

THE ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

**A GUIDE TO
FIELDBUS APPLICATION
for the
PROCESS INDUSTRY**

PUBLICATION N° 189 : 1997

THE ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

**A GUIDE TO
FIELDBUS APPLICATION
for the
PROCESS INDUSTRY**

PUBLICATION N° 189 : 1997

Copyright © 1997 The Engineering Equipment and Materials Users Association

ISBN 0 85931 066 3

**45 Beech Street
LONDON
EC2Y 8AD**

Telephone: 0171-628 7878

Fax: 0171-628 7862

e-mail sales@eemua.co.uk

website www.eemua.co.uk

EEMUA

AVA Documents
Document Sharing Hub

THE ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

The Engineering Equipment and Materials Users Association—EEMUA—was formed in 1983 by the Amalgamation of the Oil Companies Materials Association (OCMA) and the Engineering Equipment Users Association (EEUA). It is an organisation of substantial purchasers and users of engineering products, whose members include leading national and multi-national companies in the petroleum, gas, chemical and energy industries. A list of Full and Associate Members (the latter being limited to membership of three technical committees) is given below. EEMUA is concerned with the design, installation, operation and maintenance of the engineering plant used by members in pursuing their business activities.

The Association aims to reduce members' costs by providing the opportunity for them to share resources and expertise in order to keep abreast of technological developments and improve the effectiveness and efficiency of their engineering activities. EEMUA supports the British Standards Institution, works with other institutions, associations, government departments, regulatory authorities and the Confederation of British Industry, and is also actively involved with other standards-making bodies, both national and international, such as the American Petroleum Institute.

Work, which is carried out in-house by members alone or with the help of other organisations, may lead to the production of Association publications. These are prepared primarily for members' use, but are usually offered for sale and thus for more general use. Such publications may also be submitted, normally through the British Standards Institution, as bases for appropriate national, European or international standards.

A list of current EEMUA Publications which may be purchased from the Association is given at the end of this document.

Full Members

Associated Octel
BG
BP Amoco
Caltex Petroleum
Conoco
Dow Corning
Eastern Generation
Esso/ExxonMobil
Eutech
Foster Wheeler Energy
Lindsey Oil Refinery
National Power
PowerGen
Shell

Associate Members

AstraZeneca
BASF
D&C Engineering/MERCON [Netherlands]
Elf Exploration UK
Flexsys
Phillips Petroleum UK
Pilkington Technology
Royal Vopak (was Royal Pakhoed)
[Netherlands]
Texaco
UOP

ABOUT THIS PUBLICATION: LEGAL ASPECTS

In order to ensure that nothing in this publication can in any manner offend against or be affected by the provisions of the Restrictive Trade Practices Act 1976, the recommendations which it contains will not take effect until the day following that on which its particulars are furnished to the Office of Fair Trading.

As the subject dealt with seems likely to be of wide interest, this publication is also being made available for sale to non-members of the Association. Any person who encounters an inaccuracy or ambiguity when making use of this publication is asked to notify EEMUA without delay so that the matter may be investigated and appropriate action taken.

It has been assumed in the preparation of this publication that the user will ensure selection of those parts of its contents appropriate to the intended application and that such selection and application are correctly carried out by appropriately qualified and experienced people for whose guidance the publication has been prepared. EEMUA does not, and indeed cannot, make any representation or give any warranty or guarantee in connection with material contained in its publications, and expressly disclaims any liability or responsibility for damage or loss resulting from their use. Any recommendations contained herein are based on the most authoritative information available at the time of writing and on good engineering practice, but it is essential for the user to take account of pertinent subsequent developments or legislation.

All rights are reserved. No part of this Publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means: electronic, mechanical, photocopying, recording or other.

Infringing the copyright is not only breaking the law, but also, through reduction in the Association's income, jeopardising the availability of future publications.

