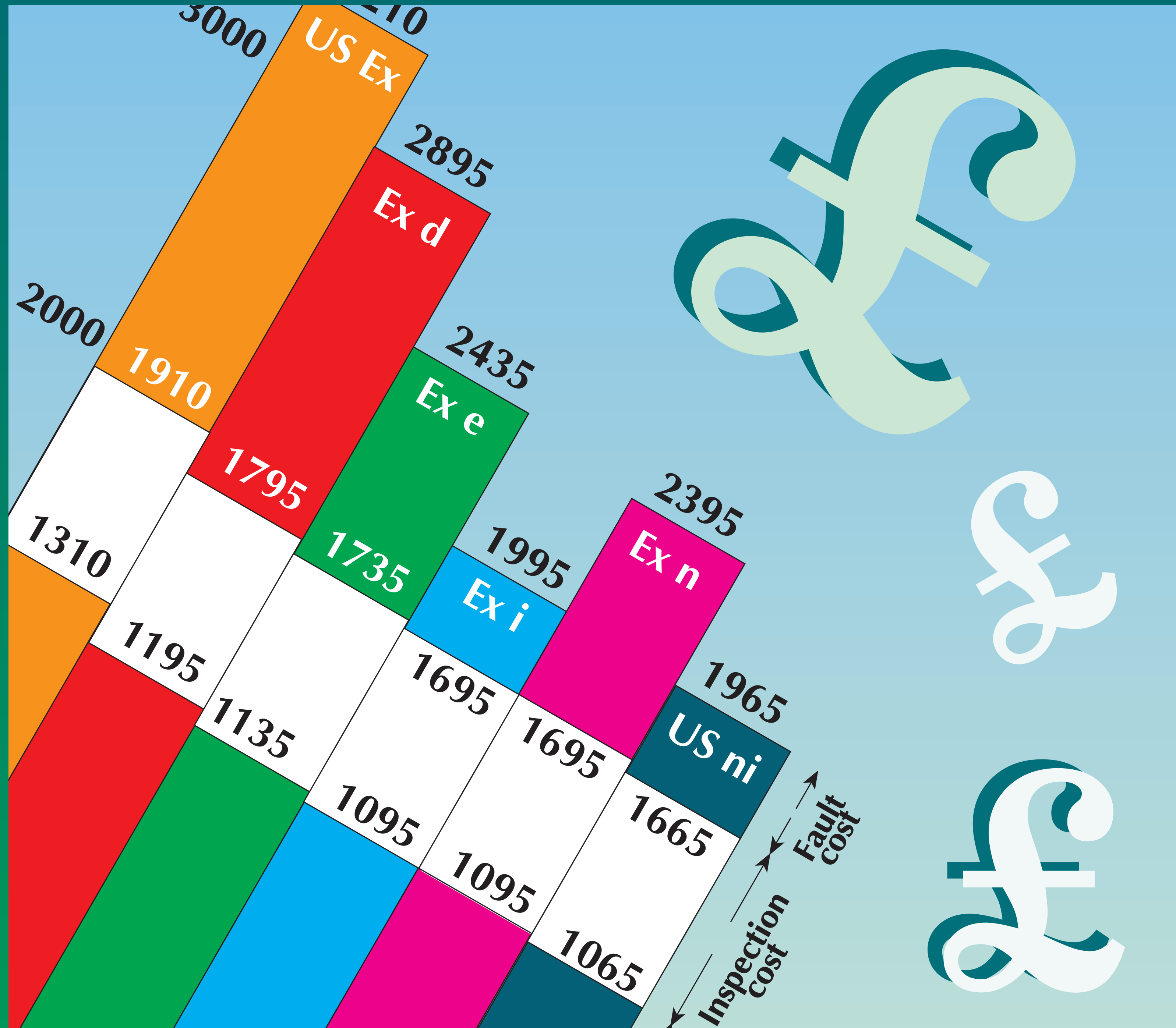
Cost comparison of methods of explosion protection



TP1110-3

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The MTL Instruments Group

ATEX APPENDIX

A simple introduction to the ATEX directives which are relevant to all methods of protection.

ATEX 100A Directive
Safety of Apparatus

Directive 94/9/EC
(23 March 1994)
Provisional 1 March 1996 Mandatory 1 July 2003

(Existing Parallel Directive 76/117/EEC + amendments will be repealed on 1 July 2003)

Directive requirements (Annex I)
- Categorisation of equipment

Essential Safety Requirements (ESR) include:
- Principle of integrated safety
- Consideration of environment
- Marking
- Instructions
- Choice of materials
- Potential ignition sources
- Risk caused by software
- Risk from gas, vapours, mist and dust

Covers design of apparatus applicable to European Economic Area plus some others.

ATEX 137A (118A) Directive
Safety of Installation

(Tentative Analysis based on draft document (Dec 98) hence use with care)
(Probable implementation date 1 July 2003)

INTENTIONS
Prevent explosive atmospheres
If not: Avoid ignition of explosive atmospheres
If not: Mitigate effects of explosion

REQUIREMENTS
Assess the risk overall - produce explosion protection document

INCLUDE
Probability of explosive atmosphere - area classification
Probability of ignition source - equipment categories
Nature of flammable materials - gas groups; ignition temperature; dusts
Scale of effect of explosion - personnel, environment and plant risk

IN ADDITION
Requirements for training and marking

Covers installations

SURFACE INDUSTRY (II)
Equipment category & intended use

Equipment category		Level of protection	Area classification
II1	G D	Two independent faults (ia) Two types of protection	Zone 0 (gas) Zone 20 (dust)
II2	G D	One fault (ib) One type of protection	Zone 1 (gas) Zone 21 (dust)
II3	G D	Safe in normal operation (n)	Zone 2 (gas) Zone 22 (dust)

Mining industries (I) has categories M1 and M2

CERTIFICATION REQUIREMENTS

Equipment category	1	2 Electrical	2 Non-electrical	3	Annex of 100A Directive
CERTIFICATION PHASE					
Certification by notified body	✔	✔			III
Certification by manufacturer			✔	✔	VIII
Unit verification by notified body	UNIVERSAL OPTION	UNIVERSAL OPTION	UNIVERSAL OPTION	UNIVERSAL OPTION	IX
SURVEILLANCE					
QA of production by notified body	✔				IV
QA of product by notified body		✔			VII
QA by manufacturer			✔	✔	VIII

Note: Internal combustion engines are electrical equipment.
Unit verification is normally used for special small quantity apparatus

Cost comparison of methods of explosion protection

TP1110-3
May 2000

By
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Introduction

The problem with attempting to make a comparison of cost is that there are an infinite number of variations in the way each loop can be constructed. This presentation concentrates on two specific loops, a switch transfer loop and a 4-20 milliamp transmitter loop, because these are representative of a conventional process industry control system.

The costs quoted are ratios rather than absolute values although they are the approximate cost in Pounds Sterling. None of the costs quoted are beyond question but they are the author's best estimate. Possibly this comparison is best used by reading and understanding it as it is presented and then if you consider the values chosen to be unrepresentative, redrawing the diagrams using the different estimates that you have chosen. With the variations tried by the author it is only if one or more of the fundamental assumptions made is challenged that the conclusions are changed significantly.

The paper is presented as a collation of the slides used in presenting the lecture, with a few words of explanation inserted so that the document can stand alone. The diagrams use colour to characterise the methods of protection utilised in accordance with the key below.

This document has been updated in December 1999, in particular the first seventeen slides have been amended and some information on the ATEX directives appended.

It is intended to continuously review this document. If you have any comments or criticisms, (preferably constructive) the author would appreciate receiving them so that they can be incorporated.

KEY:

US Ex	Ex e	Ex n
Ex d	Ex i	Us ni

The National Electrical Code currently permits both existing US practice and IEC techniques to be used.

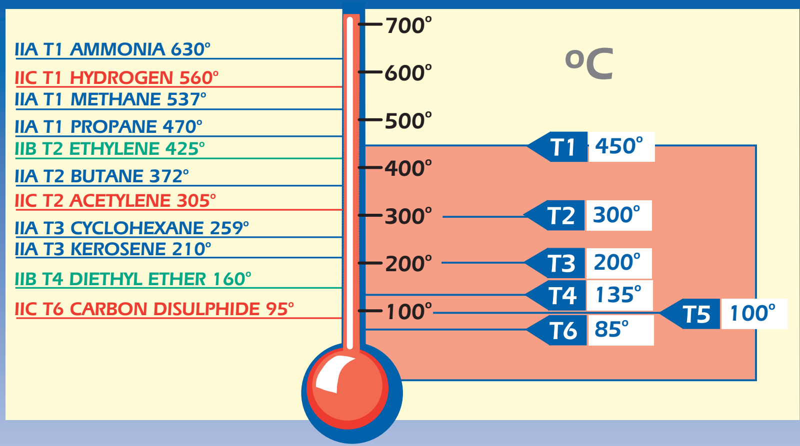
Typical gas hazard	IEC 60079-0 CENELEC EN 50014	North America NEC Article 500 (Class I)*	Minimum ignition energy (microjoules)
ACETYLENE	IIC	A	20
HYDROGEN	IIC	B	20
ETHYLENE	IIB	C	60
PROPANE	IIA	D	180

*North American hazard categories: Class I (Gases & Vapours); Class II (Dusts); Class III (Fibres)

APPARATUS (GAS) GROUPING

1

There is no correlation between Gas Group and Ignition temperature.



Small component relaxation

SURFACE AREA	T4 CLASSIFICATION
<20mm^2 ⩾20mm^2 <10cm^2 ⩾20mm^2	Surface temperature ⩽275°C Surface temperature ⩽200°C Power dissipation ⩽ 1,3 W* at 40°C ambient

*Reduced to 1,2 W with 60°C ambient or 1,0 W with 80°C ambient

APPARATUS TEMPERATURE CLASSIFICATION (T CLASS)

2

Areas are classified with regard to the probability of a potentially explosive atmosphere being present and the length of time for which it is likely to exist.

	Guideline figures	Flammable atmosphere present continuously >1000hrs/annum	Flammable atmosphere present intermittently >10<1000hrs/annum	Flammable atmosphere present abnormally <10hrs/annum	Standard
IEC/CENELEC/EUROPE	Gas	Zone 0	Zone 1	Zone 2	IEC 60079-10
	Dust	Zone 20	Zone 21	Zone 22	IEC 6124-3
NORTH AMERICA	NEC 505 Gas	Zone 0	Zone 1	Zone 2	Listed in NEC 505-5
	NEC 500 Gas & Dust	Division 1		Division 2	Listed in NEC 500-3(c)

AREA CLASSIFICATION

3

STANDARDS FOR METHODS OF PROTECTION

	Code	CENELEC EN	IEC 60079	Permitted Zone / ATEX category 0 / 1	1 / 2	2 / 3	Remarks
Explosion prevention & protection-pt. 1		1127-1					Basic concepts and methodology. Further sections imminent
Category M1		50303					Mining equipment operated in gas atmosphere
Electrical equipment for dusts (D)		50281-1-1					Enclosure protected - construction and testing
Electrical equipment for dusts (D)		50281-1-2					Enclosure protected - selection, installation & maintenance
GROUP II ELECTRICAL APPARATUS for gas atmospheres							
Category 1G		50284	-26				Permits combined methods of protection
General requirements		50014	-0				Basic electrical requirements
Oil immersion	o	50015	-6				Protection by gas exclusion - transformers
Pressurised	p	50016	-2				Protection by gas exclusion - analysers
Powder filled	q	50017	-5				Protection by gas exclusion - weighing machines
Flameproof	d	50018	-1				Prevention of propagation of internal explosion - dc motors
Increased safety	e	50019	-7				Prevention by design - induction motors
Intrinsic safety ia	ia	50020	-11				Low energy. Safe with two faults - level measurement
Intrinsic safety ib	ib	50020	-11				Low energy. Safe with one fault - displays
Intrinsically safe systems		50039	-25				Considers combination of intrinsically safe apparatus
Encapsulated	m	50028	-18				Protection by gas exclusion - solenoid valves
Type of protection 'n'	n	50021	-15				

4

Codes of Practice

SUBJECT	STANDARD IEC 60079-	BS/EN 60079-
Classification of hazardous areas	-10	-10
Electrical installations	-14	-14
Inspection and maintenance	-17	-17
Repair and overhaul	-19	-19
Data for flammable gases	-20	

CENELEC Marking	IEC Marking	SUB DIVISIONS OF TYPE n
R	R	Restricted breathing enclosures
L	L	Energy limited apparatus
P	Z	Simplified pressurised enclosure
C	C	Otherwise protected sparking apparatus
A	A	Non-sparking apparatus

EN50284 and EN1127-1 are also relevant.

