

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

MANUAL

FIELDBUS DESIGN, INSTALLATION, OPERATION & MAINTENANCE

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This new PTS **32.30.10.10** - Fieldbus Design, Installation, Operation & Maintenance has been developed with the objective to specify the minimum and fit-for-purpose, requirements of a Fieldbus System.

This PTS also includes PETRONAS Lessons Learnt and PETRONAS Best Practice for the subject matter in the Fieldbus Design, Installation, Operation & Maintenance

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PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU/Divisions in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, it is expected of them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the owner.

The right to use PTS rests with three categories of users:

- 1) PETRONAS and its affiliates.
- 2) Other parties who are authorized to use PTS subject to appropriate contractual arrangements.
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) and 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, PETRONAS disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any PTS, combination of PTS or any part thereof. The benefit of this disclaimer shall inure in all respects to PETRONAS and/or any company affiliated to PETRONAS that may issue PTS or require the use of PTS.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, PTS shall not, without the prior written consent of PETRONAS, be disclosed by users to any company or person whomsoever and the PTS shall be used exclusively for the purpose they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of PETRONAS.

The copyright of PTS vests in PETRONAS. Users shall arrange for PTS to be held in safe custody and PETRONAS may at any time require information satisfactory to PETRONAS in order to ascertain how users implement this requirement.

1 INTRODUCTION

1.1 SCOPE

This PTS specifies the requirements for the design, installation, operation and maintenance of Fieldbus installation. This PTS shall be used for new projects and existing installations, where Fieldbus system is being implemented. The objective is to specify the minimum and fit-for-purpose, requirements of a Fieldbus system

This PTS is developed together with the Technical Professionals and experienced Fieldbus users of Skill Group 14. The Custodian of this PTS shall be consulted for any deviation from these PTS.

Do NOT use Fieldbus for any Process Shutdown System

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorized by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS group and to contractors and manufacturers/suppliers nominated by them.

All publications referred to are listed in Section 10.

1.3 DEFINITIONS

1.3.1 General Definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier/Vendor** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor or the Plant Owner.

The **Plant Owner** is the PETRONAS instrumentation party responsible for the operation and maintenance of the equipment, who in turn, is responsible to the plant management.

The **Principal** is the PETRONAS party which initiates the project (new or revamp) and ultimately pays for its design and construction. The Principal will generally specify the technical requirements.

The **Custodian** is the originator and technical owner of these PTS.

The word **Shall** indicate a requirement.

The word **Should** indicate a recommendation.

1.3.2 Technical Definitions

Application Layer

The Application Layer is a layer in the communication stack containing the object dictionary

Bus

A bus is an interconnected network of devices. A larger bus can be formed by multiple segments connected through repeaters. A bus typically has a single segment. Therefore the terms “bus” and “segment” are often used interchangeably although there is a difference.

Fieldbus Coupler

A coupler is an optional physical specialized wiring block between a trunk and spur to the devices.

Cycle

The scanning of inputs, execution of algorithms and transmission of output values to devices.

Data Link Layer

The Data Link Layer (DLL) controls transmission of messages onto the Fieldbus, and manages access to the Fieldbus through the Link Active Scheduler (LAS). The DLL is defined in IEC 61158 and ISA S50. It includes Publisher/Subscriber, Client/Server and Report Distribution Services.

Deterministic

The ability to calculate maximum worst-case delay when delivering a message between any two nodes in a network. Any network protocol that depends on random delays to resolve mastership is non-deterministic.

Device Description

A Device Description (DD) provides an extended description of each object in the Device and includes information needed for a control system or host to understand the meaning of data in the device

FISCO

Fieldbus Intrinsic Safe Concept. Allows more power to an IS segment for approved FISCO devices, allowing for more devices per IS segment. FISCO eliminates the requirement of calculating entity parameters of capacitance and inductance when designing networks.

Flexible Function Block

A Flexible Function Block (FFB) is similar to a Standard FB, except that an application specific algorithm created by a programming tool determines the function of the block, the order and definition of the block parameters, and the time required to execute the block. Flexible Function Blocks (FFBs) are typically used for control of discrete processes and for hybrid (batch) processes. A Programmable Logic Controller (PLC) can be modeled as a Flexible Function Block device.