Index of Contents

- 1. Introduction**
- 2. Background**
- 3. Future Revisions**
- 4. Relevant Standards and Documentation**
- 5. Basic Design Considerations**
 - 5.1 Introduction
 - 5.2 Design Philosophy
 - 5.3 Interoperability
 - 5.4 Failure Modes
- 6. Cabling and Physical Connections**
 - 6.1 Bus Segment Topology
 - 6.2 Cable Selection
 - 6.3 Field Terminal Boxes
 - 6.4 Power Supplies
 - 6.5 Earthing
 - 6.6 Hazardous Areas
- 7. Configuration**
 - 7.1 Hardware
 - 7.2 Control Loops
 - 7.3 Alarm Handling
 - 7.4 Bus Scheduling
 - 7.5 Cross Bus Networks
- 8. The use of Fieldbus in Instrument Protection Systems**
- 9. Documentation and Tagging**
 - 9.1 Instrument and Function Block Tagging
 - 9.2 Fieldbus Locator
 - 9.3 Bus Segment/Control Scheme Diagram
 - 9.4 Schedules
 - 9.5 Data Sheets
 - 9.6 Other Documents
- 10. Design, Installation and Commissioning**
 - 10.1 Design Schedule
 - 10.2 Design Responsibility
 - 10.3 Configuration
 - 10.4 Testing
 - 10.5 Installation
 - 10.6 Configuration Download
 - 10.7 Commissioning and Loop Checking
- 11. Maintenance**
- 12. References**
- 13. Appendices**

1. Introduction

This document contains guidelines to help the end user specify the design, installation and maintenance of Fieldbus based control and instrumentation systems for process industries. The intent is to set down levels of performance to cover the safety, operation and maintainability of the overall system.

The scope of this document covers control and instrumentation for general process plant. Some guidance is given on the use of Fieldbus in instrument protection systems but it is not in the scope to cover other protection systems such as Fire and Gas, auxiliary equipment such as HVAC or equipment monitoring systems such as those found on a large compressor although many of the recommendations made in this document may be equally relevant.

The guidelines set out what is considered to be good industry practice in what is a developing technology. At the time of publishing there were only a few trial sites in existence and the pace of introduction of the technology is still unclear. It will be largely dependent on the ability of manufacturers to supply product.

The User is advised that these guidelines supplement rather than replace the need for adequate training of personnel in this new technology. Training in Fieldbus is available from SIRA in the UK and the Instrument Society of America (ISA) in the US.

2. Background

Fieldbus offers a number of potential changes from current analogue signal transmission. These can be summarised as:-

- The ability to connect multiple field devices to a single bus segment.
- The ability to transmit diagnostic information from the field device to a central host system.
- The ability to migrate simple control algorithms from the central host system into the field devices.

Faced with these new opportunities the Instrument & Control committee of EEMUA considered it essential to the timely introduction of the technology to develop a set of guidelines and provide some form of common approach within the industry. The purpose of this document is to provide guidance to end Users, their Contractors or Suppliers to help them through the phases of a Fieldbus based system life cycle.

Throughout the development of the guidelines the Fieldbus sub-committee have been in discussion with representatives of the Fieldbus Foundation and the guidelines themselves reflect the specification of the Foundation equipment. Although the Guidelines have been based on Fieldbus Foundation technology many of the principles recommended could equally apply to other Fieldbus protocols which base their Physical Layer on IEC1158-2.

The Guidelines are directed at the lower speed 31.25 kbit/s bus mentioned in the IEC 1158-2 Standard. The specifications for the higher speed 1 Mbit/s and 2.5 Mbits/s bus segments included in the Standard are still being developed and will in any case be of primary interest to manufacturers and system integrators rather than the end user. The guidelines also concentrate on the voltage mode wire medium. Fibre optic and wireless media standards are available but have still to gain the support of the majority of manufacturers.

The contents of the guidelines rely heavily on current experience with Distributed Control Systems and Smart field devices using protocols such as HART.

3. Future Revision

Fieldbus is a developing technology which will require a periodic review and revision of these guidelines. Comments on the document are welcome and should be addressed to:

EEMUA
45 Beech Street
London EC2Y 8AD

for the attention of the INC committee

4. Relevant Standards and Documentation

4.1 Fieldbus Foundation Literature

The User is advised to read the Fieldbus Foundation's "Physical Layer Installation Manual" and "Technical Overview" as a means of introducing the terminology and concepts associated with Fieldbus.

As with any new technology Fieldbus brings with it a new set of jargon. The User is strongly recommended to read the above documents and undertake some formal training before attempting to understand these guidelines.

