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Shunt-Diode Safety Barriers and Galvanic Isolators – a Critical Comparison

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Introduction

The discussion on the relative merits of galvanic isolators and shunt diode safety barriers has been carried on for many years. The majority of other articles on this subject have aimed to prove the superiority of one technique over the other. This paper brings together the illustrations which have accumulated over a considerable time in response to various questions raised at presentations. It attempts to make balanced arguments so that the reader can decide the most suitable technique for a particular application.

It ends with a score sheet which might be found useful if a decision is not completely self revealing.

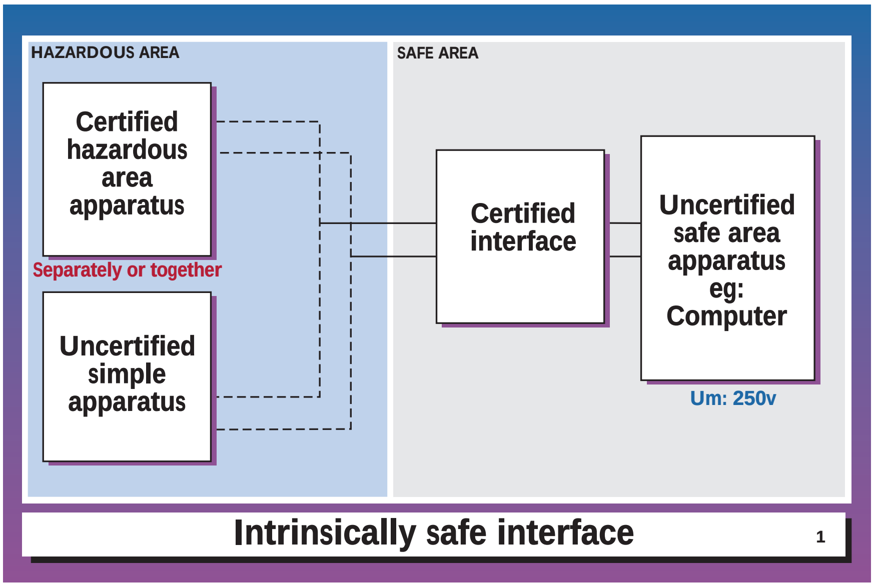
The paper has evolved over a considerable time, however it is unlikely that it covers all aspects and will inevitably need to be revised as techniques develop. If you have any comments on the contents or omissions within this document the author would like to receive them. In this way the document will become more comprehensive and more valuable.

Figs 1 and 2

The basic function of an intrinsically-safe interface is to remove the necessity for certifying the safe-area equipment. The equipment in the safe area is usually complex, needs to be flexible and contains considerable power. Therefore it can inject significant levels of energy into the hazardous area, particularly under fault conditions.

An ideal interface allows the normal low energy signal to pass with as small a voltage drop as possible and with very little attenuation. If however a fault develops in the safe-area equipment then the interface changes its transfer characteristic and restricts the energy transferred to the hazardous area to a safe level.

Shunt-diode safety barriers were developed in the late 1950's as process control computers were more widely applied to the chemical industry and are generally regarded as being the older technique. However, intrinsically-safe relay isolators for switch inputs have been available for many years (quite how many I have not been able to establish) and analogue isolators were available in 1953. The recent growth in the use of both types of isolators has resulted from improved performance and lower cost, not to any change in fundamental principles.



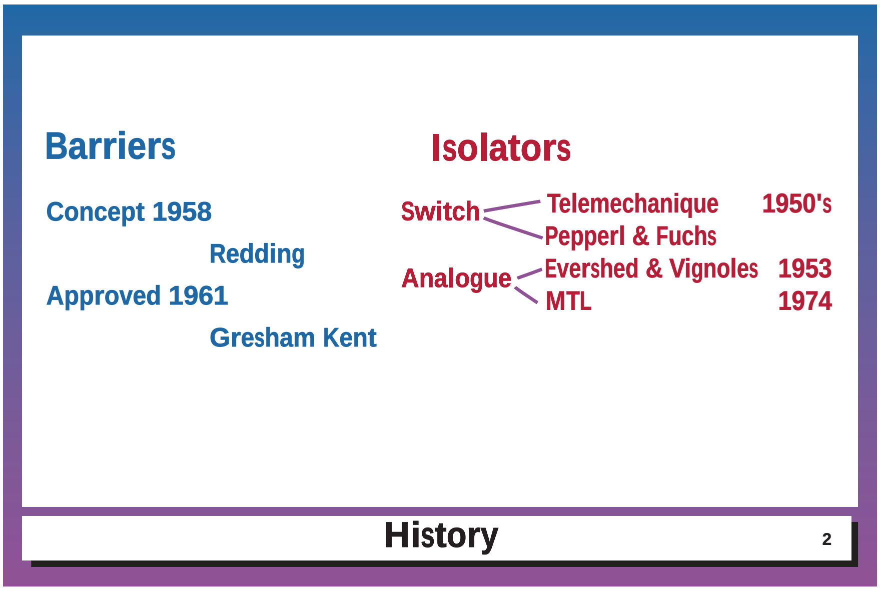
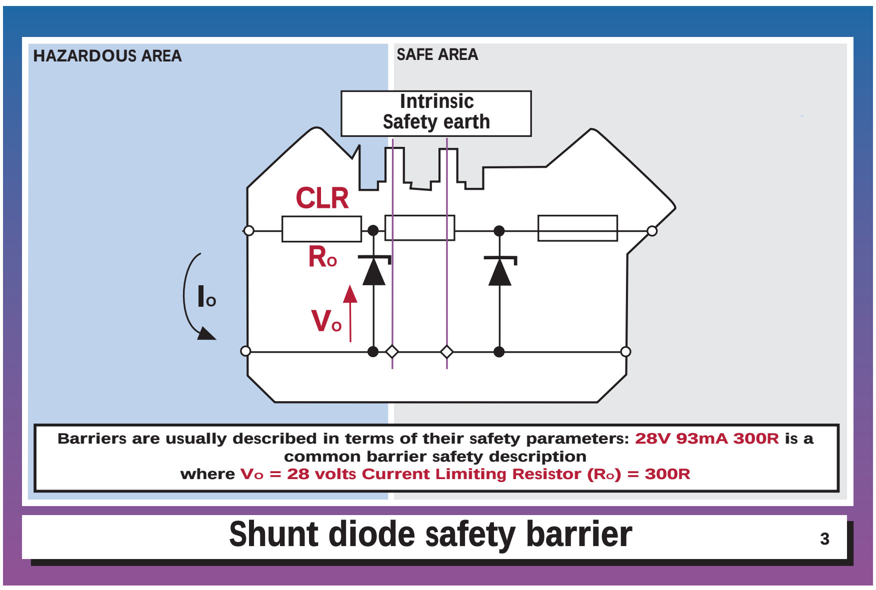
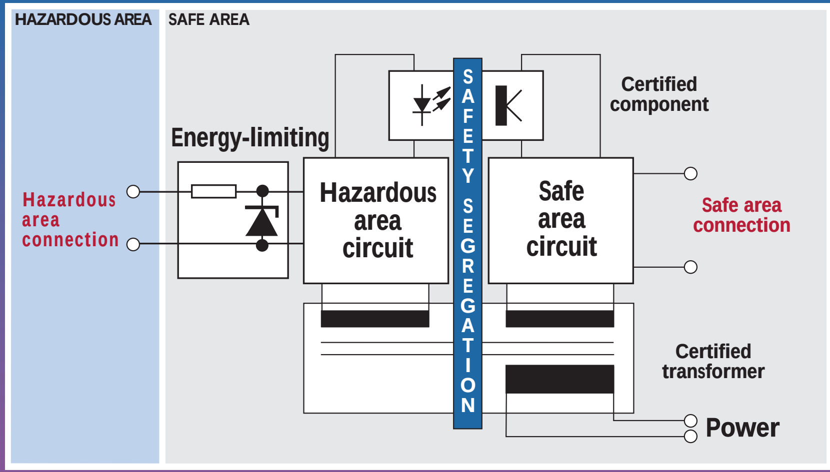


Fig 3 and 4

Fig 3 illustrates how a shunt diode safety barrier is constructed so as to limit the current and voltage available from the hazardous-area terminals. The fuse restricts the fault power, the zeners restrict the voltage and the current limiting resistor [CLR] restricts the current.



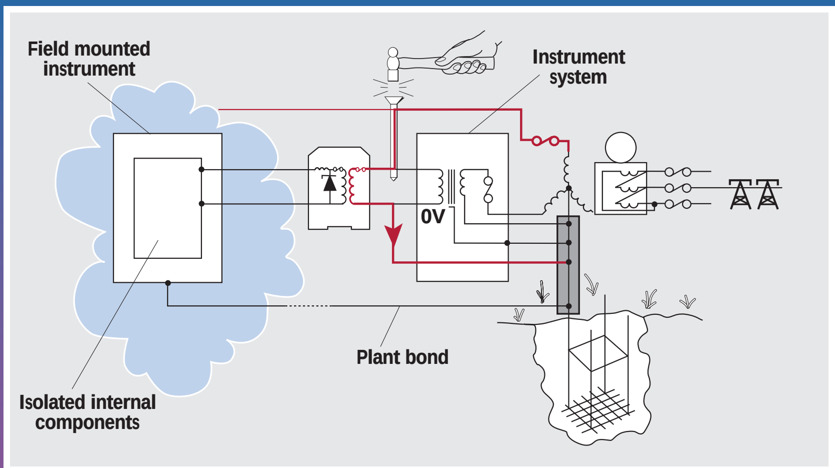
The galvanic isolator illustrated in Fig 4 breaks any direct connection between safe- and hazardous-area circuits by interposing a layer of insulation between the two. The power transfer is usually via some form of transformer and the return signal via an optocoupler, transformer, or relay. The final power limitation is achieved by using a diode resistor network very similar to that of a shunt-diode barrier.