Requirements for construction, testing and marking applicable to all methods of protection.

Some clauses excluded by Intrinsic Safety standard.

IEC IEC60079-0 third edition 1998-04

CENELEC EN50014 : 1997-06 + Amendment No. 1 1999-02
+ Amendment No. 2 1999-02

EN1127-1 : 1998
contains some basic non-electrical requirements

General requirements

5

Ex p

Apparatus Standard

CENELEC EN50016 : 1995
IEC IEC 60079-2 : 1983-01

ATEX Category

2G

Permitted in Zones 1 and 2
Excludes gas by positive pressure (50Pa)
Includes continuous dilution and static pressurization
Application Solves otherwise intractable problems such as analytical instruments

Pressurization Ex p

6

Ex o

Apparatus Standard

CENELEC	EN50015 : 1998
IEC	IEC 60079-6 : 1995-04

ATEX Category

2GD

Permitted in Zones 1 and 2 : 21 and 22
Protects by immersion in oil
Application Heavy current switchgear and transformers, very occasionally used for instrumentation

Oil filling Ex o

7

Ex q

Apparatus Standard

CENELEC	EN50017 : 1998
IEC	IEC 60079-5 : 1997-04

ATEX Category

2GD

Permitted in Zones 1 and 2 : 21 and 22
Protects by submersion in quartz (glass balls)
Application Protection of high power electronics; starters for Ex e lighting

Sand filling Ex q

8

Ex m

Apparatus Standard

CENELEC	EN50028 : 1987
IEC	IEC 60079-18 : 1992-10

ATEX Category

2G

Permitted in Zones 1 and 2
Protects by immersion in encapsulant
Application Solenoid valves; power supplies

Encapsulation Ex m moulding

9

A construction technique relying on good quality materials, design and assembly to eliminate any sparks or hot spots

"Erhochte sicherheit" German in origin, means "increased safety"

No discontinuous contacts are permitted so Instrumentation is rarely Ex e protected. i.e no zero/span potentiometers or switches

Applications include induction motors, lighting fittings, junction boxes, terminal housings and anti-frost heaters

Enclosures need not be strong enough to contain an explosion but must be weatherproof; IP 54 is usual minimum, impact resistant and solvent-proof

Installation is permissible in both Zones 1 and 2

Ex e - increased safety 10

Ex e

Apparatus Standard

CENELEC	EN50019 : 1994
IEC	IEC 60079-7 : 1980-8 Ed. 2.2 consolidated edition

ATEX Category

2G

Permitted in Zones 1 and 2
Prevents sparking and hot spots by careful construction
Application Motors, lighting and terminal boxes

Increased safety Ex e Erhochte sicherheit 11

A construction technique:

- No incendive sparks
- No hot surface
- Faults not considered
- Enclosures IP54; 7Nm impact test
- Zone 2 only

Used for: Lighting, junction boxes, rotating machines

Type n principles 12

Updated IEC standard expected May-June 2000

Ex n

Apparatus Standard

CENELEC	EN50021 : 1999
IEC	IEC/TR 60079-17 : 1996-12

ATEX Category

3G

Permitted in Zone 2 only
Utilises relaxed version of almost all methods of protection
Application Everything in Zone 2; large motors very significant

Zone 2 Apparatus Type n 13

US practice distinguishes between non-arcing (higher currents) and non-incendive circuits.
FM approval standard Class number 3611 Oct. 99 relevant.

No incendive sparks

No hot surfaces

Faults within the apparatus not considered

Restricted live working if 0.9 safety factor applied to cable faults

Requires expertise in preparing system documents

Non Incendive 14

Ex d

Apparatus Standard

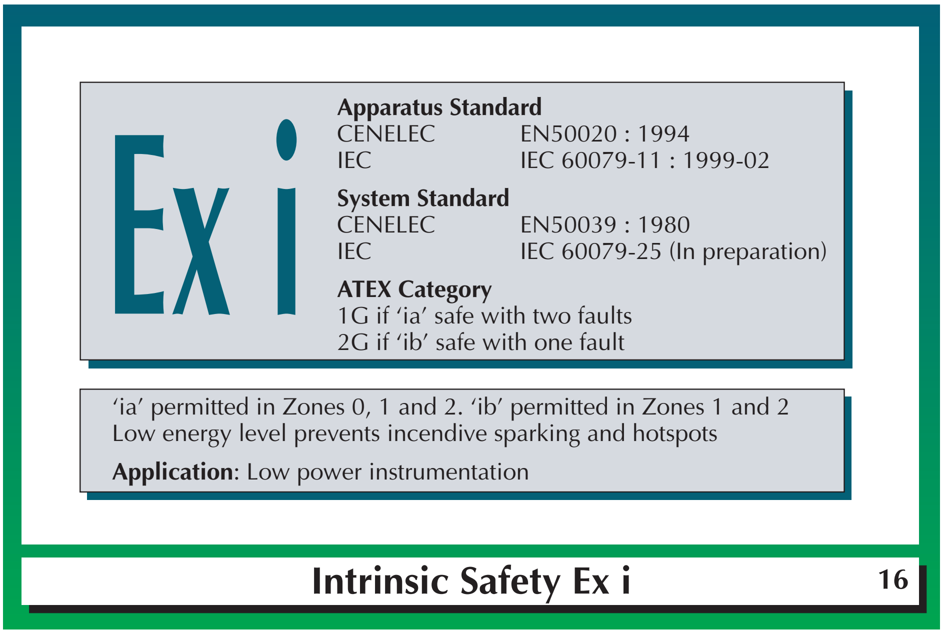
CENELEC	EN50018 : 1994
IEC	IEC 60079-1 : 1998-08 Ed. 3.2 consolidated edition

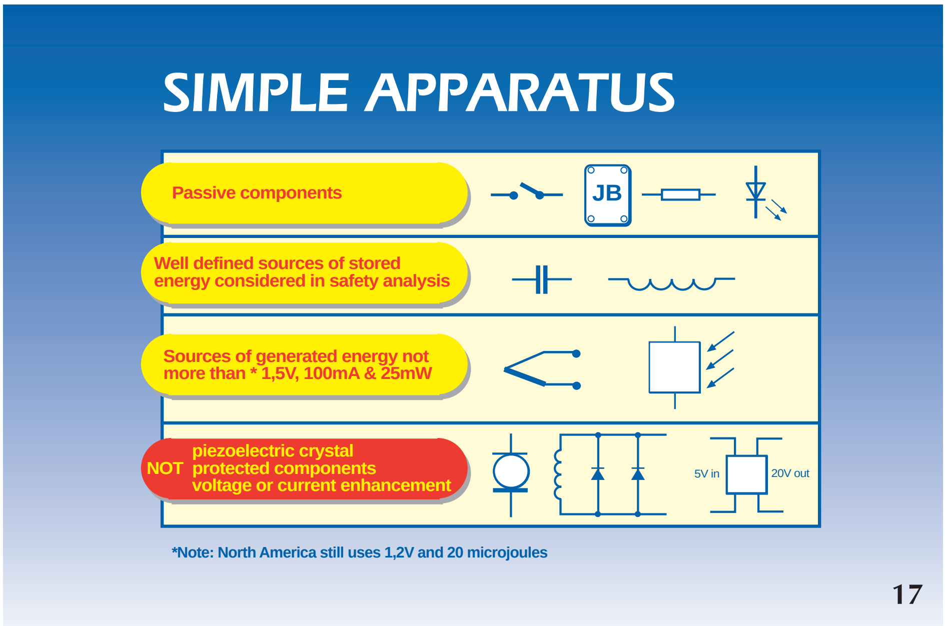
ATEX Category

2G

Permitted in Zones 1 and 2
Contains explosion prevents propagation
Application Switchgear; higher power instrumentation

Flameproof Ex d Druckfeste 15



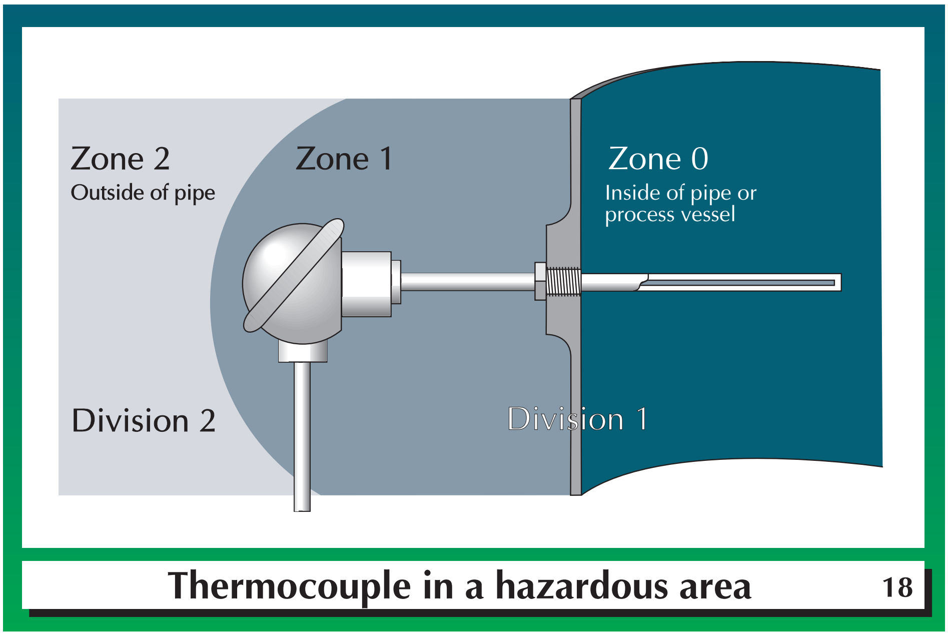


Slide 18

This slide is making the point that instrumentation frequently affects area classification. The thermocouple sheath and its coupling to the process pipe both offer possible sources of release.

The question to be answered is what is the area classification both before and after the installation. It may be changed.

In the authors opinion, thermocouples, orifice plates d.p. cells, control valves etc. all generate their own Zone 1 Division 1 locations. Some equipment such as analysers require very special consideration.



Slides 19 to 24

These slides attempt to summarise the advantages and disadvantages of the different methods of protection. Of necessity they oversimplify some of the situations. There are a number of points which may be disputed but most of the arguments are those generally accepted.