4.2 Fieldbus Standards

The position with regard to Fieldbus Standards is confusing. There are in fact many (40+) different field communication standards which could claim "Fieldbus" status. They vary widely in terms of the level of data transfer, degree of message transfer determinism, degree of interoperability, etc. These guidelines are based on the requirements for the "Process Industry" and interpret Fieldbus as defined by the work of the joint IEC/ISA committee. In brief these requirements can be summarised as:-

- Fast enough to meet the requirements of process control.
- Deterministic communications
- power down the wire (as in 4-20ma) for small items such as transmitters
- The ability to communicate multiple data to and from the field.

Much effort has been expended by the joint ISA SP50 and IEC TC65C, Working Group 6 committees in developing a single international Fieldbus Standard for use in Industrial Control systems. At the time of publishing only Part2 - Physical Layer Specification and Service Definitions - had been passed and is available as IEC 1158-2.

In Europe CENELEC have accepted EN50170. This is actually three existing National European Standards incorporated under one title. The Standard only deals with the communication protocol and does not include for any User Layer type applications. It should be noted that the three standards are completely different and incompatible. The three standards are :-

- German DIN 19245 Profibus DP Standard
- French UTE C4660X WorldFIP Standard
- Danish P-Net Standard

Of the actual standards published in EN 50170 only the WorldFIP standard can meet the requirements of IEC1158-2. Profibus PA which covers the Physical Layer requirements for the Process Industries is available on the market but has not yet been incorporated into EN50170 at the time of publishing.

The Fieldbus Foundation Specification, which is based on IEC 1158-2, has been accepted as a British Standards Institute draft (DD238) and has been put forward for voting as another part of EN50170.

Apart from some Physical Layer requirements the end User has very limited interest into how the protocol works and should bear this in mind when quoting standards in specifications. It is the recommendation of this Guideline that the end User specifies his functional requirements for systems and field equipment based on one of the protocols.

It was the view of the EEMUA sub-committee that the Fieldbus Foundation provided a protocol that was best supported by our major suppliers of instrument and control equipment, were providing a User Layer based on Process Industry requirements and was most likely to find global approval. This does not imply any disapproval of the other protocols which the members have and may continue to use in the future

5. Basic Design Consideration

5.1 Introduction

The application of Fieldbus technology opens up the opportunity to the User of extending digital communication into the field instrument. The advantages of the technology can be summarised as:-

- Offering a reduction in field cabling and terminations by using a common communications medium for several devices.
- Providing a common operating system for the transfer of information between field instruments and the control centre.
- The migration of control from centralised control processors into the field instrument thus reducing the controller requirements in the host system.

The benefits will be application specific and will involve a mixture of Capital and Operating costs. They may include other benefits due to control systems requiring smaller equipment rooms, power supplies, air conditioning, etc.

It is expected that the greatest benefits will be derived from the increasing intelligence of field devices which digital communications makes possible. Current developments in multifunctional transmitters, sensor diagnostics and a local device data base should lead to:-

- *Fewer field devices and process penetrations*
- *Less maintenance through improved reliability*
- *Reduction in consequential losses due to instrument failure*
- *Automated data collection for maintenance management systems.*

The perceived disadvantages are those associated with common mode failures in a bus segment and the extra complexity over the traditional 4-20 mA approach. Fieldbus installations need to strike a balance between the desire to reduce capital cost and the requirement for plant safety and maintainability.

The potential advantages will only be met if true interoperability between devices is achieved.

5.2 Design Philosophy

Foundation Fieldbus which follows IEC1158-2 has three official speeds; a low speed bus at 31.25 Kbits/s and two high speed buses at 1Mbits/s and 2.5 Mbits/s. Most of the contents of this document are directed at the design considerations for the low speed bus. Only the 31.25 Kbits/s allows for bus power and Intrinsic safety but for pragmatic reasons will be non-redundant.

Before starting to design a Fieldbus installation some basic philosophies have to be agreed. An overall Control System philosophy should be prepared to identify the basic requirements for reliability, operator interface, higher level systems, protection systems, etc. For Fieldbus based systems the following items need to be considered;

- *Bus segment topology* - A statement is required on the principles to be used in running the field cabling. This should include the type of cable to be used, basic rules on the running of trunks and spurs, star connections, etc. including distance limitations. It should also include guidance on the level of security required to cover the various possible power supply failures.