Function Block

A Standard Function Block (FB) is built into Fieldbus devices as needed to achieve the desired control functionality. Automation functions provided by Standard FBs include Analog Input (AI), Analog Output (AO) and Proportional/Integral/Derivative (PID) control. There can be many types of FBs in a device. The order and definition of Standard FB parameters are fixed and defined by the specifications.

Gateway

A Gateway translates another protocol to Fieldbus, for example HART to Fieldbus or Modbus to Fieldbus.

Link

A Link is the logical medium by which devices are interconnected. It spans one or more physical segments interconnected by bus Repeaters or Couplers. All of the devices on a link share a common schedule which is administered by that link's current LAS.

Link Active Scheduler

A Link Active Scheduler (LAS) is a deterministic, centralized bus scheduler that maintains a list of transmission times for all data buffers in all devices that need to be cyclically transmitted. Only one Link Master (LM) device on a Fieldbus Link can be functioning as that link's LAS.

Link Master

A Link Master (LM) is any device containing Link Active Scheduler (LAS) functionality that can control communications on a Fieldbus Link. There must be at least one LM on a Link; one of those LM devices will be elected to serve as LAS.

Link Object

A Link Object contains information to link Function Block (FB) Input/ Output (I/O) parameters in the same device and between different devices. The Link Object links directly to a Virtual Communications Relationship (VCR).

Object Dictionary

An Object Dictionary (OD) contains all Function Block (FB), Resource Block (RB) and Transducer Block (TB) parameters used in a device. Through these parameters, the blocks may be accessed over the Fieldbus network.

Physical Layer

The Physical Layer receives messages from the Communications Stack and converts the messages into physical signals on the Fieldbus transmission medium, and vice versa.

Repeater

Repeater is an active, bus-powered or non-bus-powered device used to extend the range over which signals can be correctly transmitted and received for a given medium. A maximum of four Repeaters can be used between any two devices on Fieldbus network. Repeaters connect segments together to form larger networks.

Resource Block

A Resource Block (RB) describes characteristics of the Fieldbus device such as the device name manufacturer and serial number. There is only one Resource Block (RB) in a device.

Segment

A segment represents a cable and device installed between a pair of terminators. Segments can be linked by Repeaters to form a fresh signal and elongate the Fieldbus.

Splice

A Splice is a Spur measuring less than 1m in length.

Spur

A Spur is a branch cable connecting to the device to the Trunk.

Terminator

A Terminator is a shunt that converts transmitted current signal to a voltage signal. It is placed at or near each end of a transmission line. Only two Terminators shall be used on a segment.

Topology

Topology refers to the shape and design of the Fieldbus network (for example, tree, bus, daisy chain, point-to-point, chicken foot, etc.).

Transducer Block

A Transducer Block (TB) decouples Function Blocks (FBs) from the local I/O functions required to read sensors and command output hardware. Transducer Blocks (TBs) contain information such as calibration data and sensor type. There is usually one TB channel for each input or output of a FB.

Transmitter

A Transmitter is an active Fieldbus device containing circuitry which applies a digital signal on the bus.

Trunk

A Trunk is the main cable-between the control system and the devices in the field.

User Application

A User Application is based on “blocks”, including Resource Blocks (RBs), Function Blocks (FBs) and Transducer Blocks (TBs), which represent different types of application functions.

User Layer

The User Layer provides scheduling of Function Blocks (FBs), as well as Device Descriptions (DDs) which allow the host to communicate with devices without the need for custom programming.

Virtual Communication Relationship

Configured application layer channels that provide for the transfer of data between applications.

1.4 ABBREVIATIONS

Abbreviations	Description
AI	Analog Input
AO	Analog Output
BPS	Bulk Power Supply
CAPEX	Capital Expenditure
CCR	Central Control Room
C/S	Client/Server
CCF	Common File Format
DCS	Distributed Control System/Digital Control System
DI	Discrete Input
DD	Device Description
DLL	Data Link Layer
DO	Discrete Output
EDDL	Enhanced Device Description Language
ESD	Emergency Shut Down
FAR	Field Auxiliary Room
FAS	Fieldbus Access Sub layer
FB	Function Block
FF	FOUNDATION Fieldbus
FFB	Flexible Function Block
FFPS	FOUNDATION Fieldbus Power Supply
F&G	Fire And Gas
HIST	Host Interoperability Support Testing
HMI	Human Machine Interface
HSE	High Speed Ethernet
IEC	International Electro Technical Commission
I/O	Input Output
IPS	Instrument Protective Function
IS	Intrinsic Safety