The overall balance is fairly static but with all methods of protection, problems come and go over a period of time. All the CENELEC methods of protection committees are wrestling with the problems of batteries at the present time. Sparking within high voltage Ex e and Ex N motors has created a seemingly insoluble problem.

1 Good robust box (heavy)
2 Very much preferred technique in US
3 Safe area apparatus not certified
4 Frequently not temperature classified
5 More flexible than Ex d e.g. batteries allowed
6 Installation practice and maintenance require skill but this is widely available

1 Enclosure material choice limited (Aluminium predominates)
2 Not always highest gas classification
3 No live maintenance
4 Tapered thread entry for conduit reduces versatility
5 Conduit seals make changes difficult
6 Not acceptable in many areas of the world

US Explosionproof (pros & cons) 19

1 Good robust box (heavy)
2 User acceptability high in UK
3 Safe area apparatus not certified, cables not certified
4 Temperature classification T6 [normal operation]
5 Best solution for high power sparking apparatus

1 Enclosure material choice limited
2 Impractical in IIC [only H_2 sometimes]
3 Competent maintenance and inspection needed. No live maintenance
4 Inflexible: Contents and holes specified
5 Glands and accessories complex
6 Electrical protection “tight and quick”

Americans – explosion proof
Germans – Ex e terminals
Norwegians – Deluge

No direct contact with process

Ex d (pros & cons) 20

1 Good enclosures [IP65]
2 Acceptable in most of Europe
3 Not gas conscious 0_2 enriched & dust
4 Cables & terminals & junction boxes much more serviceable than Ex d
5 Only technique for high powered batteries

1 No live maintenance
2 Requires high level of competence in maintenance and inspection
3 Inflexible without a German expert
4 Electrical protection critical
5 American – Division 2
Italian – Zone 2
6 Incompatible with instrument construction – no potentiometers
no printed circuit
combination with Ex m?

Ex e (pros & cons) 21

Ex i (pros & cons) 22

1 Enclosure to suit purpose

2 Suitable Zone 0

3 Usually IIC T4

4 Simple Apparatus rules offer great flexibility

5 Internationally accepted technique

6 Permits live maintenance, personnel safe

1 A low power technique

2 Perceived as complex

3 Temperature class usually T4 CS_2 is T5

4 Cable parameters cause concern. No problem in IIB, Long cables in IIC

Ex n (pros & cons) 23

1 Simpler

2 More reliable

3 Lower perceived cost

4 Permits almost anything to the politically astute. Needs good documentation

5 Acceptable UK
Holland
Australia

1 Lower level of safety

2 No live maintenance

3 Acceptable only in Zone 2 (watch area classification change)

4 Standard attempts to cover relaxed everything

5 Third party certification difficult to obtain to ill defined standard
No provision for systems

6 Division 2 practice in North America

US Non Incendive (pros & cons) 24

1 Simpler

2 More reliable and some live maintenance

3 Lower cost

4 Flexibility high, if certification not required

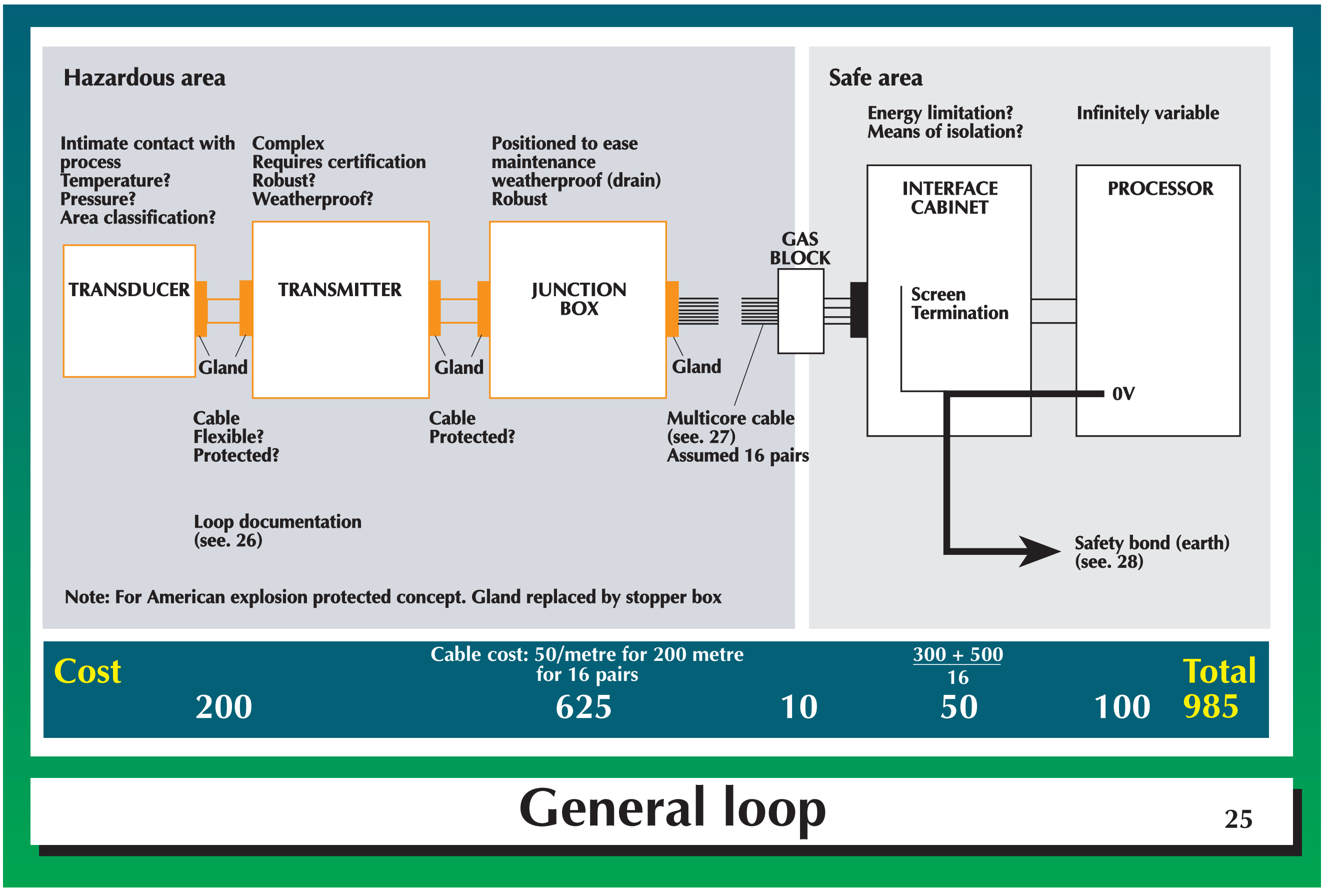
5 Acceptable in some other parts of the world, if you talk fast

1 Lower level of safety

2 Division 2 restriction can cause problems if classification changes

3 Requires great skill in preparation of certification drawings

4 Drawings impose restrictions if one must be legal

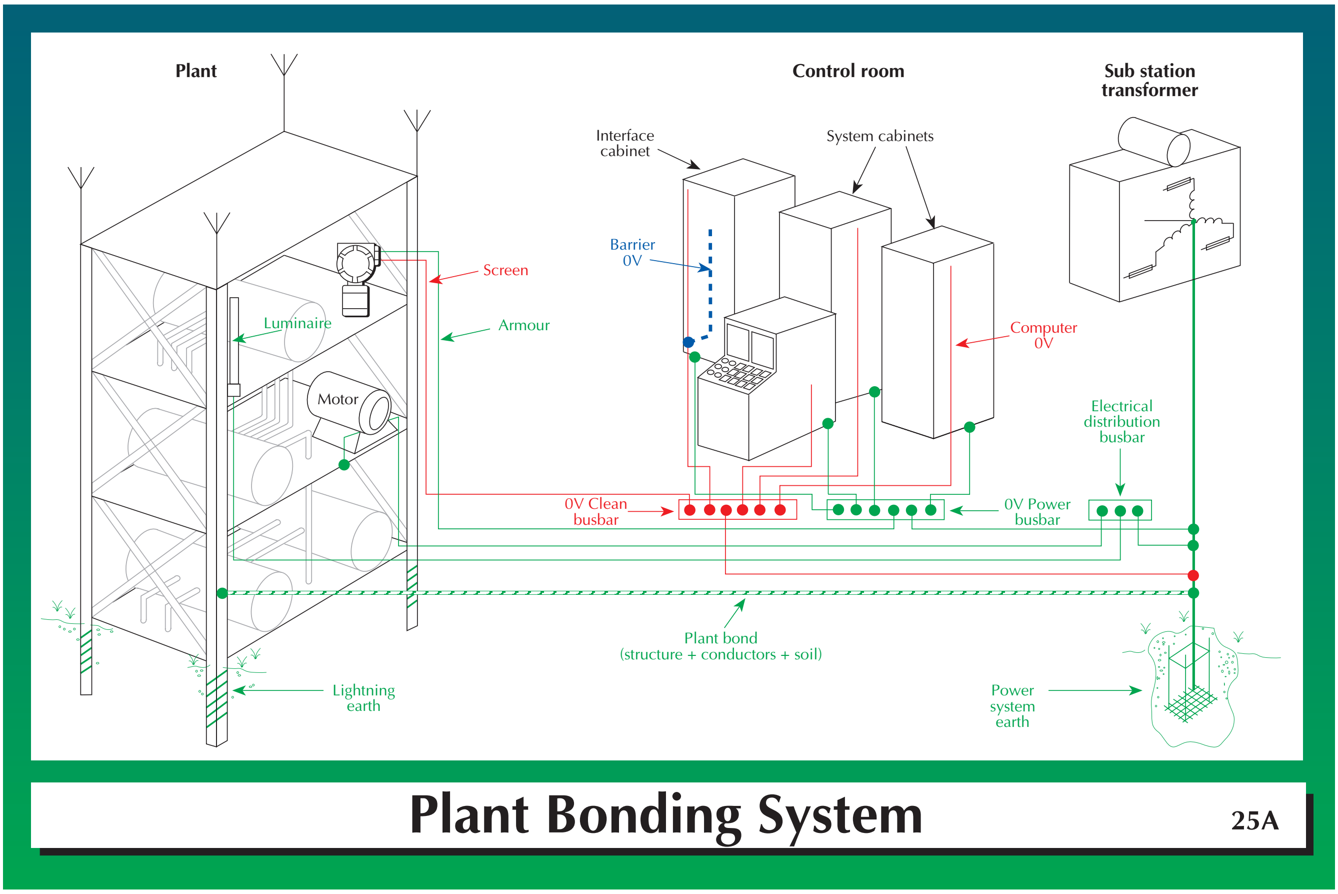


Slides 25 to 28

The general loop sets the scene for the remaining analysis and assumes sixteen transducers feeding into a junction box via a multicore into an interface cabinet.

The assumption is made that the documentation requirement (see 26) the multicore cable (see 27) and the safety bond (see 28) is the same for all methods of protection.

The part cost of the multicore is one of the dominant costs in the whole system and there are very wide differences in



this cost. However the length of 200 metres and the cost assumed is not unrepresentative and variations in this cost do not significantly affect the overall argument. Theoretically the cost of an intrinsically safe multicore could be lower but in practice it is usual to use an armoured or heavily braided cable to ensure operational integrity.

Great stress has been placed on the cost of intrinsic safety earthing but in practice the need for adequate earthing is independent of the method of protection.

Fig 25A illustrates the earthing and bonding system of a typical plant. The incoming electrical substation transformer usually has a neutral bonded to an earth mat. Other major earth connections are determined by the lightning protection requirements. These earth mats are cross bonded by the structure, deliberate cross connections and less positively via the soil.