- *Bus segment connections* - guidelines are required on the number and types of equipment that can be connected to each bus segment taking into consideration physical constraints, the possibility of bus segment failure and the need for future expansion.

Also required is guidance on how to connect simple instruments such as thermocouples or switches and a policy regarding the application of multivariable instruments.

- *Configuration* - Basic rules are required on where to locate the control algorithms and on the options for algorithm configuration. The same is true of alarms. Any fast loop or alarm Sequence of Event requirements should be identified.

The tools and preferred method of configuration need to be identified and a change control procedure developed.

- *Network* - The overall network performance requires consideration and the need, if any, for function block scheduling identified

- *Maintenance* - A maintenance philosophy should be prepared to identify the preferred method of maintenance and what tools are required.

5.3 Interoperability

Fieldbus based devices can be specified with various levels of interoperability. The levels can be summarised as;

- *Not-interoperable* - A device that uses the communication protocol but has manufacturer specific Function Blocks and device parameters which have not been disclosed.
- *Limited interoperability* - as above but where some, but not all, of the device parameters have been disclosed.
- *Function block interoperable* - The manufacturer has specified function blocks as per the specification and disclosed manufacturer specific device parameters

- Function block interoperable - The manufacturer has specified function blocks as per the specification and disclosed manufacturer specific device parameters
- Fully interoperable - The manufacturer has specified Function Blocks and followed the Device Profile as per the User Layer specification. Any manufacturer specific device parameters have been disclosed.

These levels are based on the Fieldbus Foundations' specifications and differ from the those which are being prepared by IEC TC65C Working Group 7. The specifications for the User Layer are based on Function Blocks and Device Profiles which set out a basic set of device parameters. Manufacturers can add their own device parameters. These manufacturer specific parameters can then be disclosed by delivering the Device Description to the Foundation.

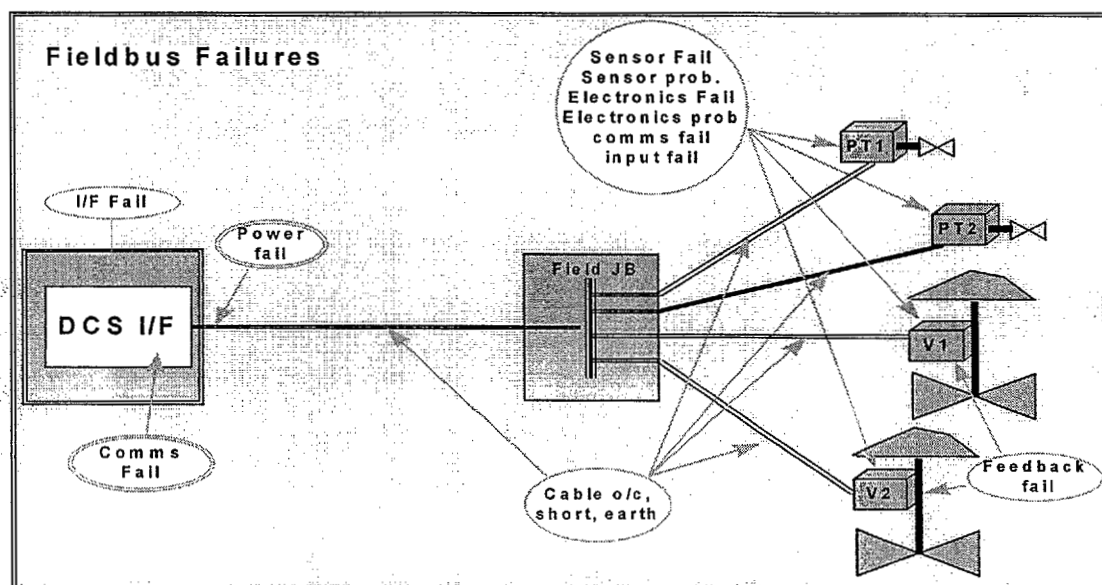
5.4 Failure Modes

The Fieldbus Foundation communication protocol has been designed to be deterministic and very robust. Basically the communications will work and a message will arrive correctly or it will not work. The possibility for degraded or erroneous messages being acted on by a device are minimal. The reliability of the bus segment as part of a control or information system will depend on the reliability of the connected devices. *A list of possible failures and their impact is included in the discussion in Appendix 2.*

The lower speed bus cannot support redundancy, the higher speeds can. The User should consider redundant bus segment/host system interface cards where multiple bus segments are installed on a single interface card giving rise to the possibility of a common mode failure which could fail several bus segments at the same time.