IT	Information Technology
ITC	Individual Twisted Cable
ITK	Interoperability Test Kit
LAS	Link Active Schedule
LM	Link Master
MAI	Multi Analog Input
MAO	Multi Analog Output
ML	Manual Loader
MOV	Motor Operated Valve
MV	Manipulated Variable (Controller Output)
NM	Network Management
OD	Object Dictionary
OPEX	Operational Expenditure
PCS	Process Control System
PAS	Process Automation System
P/S	Publish/Subscribe
PD	Proportional/Derivative Control
PID	Proportional /Integral /Derivative Control
PV	Process Variable
PLC	Programmable Logic Controller
RA	Ratio
RB	Resource Block
SIL	Safety Integrity Level
SM	System Management
SP	Set Point
SS	Safety Systems
TB	Transducer Block
TCoO	Total Cost of Ownership
TPE	Thermo Plastic Elastomer
VCR	Virtual Communication Resource

2 GENERAL

To ensure standardization across the PETRONAS Group of companies, based on the most prevalent use across the oil majors and based on capability building across the Group, the FOUNDATION Fieldbus shall be the only Fieldbus technology approved for use in the Group for process instrumentation and control applications.

2.1 SYSTEM PHILOSOPHY

All instrumentation devices used in the Fieldbus system shall be approved by the Fieldbus Foundation and shall have the checkmark symbol, as follows:



Approved devices can be found on the Fieldbus Foundation website:
<http://www.Fieldbus.org/>

The FOUNDATION Fieldbus device shall be at least ITK 4.6 compliant, which allows for on-line firmware upgrades. It is recommended that the selected ITK version shall remain unchanged thorough-out the project phase, until commissioning and one (1) year operation, to avoid discrepancies in the various devices installed in the network.

FOUNDATION Fieldbus (hereinafter known as Fieldbus) devices shall be capable of supporting incremental device description (DD) for extra functionality and/or software revisions in device memory. The internal software of the Fieldbus instruments shall be configured by the manufacturer to include at least the serial number, tag name and process service description.

The Fieldbus devices shall not be polarity sensitive. Older Fieldbus devices were polarity sensitive and, if connected incorrectly, will not work. These older devices shall be progressively replaced.

The field devices shall generally be 2-wire bus powered from the host system. The bus-powered Fieldbus devices typically require 10-30 mA current and shall be between 9 to 32 VDC. It is recommended that a margin of at least 1VDC be maintained at the field end of the bus i.e. at least 10VDC. Any segment that is designed to operate below 15 VDC shall carry a warning on additional loads in the segment documentation. The minimum segment voltage shall be shown on the network/segment documentation.

Devices that require external power, e.g. 4-wire devices, shall have their power isolated from the Fieldbus signal. Bus-powered, 2-wire devices are the recommended standard.

Devices should strive for minimum power consumption.

The fields devices shall be provided with a maximum of 60 mA current limiting short-circuit protection. For practical purposes, this means that all field devices shall draw no more than 50 mA, since approximately 10 mA will be needed to activate the short-circuit protection circuitry.

The Fieldbus equipment shall be designed to withstand vibration forces of up to 1.0 g over the range of 5 to 100 Hz, and for a 5 msec duration a vibration force of 4.0 g over the same range. Networks, Data, I/O highways are required to have an approved type of electrical isolation at the point of connection to the Host System hardware, Fieldbus junction box, and the field.

All Fieldbus devices shall be certified by an internationally recognized testing laboratory, and labeled for the Hazardous Area classification where they will be installed.

The Fieldbus system shall only be used for purposes of monitoring and/or control. The Fieldbus system shall NOT be used for safety shutdown purposes.

The overall Fieldbus system design should be well under-stood before the network and individual segment design is started. The P&ID's, Instrument Location drawings and Plot Plans are needed to effectively design Fieldbus segments.

Prior to defining Fieldbus segments, the process control strategy and philosophy shall be complete, the P&IDs available, and instruments selected with locations determined. This is a necessary condition to allow for the design of control in the field, which requires all devices for the loop to be part of the same network/segment.