Electrical apparatus such as luminaires and motors are bonded to the structure and have a fault return path to the electrical distribution busbar via the cable armour. The safe area structures are normally returned to the power 0V busbar.

The computer 0 volt and cabling screens are returned to the clean 0V busbar which is bonded to the power system at one point; the neutral earth mat bond.

Where a barrier 0V is used it is connected to the clean 0V busbar as illustrated and is not a significant addition.

The costs attributed to part of the interface cabinet and system processor are arbitrary.

These arguments give a base cost per loop of 985.

Requirement

To make a clear statement of what has been installed where?

Must be in installers "language"

To confirm the engineering design and to enable subsequent inspections to be carried out

Documentation 26

Requirement

Remain undamaged for operational and safety reasons

American explosion proof

Ex d, Ex e and Ex n incendive spark if broken

Ex ni and Ex i interconnections not considered in analysis operational integrity dependent on method of protection

Usual Construction

American explosion proof protected and supported by conduit

European practice: Frequently cable tray mounted

Armoured or toughened outer sheath for protection

Screens individual pairs or overall for interference avoidance

Resistant to chemicals

Non flame propagating

Non toxic fumes

Non smoke, etc

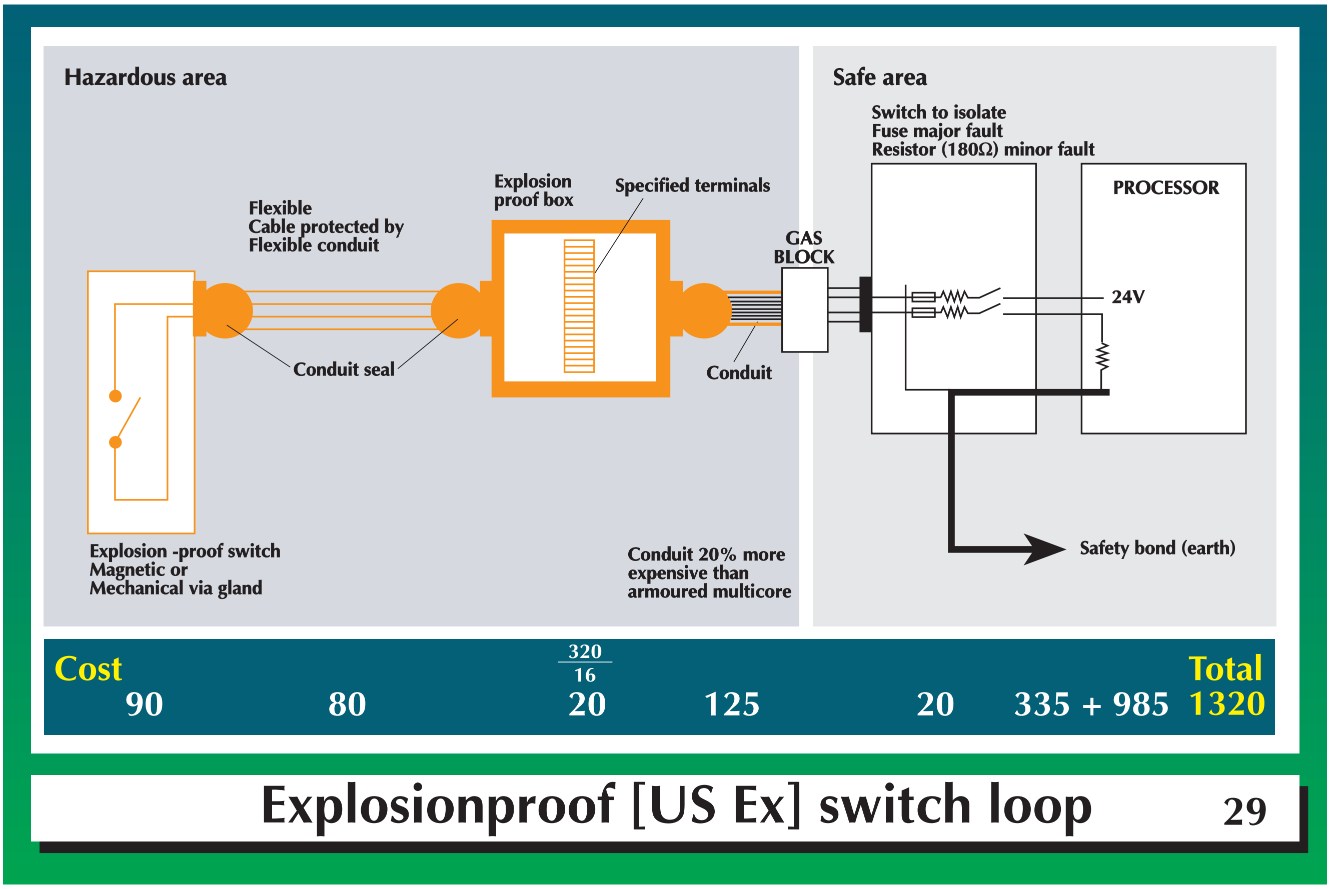
Multicore Cable 27

Requirement

1. **To prevent significant (>10V) potential differences in fault conditions**
2. **Provide return path for fault currents so as to operate protection devices [fuses & etc]**
3. **Provide return path for capacitive currents which might cause interference problems**
4. **Provide termination point and reference potential for field wiring screens**
5. **Lightning protection if required**

Not method of protection dependent

Safety Bond 28



Slide 29

The additional costs of the explosionproof switch loop are attributed as follows.

The switch itself would need to be certified.

The cable between the switch and the junction box would need flexible conduit with stopper boxes.

Part of the cost of the explosion proof junction box.

The multicore cable is replaced by conduit and cables which is more expensive than the corresponding multicore and cable trays [a 20% premium is used].

The need for circuit protection of all leads into hazardous areas is common to all methods of protection. The necessary combination is an isolating switch, a resistor for low voltage faults and a fuse for high power faults. The mounting cost for these is significant.

Slide 30

The significant cost reduction is the absence of the 20% increased cost of conduit over armour.

The assumption is made that American explosionproof boxes and CENELEC flameproof [Ex d] boxes are similar in cost.

Slide 31

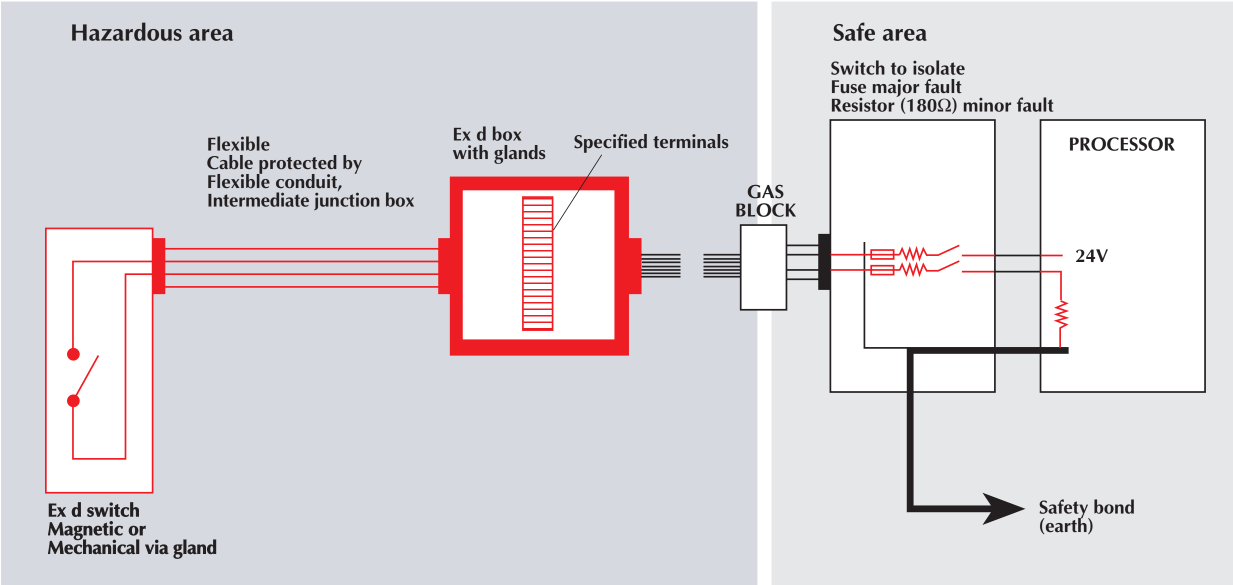
Slight reduction in cost by using encapsulated switch with flylead into a lower cost Ex e junction box.

Slide 32

Further reduction in cost of switch and associated lead because it is simple apparatus.

The Ex e junction box and multicore cables are retained because of operational reliability concerns even though theoretically lower cost items could be used.

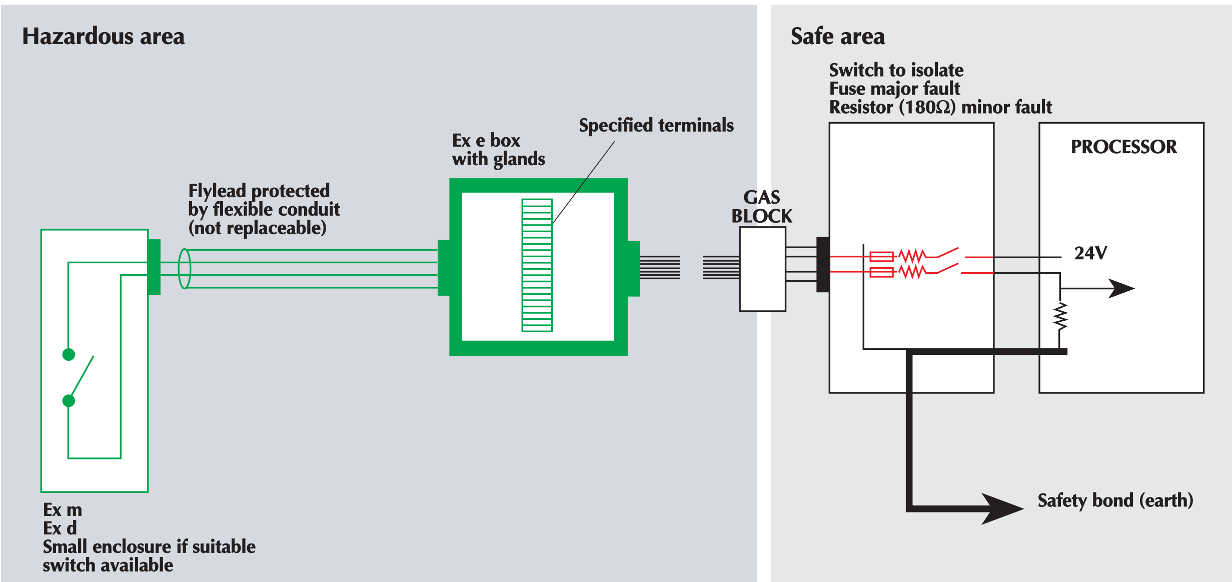
Increase in cost is the interface or barrier



