Intrinsic safety - the appropriate technique for Zone 2

See footnote on back page before commencing to read this document

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1 Introduction

Concern for safety, economy and ecology has led to progressively more effective steps being taken to reduce the possibility of significant leakage of flammable substances on all types of petrochemical plant. As a consequence, the major part of most potentially hazardous plants are now designated Zone 2. In practice, if large areas of a plant are designated as Zone 0 or Zone 1 then inspection authorities are likely to ask if all reasonable measures have been taken to minimise leaks. This tendency to classify the major part of the plant as Zone 2 naturally suggests that the precautions considered necessary for the use of electrical equipment can be relaxed, and the possibility of using type 'N' equipment naturally follows. This document explains why, in the particular case of process control instrumentation, this apparently logical progression is not a sound idea and why intrinsic safety is still the preferred technique.

The basic arguments can be summarised as follows:-

> Instrumentation is frequently on the boundary between Zones and can affect area classification; hence the required area classification is fundamentally different.
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> The type 'N' standard is written predominately for heavy current equipment such as motors and lighting fittings and is therefore not appropriate for instrumentation.
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> Instrumentation, of necessity, requires live working and this has significant implications for work permits and documentation.
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> Gas clearance certificates can rarely be safely applied to instrument systems.
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> The installation and inspection requirements of type 'N' equipment are more onerous and less well defined than those for intrinsic safety. In practice, the differences narrow down to insignificance for the majority of applications.
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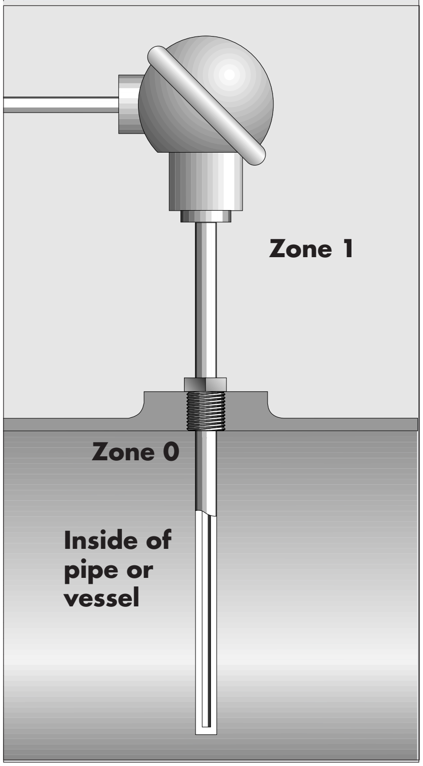
> The cost of an intrinsically safe installation is not significantly different from a type 'N' installation and therefore, since it is safer, intrinsic safety should be the preferred solution.

These points are more fully considered in the remainder of this document.

2 Area classification and instrumentation

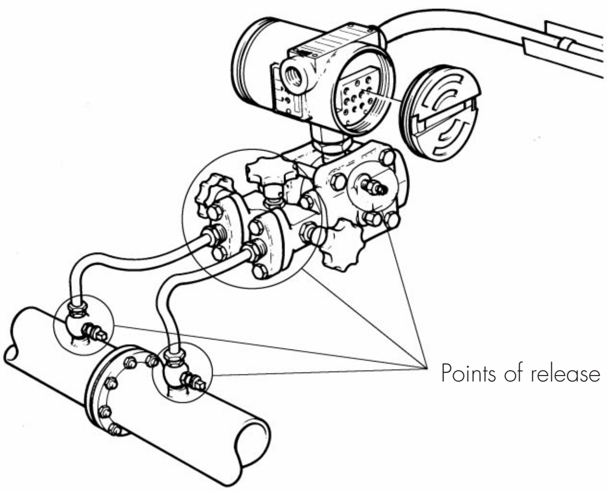
The possibility that process instruments that are directly in contact with a flammable process fluid may affect area classification has always been a matter of concern. As a result, the appropriate area classification for a given application is usually questioned. The problem is best illustrated by reference to the thermocouple well installed in the side of a process vessel—as shown in figure 1. The screwed fixing of the thermowell might possibly develop a small leak, creating a small Zone 1, which would remain undetected for a considerable time. Another Zone 1 is created within the thermowell if it leaks as a result of damage. If the thermocouple itself becomes hot, because of an electrical fault in the sensing instrumentation, the outside of the thermocouple well (which is Zone 0) is heated creating a temperature classification problem. Because of the difficult problem of deciding on the relevant area classification at this interface between zones, it is common practice to use an 'ia' system to avoid an expensive and inconclusive argument. The basic point is that the installation of the thermocouple modifies the area classification and hence an installation appropriate for a Zone 2 area is no longer adequate.

Figure 1: Thermocouple installation



Similar arguments can also be developed for the standard differential pressure cell installation shown in figure 2. The orifice plate flanges can be made so that they do not release with a moderate process pressure. The sample pipe unions would possible produce a secondary source of release and the leakage around the valve spindles could be a small

Figure 2: Typical differential-pressure instrument installation



primary source. The plug in the side of the instrument will release a small quantity of gas when the instrument is calibrated, and this release is a primary source. The volume which becomes hazardous is a function of the process pressure and the lower flammable limit of the gas involved.

The differential pressure cell assembly should be mounted and located in a position that permits the free flow of air around it and protects it from mechanical damage; otherwise its surrounding area classification is adversely affected. The two requirements need some thought, but are not incompatible. However, additional weatherproof housing and sun and weather shelters can cause problems, if not thoughtfully designed. A further concern is the possibility of the process gas entering the differential pressure cell (dp cell) body and being transmitted along the cable.