A control implementation strategy guideline shall be created for all Fieldbus projects and approved by the Principal or Plant Owner. The guideline shall define the typical control strategies, with control modules, function blocks and all parameter configurations defined. This guideline shall set the function block and control module philosophy for the current and future Fieldbus projects at the particular facility. As part of the guideline, a narrative shall be provided for each typical function block and control modules to describe in detail the parameter settings and subsequent blocks/module operation. Included shall be narrative discussion on parameter configuration and operation for signal status, bad value determination, failure mode switching, initiation feature, anti-reset windup feature, etc. The guideline shall highlight any differences in configuration or operation between the FOUNDATION Fieldbus and conventional 4-20mA control strategies, if a mixture of FOUNDATION Fieldbus and conventional control strategies are used. This shall form the basis for configuration of the devices and control system behavior during Abnormal Situation and is critical for the safe and reliable operation of the facility. The control system vendor shall produce configuration options and defaults for the specific host system wide settings, configuration strategies, devices and asset management software. The Principal or Plant Owner shall approve all configuration options and defaults. A typical example of default settings for a control loop can be :-

- Loop mode shall default to manual for Bad PV, condition is alarmed and indicated by graphics and faceplate colour change and blanked out data indication.
- Loop mode shall ignore Questionable PV, condition is not alarmed but is indicated by graphics and faceplate colour change.

All personnel executing design, projects, installation, testing, commissioning, technical operation and maintenance shall have undergone certified training by any approved party. The certified training shall be for a minimum of two (2) weeks, covering both theoretical aspects and practical training on FOUNDATION Fieldbus.

2.2 DEVICE DIAGNOSTICS

Device integration and diagnostics shall be based on FOUNDATION Fieldbus approved technologies, such as, EDDL technologies. The device diagnostics shall be able to provide key information on the ability of the device to measure and/or control the process, including, but not limited to, basic device failure diagnostics and advanced diagnostics.

2.2.1 Basic Diagnostics

Basic diagnostics are the device failure diagnostics that shall be viewable from any process control host. They help determine common problems with the device, communication path and host. Diagnostics that indicate device failure should force the loop to the required safe failure mode, as per the control narrative, with appropriate warnings and alerts as per Section 5.5.

2.2.2 Advanced Diagnostics

Advanced diagnostics includes full device diagnostics that is determined without removing the device from the network. Advanced diagnostics is available as on-line and off-line.

2.2.3 Online Advanced Diagnostics

Online diagnostics perform their functions while the device is performing its normal process function and provides the capability to alert in real time if a problem needs attention. This function is a primary benefit of FOUNDATION Fieldbus and should be supported by all devices installed in the facility.

2.2.4 Offline Advanced Diagnostics

Offline diagnostics have limited benefits, as it requires the device to be taken out of normal operation.