The most likely cause of a fatal failure of the bus is through power supply problems. Loss of power supply or any fault on the bus that draws the bus voltage below the minimum 9 volt threshold will stop communications.

A total loss of power should cause any actuators to move to a preconfigured desired position e.g. fail-safe. A fault where the current is drained such as in a partial short circuit and the bus voltage falls below the threshold may not have the same effect. This may leave the actuator in an indeterminate state. It is recommended to configure any final element in a loop to move to the desired safe position on loss of communications.



6. Cabling and Physical Connections

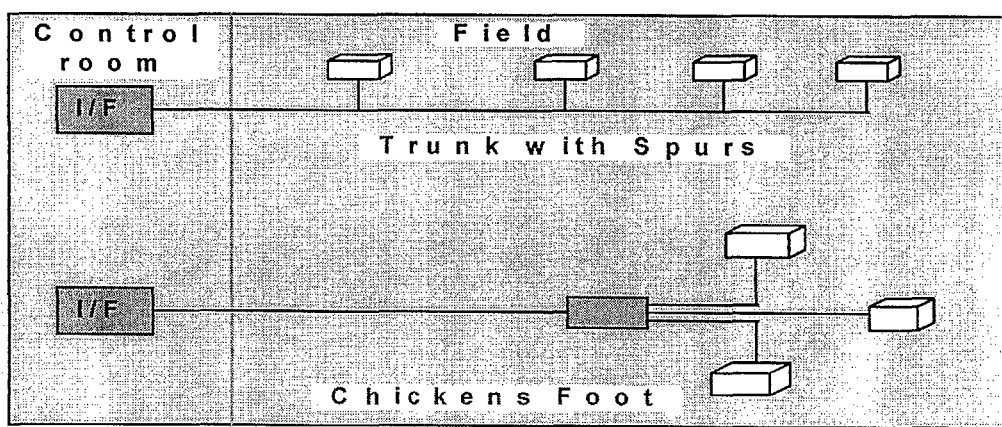
6.1 Low Speed Bus Segment Topology

Fieldbus allows the designer to connect instruments in a number of different configurations. The three basic choices are the "trunk with spurs", daisy chain (basically a trunk without the spurs) and a tree and branch arrangement known as the "chicken's foot". However it is possible to combine the different approaches on the same bus segment so long as some of the basic rules regarding number of connections and cable lengths are met (*see Appendix 1*).

The attraction of the "Trunk with Spurs" (and daisy chain) approach is that it will be possible to minimise the cabling requirement. The disadvantages are:-

- The requirement to install spur "couplers" boxes on the trunk
- Problems associated with connecting a new instrument to the trunk on-line.
- Design engineering time associated with determining the optimum trunk routing.

For the above reasons the trunk and spur approach will be attractive to suppliers of "packaged" type equipment e.g. large machines, process dryers, etc., where they provide multiple units to a standard design and the same, or similar, cable layout could be used several times. In this situation the design effort required to optimise the cable layout would be worthwhile. Also the need to install additional instruments on these types of unit is small.



In general process plant applications the preferred method is the Chicken's Foot. The designer will run a cable from the central control equipment to a junction box in the field. From this box individual spurs will be run to the field devices. The attractions of this approach are:-

- Cabling design is similar to traditional methods.
- Provision can be made in the junction box for adding future instruments.

to individual routing where cable support (e.g. tray) and installation labour costs would be increased.

6.2 Cable Selection

Low speed Fieldbus does not require special communication grade cable. The standard was specified to work on new and existing cable installations. The quality of the cable impacts on the maximum length over which the communications can work reliably. To achieve good performance over reasonable distances requires the cable to meet certain criteria. The optimal cable is given in the 1158-2 (see Appendix 1) and this cable is recommended for new installations. The outer construction should be designed to meet the User's normal requirements for safety and durability (e.g. armoured, etc.)

A number of manufacturers have designed cable specifically for Fieldbus communications. These cables tend to have lower signal attenuation than standard specifications.