Recent dp cell designs are less prone to this problem. The use of a weatherproof drain plug in the instrument body prevents a build up of pressure and also solves any condensation problems. A compactly constructed cable together with a conventional weatherproof gland will effectively prevent the transmission of gas along the cable, provided that there is no significant pressure build up. The release of gas during the calibration procedure means that live working with gas clearance certificates is not possible, and the extension of the Zone 0 to the inside of the measuring instrument makes Ex d apparatus questionable and Ex N impossible. Intrinsic safety, in this particular case, is the only acceptable method of protection. Whether it should be Ex ia or Ex ib is debatable, but since there are many Ex ia certified dp cells, it is simpler to use Ex ia equipment which meets the requirements without question.

Other types of instrumentation quite frequently used in a nominal Zone 2 can create their own small localised Zone 0 and Zone 1 environments. Perhaps the most complex situation arises from analysers which normally sample the process fluid and thus become possible sources of release. Frequently these systems rely on pressurisation, which requires clean air from a safe source and somewhere to exhaust the flammable gases. The questions which have always to be asked are: 'What is the area classification before the installation of the instrumentation', and 'What will be the area classification after the installation?'. If the instrument is directly monitoring a hazardous process fluid it will almost always generate a Zone 1 area, and occasionally a Zone 0.

Another aspect of area classification is the stability and details of the area classification diagram when the instrumentation is purchased. If full advantage of the Zone 2 relaxation is taken but the area is subsequently reappraised and modified to a Zone 1, then it can be quite difficult and very expensive to change the instrumentation. This can, and does, happen since some of the circumstances which can create small Zone 1 areas are not apparent until quite late in the plant construction.

Sometimes the decision not to lower the safety standard within a Zone 2 is based on other factors. For example, if there is a possibility of a large gas cloud in Zone 2 and the resultant explosion would cause significant damage, then it might not be thought desirable to lower the level of protection. This concern for consequential damage is being more frequently considered as the practice of preparing comprehensive safety cases is extended.

Similarly, if part of the precautions following a major release is to close down all but essential electrical equipment, it is frequently necessary that the instrumentation remains energised so that plant shut down can be carried out in a controlled manner. In these circumstances, it is difficult to argue that the safety requirements of the essential equipment can be relaxed to those of being 'safe in normal operation'; consequently, intrinsically safe equipment of category 'ia' is preferable, with category 'ib', possibly, being acceptable.

3 Standards for Zone 2 instrumentation

For the last thirty years the subject of instrumentation in Zone 2 has been debated without any significant progress towards a consensus opinion on what is required. The situation has been further confused by the publication of the ATEX directive and the proposal for category 3 equipment constructed to the Essential Safety Requirements (ESR).

The simplest interpretation of the ESR for category 3 equipment is that it should be good quality electrical equipment, which does not produce sparks capable of causing ignition or get hot in normal operation. The directive also allows self certification and quality control. This is more or less the position affecting manufacturers and users in the United Kingdom some thirty years ago. Unfortunately, not everybody was content to live with this responsibility, and hence an attempt was made to write a standard which defined the requirements, and against which third party certification could be achieved. This became the type 'N' standard, the 'N' being derived from 'Non-sparking', 'Non-incendive' or 'Nearly good enough(!)' depending on which sources you prefer to believe.

The type 'N' standard was originally written around motors and lighting fittings because the major cost savings were most easily made in those areas, and because the manufacturers of this equipment were strongly represented on the committee. However, since the requirements of the Ex 'e' standard and the Ex 'N' standard have moved more closely together, the economic differential between the two techniques (even for lighting fittings and motors) is no longer very significant.

Regrettably, the standard has grown to embrace every possible technique which can be used for any product which a particular manufacturer represented on the committee wants to sell. The result is largely unworkable and the complexity of the resulting standards is well illustrated by considering the marking requirements which are included in the draft CENELEC standard prEN50021. The marking requirements have fourteen separate subsections which include:-

> '...c) the symbol EEx n;
> d) the symbol:
> V - for non-sparking apparatus
> W - for sparking apparatus in which the contacts are suitably protected other than by restricted-breathing enclosure, energy-limitation and simplified pressurisation
> R - for restricted-breathing enclosures
> L - for energy-limited apparatus
> P - for enclosures with simplified pressurisation
>
> NOTE: For associated energy-limited apparatus the symbols EEx nL or L should be enclosed in square brackets:
> e.g., EEx nR [L] IIB T4 for apparatus suitable for installation in a hazardous area.
> [EEx nL] IIB for apparatus not suitable for installation in a hazardous area...'

The marking requirement is reduced to seven sections for small apparatus, but is still a formidable memory test for all those technicians who attend training courses and who spend fruitless hours vainly attempting to learn what the marking means. It will eventually be supplemented by the marking requirements of the ATEX directive. The capital 'N' becomes a small 'n' because there is now an IEC recommendation which will probably become a standard and a provisional EN50021 which may possibly become a standard. The prEN50021 will shortly be reissued for further comment, but it is still the current state of the art and hence used as the basis of this document. Some German organisations have issued certificates to prEN50021! Issuing certification to a draft standard is a departure from previous practice and could result in an interesting legal position if it is challenged. The related code of practice is IEC 79-14, which has recently been revised. It will be used by CENELEC and hence is used as the other reference source for this document. There are numerous other documents, which discuss what is acceptable in Zone 2, but they differ considerably in content and hence would only add to the confusion if included.

The draft prEN50021 has a section on energy-limited apparatus which is based, according to an introductory note, 'upon the philosophy of intrinsic safety' and is intended to complement clause 13 which relates to 'instruments and low power apparatus'. There follows a number of clauses which appear to have been chosen in a random manner from the intrinsically safe standard. For example, it is difficult to see why only in energy-limited circuits is it desirable to protect against polarity reversal of the supply or inserting plugs in the wrong socket. The section flirts with the possibility of a system analysis but carefully avoids using the term system. It also carefully avoids explaining how associated safe-area apparatus is to be used although it is a defined term.