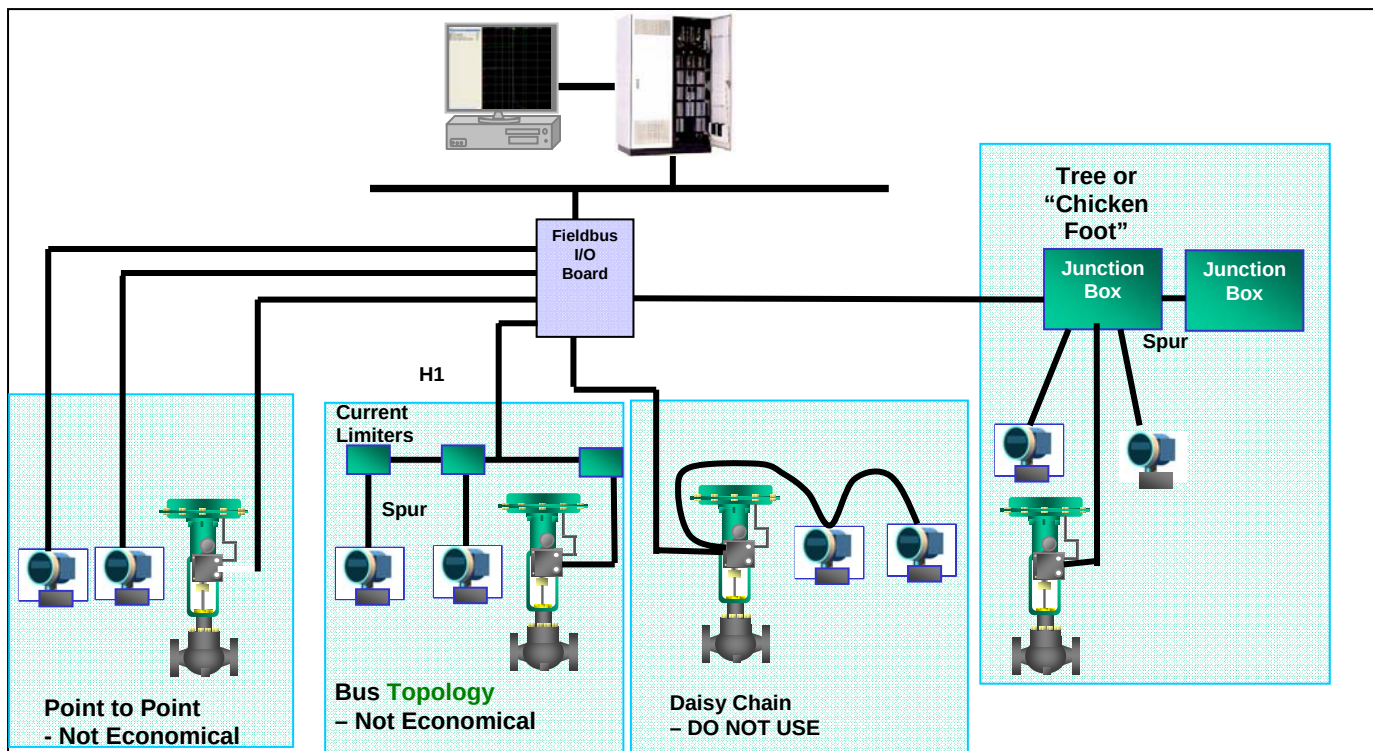
3 SEGMENT DESIGN GUIDELINES

3.1 FIELDBUS TOPOLOGY

Components of Fieldbus segments or networks can be connected together in various topologies. The topology selected is usually driven by the physical device location in order to reduce installation costs. Hence, control narratives and plot plans are used in addition to P&IDs and instrument indexes in the design of a Fieldbus segment.

Spur connections shall be connected to current-limiting connections to the bus to provide short-circuit protection, and to provide the ability to work on field devices without a hot work permit. This current limiting connection should provide an intrinsically safe connection to the field device.

There are several possible topologies for connecting the Fieldbus instrumentation in a system, as follows:-



Topologies where devices cannot be added or removed from a network/segment without disruption to other devices in the same network/segment shall not be used, such as Daisy Chain topologies. Only the Tree or “Chicken foot” topology shall be used for Fieldbus system that is used for control purposes.

3.1.1 Point-to-Point Topology

This topology consists of a network having only two devices. The network could be entirely in the field (e.g. a transmitter and valve, with no connection beyond the two) or it could be a field device connected to a host system for control or monitoring.

Point-to-point topology should not be used due to uneconomical reasons.

3.1.2 Tree Topology (Chicken Foot)

This topology consists of a single Fieldbus segment connected to a common junction box to form a network. It is practical if the devices on the same segment are well separated but in the general area of the junction box. When using this topology, the maximum spur lengths must be considered. Maximum spur lengths are discussed in Section 3.6.3.

This topology also allows maximum flexibility when configuring and assigning devices to networks/segments.

3.1.3 Bus Topology

This topology consists of Fieldbus devices that are connected to a trunk through a length of cable called a spur. This technology is technically acceptable but is not generally a good economic choice.

3.2 BULK POWER SUPPLIES

The 24VDC bulk power supply unit, supplying the Fieldbus system, shall be redundant. Two separate, independent, power circuits should provide the source power to the bulk power supply unit. The bulk power supply unit should be fed from redundant UPS power or have battery back-up supply for 30 minutes. The bulk power supplies shall have the necessary failure alarms. The negative leg of the bulk power supply unit should be grounded. The bulk power supply unit may be either dedicated solely to the Fieldbus network or shared between the Fieldbus network and the conventional 4-20mA instrumentation.

The bulk power supplies shall have overcurrent protection for each of its feed.

