prepared, it could still be a long time before it was used and even then only with additional requirements.

The International Recommendations for Flameproof Enclosures, I.E.C. Publication 79, were being revised at present and probably certain parts would be available within the next twelve months.

He would rather not predict on the matter of intrinsic safety. There were too many unknown quantities to be considered, unknown in the sense that the attitudes of other countries varied a great deal so that a consensus of opinion would have to be taken.

In this country, the method of oil immersion, discussed in the I.E.C., was not acceptable, although the I.E.C. recommendations would be published shortly. The same thing applied to the sand-filling system.

Nationally, it was hoped that a central organisation would be set up in the not too distant future to help to co-ordinate the various activities and the work of the various authorities concerned with this particular subject.

There was no mention of the problem in B.S.229, but in the Code of Practice C.P. 1003 on the use of flameproof equipment there was a warning that aluminium-cased equipment should not, in general, be used where there was high risk of impact with steel or other rusty tools, *etc*.

In lighting fittings which were mounted well out of the way, there was no reason why impact should be a hazard but on portable equipment the Factory Inspectorate did not like the use of light alloys.

Mr. Myers said he had not in mind impact ignition from casings but the fusing of aluminium conductors. Sparking produced might be of greater incendivity and cause ignition of the atmosphere surrounding the apparatus whereas the fusing of copper might not.

Mr. Riddlestone said that this was a wider field and the problem was not solely related to the use of aluminium. In some countries any equipment such as a contactor or a switch of more than a certain power level was tested for both flameproofness and electrical performance simultaneously, in the presence of the flammable gas. This was because of the possible effect of a flame on the electrical characteristics of the equipment. Because of the ionised gas in the flame, it was possible to get flashover or arcing which would not occur in the absence of the burning gas.

His department was at present doing work on this and it was known that, even with copper conductors, it was possible to get ignition outside the flameproof enclosures when arcing took place internally although with the same gap arrangement there would be no such external ignition if the standard low energy spark ignition source were used inside the enclosure. This effect was much more significant with aluminium conductors. However, there was a large safety margin in the present design of flameproof joints and this effect might not constitute such a hazard as it might appear to do, provided adequate fault protection was provided on the system so that the pressures developed by arcing were not sufficient to cause physical damage to the enclosure.

Mr. P. L. Klaassen asked what the position was with regard to fluorescent lamps.

He said that non-sparking motors had been used widely in great numbers and he knew of no ignition by non-sparking motors. Was it true that, as some experts in the electrical field told him, that a flameproof motor might be very flameproof in the beginning of its life but after a few repairs, might not be all that flameproof any more, because covers had been moved, things might have been damaged, gaps become wider? If that were the case, he would be in favour of increased safety on non-sparking motors.

Mr. Riddlestone said that it was true that if a fluorescent lamp were damaged, particularly with the hot cathode type used in this country, there could be ignition, and this was one reason why in Germany they insisted on using the cold cathode type of tube.

As far as the non-sparking motor was concerned, this was a question that could be argued indefinitely. Flanges on all flameproof enclosures deteriorated with time but the safety margin inherent in the flange-joint on flameproof enclosures was very high. The permitted gap for a 1 in. flange in the Group II series of gases was 0·016 in. In practice, most manufacturers worked to a very much smaller figure and, moreover, the gap at which there would be flame transmission was about double that figure.

There was also a safety margin in that the specified gaps were based on the worst possible combinations of gas concentration, *etc*., which very rarely occurred. There were therefore many safety factors inherent in this method of protection, so that the other factors such as corrosion, warping of flanges, *etc*., did not have quite the effect that might be anticipated from a superficial examination of the figures in his paper. There was, however, much to be said for increased safety. A big difficulty was deciding how to specify the increased level of safety and how to achieve it. For example, what level of insulation was sufficient to avoid breakdown? That was a matter of experience which at present was not very widely available in the U.K. as far as this particular type of protection was concerned. Also, economics came into it. With increased safety one deliberately ran equipment at a lower temperature than would normally be permitted, which meant that, effectively, the motor was being run at a lower rating than could be used for the same size of machine in a flameproof enclosure. For the smaller machines, the additional cost that this entailed outweighed the extra cost of a flameproof enclosure. For the larger machines, that was not so, and it was appreciably less expensive to make a large increased safety motor than a large flameproof motor.

Mr. H. Phillips said that he had one brief comment about flameproof enclosures for fluorescent lighting fittings. If there was an ignition at one end of these very long enclosures there was a possibility of pressure-piling and the pressure attained by the explosion at the far end of the enclosure might be greatly in excess of the normal explosion pressure.

Mr. Riddlestone said that that was quite true and that the enhanced pressures due to pressure-piling and the probability of its occurrence were difficult to predict.

NOTE.—*Since the preparation of this paper and the subsequent discussion on it a number of the changes which were anticipated have taken place. In particular, the British Approvals Service for Electrical Equipment in Flammable Atmospheres (BASEEFA) has been set up by the Ministry of Technology to centralise the certification work for this type of equipment and to promote research and development of new standards.*

The B.S. Guide to the Selection of Electrical Equipment for Division 2 *Areas has been published as B.S.*4137 *and the I.E.C. Recommendations for Sand-Filled Equipment have been issued in Publication* 79–5.