It can be argued that the instrument fraternity requires an intrinsically safe system without faults. This has been frequently proposed within the IEC by the Ukraine and others but has always been opposed by the United

Kingdom. Quite why the idea has been so opposed is not completely understood by the author, but the proposition was rejected by the British Standards committee in a very short time by an overwhelming majority. The reason for doing so appeared to be that to introduce a third level of intrinsic safety was thought to be yet another over complication which, in reality, would make very little difference in cost. It is well known that several members of the BSI committee regret having agreed to the 'ia'/ 'ib' split and the prospect of a third subdivision is likely to remain anathema to that group of people. There is little possibility of support from the BSI committee in the foreseeable future for the creation of a third 'ic' standard.

If it is accepted that the type 'n' standard is not really suitable for instrumentation, and that an 'ic' intrinsic safety standard is unlikely to emerge in the foreseeable future, then what is the possible way forward? There seems no alternative but to use intrinsically safe systems and equipment in Zone 2 for which there is available a wide range of third party certified apparatus, together with a well tried and documented code of practice for both installation and maintenance which is acceptable world wide.

4 Live Working

A fundamental difference between mains voltage apparatus and low-voltage instrumentation is the need to be able to work on the latter without de-energising it. It is very difficult to fault-find or calibrate instrument loops with the equipment switched off; hence the desirability of 'live working' being permitted within the hazardous area.

IEC 79-17 is a recent publication covering the subject of live maintenance in hazardous locations, and this suggests in some detail the live maintenance permitted on intrinsically safe circuits. To summarise, it permits live working using certified test apparatus and includes all the things which would normally be necessary in the hazardous area. This is reasonable since intrinsically safe circuits are evaluated under conditions of open and short circuiting of field wiring. The code also has some small reservations about live working on associated safe-area apparatus which are quite understandable. It is important to stress that the ability to work live in hazardous areas, and the assurance that the requirements of intrinsic safety and the low voltage directive ensure that the electrocution risk is removed, in no way removes the need to comply with the requirements of plant operational safety. The majority of installations have a permit-to-work system which must be complied with in all circumstances, whatever the method of protection utilised. The permit to work system always has significant cost.

IEC 79-17 suggests that live working is permitted on Zone 2 installations, provided that it can be demonstrated that an incendive spark or hot spot cannot be caused by the activity. The analysis would need to take into account the whole circuit including the equipment in the safe area. Without some sort of interface, such as a barrier, this type of analysis is virtually impossible except on very rare occasions. With a conventional type 'n' apparatus wired directly into a computer interface such an analysis is impossible, and it seems strange even to propose it. Apparatus which complies with the energy-limited criteria may be safe from a live working viewpoint if the total circuit has been adequately analysed. However, the marking of most type 'n' apparatus indicates more than one sub-method of protection and it is usually not obvious which part of the apparatus cross refers to which mark. Relying on marking, whatever the method of protection, can be misleading and with type 'n' apparatus the possibility of getting it wrong is particularly high. It is not easy to see how a technician can safely ascertain whether a particular circuit or apparatus is safe for him to work on without isolating it. Some very distinctive marking is a minimum requirement, and is usually not provided.

Similarly, there is a suggestion that fault finding with a gas clearance certificate is permitted. With conventional electrical equipment and a gas clearance certificate it is reasonably safe to fault find because a spark or hot spot is usually created either at the point where the fault finding is taking place, or within the safe area. An instrumentation loop is however significantly different in that a fault injected at one point may create a hazard at another interconnected piece of equipment. For example, the application of a defective piece of test gear to the thermocouple connections of an instrument system—comprising a thermocouple, thermocouple converter, indicator and computer interface—could also produce an incendive situation at both the thermocouple converter and the indicator. Hence, an effective gas clearance certificate would need to embrace all three locations. This is not an easy situation to arrange, and monitor, without a considerable number of people and significant cost. In most instrument situations gas clearance certificates are not meaningful as they should embrace the whole of the instrument circuit within the hazardous area, and this is not feasible.

It can be argued therefore that live working on any instrument system, other than intrinsically safe systems, is impractical. If a circuit has to be isolated before maintenance work is carried out, the IEC code of practice specifies that 'Isolation in this context means withdrawal of fuses and links, or the locking off of an isolator or switch'; elsewhere, it specifies that all outgoing conductors should be fused and isolated. If this is literally applied to all type 'n' installations considerable expense and space is involved. A compromise of fused switched terminals is often adopted for low-voltage instrument systems, but this cannot be said to comply with the requirements of the standard, and even this unsatisfactory compliance is not insignificant in cost.

The inevitable conclusion is that live working on type 'n' circuits, by virtue of detailed analysis or gas clearance certification, is not practical. Working on isolated circuits is difficult, and the means of isolation is expensive, if carried out in accordance with either practice. The final conclusion must be that an intrinsically safe installation presents the only practical solution.

5 Installation Practice

A significant problem with type 'n' equipment is that there is no adequate code of practice for installation of instrumentation. The attempt to avoid introducing the 'system' concept into this technique has lead to several clauses in IEC 79-17 causing possible confusion. For example, nearly all the techniques used within the type 'n' concept require a reasonable standard of enclosure, except for energy-limited apparatus where exposed sensing elements are permitted, providing they are not 'impaired by contact with solid foreign bodies or liquids'. (It is interesting to speculate what a 'foreign body' is in an IEC standard—presumably a man from outer space.) A technician could, however, be forgiven for believing that an exposed strain gauge, which he knows will malfunction when submerged in water, should be questioned if it is part of a type 'n' circuit. The requirements for cables are not relaxed for energy-limited circuits— which is surprising—but not very restricting since reliable cables are necessary for operational security. Cable parameters become part of the requirement when considering limit switches utilising energy-limited techniques, but since this also requires knowledge of the effective output capacitance and inductance of the safe-area equipment, it does not seem to be a very practical technique. For cable parameters which have a unity factor of safety, if the voltage is less than 30 V and the short circuit current is less than 100 mA, then the cable parameters are never a significant problem but, as in intrinsic safety, they create problems because they have to be considered. The disadvantage, compared with intrinsic safety, is that they have to be evaluated for each circuit, and there is no guidance on how to establish the circuit voltage or the short circuit current. The type 'n' standard does not include the use of the L/R ratio which frequently proves useful in intrinsically safe circuits. It should be noted that if the maximum short circuit current permitted for a given voltage is used—given by the tables in the appendix to the type 'n' standard—then the permitted inductance determined from the curves is zero. Hence the absence of a permitted L/R ratio is a significant limitation.