If the plant site already has an existing bulk power supply for conventional 4-20 mA instrumentation, this bulk power supply may be used to supply the Fieldbus power supply unit. The available spare capacity of the bulk power supplies shall be verified to meet the overall required demands. The Plant Owner shall approve, in writing, the use of the existing bulk power supply.

3.3 POWER CONDITIONER

Power conditioner is required for each Fieldbus network or segment to prevent the DC power supply from short circuiting the AC communication. The power conditioner shall be isolated, load sharing and output current limiting. The power conditioner shall be impedance matched to the Fieldbus signals. For control purposes, the power conditioner shall be redundant. Redundant power conditioners shall provide flawless transfer of power between one unit to the other. For monitoring purposes, redundant power conditioners are also recommended.

The power conditioners should be powered from the redundant bulk power supply units. The power conditioners units shall have alarms and diagnostics features.

3.4 TERMINATORS

Every Fieldbus segment shall have exactly two terminators. Terminators are necessary to prevent signal noise, arising from signal reflections, in event of wiring short or open circuit and convert transmitted current signal to a received voltage signal. The terminators are 1 μ F capacitor in series with a 100 Ω resistor. Self fabricated terminators shall not be used. Terminator that is located in the field shall be installed in a junction box. Terminators shall not be installed in the Fieldbus devices.

3.5 REPEATERS

Repeaters clean up the signal, by boosting it, re-timing it, and thereby improving the reliability of the Fieldbus network communications.

Repeaters replace one of the field devices in the network count, allowing the addition of the equivalent of an entire new segment by effectively splitting the network into a number of smaller segments. By adding a repeater, a new segment can be connected and terminators are required on each end of this new segment. Repeaters also provide the capability to increase the number of devices on a network to a maximum of 240 devices. However, note that the host system and network schedule limit will likely to be exceeded, before the physical maximum number of devices can be reached.

Some typical uses of repeaters would be :-

- a. If a segment (network) needs to extend further than the 1900 meter length constraint, then a repeater may be considered.
- b. A repeater can be used, with wire lengths of less than 1900 m, to improve the Fieldbus network robustness and reliability by boosting the communication signals.
- c. The most common use of repeaters is not to get longer distance, but to join IS segments together. Generally, an entity barrier only supports 3-4 devices and many barriers are required on a network to get loading of 16 devices per network.
- d. In the cases where it is economically justified, a repeater may be considered to extend the total segment length. This would typically be in cases where the H1 interface card cannot be located relatively close to the process (e.g. flare systems).

When Fieldbus repeaters are used, the overall design shall be reviewed and approved by the Principal engineer. When repeaters are used, the location of the repeaters shall be accessible. The Fieldbus repeaters shall be clearly marked on the Fieldbus network drawing.

3.5 JUNCTION BOXES

It is recommended that all trunk and spur connections in the field junction boxes, including pass-through trunk pairs without spurs, be terminated on Fieldbus couplers specifically designed and approved for Fieldbus networks. Inactive spare Fieldbus trunk pairs may be terminated on conventional terminal blocks. However, the use of conventional terminal blocks shall be documented, to enable future replacement, when the inactive pairs are re-activated, sometime in the future.

The design of the junction box shall include power isolation switches for maintenance of a section of the segment, without affecting the rest of the segment.

An alternate connection may be provided by weatherproof molded "bricks" that can be used without a junction box with factory molded plug connectors.

Conventional, 4-20mA, terminal blocks may be used but the wiring to all devices in the network shall be done via parallel connections.

If weatherproof molded “bricks” or conventional terminal blocks are used, the following requirements shall be met:-

- a. Two (2) dedicated connections for the Fieldbus homerun/trunk cable.
- b. Integral short-circuit protector for spur connections, where the maximum current to spur is limited by the area classification and current available to the network. The spur circuits shall have a non-incendive rating. The short-circuit protector can be connected to the terminating block at the homerun or main network cable.

Wiring Blocks with integral short-circuit protectors will prevent a fault (short-circuit) in the device or spur cable run from bringing the entire FF segment down. Typically an additional 10 mA load is added when this spur is short-circuited.