Galvanic isolation 4

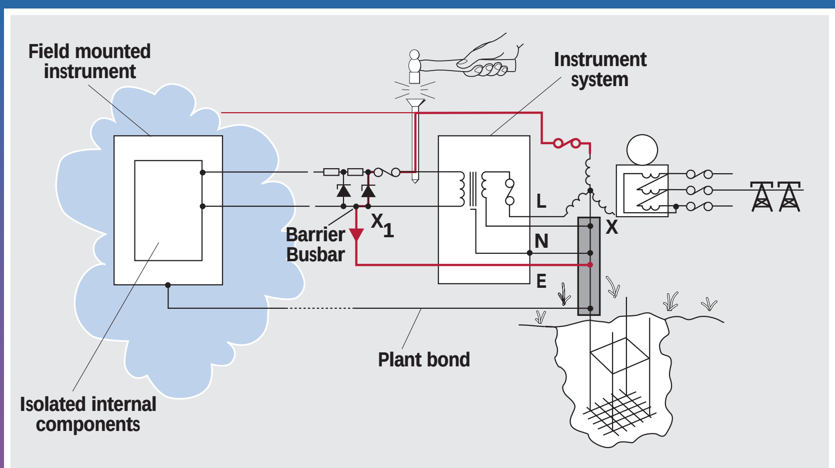
Figs 5 and 6

Since the hazardous-area circuit from an isolator is not directly connected to the safe area circuit, it is usual to regard the fundamental action as effectively blocking the excessive energy at the layer of insulation. In practice the 0V of the instrument system is normally returned to the neutral star point for interference avoidance and safety reasons. The resultant fault current is thus returned to the neutral star point in the usual way, rupturing the protective fuse and removing the fault, in a relatively short time.



Galvanic Isolator under fault condition 5

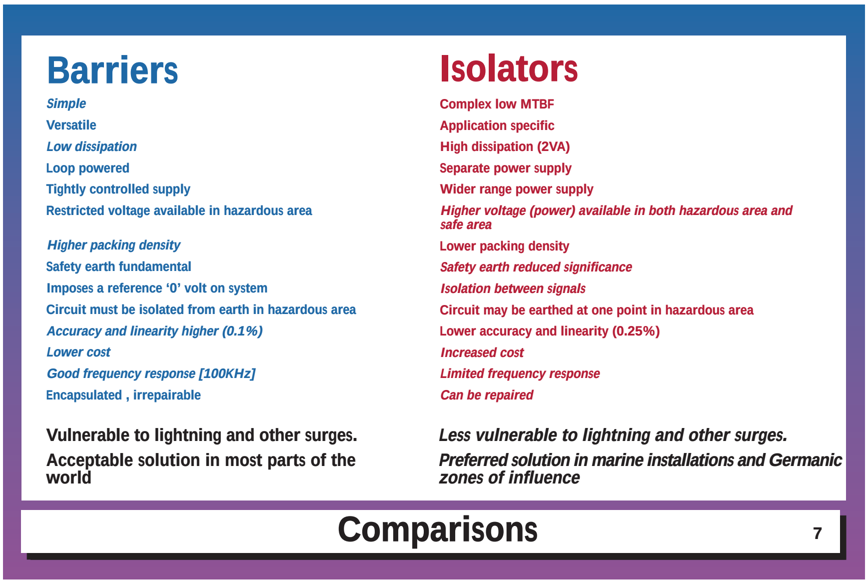
The conventional fault consideration of the shunt-diode barrier is illustrated in Fig 6 where the fault current is returned to the neutral star point within the safe area in much the same way. The important difference is that the transient voltage difference between the barrier busbar and the neutral star point [X_1 X] is now transferred to the hazardous area and hence must be restrained to a low level [less than 10V]. In consequence the busbar to neutral star point bond on the shunt diode safety barrier must be of low resistance and be secure, since it is critical to safety.



Barrier under fault condition 6

Fig 7

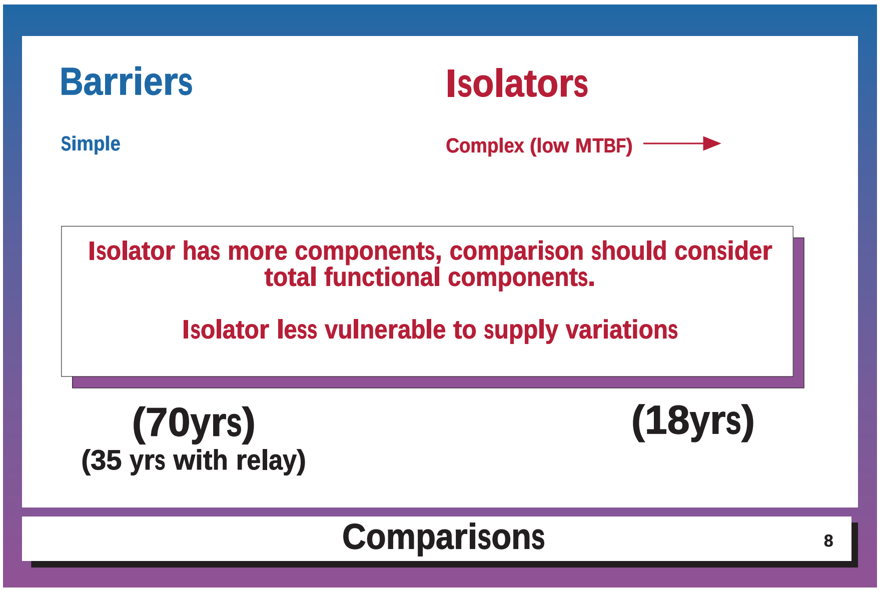
Fig 7 lists the relative merits of isolators and barriers and the significance of these factors varies with the particular installation. The remainder of the document expands these points of comparison so that they can each be evaluated.

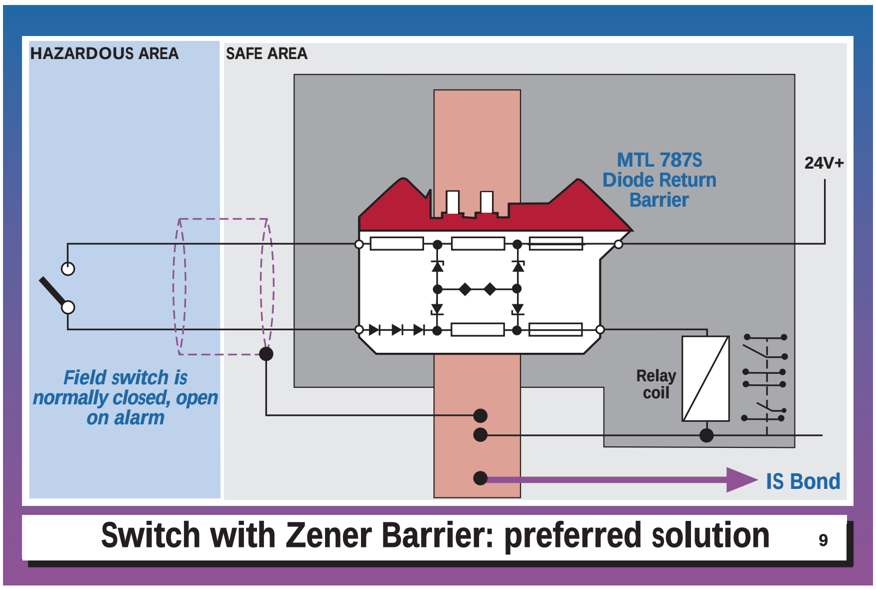


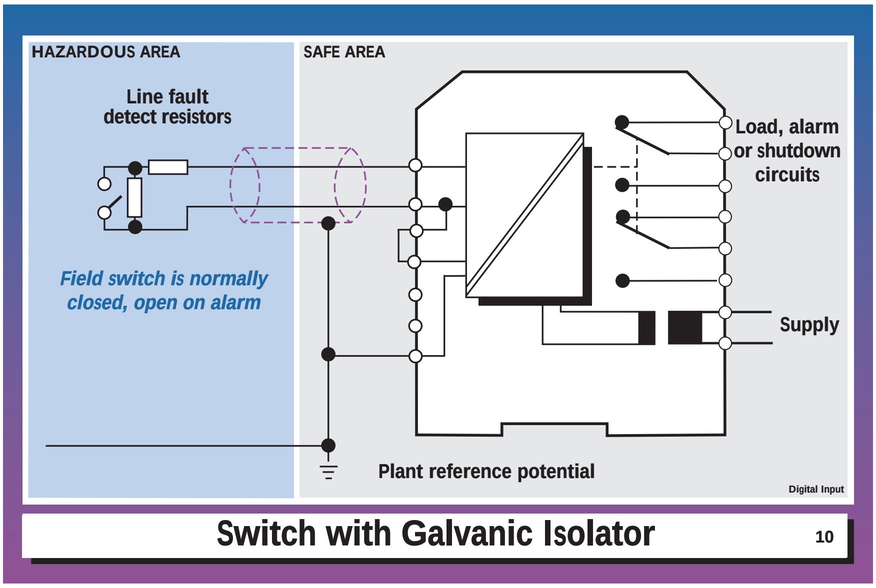
Figs 8, 9 and 10

In general the lower number of components and basic simplicity of the shunt-diode safety barrier means they are considered to be more reliable.

A more accurate comparison has to compare the reliability of an isolator with the barrier plus additional components required to accomplish the same function. For example Figs 9 and 10 show the usual switch contact transfer using a barrier relay combination which should be compared with the more complete functions of the isolator. This reduces the apparent superiority of the barrier.