If the cable parameters of a type 'n' circuit are to be determined from the available tables, then the output voltage from the power supply has to be defined and the current limitation achieved by a resistor. Any other technique requires the use of 'spark test' apparatus, and someone who knows how to test 'non linear' circuits. Test apparatus is not readily available, except in test houses, and only a select few of these are even aware of the problems of testing non linear sources; consequently, the use of resistive limited voltage sources is the only practical solution.

An interesting side effect to the use of resistive limiting is the physical size of the current limiting resistors. If for example a 28 V source is used for IIB, and the permitted maximum current of 448 mA utilised, then the power rating of the 62.5 W resistor, with the required factor of safety, needs to be 18.8 W. Such a resistor is physically quite large and will dissipate a lot of heat. Fuse protection of the current limiting resistor will reduce its size but will also limit the available power, particularly since the fuse has to operate with a factor of safety of 1.5 on its rating under normal conditions. To achieve an acceptable level of reliability (≥ 10,000 hours) a 50 mA fuse will normally need to operate at 33 mA; however, for certification purposes a fuse is permitted 1.7 times its rating (1.7 x 50 mA = 85 mA) to flow for some time (approx. 10 minutes). The 62.5 W resistor therefore requires a rating of 1.5 x 0.45 W, i.e. 0.68 W, which is not unreasonable, but the useable current is low and the permitted inductance will be zero. The reliability of the system will also be low as the fuse will blow if the field wiring is shorted.

prEN50021 suggests that voltage limiting can be accomplished by using a shunt zener diode in association with the current limiting resistor and fuse, thus defining the available voltage and current with some certainty (see figure 3b). In some older type 'N' designs these components were included in the field mounted apparatus. However, it is more convenient to mount them as associated safe-area apparatus since this also protects the associated field wiring.

As far as is known to the author a suitable unit which embraces all the necessary components is not commercially available. Ironically, the MTL7000 Series shunt diode safety barrier version shunt, which includes a replacement fuse and a means of isolation, meets all the necessary criteria with something to spare and is the most convenient economic solution. It would be necessary to clearly mark an installation using these devices as not being intrinsically safe, but in the absence of any other commercially available alternative this solution has much to commend it.

One of the principal advantages of the intrinsic safety technique is the 'simple apparatus' clause. This permits suitable low energy generating or storing apparatus such as switches, thermocouples, resistors etc., to be used in intrinsically safe circuits without being marked and without modifying the certification of the circuit. It is surprising that a similar clause is not included in the energy-limited section of the type 'n' standard. Its absence means that each piece of apparatus must be subjected to the full investigation of the standards requirements and each piece of apparatus must be marked. In some cases these requirements are not restrictive. For example, the types of terminal and junction box used to ensure operational integrity are frequently those which comply with the increased safety (Ex e) requirements—meeting the type 'n' requirements in everything except marking. Exactly the same terminals and boxes are used in intrinsically safe circuits, but in these circumstances there is no marking requirement. It would be an unusual type 'n' installation if the marking was changed but nevertheless the requirement is in the standard.

The requirements of a switch in an energy-limited circuit are presumably not dissimilar to those of an intrinsically safe 'simple apparatus' switch but, again, examination and marking to the standard is required. There are no stated restrictions on multiple earthing in the type 'n' standard—presumably since multiple earthing of power circuits is not permitted because of other regulations—however, single point earthing is usually preferable and safer. It is this lack of positive guidance which is the principal problem of the type 'n' standard. The standard answers all the easy questions, for which the answers are obvious, and avoids the difficult questions where assistance is desirable.

If a switch circuit cannot be considered as energy-limited because the information on all the interconnected apparatus and cables is not complete, then the switch must comply with some other part of the standard. The probability is that the switch which is best suited for the application is either not available, or very expensive.

The fundamental problem is that the requirements of the 'energy-limited' concept and those of the normal type 'n' power systems are incompatible. The installation code is reasonably adequate for power installations but is not sufficiently comprehensive for the low-energy technique. As a result, everyone utilising this technique has to improvise and make their own decisions as to what is adequate. These decisions are not too onerous if they only have to be made occasionally, to solve particular problems—providing there is sufficient expert advice available. If however, an individual has to generate and maintain a whole plant system, then it is unlikely to be adequately safe, and certainly not as safe as a system based on a well established code of practice; written by a number of experts, contemplated in some depth and modified on the basis of experience.

Figure 3:

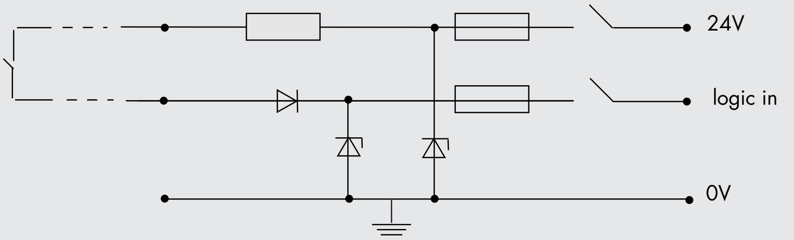


Fig 3a) Minimum requirements of a non incendive interface

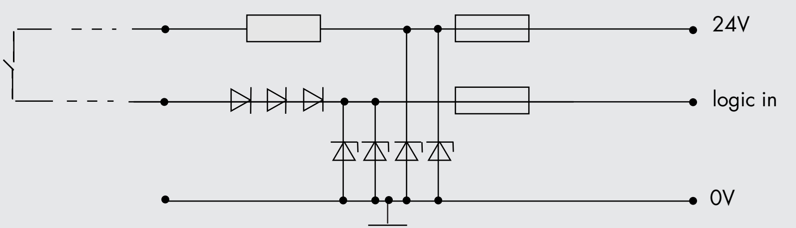


Fig 3b) Minimum requirements of a shunt diode safety barrier

There are many unanswered questions on type 'n' installations which are relevant to instrumentation systems. One of the many is 'what is the permitted practice in junction boxes?' In particular, consider a case where the junction box takes signals from a multicore cable and feeds these forward along individual cables. If the junction box is opened without using a gas clearance certificate, do all the circuits within the junction box have to be isolated—with the resulting shutting down of a large section of the plant—or just the circuits that will be worked on? If a gas clearance certificate is used, does its application have to consider the possible faults on all the circuits within the box? Are there any special segregation requirements between energy-limited and other circuits? What are the segregation requirements between extra-low-voltage circuits and higher voltage circuits from the viewpoint of an electrocution risk? The only practical solution seems to be to use separate junction boxes and multicore cables for energy-limited circuits in the same way as for intrinsically safe circuits. One thing is clear, type 'n' circuits cannot share a multicore with intrinsically safe circuits. Theoretically, they could share a junction box, but this is not desirable since it leads to complications in maintenance procedures.

The advantage of intrinsic safety is its well established and well understood installation code. Its status as an established technique with well defined requirements, which avoid 'reinventing the wheel' for every installation, make it easier to install and maintain. Figure 3 compares the basic requirements of an energy-limited type 'n' circuit with a conventional intrinsically safe switched circuit.

If, perversely, a decision is made to proceed with a type 'n' installation it is important to decide who is to provide the necessary documentation. The other decision to be made is—who is to bear the cost of this documentation? A cost which is always significant and generally twice as much as the available budget!

6 Inspection

The requirements of inspection are not significantly different for the two techniques if the energy-limiting technique is used for type 'n'. If other techniques such as 'restricted breathing' are used then inspection becomes quite a lengthy and complex process. The most recent publication on inspection and maintenance is IEC 79-17. This contains suggested check lists for the different methods of protection, and both energy-limited type 'n' and type 'i' have fourteen checks which are considered relevant.

Basically, both types of installation require an initial inspection which checks that the installation conforms to the documentation. Subsequent inspections are necessary to confirm that there has been no appreciable physical deterioration or unauthorised modifications. The time involved and the success of these inspections is heavily dependent on the quality of the documentation and the expertise of the person doing the inspection. The advantages of intrinsic safety are the ability to open enclosures without isolation, clear documentation requirements and many prior examples of what is required. In contrast, type 'n' installations tend to become mixtures of several techniques and the documentation for what has to be inspected can be complex.

7 Mixed Systems

Instrumentation is frequently in contact with the flammable process material and so it is usual for there to be at least some intrinsically safe instrumentation on the plant.

If a decision is made to use type 'n' equipment on the same plant, then it is necessary to ensure that the two systems are easily distinguishable from each other. This is essential, principally because they require marginally different maintenance and inspection procedures, and the apparatus is frequently the same but used differently. In some ways it would be easier if the differences were greater.

There is only a limited amount of apparatus certified to the type 'n' standard. The situation may change if the technique becomes internationally acceptable, but this is unlikely unless the use of type 'n' equipment is clarified, and North America is persuaded away from the very variable 'non-incendive' techniques which are currently accepted there and by some other end users. This absence of choice means that intrinsically safe equipment is frequently purchased for use in type 'n' circuits. This has the merit of standardising the apparatus available on the site but means that it is labelled in a confusing manner. It is possible to deface or remove the labelling and replace it with another label when the equipment is put into use. The concept of renewable and changeable certification labels would not appeal to most manufacturers and would give certification organisations a heart attack—if they have such an organ. The defacing of the label would limit the subsequent use of the modified apparatus, which is also not desirable.

Concern has been expressed about connecting intrinsically safe apparatus to a non-intrinsically safe source and thus creating damage to safety components. If this argument is accepted, the re-cycling of intrinsically safe apparatus from type 'n' circuits should not be permitted. If however the apparatus is functioning correctly the possible risk is small and acceptable.

If there is both intrinsically safe and type 'n' instrumentation then the problems of inspection and maintenance are belong, primarily, to the instrument technician. There are technicians adequately trained in intrinsic safety practices and there are a number of well established training courses available for anyone who wishes to learn. There is no well documented, adequate code of practice for type 'n' instrumentation, and hence there are no effective training courses or pools of trained technicians. This means that anyone using type 'n' instrumentation must train the relevant technicians in the particular interpretation of the code being utilised on a particular site. If the installation uses both methods of protection the technician must be skilled in both sets of requirements, and must have a clear understanding of what type of circuit is being working upon. The problems that can arise if there is any possibility of confusion are obvious.

As discussed previously, it is not permitted to mix intrinsically safe circuits and type 'n' circuits in the same multicore cable, and the use of separate junction boxes has much to commend it. These comparatively small details of incompatibility increase costs and complicate installations.

Inevitably, some of the instrumentation has to be intrinsically safe and hence it is desirable that all of the instrumentation is intrinsically safe. Avoiding the problems of multi-discipline education and possible errors of handling more than one method of protection generates a better defined and safer plant. It is tempting to argue that some of the requirements of intrinsic safety could be relaxed in Zone 2, particularly the irritating factors such as cable parameters and the need for certification and surveillance. However, any relaxation means that a different set of requirements then applies with all the attendant problems of additional education and documentation.

8 Cost

The most powerful argument in favour of reducing the safety requirement for type 'n' instrumentation is the large reduction in cost. However, the ill-defined requirements of type 'n' instrumentation prevent the apparent advantage of reduced hardware cost being realised, and instead, there are additional documentation costs.