Fieldbus may be run in multicore cables with other types of 24 volt signals and other protocols such as HART, although it is advisable to screen each pair(*there may be interference with the HART signal if you don't*).

Fieldbus can deliver DC power and communications on the same pair of wires and this is expected to be the most common approach for instruments such as standard process transmitters. The individual cores need to be colour coded for polarity.

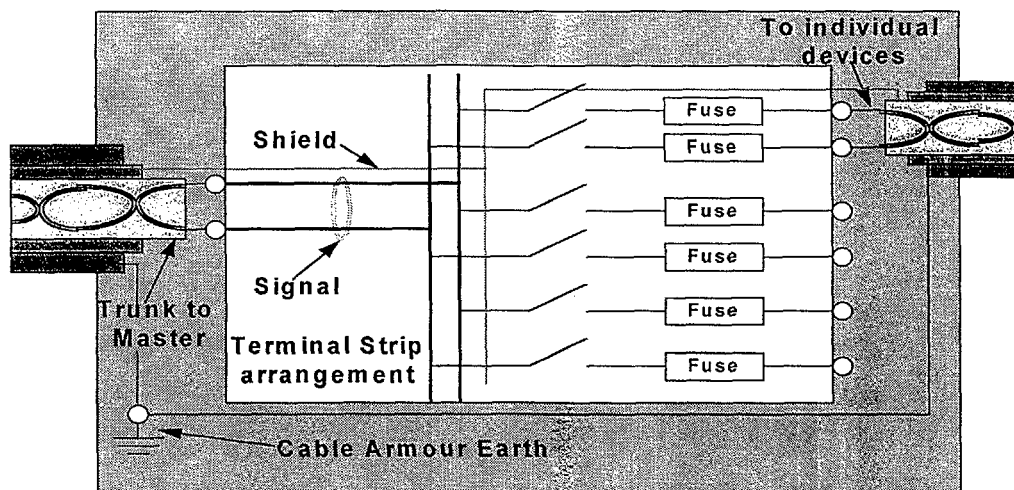
Some field devices may require a separate power supply e.g. a Coriolis meter or process analyser, and a four wire connection will be required. It is permissible to run both the power and the communication on different pairs in the same cable.

6.3 Field Terminal Boxes

Field termination boxes should meet the normal requirements for weatherproofing and any hazardous area certification. The User should consider his maintenance practices when deciding where to locate the boxes as it is possible that there may be an increased need to enter the box due to Fieldbus.

Boxes may be used for single or multiple bus segments. Where multiple bus segments are installed in a box, the terminal strips associated with any single bus segment should be physically segregated from other the bus segments.

It is recommended that terminal strips are fitted with some form of isolator to enable the power to be disconnected for individual field devices.



Chicken's Foot Junction Box

6.4 Power Supplies

Power supplies must meet the criteria and performance specified in IEC 1158-2. The low power signalling option is preferred. Power is delivered at a nominal 24V and should be available to any device on the bus at a minimal value of 9V (with a maximum value of 32 volts). Power is polarised so the cables and terminals should be suitably marked.

The end User must define his requirements for the security of the power supply. The power supply may be connected anywhere on a bus segment, however in practice it will most probably be supplied as an integral element of the host control system manufacturer's Fieldbus interface card arrangement but this may not be always the case.

Where Intrinsic Safety barriers are used, the power supplies must be matched with the barrier type.

The individual bus segment power supplies should be protected from overcurrent due to faults on the bus segment cable or devices. A current limiting arrangement is preferred to fuses as they are more tolerant to temporary faults such as may occur when work is being done. Power supply type faults on a bus segment should not be able to cause failures of other bus segments.

6.5 Earthing

Fieldbus conductors are non-earthed and electrically isolated from the connected devices and power supply.

Earthing requirements for individual devices, cable shields, armouring, etc., should meet the User's normal requirements and take into account any requirements to comply with EMC regulations and protection against

lightning. It is recommended that cable shields are earthed at one point only. Earthing shields at each end may introduce circulating currents into the shield that may effect the communications.

6.6 Hazardous Areas

Fieldbus installations must be properly certified for use in hazardous areas in respect of zone, gas group and temperature. The type of hazardous area protection adopted is a matter of policy for the user. All the currently recognised methods can be used with the low speed Fieldbus.