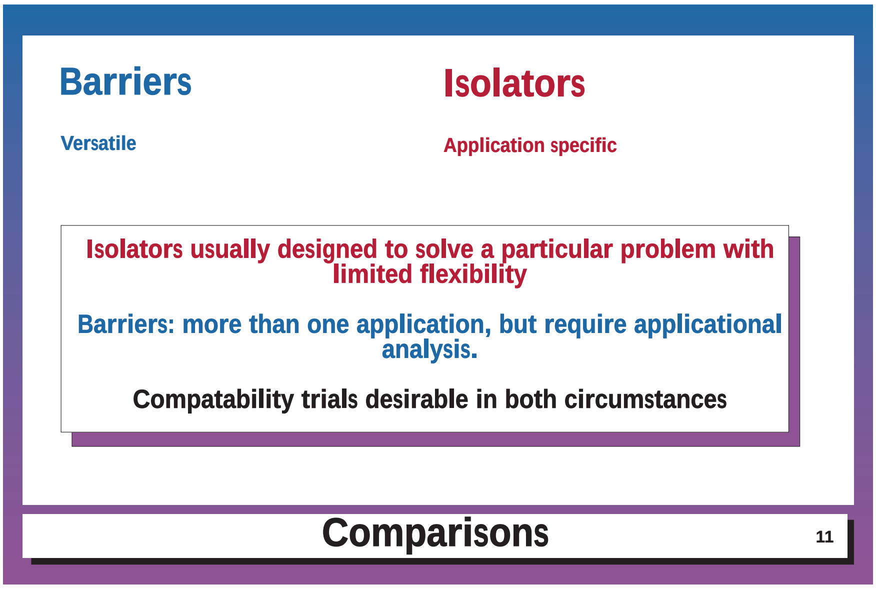
Figs 11 and 12 and 16

In general barriers are more versatile than isolators. For example the MTL787S barrier of Fig 16 is identical with that used in the switch application of Fig 9.

If the flexibility of barriers is exploited to solve a new application then an analysis taking into account possible resistive drops and leakage currents is desirable, as indicated in Fig 16.

Whenever a different untried combination of an intrinsically safe interface and field mounted equipment is proposed, it is advisable to try an experimental interconnection under laboratory conditions. A satisfactory trial increases the probability of the final installation working.

Fig 12 shows an isolator for use with a conventional 4 to 20mA transmitter. The isolator is designed for use with this type of transmitter and is not useful for any other function.



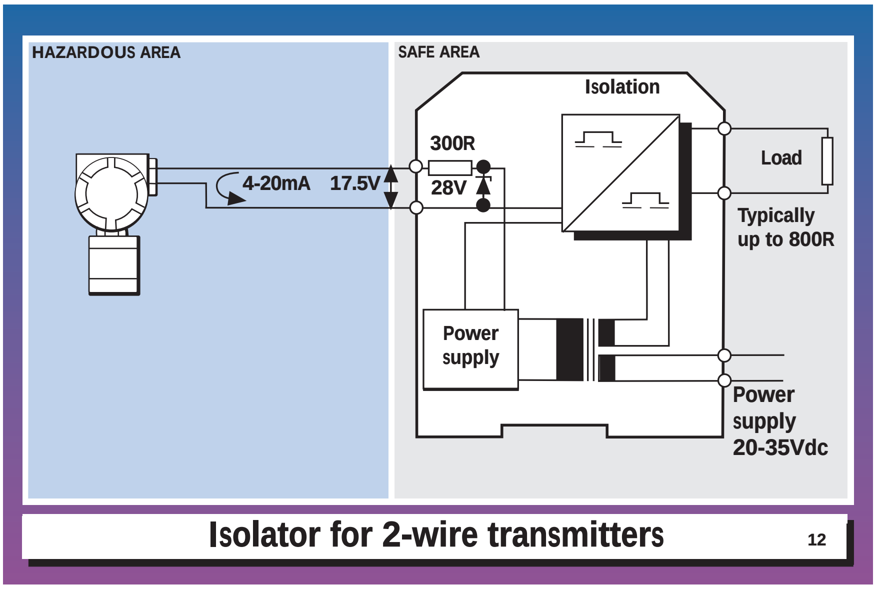
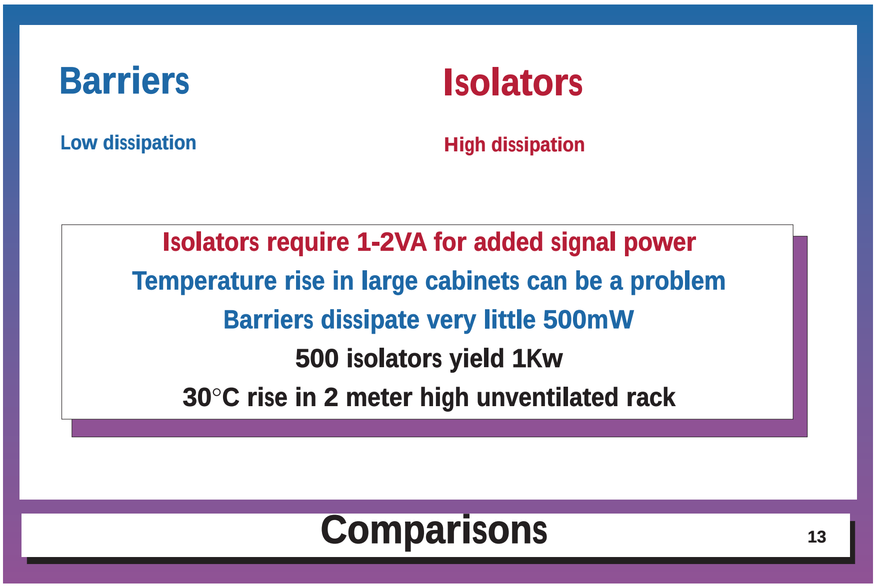


Fig 13

Isolators require additional power which utilises space, dissipates more heat and increases cost. The use of a well ventilated (possibly force ventilated) cabinet becomes a necessity if isolators are closely packed.

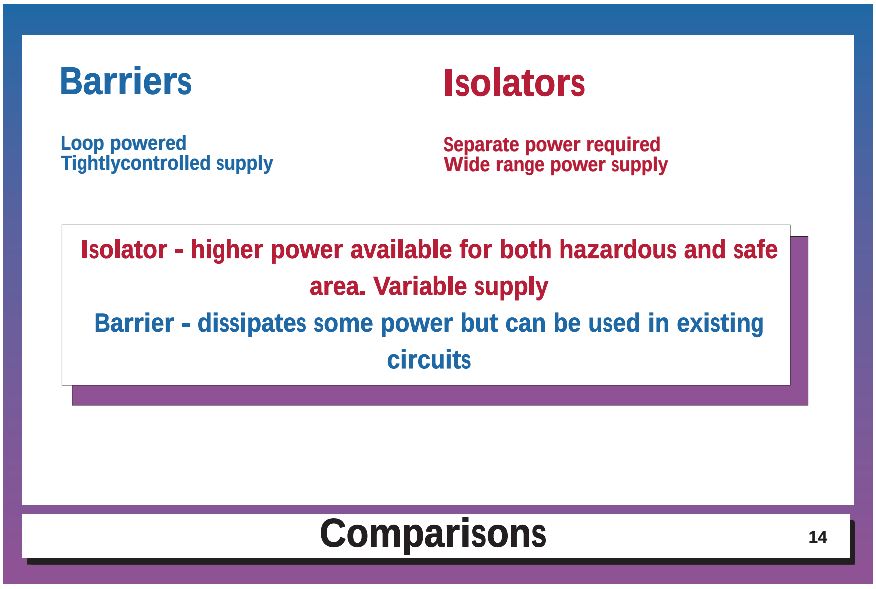
It must be remembered that for both barriers and isolators the maximum permitted ambient temperature is the air temperature immediately adjacent to the apparatus i.e. the temperature inside the enclosure. This temperature may be raised by other adjacent electrical equipment.

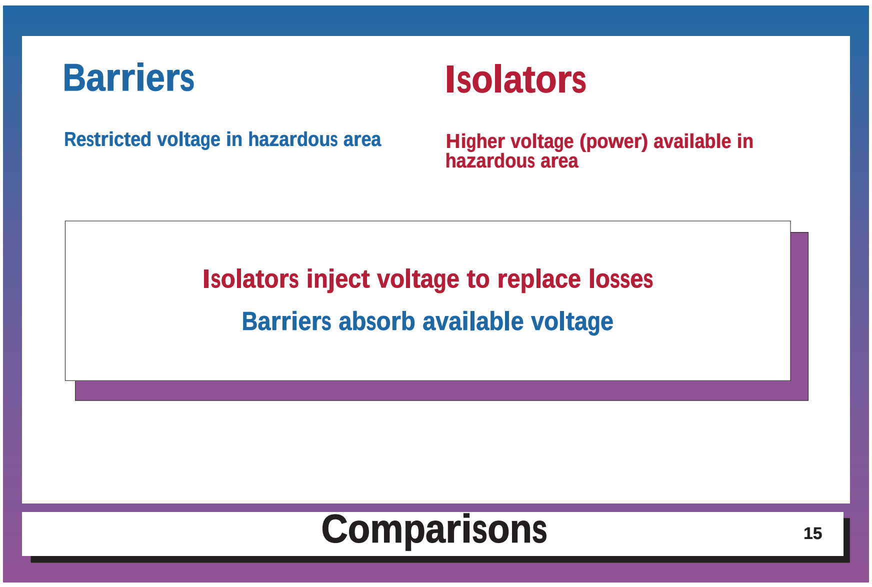


Figs 14, 15, 16, 17, and 18

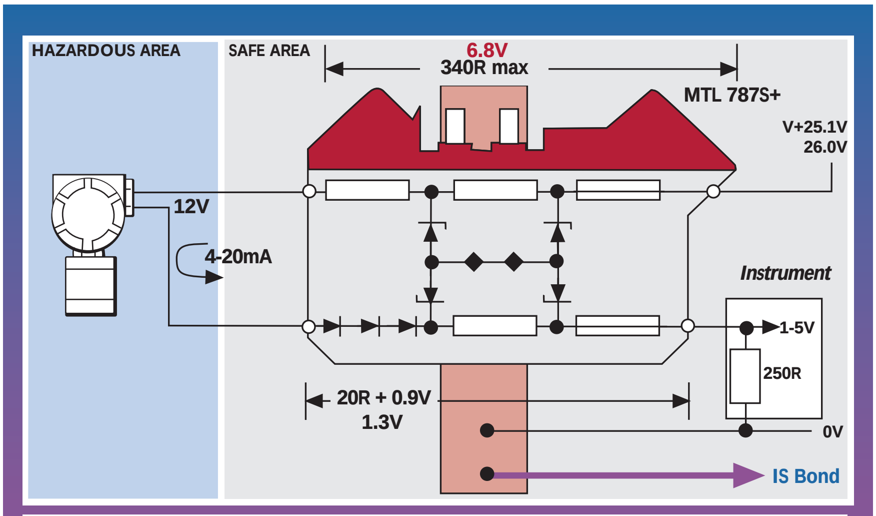
Barriers may have over-voltage protection to counteract large supply variations but the protection absorbs line volts.