There are many costs which are difficult to quantify with any precision but it is worthwhile to consider two simple commonly occurring applications. The costs proposed here are estimates and may be questioned. Providing that the basic arguments are accepted, varying the cost in the areas where the two systems are marginally different has very little effect. The two applications considered compare the energy-limited technique of type 'n' with intrinsic safety rather than any of the other techniques, since in these particular applications the energy-limited technique would appear to have lower cost and greater flexibility than the other type 'n' techniques.

For example, if the preferred method is to operate the limit switch at 110 V, then the switch would need to be protected by the sub-technique of encapsulation or hermetic sealing, and marked with Ex nW. A typical example is an encapsulated reed switch. The purchase price resulting from the testing and documentation would be high (possible £120) and there would only be a limited range of products available.

If the energy-limited approach is used, any adequately robust weatherproof switch will meet the requirements of the type 'n' standard, provided that a not too rigid interpretation of some of the requirements is made. The standard requires special marking of the product by the manufacturer, and this means a switch manufacturer has to be prepared to spend time understanding the standard, applying the marking, checking with its insurance company and contemplating its responsibility. It is unlikely that all switch manufacturers will wish to be involved, and those who are prepared to be involved will charge a significant premium to recover their costs and make a profit. Hence the resulting switches will not be low priced but possibly cost around £75.00. The standard implies that for someone, with adequate expertise, to take a standard product and appropriately mark it is not acceptable, but possibly the term 'manufacturer' could be more broadly defined to allow this. The major part of the problem however, is deciding which parts of the confusing type 'n' standard are relevant. There is a significant problem if an end user insists upon type 'n' equipment being certified by a third party since the range of available switches is very restricted and is also expensive.

The 'simple apparatus' rules for intrinsic safety have been further clarified in the second edition of EN50020, and hence any type of limit switch which is reasonably protected from the environment satisfies the requirements. It is desirable to identify the switch so that it can be inspected against the relevant documentation, but this can be done using the preferred method of tagging used for instrumentation on the particular site. The cost involved is therefore relatively low, possibly £35.00 plus the cost of a plant identification label, giving a total of £45. The decision as to suitability lies with whoever has the relevant expertise, and can be the system supplier, the contractor or the end user. The concept of 'simple apparatus' being freely added to an intrinsically safe system is well established and widely accepted.

The two switch circuits are compared in figure 4 which demonstrates that the major part of the circuit is identical in each of the two systems. Theoretically, some of the cabling requirements could be relaxed for the intrinsically safe circuit, but in practice, the basic requirement of operational reliability means that high quality installation practice must be observed. For example, the junction box is an Ex e approved box because this provides an economic and reliable connecting system with a reasonable level of robustness and weatherproofing. The costs of these common items are defensible but, since they are common to both systems, they do not have a first order effect on the argument and are not discussed in detail.

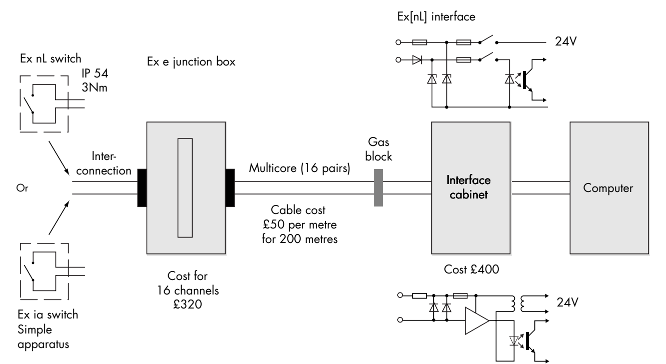
The interfaces shown have a marginal effect on the system cost. The type 'n' interface does not exist as a proprietary item. If the isolator is a full-scale, lockable, two-pole switch, which is the requirement, then the whole system is impractical, and hence the assumption has been made that a blade-switch incorporated in a terminal is adequate. Similarly, if the interface was constructed by wiring the individual items within a panel the cost would be very high. For the purpose of this costing exercise it has been assumed that a shunt diode safety barrier, MTL 7187, has been used and that the opto-coupler is within the computer interface. This is not the optimum technical solution but it does provide a practical available answer at a reasonable cost.

The choice of the intrinsically safe interface is very wide and is a balance between the facilities required and cost. The choice is briefly illustrated in figure 5 which offers a range of options which includes shunt diode safety barriers. In almost all switch applications, isolators are preferred because of the convenient packaging which combines almost all the preferred input and output options. For this comparison the cost per channel for the two channel isolator was taken as representative.

The other significant cost difference is in the creation of the relevant documentation. The requirements are not significantly different, since they both require safety documentation which adequately demonstrates safety. This documentation has then to be translated into a practical installation loop diagram which enables the initial installation and inspection procedures to be carried out, and forms the basis for subsequent inspection and maintenance procedures. With an intrinsically safe installation the safety documentation largely consists of collecting the relevant certificates and bringing the extracted information together into the document. With a type 'n' installation it is unlikely that well-defined certification documents will be available, although it can be argued that the manufacturer has a 'duty' to provide them. Usually this means that the safety documentation has to state the basis on which the equipment is considered safe. This has to be done in considerable detail because, if at some subsequent time, modifications to the system have to be made then the basis of the original design has to be known for a safe modification to be made. This safety document has then to be converted into an installation document which has to be detailed and include requirements for labelling of apparatus as required. Similarly, detailed fault-finding and inspection procedures have to be written so that technicians know precisely what they are permitted to do. The cost of this type of documentation is high and the figures of £200 and £150 for a loop assume that the documentation is done by someone with considerable expertise and the cost of the documentation is spread over a number of similar loops. The numbers are fairly arbitrary but reflect the additional difficulty arising from type 'n' documentation. If the documentation is minimised, or not attempted in either or both systems, then the cost and the differential is reduced.