Cost		320 / 16			Total
90	80	20	20	210 + 985	1195

Ex d switch loop

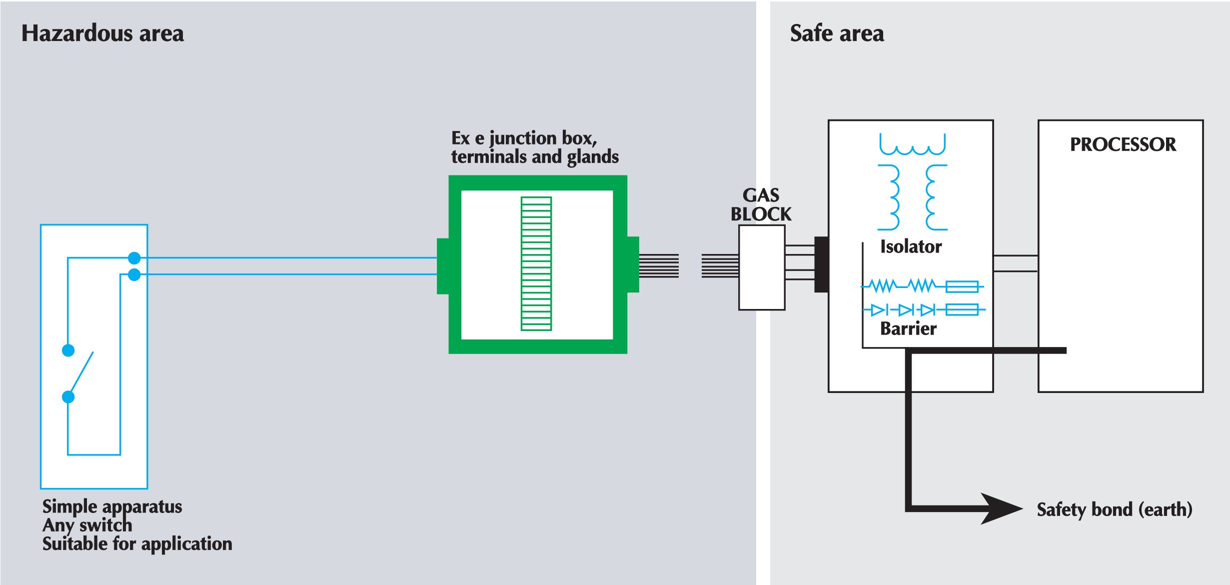
30



Cost		160 / 16			Total
60	60	10	20	150 + 985	1135

Ex e switch loop

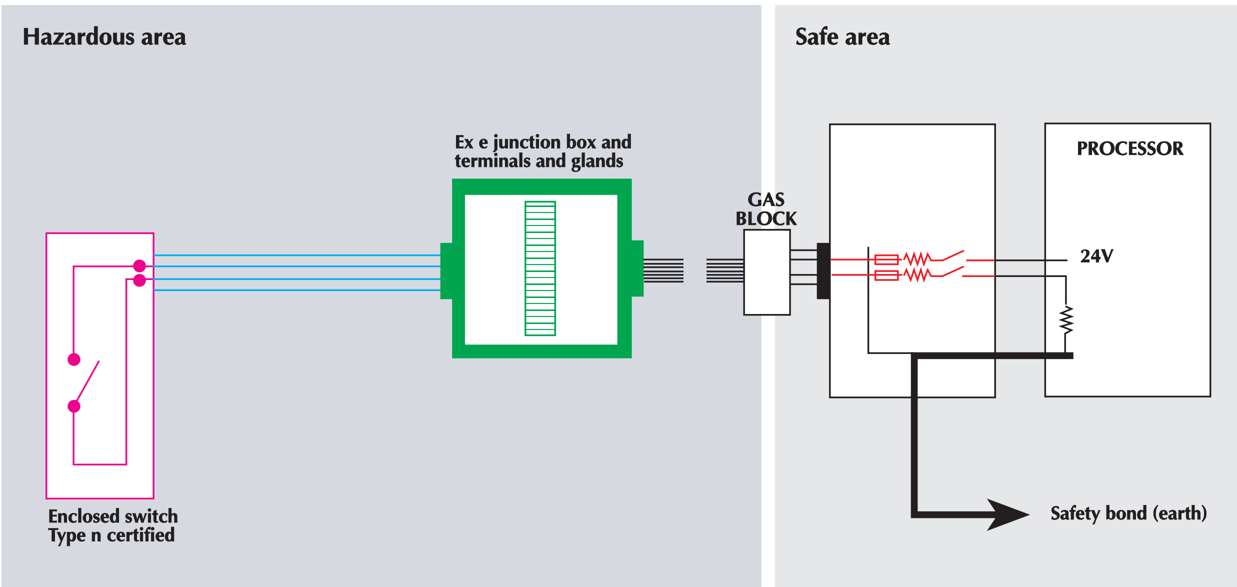
31



Cost					Total
30	20	10	50	110 + 985	1095

Ex i switch loop

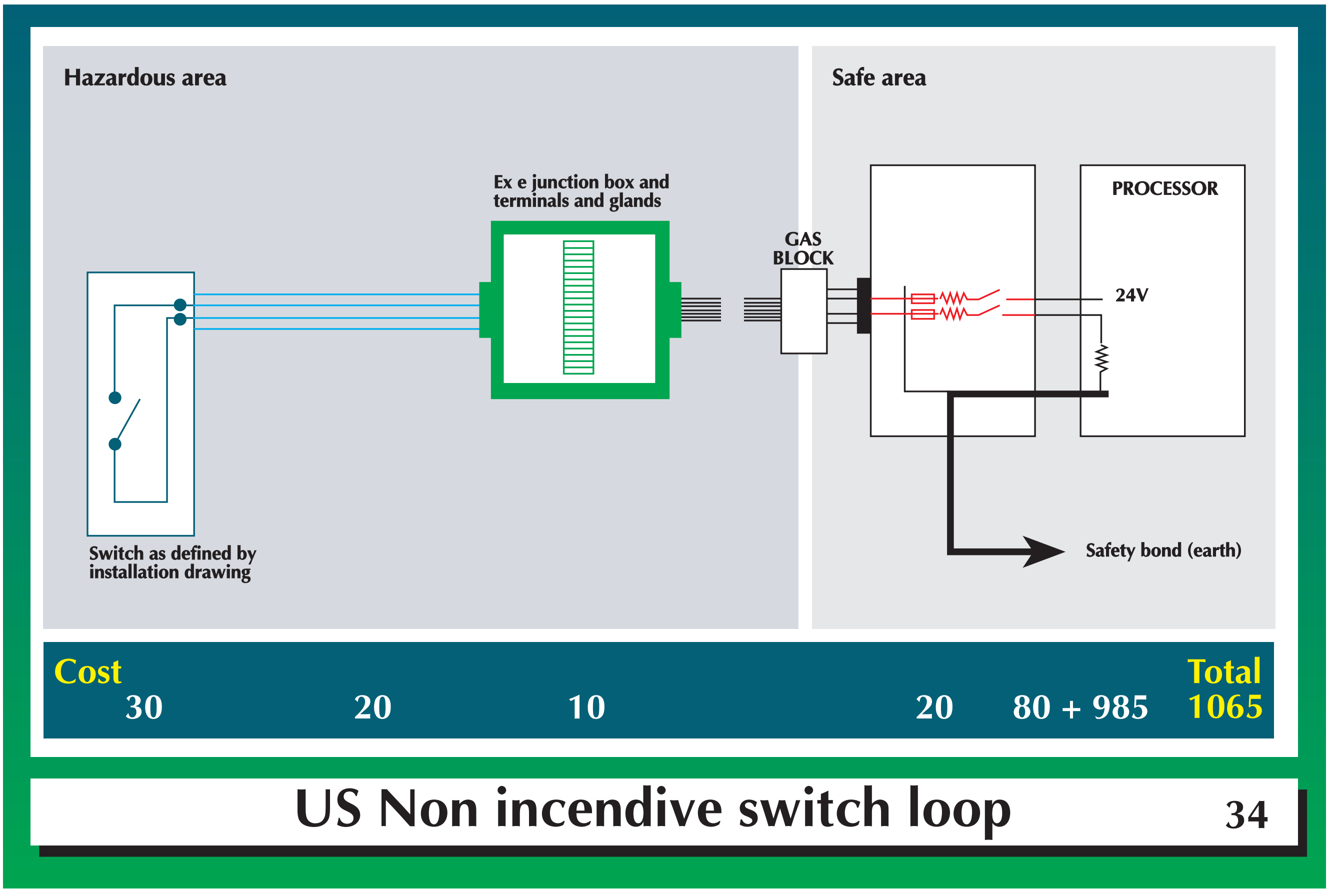
32



Cost					Total
60	20	10	20	110 + 985	1095

Ex n switch loop

33



Slide 33

No simple apparatus rules, hence certified switch.

Lower cost interface.

Slide 34

Switch defined by installation drawing; effectively simple apparatus.

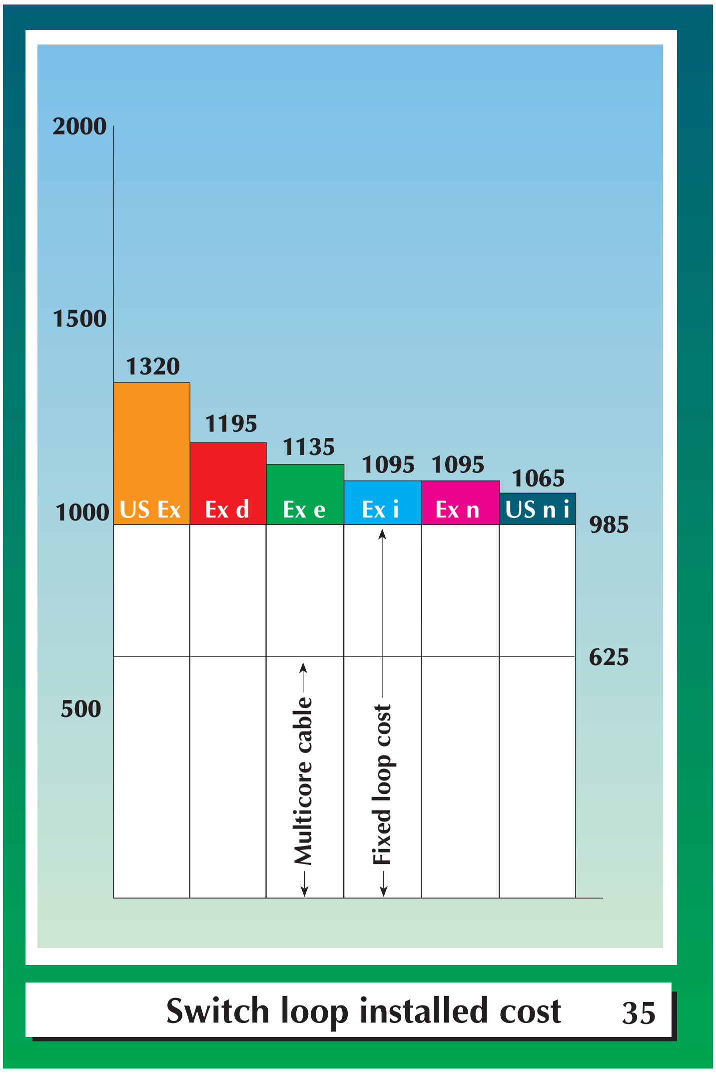
Lower cost interface.