Conventional barriers restrict the available hazardous-area line volts. For example, the conventional diode return barrier transmitter combination of Fig 16 has a maximum line voltage drop of 0.9V. By comparison the MTL3041 circuit of Fig 17 has 5.5V available for line voltage which readily permits the use of loop powered local indicators as shown in the diagram.

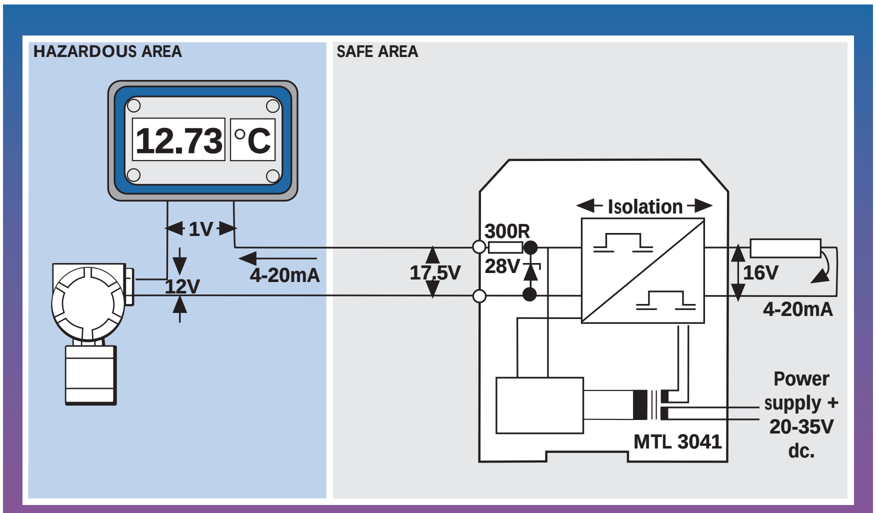




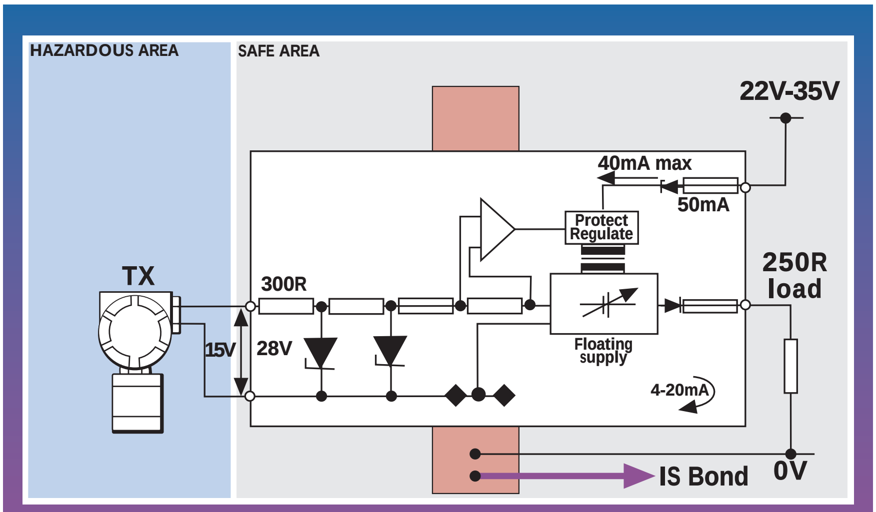
Active barriers such as the MTL706 shown in Fig 18 permit more line voltage and are tolerant of supply voltage variation. They consume additional power, but offer an alternative to isolators if there is a strong preference for a barrier solution.



Transmitter with diode return barrier (MTL 787S) 16



Loop-powered 4-20mA Indicator 17



MTL 706 schematic 18

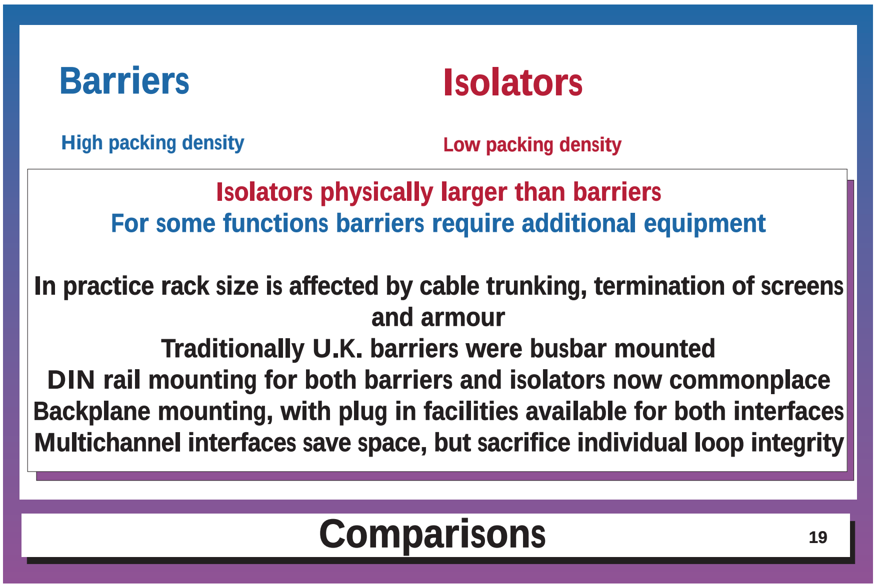
Figs 19 and 20

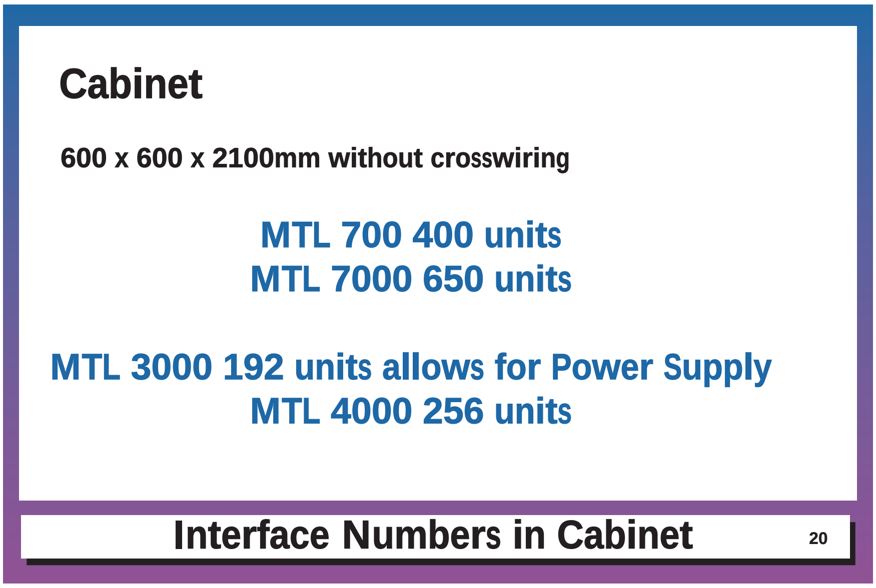
The number of interfaces which can be mounted in a cabinet is largely determined by the size of cabling to be accommodated and the degree of accessibility to be achieved. Facilities for cross wiring also use considerable amounts of space.

The numbers quoted are those for generously designed racks and higher density can be achieved at the expense of accessibility and temperature rise. The figures available do however demonstrate the higher packing density which can be achieved with barriers.

The number of mechanical variations available in both barriers and isolators is increasing and each has its particular merits.

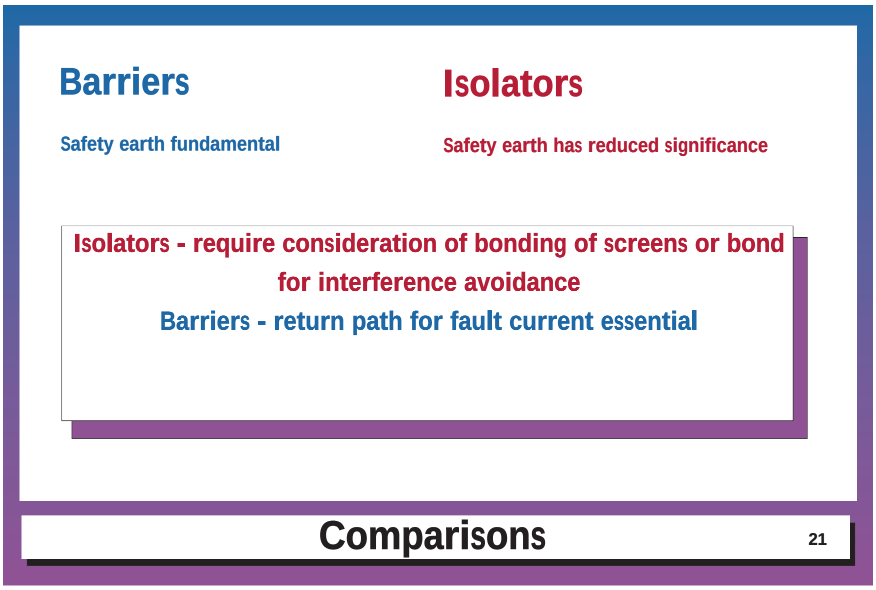
The discrete use of multichannel units can also effectively increase the number of channels per cabinet. However single loop integrity is sacrificed and some thought as to whether this is significant or not is essential.