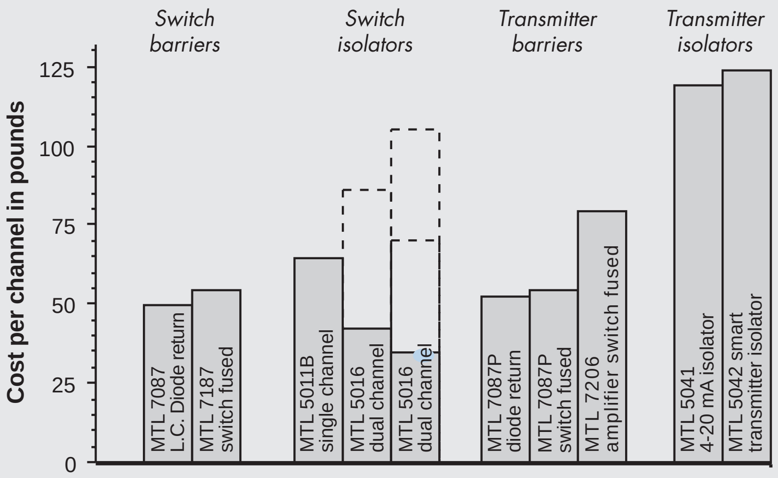
Figure 4 shows an estimated cost for the common items to be £800, and the total cost of the type 'n' system is £1132, compared with £1038 for the intrinsically safe system. Hence, there is only a marginal difference in total cost which is largely determined by the components which are common to both systems.

Figure 4: Cost comparison of Ex nL and Ex ia switch circuits



	Document-ation								Increment	Total
Ex nL	260	75	-	-	-	-	57	-	332	1132
Common	-	-	20	20	625	10	25	100	800	-
Ex ia	150	45	-	-	-	-	43	-	238	1038

Figure 5: Cost of interfaces



The long term cost of ownership of these systems is not appreciably different unless maintenance and repairs have to be carried out under gas clearance certificates. The procedure for obtaining gas clearance certificates is always more difficult than it first appears. At most sites two signatures from senior members of staff are necessary and such people are rarely instantly available. Many sites restrict the number of certificates issued at any one time and instrumentation is low on the list of priorities. The cost of an instrument repair is included in figure 6 which also includes the cost of maintaining a gas clearance certificate during the time the fault is being repaired. If the end user is sufficiently confident that no ignition capable spark can be generated during the fault finding, and the written procedures clearly indicate this, then there is no significant difference in the type 'n' fault finding cost from that of the intrinsically safe loop.

The inspection procedure for the two systems is almost identical and hence there is no appreciable difference in cost. If an arbitrary figure of £60/annum is used the 10 year cost of inspection is £600 per loop. Similarly, if two faults per loop occur in a 10 year period the total cost of maintenance and fault finding for

Figure 6: System costs

METHOD OF PROTECTION	Ex i	Ex nL
Cost of permit to work	50	50
Gas clearance certificate		100
Maintenance of gas clearance	200	
Technician	100	100
Total cost of repair	150	450
Repair cost in 10 years	300	900
Inspection cost per year	60	60
Inspection cost in 10 years	600	600
10 year cost of repair and inspection	900	1500
SWITCH CIRCUIT		
Initial cost	1038	1132
10 Year ownership cost	1938	2632
TRANSMITTER CIRCUIT		
Initial cost	1570	1560
10 year ownership cost	2470	3060

ten years is £900, and £1500 for Ex i and Ex n switch systems, respectively.

When added to the initial cost this gives a ten year cost of ownership for the Ex n system of £2612 compared with £1938 for the Ex i system. These figures can be questioned but the overall analysis demonstrates that the cost of the Ex n system is marginally higher however these numbers are varied. If some technique for working live on type 'n' installations without using gas clearance certificates can be devised it would increase the documentation cost, but considerably reduce the fault-finding cost. The difference in system cost would be smaller but still in favour of the intrinsically safe system.

Figure 7 shows a similar analysis of the initial cost of a transmitter circuit. In practice, most transmitter manufacturers only ever manufacture one type of transmitter, regardless of the method of protection, and only the label changes. Usually there are small price differences but this is primarily to exploit market perceptions rather than due to any significant difference in manufacturing cost. Because of the wider international acceptance of the technique the majority of manufacturers have intrinsically safe versions of transmitters. Some have type 'N' versions certified to older standards and presumably type 'n' versions will emerge.

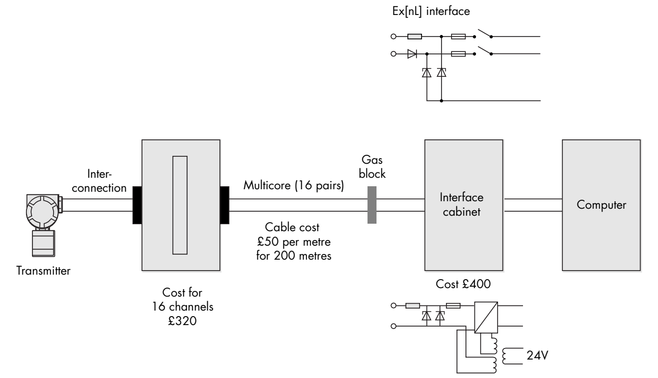
An essential requirement is that there should be adequate safety documentation and installation and maintenance instructions supporting the product. Without these, end users will incur considerable increased cost compiling the documentation.

The common costs and arguments are identical to those of the switch current and only the interfaces differ. The Ex n[L] interface is best served by utilising a shunt diode safety barrier. This has unnecessarily duplicated components, but is available, and is considerably more economic than constructing the interface from individual components. In practice the lower resistance version (i.e., the P version) of the 28 V diode return barrier is used, the MTL 7187P being the usual solution. Occasionally, using the barrier with a buffer amplifier, the MTL 7206, is a convenient way of developing further output capability. The intrinsically safe circuit frequently uses an isolating interface and this results in additional cost. The relative cost of the barriers and isolators compatible with transmitters is shown in figure 5.