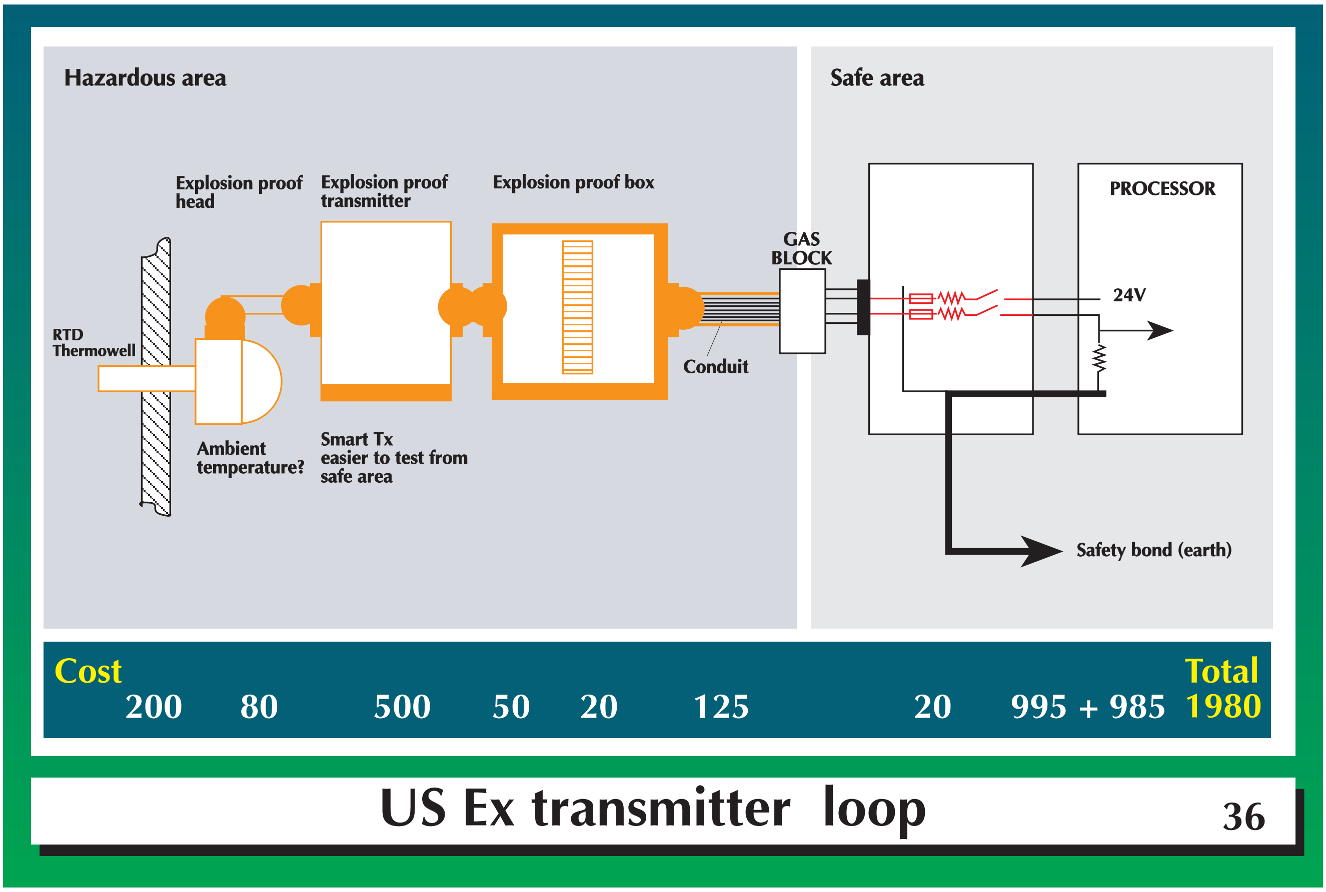
Slide 35

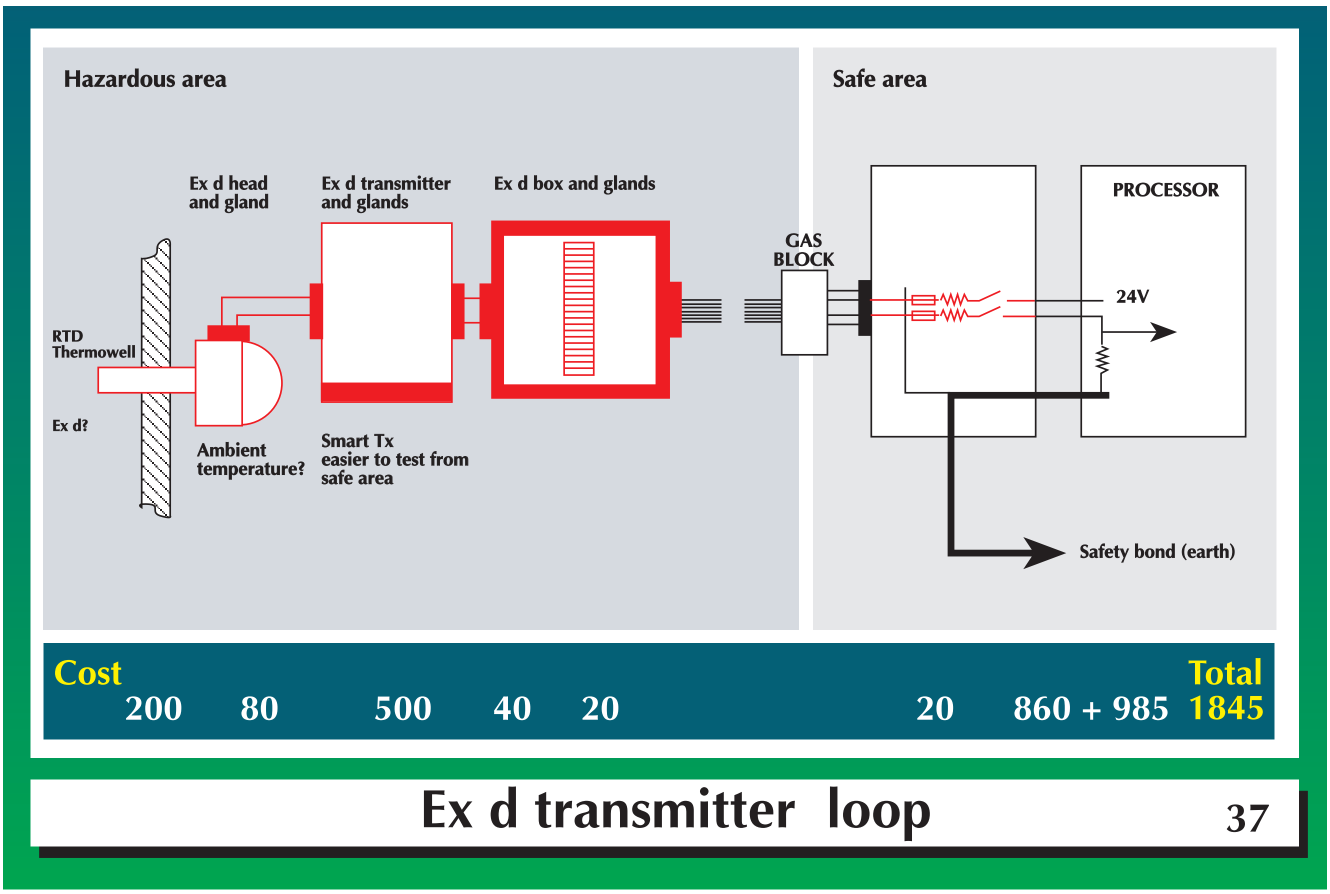
Compiled switch cost.

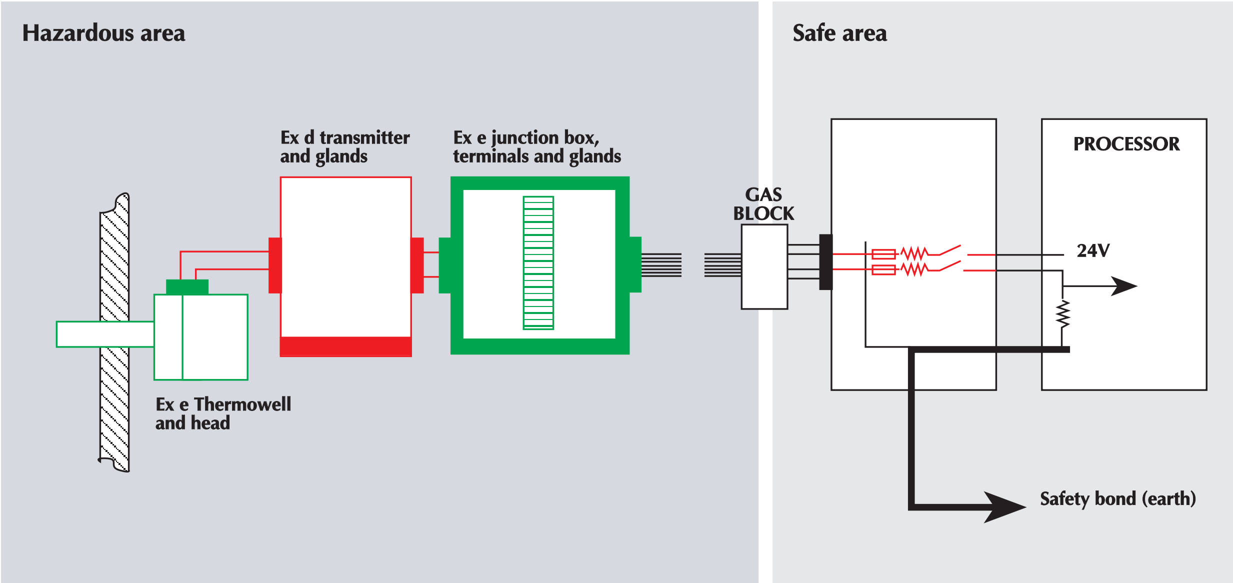
Shows all costs dominated by fixed loop cost and cable cost in particular.

In practical terms very little difference exists between the methods of protection.




Hazardous area
Safe area
Explosion proof head
Explosion proof transmitter
Explosion proof box
RTD Thermowell
GAS BLOCK
PROCESSOR
24V
Conduit
Ambient temperature?
Smart Tx easier to test from safe area
Safety bond (earth)
Cost
200 80 500 50 20 125 20 995 + 985
Total
1980
US Ex transmitter loop
36

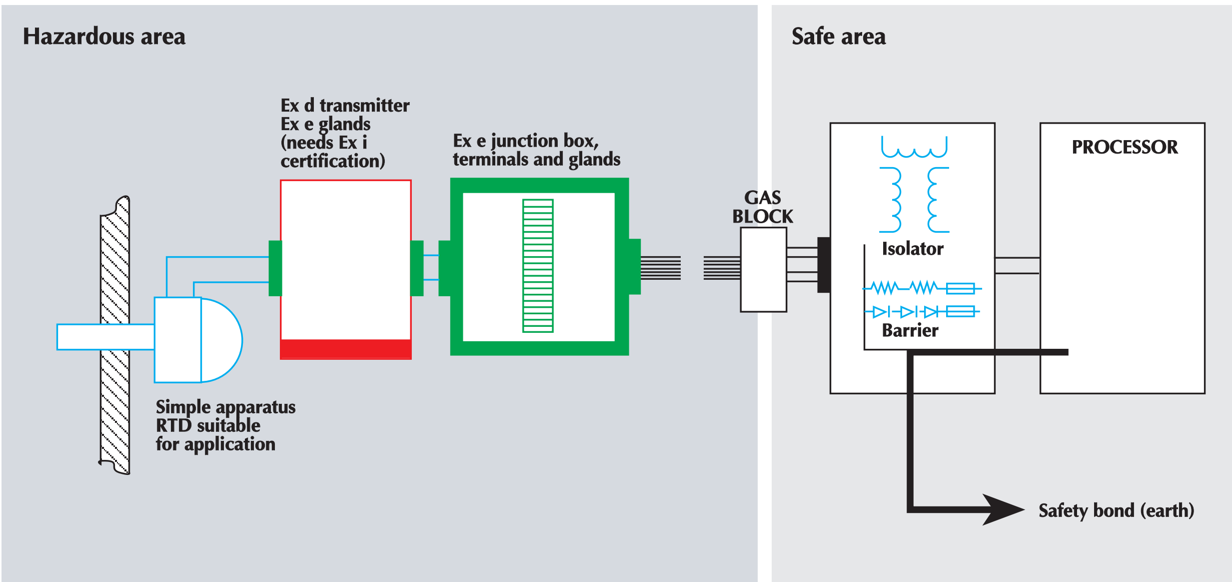

Hazardous area
Safe area
Ex d head and gland
Ex d transmitter and glands
Ex d box and glands
RTD Thermowell
Ex d?
GAS BLOCK
PROCESSOR
24V
Ambient temperature?
Smart Tx easier to test from safe area
Safety bond (earth)
Cost
200 80 500 40 20 20 860 + 985
Total
1845
Ex d transmitter loop
37