Figs 21, 22, 23, 24 and 25

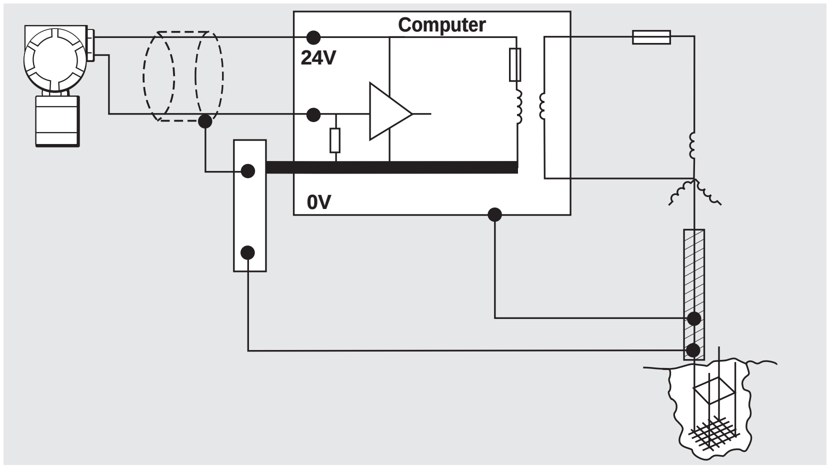
There is normally much emphasis on the necessity for correct bonding of the shunt-diode safety barrier's '0' volt busbar. However the development of the required bonding system from Fig 22 showing the requirements for structure, computer 0V and screen to the slightly modified system of Fig 23 illustrates that there is no difficult requirement. To avoid significant differences within the hazardous area the bond should have a low resistance [0.1Ω] and be of high integrity. The



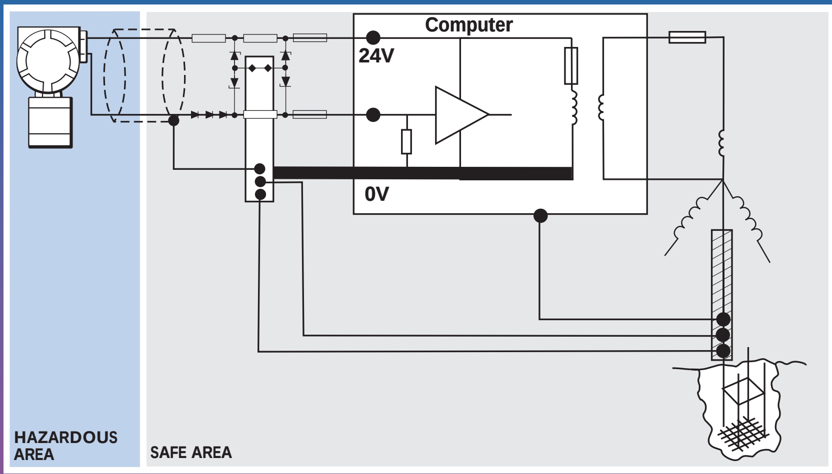
possibility of installing a second lead (as indicated by the broken line) for monitoring purposes should be considered. However the presence and integrity of the bond is essential in all types of installation.

The isolator bonding system illustrated in Fig 24 is identical with that of the non-hazardous system, but the 0V bond has some safety implications.

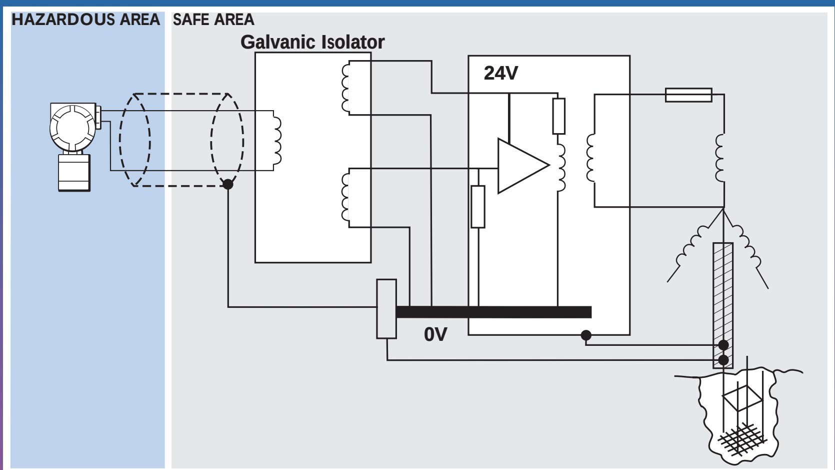
The overall earthing system illustrated in Fig 25 emphasises that the instrument system bonding is only a part of the total system. The requirements are only marginally affected by whether barriers or isolators are used.



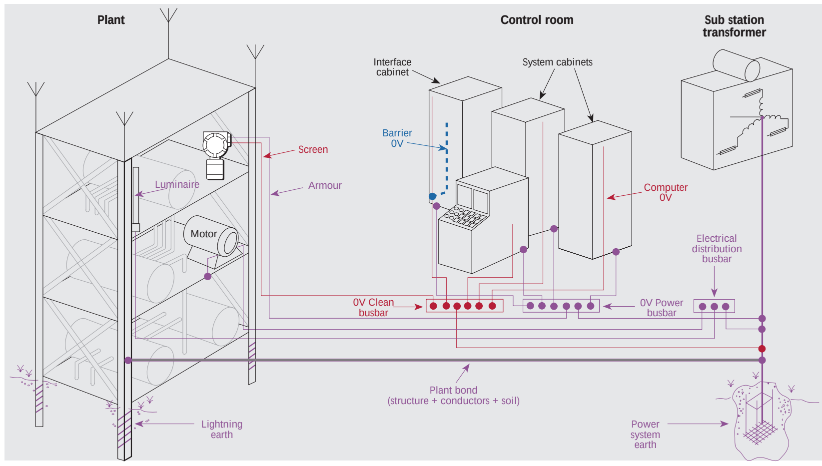
Standard bonding practice 22



Shunt diode safety barrier bonding system 23



Galvanic isolator bonding system 24



Plant bonding 25

Figs 26, 27 and 28

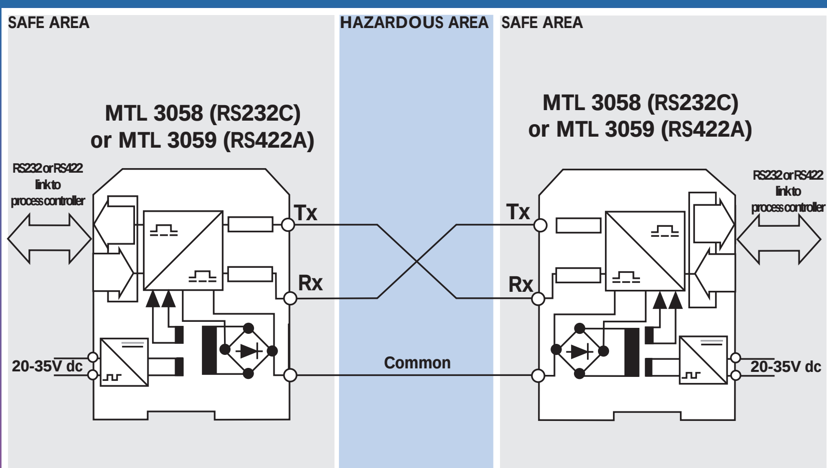
Where signals have to be transferred across a hazardous area using intrinsically-safe cabling, the preferred technique is to use galvanic isolation at both ends. Fig 27 illustrates a system frequently used between analyser houses and control room.

If a signal has to be transferred to a remote location in the safe area, Fig 28, the use of an isolator at the interface removes concern over possible potential differences between earth mats. The extra voltage needed to drive the interconnecting cables is also useful. For these reasons isolators are the preferred solution, in these particular circumstances.