Applying IS protection to bus segment networks requires more care due to multiple devices being protected through a single barrier. The Fieldbus Foundation has prepared an application note on "Intrinsically Safe Fieldbus Systems" which explains how to apply IS Fieldbus networks. It also proposes an approach to certification based on the "Entity Concept".

It is recommended that IS bus segments are individually certified and that a full set of documentation is provided by the designer to show the calculations of how the requirements were met. Any future modifications to a bus segment, whether to install extra devices or to replace a device with another, will require the User to amend the calculations to verify that the applicable constraints are not exceeded.

7 Configuration

7.1 Hardware

The User is faced with a number of choices when deciding which devices to connect to a particular bus segment. The current IEC specifications gives the following examples of the number of devices that can be connected to a bus segment:-

- 32 devices if they are separately powered from the bus segment.
- 12 devices if they draw power from the bus segment.
- 6 devices for an IS installation with 4 devices on the hazardous side of the barrier.

These examples are mentioned in the standard and were based on what the committee thought would be possible at the time based on certain assumptions with regard to wire size, supply voltage, device power draw, etc. It may be possible to increase these figures by increasing cable size, increasing bus voltage, etc..

The User can chose to connect devices either on a loop basis or based on their location. Choosing devices based on a location basis suits the trunk and spur topology and minimises cabling. However for process type applications it suffers from two major disadvantages:-

- It would result in a number of "cross bus segment" loops (i.e. where a device on one segment had to transmit a value to device on another segment) which could place a burden on any bridging network across the various bus segments and would complicate function block scheduling.
- It could result in multiple control loops sharing bus segments with consequent common fault modes. This may impact on how plant protection systems such as relief systems are designed (i.e. two valves on a single bus segment).

For process applications the loop approach is recommended. The procedure to be adopted would be to follow the following steps:-

Step 1. Select all instruments associated with a particular control loop. Allocate the bus segments on this basis.

Step 2. Check what instruments remain. Allocate these to bus segments based on locality (and the limitations on the number of devices that can be connected to a bus segment).

Step 3. Check the bus segment allocation against the instrument location drawings to ensure a sensible cabling arrangement. *(Regardless of the comments made above about minimising cross bus segment loops it would be wasteful to run cable large distances just to maintain the loop criteria).*

For process plant it is recommended that the principle of single loop integrity should be maintained. This requires restricting one loop to a bus segment. Multiple loop bus segments would be acceptable where failure of the bus segment would not infringe any plant protection system design basis or place a burden on the operator.

It may be uneconomic to provide many simple instruments such as limit switches, thermocouples, etc., with a Fieldbus interface. The User faces a number of alternatives of how to access the information onto the control and monitoring network. The choices are :-

- Wire them up in the traditional manner
- Wire them to a Fieldbus instrument that can accept an auxiliary input.
- Wire them up to a multiplexer with a Fieldbus interface.
- Install a low level sensor bus segment with a gateway to a Fieldbus segment.

Wiring up to another instrument is a practical approach for items such as single thermocouples (wire to the nearest flow or pressure transmitter) or limit switches on valves (which could be input into the positioner).

Wiring up to a multiplexer is the recommended approach where a number of simple instruments are located together e.g. thermocouples around a process Reactor.

Installing a lower level bus segment sub-network may be beneficial where there are a large number of simple instruments, especially digital input and output, such as on auxiliary process plant (e.g. Dryers or Absorber package units) or material handling plant. These sub-networks need gateways to translate from the lower level protocol to Fieldbus. Issues relating to synchronisation of sampling and latency of data transfer between busses can be significant and need to be checked.

7.2 Control Loops

Fieldbus offers the opportunity to migrate control functionality from the central control system to the field device. The designer can consider the bus segment to be a "virtual controller" and is free to locate the control algorithms in any of the connected devices (see Appendix 2). It is considered that most installations will take this opportunity as migration to the field will lead to a more fault tolerant system and save in host system controller costs.

There will be differences between manufacturers as to what control functions they provide within their devices. The user is advised to specify the minimum requirements to the supplier. The differences will be:-

- The range of control algorithms that are available. The Fieldbus Foundation has specified a number of different control algorithms (Function