Cost							Total
150	80	500	40	10	20	800 + 985	1785

Ex e transmitter loop

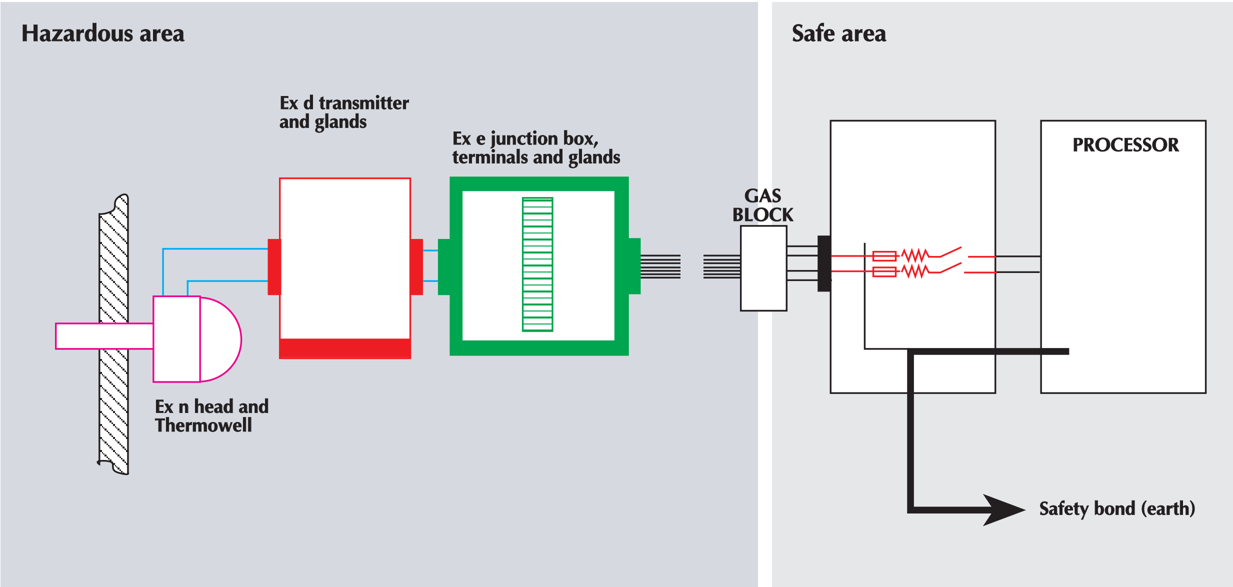
38



Cost							Total
80	20	480	20	10	60	670 + 985	1655

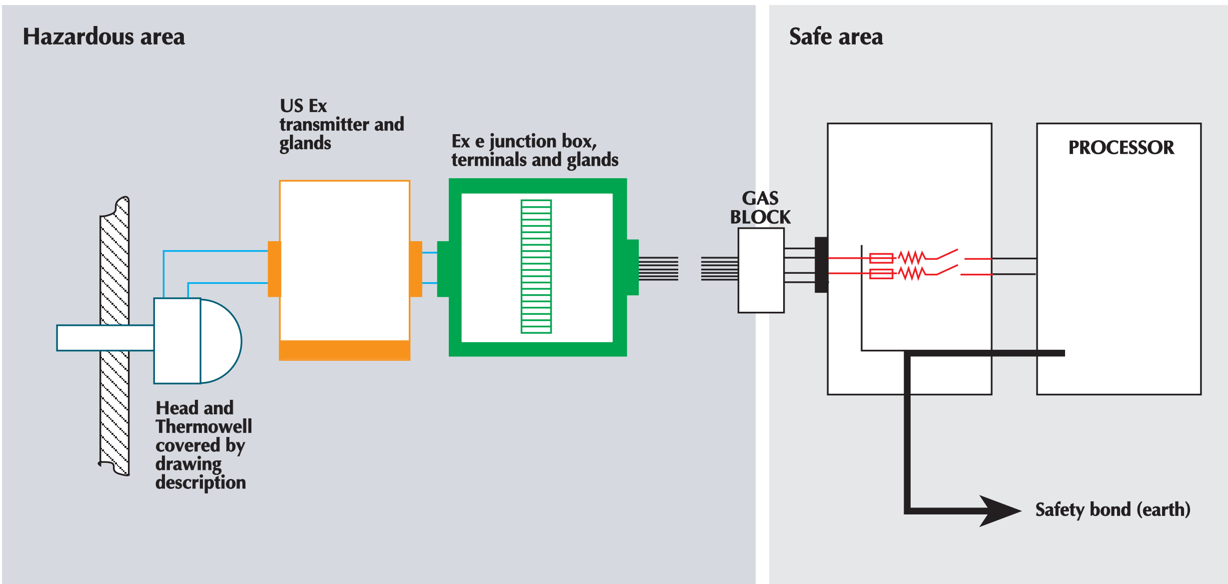
Ex i transmitter loop

39



Cost							Total
150	20	500	20	10	20	720 + 985	1705

Ex n transmitter loop 40



Cost							Total
80	20	500	20	10	20	650 + 985	1635

US Non incendive transmitter loop 41

Slide 36

Thermowell and head have to be certified, questionable whether this can include elevated temperature?
The same transmitter is used regardless of the method of protection. For this exercise the cost remains the same.
Premium for conduit extended to all cable runs.

Slide 37

Major change removal of conduit premium

Slide 38

Lower cost thermowell and head and junction box.

Slide 39

Simple apparatus thermowell and head. Increased interface cost. Theoretically transmitter cost could be reduced but it is not.

Slide 40

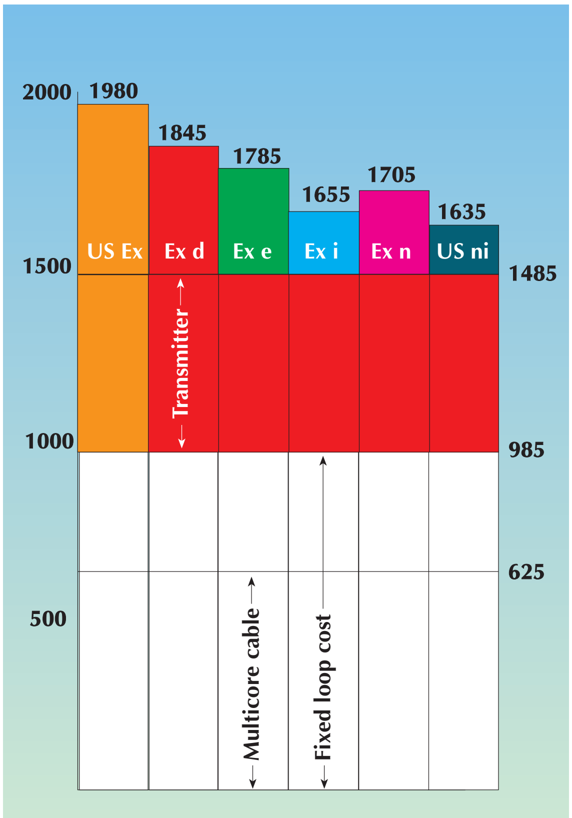
Certified thermowell and head

Slide 41

Thermowell and head covered by installation drawing.

Slide 42

The costs are dominated by the multicore cable and other fixed cost and the cost of transmitter.



Transmitter loop installed cost 42

Methods of implementing and recording are changing, partially influenced by "SMART" equipment

Annual Check

- **Installation is according to documentation**
- **Mechanical damage to equipment and cables**
- **Effectiveness of enclosures and glands**
- **Flameproof gaps?**
- **Isolation of intrinsically-safe circuits?**
- **Cost 60/loop/annum**

Inspection 43

Task	US Ex	Exd	Exn	Exi	Exe	US ni
Permit to work	50	50	50	50	50	50
Gas Clearance Certificate	100	100	100		100	
Maintaining Certificate	200 *a	200 *a	100		100	
Technician cost/fault	300 *b	200 *c	100	100	100	100
Total	650	550	350	150	350	150

Assumptions
: The need to work live
: One fault per five years

a* : 2 x factor due to difficulty with glanding
b* : increment due to difficulty with stoppers
c* : extended repair time

Cost of Repair of Instrument Loop 44

Slide 44

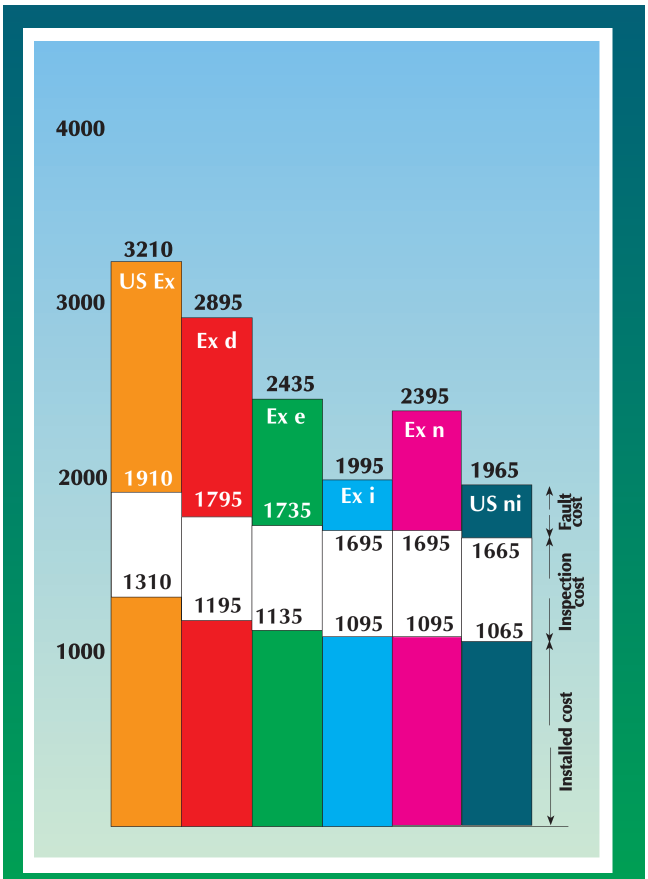
This shows the cost of gas clearance certificates, which cost money to obtain but require additional costs which double the cost of maintenance.