Barriers	Isolators
Imposes a reference 0 volt on system	Isolation between signal and power supply

Isolators usually have 3 port isolation. Interaction between circuits reduced. Fault mechanisms easier to define
Barrier 0 volt and computer 0 volt usually interconnected. Two channel barriers create pseudo 'earth free' circuits
Barrier circuits bonded at barrier '0' volt, hence must be isolated elsewhere.
Isolation necessary for transfer across a hazardous area or to remote situation

Comparisons 26



Serial data transfer across a hazardous area 27

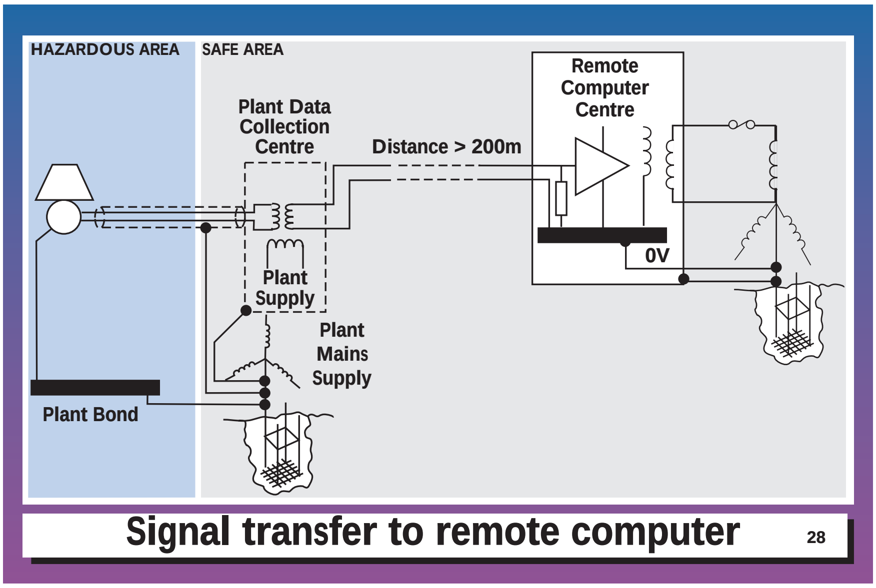
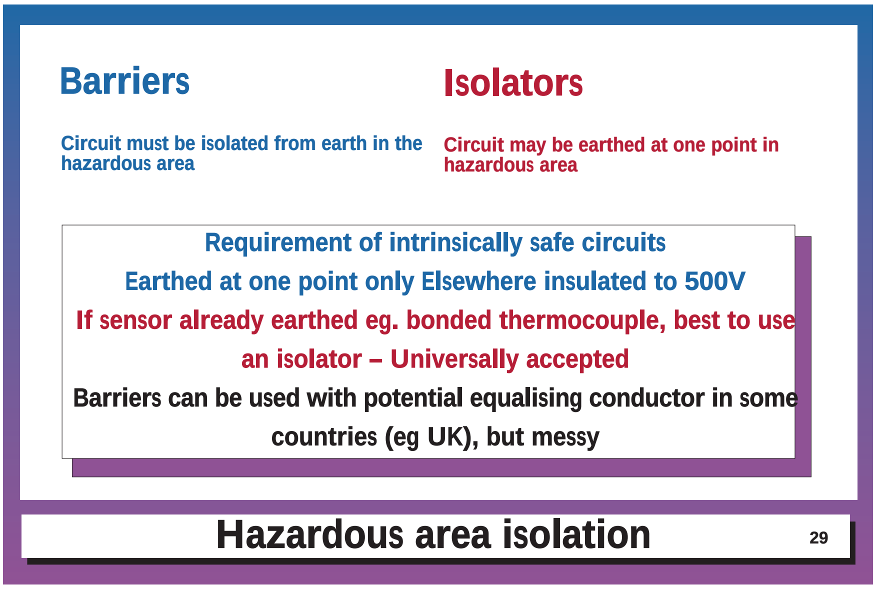
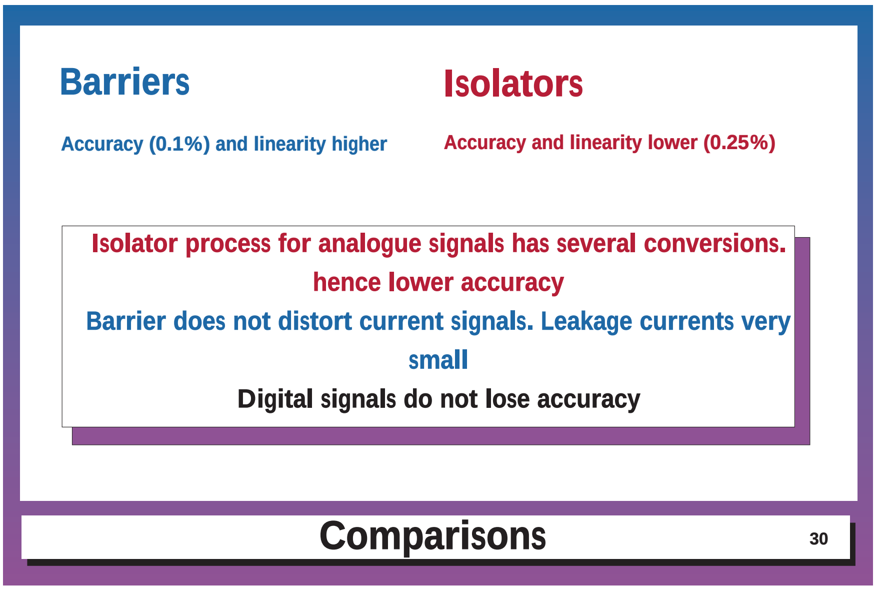


Fig 29

There is a general requirement that intrinsically-safe circuits should be earthed at one point only and elsewhere isolated to withstand a 500V insulation test. It follows that where a sensor or some other field apparatus cannot be insulated (eg. a pH sensor) then the preferred solution is to use an isolator. In some countries the code of practice permits the using of equipotential bonding conductors but this is not a universally accepted practice and should be avoided if at all possible.



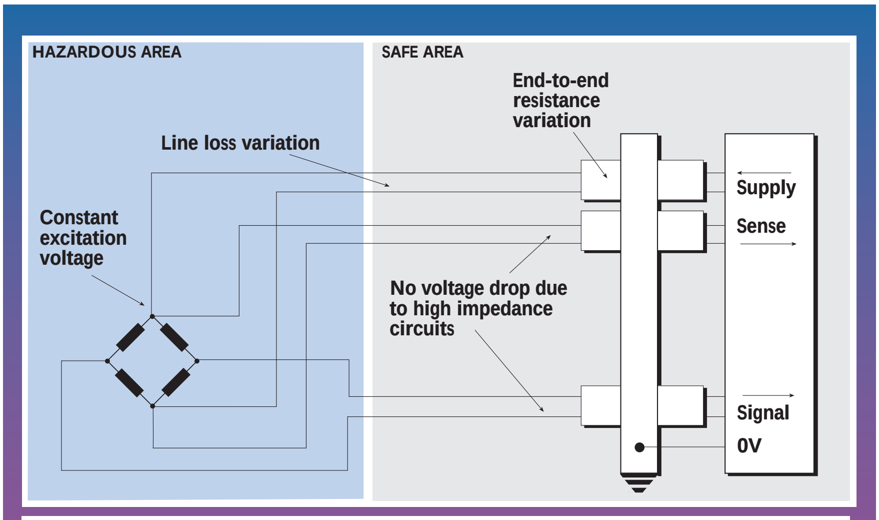


Figs 30, 31, 32 and 33

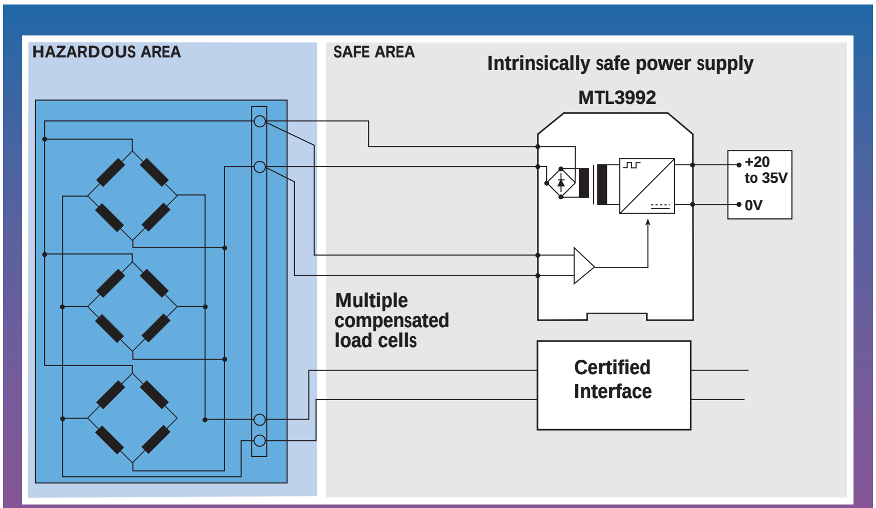
Although the changing technology of isolators has increased their accuracy, they are in general less accurate than barrier systems. Usually transfer accuracy is adequate but the temperature coefficient remains significant.

Figs 31 and 32 show comparable load cell systems where every effort is made to achieve maximum accuracy. The barrier load cell system can achieve 0.05% without difficulty, and the isolator system would achieve 0.25% if the ambient temperature varied by 25°C.

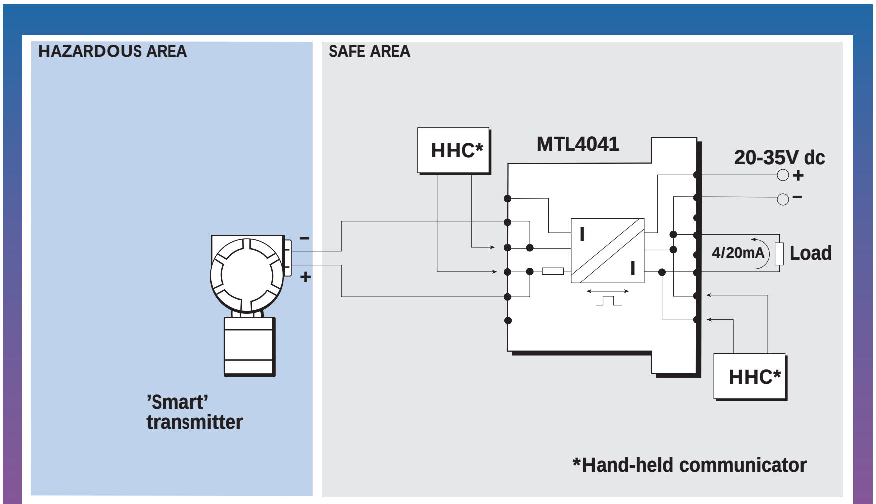
Fig 33 shows a Smart transmitter which when used with a 4 to 20mA analogue signal would expect to generate a 0.2% error at the interface. If, however, the digital representation of the measurement was used then the isolator would not introduce any error. It follows therefore that where isolators are the preferred solution for use with Smart transmitters and the highest accuracy is required then the digital signal should be used.