With the particular solutions adopted, the differences in documentation costs are cancelled by the differences in interface costs, and the n[L] system is marginally less expensive at £1560 compared to £1570 for the intrinsically safe circuits. Figure 6 demonstrates that the ten year ownership cost is £2470 for the intrinsically safe system and £3060 for the type n[L] circuit. The gap is considerably reduced if fault finding without a gas clearance certificate can be organised.

The overall conclusion is that cost is not a primary factor in choosing the technique to be adopted and hence the choice must be decided by other factors.

Figure 7: Cost of Ex nL and Ex ia transmitter circuits



	Document-ation								Increment	Total
Ex nL	200	-	-	-	-	-	60	-	260	1560
Common	-	500	20	20	625	10	25	100	1300	-
Ex ia	150		-	-	-	-	120	-	270	1570

9 Relative Safety of Intrinsic Safety compared with Type 'n'

The normal basis of the relaxed requirements of type 'n' equipment is that it is used in the hazardous area with the lowest risk and hence the acceptable precautions to be taken may be less onerous. The recent ATEX directive has enshrined this principle by defining category 1, 2 and 3 equipment as equipment which is safe with two faults, one fault and 'in normal operation' respectively. To all intents and purposes these categories are aligned with Zone 0, 1 and 2 respectively. Figure 8 attempts to calculate the probability of an explosion using a fault rate of 0.1% per annum, and the normally expected probability of gas being present in the hazardous zones. There is a mismatch, because the probability of gas being present only reduces by a factor of one hundred between zones and the fault probability is a factor of one thousand. This simple calculation suggests that the degree of compensation within apparatus, for the risk taken, is too high and also suggests that the place at greatest risk is the safe area. This is probably confirmed by experience, but it may also be influenced by the fact that the safe area is considerably larger than the hazardous area.

In the particular case of an intrinsically safe circuit versus a type 'n' circuit the safety ratio is heavily in favour of the intrinsically safe circuit. If the relative safety of the two systems can be considered on the basis of the fault count then figure 9 suggests that an 'ia' circuit is a million times safer than a type 'n' circuit and consequently is much the preferred solution. This simple argument is not a comprehensive comparison because the predominant factor in most accidents is human error, and this is arguably equally applicable to both techniques. Nevertheless intrinsically safe circuits are preferable.

Existing English law suggests that in deciding what precautions are considered 'reasonably adequate' the balance should be heavily weighted in favour of the person taking the risk as compared with the person imposing it; and the cartoon in figure 10 is frequently used.

Figure 8: Relative safety of utilisation of different equipment categories

AREA CLASSIFICATION			ATEX APPARATUS			GAS PRESENT X HAZARD = PROBABILITY OF EXPLOSION
Zone	Hours/ Annum Gas present	Probability of Gas present	Category	Faults for a potential hazard	Probability of potential hazard	
0	10^4 - 10^3	1	1	3	10^{-9}	10^{-9}
1	10^3 - 10^1	10^{-2}	2	2	10^{-6}	10^{-8}
2 Safe area	10^1 - 10^{-1}	10^{-4}	3	1	10^{-3}	10^{-7}

Assumes a fault has probability of 0.1% per annum

Figure 9: Relative safety of type 'n' versus intrinsic safety

Method of protection	No. of faults for hazard	Probability of hazard	Ratio compared to type 'n'
Type 'n'	1	10^{-3}	1
'ib'	2	10^{-6}	10^{-3}
'ia'	3	10^{-9}	10^{-6}

The price to be paid to prevent killing someone is not well documented and varies considerably. The Ministry of Transport are reported as using a figure of £660,000 in assessing road safety schemes in 1994 and a figure of ten times that has been used in some offshore industry safety case arguments.

If these arguments are accepted, then the greater safety of intrinsic safety, at no appreciable increase in cost, must rule out the use of type 'n' equipment. In practice its use can only be justified when the available intrinsically safe apparatus will not perform the required function, usually because of the restricted available power, or because there is no certified intrinsically safe apparatus. In these circumstances the greater freedom to self certify and the freedom of self surveillance can be used to produce an adequately safe system. However even in these circumstances there is a responsibility to be as safe as is practicable, rather than as dangerous as is permitted.

10 Conclusion

The conclusion drawn from this document is that the only circumstances where type 'n' instrumentation should be used is where there is no certified intrinsically safe apparatus which will accomplish the task required. In these circumstances possibly an uncertified intrinsically safe system may still be preferable.

Intrinsically safe apparatus is certainly safer and, when used in a conventional mode, is marginally lower in cost. The type 'n' apparatus standards and codes of practice are targeted at relatively heavy current mains voltage equipment and do not adequately address the question of live maintenance hence are not appropriate to instrumentation.

The problem of administering and maintaining mixed systems are considerable and consequently type 'n' instrumentation must be relegated to solving those one per cent of problems which cannot be implemented with an intrinsically safe circuit.

Over the last twenty years the author has been marginally involved in four significant type 'N', or almost type 'n', installations. After a lot of hassle all four were commissioned, and worked, but when the time arrived to modify them, or replace equipment, confusion spread rapidly. Two of the systems have been converted to intrinsically safe installations and the other two muddle on. Hence, if you must insist on creating a type 'n' installation then try to find someone who has done it successfully, and has been operating it for some time. If you find such an end user, please tell me as I would like to meet him!

Figure 10: Scales of Justice

Year 2000 update

TP1124 was written in mid 1997 and hence some of the references to standards are out of date.
In particular the state of type 'n' standards has progressed.
The CENELEC standard EN 50021 was published in 1999 and the equivalent IEC standard IEC 60079-15 has been given a positive vote and will be published this year (2000).
The intrinsic safety standards and code of practice have also been modified slightly.
The full impact of the ATEX directives, distributed systems and fieldbus has yet to be experienced.
However, with these reservations the arguments in the document are still considered by the author to be valid.

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10/00. Printed in the EU.