Slides 45 and 46

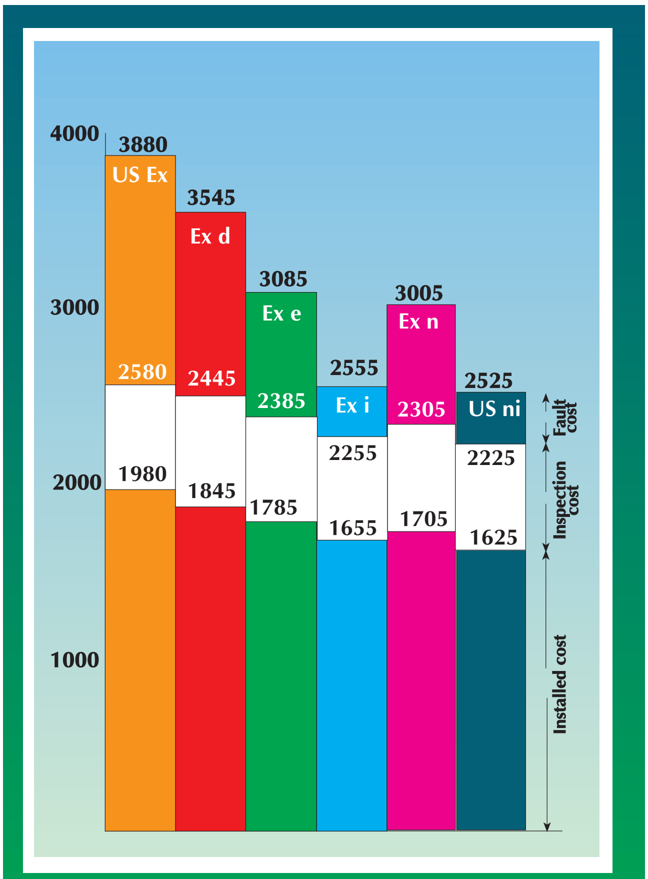
Collect the information and demonstrate a widening in cost differences.

Example of calculation of Ex d transmitter cost.

Ex d installed cost	1845
Inspection cost 60x10	600
Fault cost	
Work permit	50
Gas clearance certificate	
obtain	100
maintain (x2)	200
Technician cost (x2)	200
Cost per fault	550
Two faults	1100
Cost for ten years	3545



Cost of ten years ownership of switch loop 45



Cost of ten years ownership of transmitter loop 46

Slides 47 to 53

All make specific points which may decide the choice of technique.

Copy of Apparatus Certificate plus any installation drawings

System certificate or installation requirements

Evidence of Quality Control
eg BASEEFA Licence

Installation Manual

Notification of any special requirements for maintenance and inspection

If mixed methods of protection are used then particular care is necessary and literature must be good

Supplier? 47

Zone 0 Ex ia only

Zone 1 Ex ia ib d e m

Zone 2 Ex n & above
(Self certification more acceptable)

How definite is the area classification?

If uncertain avoid Type n

Area Classification? 48

Have you got Carbon Disulphide?

YES Equipment must be IIC T6
IS simple apparatus difficult
Not all IIC Ex d equipment is suitable

NO Sigh with relief, you can use T4 equipment

Have you got Acetylene?

YES Not all IIC Ex d equipment is suitable
Has to be checked for particle emission

NO You can also forget acetylides etc

Have you got Hydrogen?

YES You need IIC equipment
Ex d not very practicable, may not be available, may need barrier glands, and care with positioning

NO You can settle for IIB. Relax on Ex d and forget Ex i cable parameters

If possible specify IIB T4 to give maximum freedom of choice

Gas and Temperature classification 49

If unspecified will be -20 to +40°C

Ex d e n all prone to low temperature embrittlement

Ex e & n insulation properties temperature sensitive

Ex d cable softening

Ambient Temperature? 50

Approximate Power limits for intrinsically safe apparatus

	IIC	IIB
U_o	30V	42V
I_o	250mA	500mA
P_o	3.0W (1.3W)	5.0W (1.3W)

Power Level? 51

US Ex	Stopper boxes makes it difficult
Ex d	Finer points difficult if IIB gas less critical
Ex e	Near perfection essential
Ex i	Not critical if documentation good
Ex n	All things to all men Thank goodness it's Zone 2
US ni	Good if well specified

Maintenance Capability? 52

1 A uniform approach to 95% of instrumentation reducing training and possibilities of mistakes

2 Safer

3 Internationally acceptable

4 Permits live maintenance

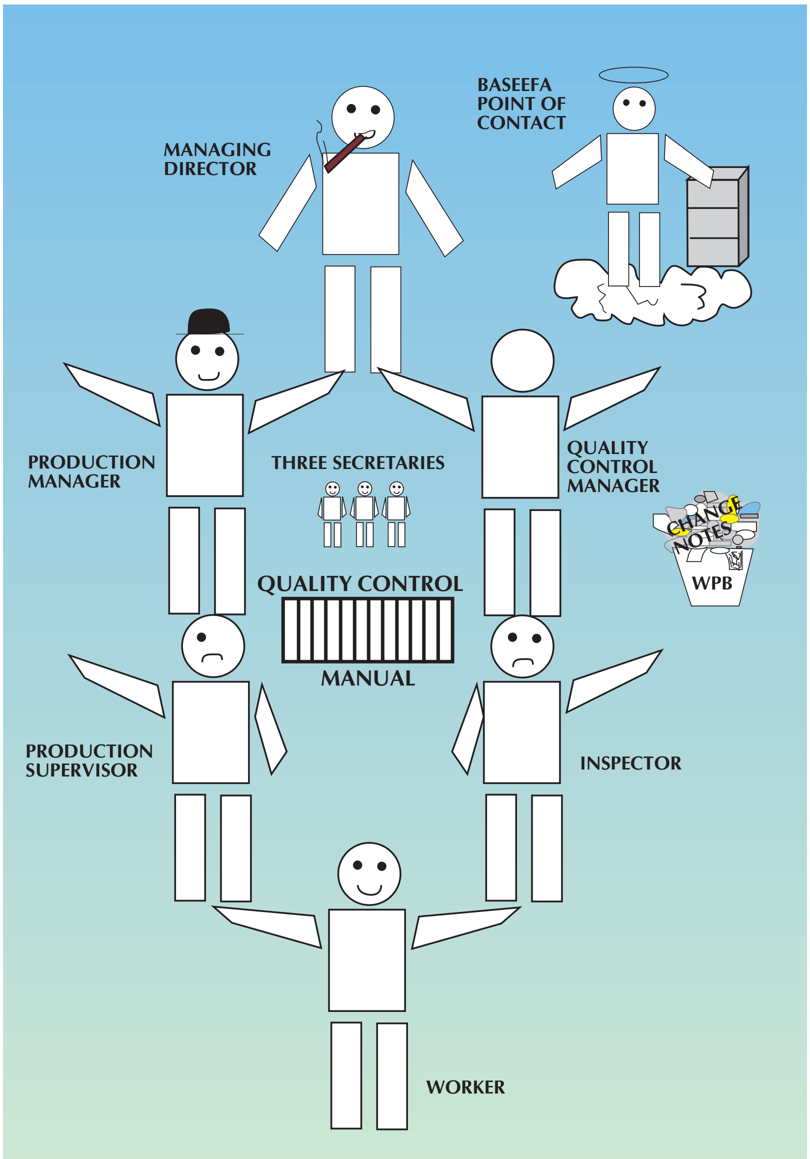
5 Independent of area classification

6 A low current technique, compatible with instrumentation. Not hampered by high power technology

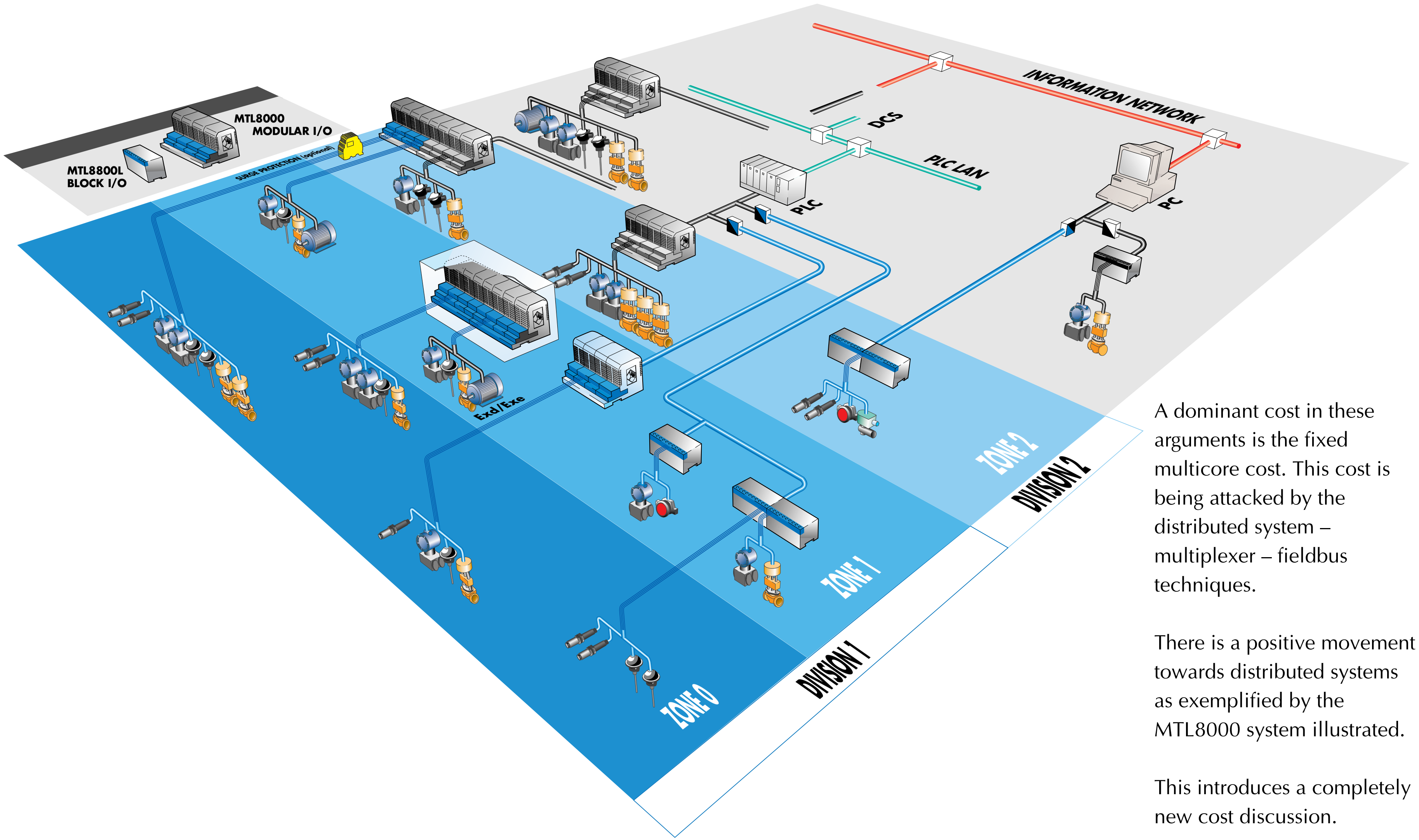
7 Arguably marginally cheaper

Why you should use Intrinsic Safety 53

Quality control requirements apply to all methods of protection to various levels. In Europe, ATEX requirements prevail. In US, certification authorities have requirements. Can become bureaucratic menace if not restrained.



BS 5750 Pile



A dominant cost in these arguments is the fixed multicore cost. This cost is being attacked by the distributed system – multiplexer – fieldbus techniques.

There is a positive movement towards distributed systems as exemplified by the MTL8000 system illustrated.

This introduces a completely new cost discussion.

Some possible variations on the theme of distributed systems 54