6-wire connection – minimised error 31



Intrinsically safe load cell power supply 32



Plug-in isolator with transmitter 33

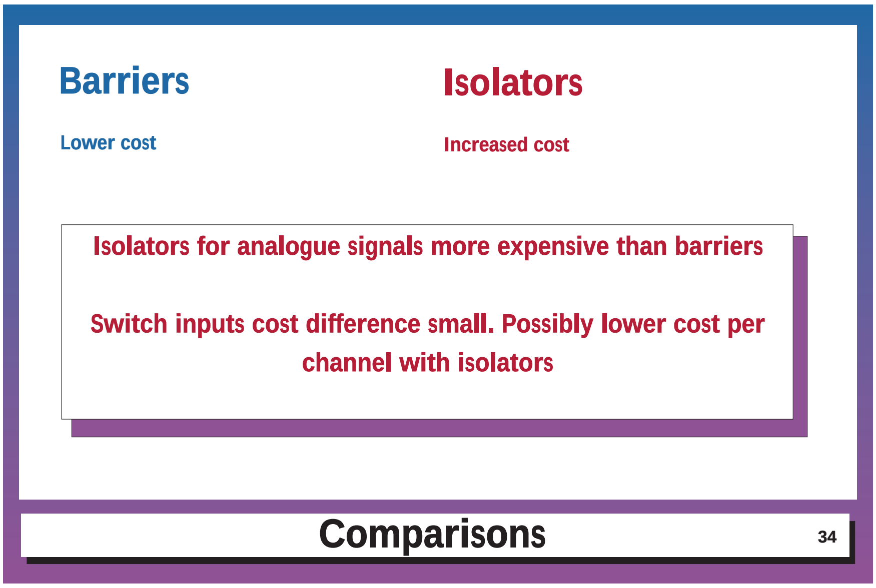
Figs 34, 35 and 36

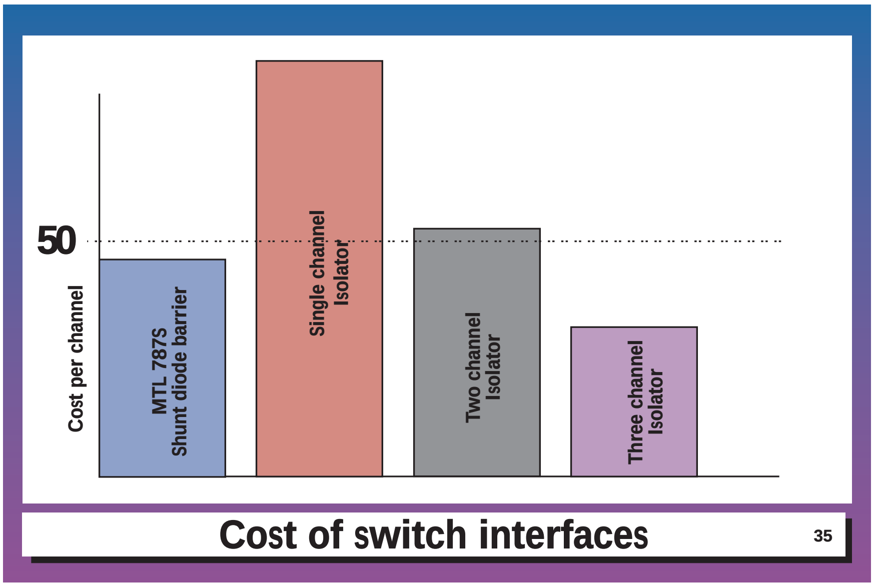
Cost comparisons are always difficult because there is very rarely a precise coincidence of function. There is however a general perception that shunt diode safety barriers are less expensive than isolators.

In practice for switch transfer purposes there is little difference in cost per channel between the two techniques. If individual loop integrity and minimum facilities are acceptable the multichannel switch isolators are lower in cost than corresponding barrier solutions as illustrated in Fig 35.

Analogue isolators are more complex than the corresponding barriers and the cost difference becomes significant as shown in Fig 36.

However, except for very large installations the cost difference is rarely the deciding factor.





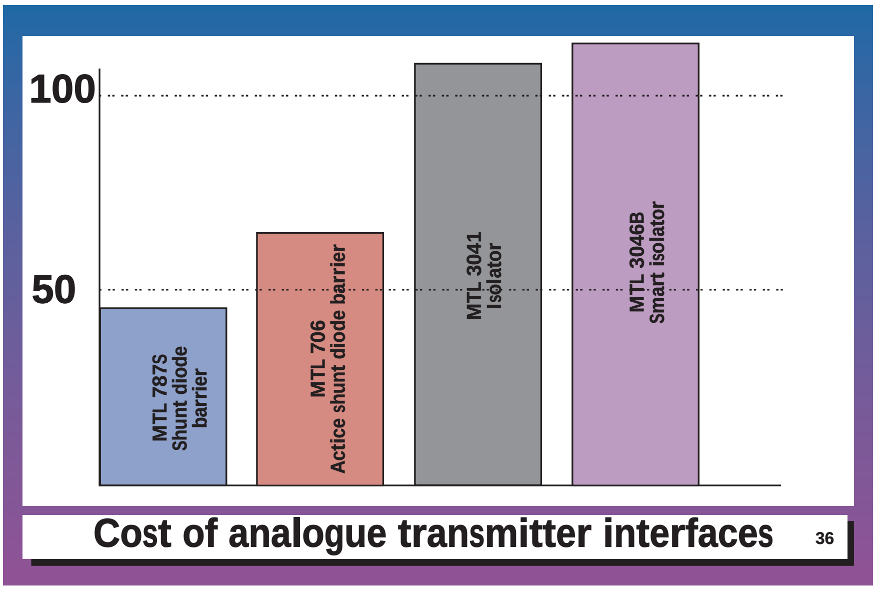
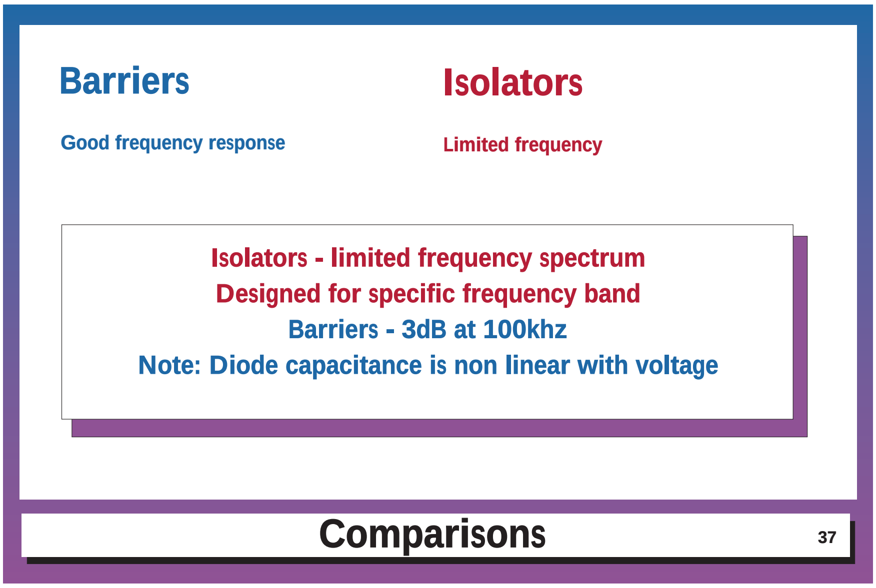


Fig 37 and 38

In general the frequency response of a barrier is determined by the value of the current limiting resistor and the diode capacitance. The diode capacitance is non-linear with voltage and hence some distortion of any high frequency signals inevitably takes place and a discussion on frequency response can be misleading. If a system frequency is higher than 50kHz the only solution is to try the system experimentally, attempting if possible to allow for the effects of interconnecting cables.

Isolators in general have to be designed to operate at the specific frequency transmitted. For example, with Smart transmitters the interface MTL3046B illustrated in Fig 38 works with the majority of transmitters, but not all. It is therefore essential to check compatibility between the particular apparatus and the isolator to be used.



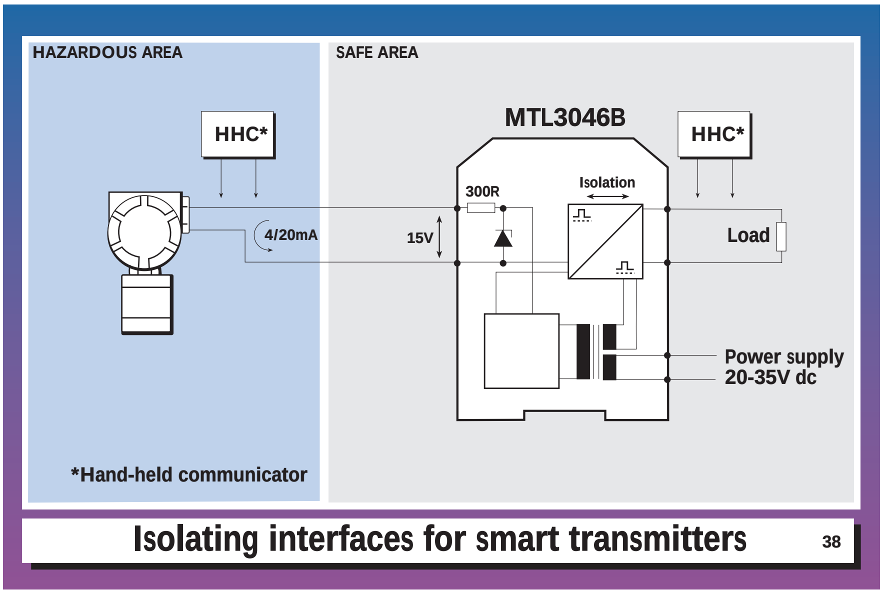
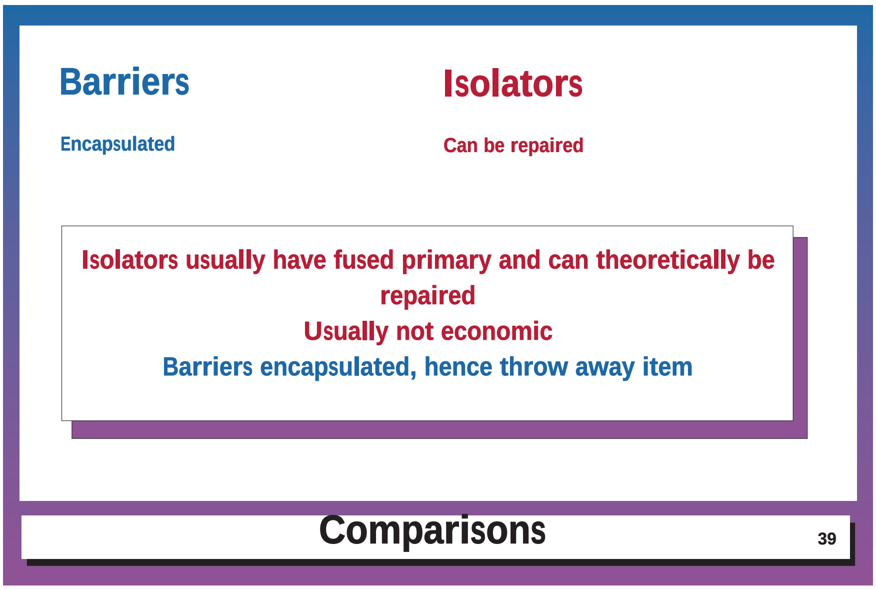


Fig 39

In general repair is not a practical proposition.

Some thought on the acceptability of barriers with interchangeable fuses needs to be given if frequent damage is anticipated and cannot be avoided.



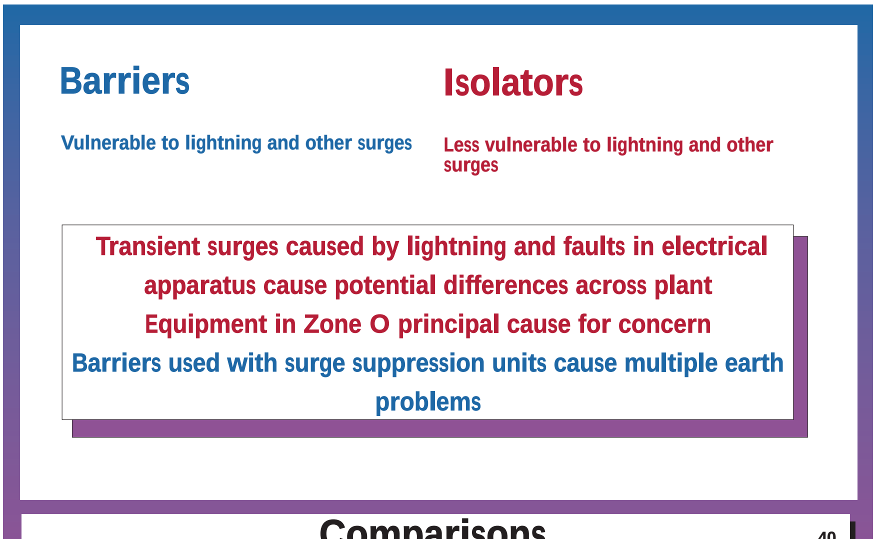
Figs 40, 41 and 42

Where there is a significant probability of potential differences across a plant due to severe electrical faults or lightning then isolators have greater immunity to damage.

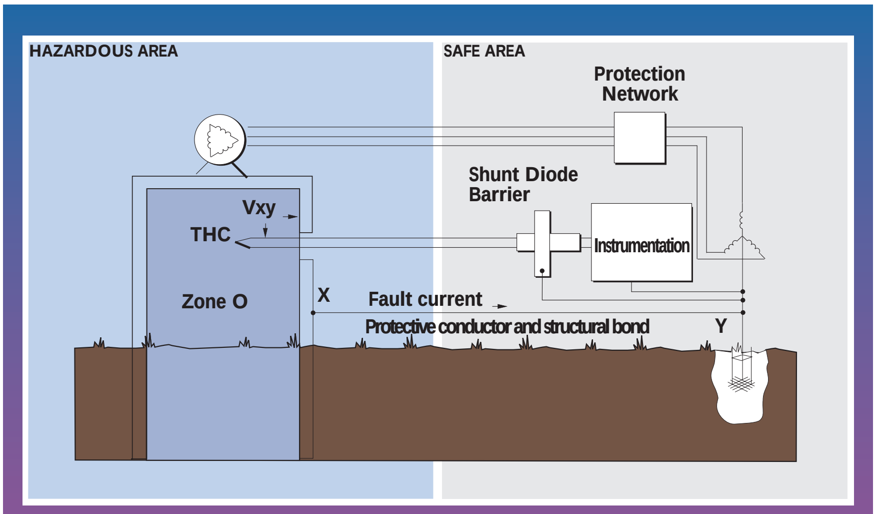
Fig 41 illustrates a possible problem with barriers. A fault current from the electric motor returns via the plant bond generating a voltage between points X and Y. If this is the case, break down occurs between the thermocouple and tank creating a potential hazard. The shunt diode barrier will sacrificially protect the instrumentation.

Intrinsically-safe isolators are routinely tested to withstand 2.5kV rms and hence offer some degree of protection to the instrumentation system.

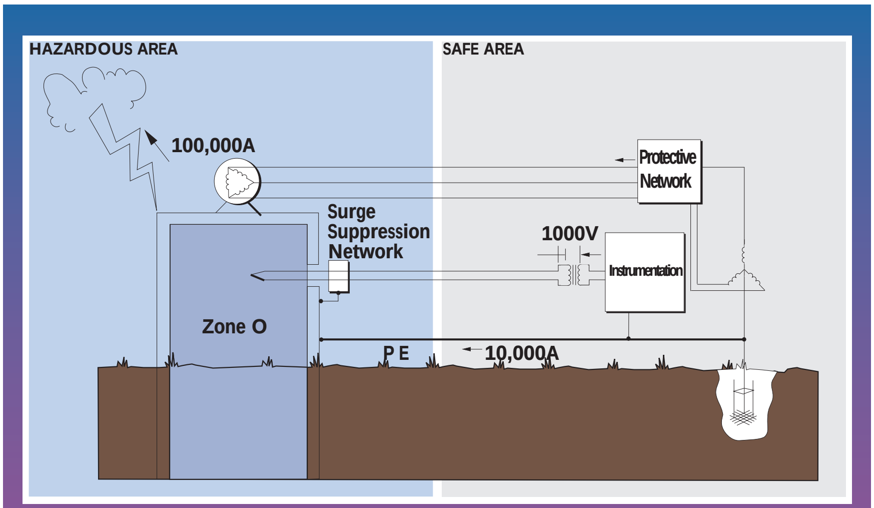
Figs 42 shows how the use of an isolator together with a suitable surge suppression network can prevent an unacceptable voltage difference occurring within the Zone 0.



Comparisons 40



Shunt diode safety barrier fault current 41



Preferred isolator - surge protection solution 42

Fig 43

The need to minimise the number of techniques used within an installation is obvious. Usually therefore, if a plant already uses shunt-diode barriers or isolators in most circumstances it is better to maintain a consistent practice.

If installation already exists and is predominantly a shunt diode safety barrier or an isolator installation then continue the same practice

1) Training of technicians
2) Spares
3) Mounting probably cheaper and more convenient

Overiding considerations 43

Fig 44

Historically, the need to avoid circulating current in ships hulls has led to the preferred practice of using isolated circuits. In general using shunt-diode safety barriers does not lead to any problems but the arguments are long and expensive.

Similarly, German engineers are trained to use and prefer galvanic isolated circuits.

Barriers	Isolators
Acceptable in most areas of the world	Preferred solution in marine installations and German zones of influence

Marine regulations – propose isolated circuits to avoid currents in hull
Easier to use isolators than argue about 2 channel barriers

German attitude – German engineers prefer galvanic isolation particularly in Zone 0
Easier to to agree than convert

Particular situations 44

Figs 45 and 46

The score sheet's principal function is to make sure you consider each of the contributing factors.

If you have a preferred technique then pursue that line, since either solution will probably be satisfactory.

Allocate marks out of 10 if the requirement is important.
eg. 8-2

Allocate marks out of 6 if the requirement is significant.
eg. 2-4

Allocate no marks if the requirement has no significance.
eg. 0-0

If total show a significant preference then follow the choice
If the argument is balanced then follow your personal preference
Whatever you do, use MTL equipment

Score sheet 45

Barriers

Rating

Prefer Barriers
Existing system predominately barriers

Simple
Versatile
Low dissipation
Loop powered
Tightly controlled supply
Restricted voltage available in hazardous area

Higher packing density
Safety earth fundamental
Imposes a reference ‘0’ volt on system
Circuit must be isolated from earth in hazardous area
Accuracy and linearity higher (0.1%)
Lower cost
Good frequency response [100KHz]
Encapsulated , irrepairable

Vunerable to lightning and other surges.
Acceptable solution in most parts of the world

Total

Isolators

Rating

Prefer Isolators
Existing system predominately isolator

Complex low MTBF
Application specific
High dissipation (2VA)
Separate power supply
Wider range power supply
Higher voltage (power) available in both hazardous area and safe area
Lower packing density
Safety earth reduced significance
Isolation between signals
Circuit may be earthed at one point in hazardous area
Lower accuracy and linearity (0.25%)
Increased cost
Limited frequency response
Can be repaired

Less vulnerable to lightning and other surges.
Preferred solution in marine installations and Germanic zones of influence

Total

Score sheet

46