- c. Pluggable (removable) ‘trunk’ and ‘spur’ connectors.
- d. Indicators for each spur connection indicating when a spur is shorted and is in overcurrent mode.
- e. Indication when bus power is available.
- f. Electrical regulatory (e.g. CSA or FM) approved for Ex n; Class I, Division 2, Groups B, C, D or Zone 2, IIA, IIB, IIC.
- g. Wire capacity: 12-24 AWG.
- h. Temperature range: -45° to +70° C.
- i. DIN rail mounting (terminal blocks).
- j. Available in four (4) spur, six (6) spur and eight (8) spur configurations.

Where multi-pair trunk cables from the marshalling panel to the field are required (for large segment usages), the junction box for the multi-pair trunk cable shall comply with the PTS for conventional instrumentation.

3.6 CABLING

Individually shielded twisted pair overall screened cables shall be used for Fieldbus network cabling. Specially designed FOUNDATION Fieldbus cabling may be used, if the cost is justifiable.

The following are typical characteristics of FF cables as per IEC Physical Layer Standards:-

Wire Size	18 GA (0.8 mm ²)
Shield	90% coverage
Attenuation	3 db/km at 39kHz
Maximum Capacitance	150 pF/m
Characteristic Impedance	100 ohms +/- 20% at 31.25 kHz

The typical Fieldbus cable specifications are as follows :-

Type	Meters/Feet	Cable Size	Impedance Ohms	Resistivity	Attenuation (db/km)	Description
A	1900 / 6270	#18 AWG (0.8 mm ²)	100	22	3	Individual shielded pairs
B	1200 / 3960	#22 AWG (0.32 mm ²)	100	56	5	Multiple pairs with overall shield
C	400 / 1320	#26 AWG (0.13 mm ²)	Unknown	132	8	Multiple pairs with no shield
D	200 / 660	#16 AWG (1.25 mm ²)	Unknown	20	8	Multiconductor, no pairing

Cables for Fieldbus installation shall be labeled Type ITC (16 gauge) and shall be installed in trays or conduits. All cables shall be single or multiple twisted pair with individual shield for each pair (Types B, C and D cables shall not be used). Multi pair cables shall have an additional overall shield.

Fieldbus cables shall be unique in colour and shall be easily distinguished from conventional 4-20 mA cables. The cable differentiation can be at the cable ends, through the use of coloured cable lugs or coloured heat shrink markers.

To minimize cost for upgrading existing 4-20mA installations to Fieldbus, Fieldbus signals and 4-20mA signals may be run together in multiconductor cables provided each wire pair is individually shielded.

Cables shall have thermoplastic elastomer (TPE) flame-retardant insulation and comply with the colour conventions and polarities of the facilities. The cables shall be suitable for the electrical area classifications and suitable for outdoor use in cable trays. The cable jacket shall be flame-retardant polyvinyl chloride (PVC).

3.6.1 Distance Constraints

The maximum allowable segment length is 1900 meters (6232 ft) except where repeaters are installed, as specified in the ISA 50.02 Fieldbus Standard. The total segment length is calculated by adding the length of the main trunk line cable and all the spurs that extend from it.

Total Segment Length = Trunk + All Spurs

The total segment length is limited by the voltage drop and the signal quality (attenuation and distortion).

3.6.2 Trunk Cable

Either specially designed FOUNDATION Fieldbus cables, Type A or 18 AWG multi-pair, individually shielded cables shall be used for all trunk wiring. Runs parallel to high power (> 240 VAC) should be minimized, with adequate spacing and shielding.

A minimum of twenty percent (20%) spare pairs shall be provided for all multipair Fieldbus segment trunk cables, with a minimum of one spare pair. This sparing requirement covers trunk cable runs between marshalling racks and junction boxes, and between junction boxes.

When re-using existing cabling, the homerun cables shall be tested for suitability and documented. Test can be carried out using the Fieldbus cable testing tools.

3.6.3 Spurs

Spurs can vary in length from 1m to 120m. The spur length is the cable length from the wiring block to the Fieldbus device. A spur that is less than 1m is considered a splice. Only one Fieldbus device shall be connected to each spur.

The maximum recommended spur length is 30m, for intrinsically safe installation.

3.7 POWER FOR FIELDBUS DEVICES

Fieldbus devices maybe bus powered or externally powered. However, wherever possible, bus powered devices are recommended.

Bus-powered devices typically require 10-30 mA of current at between 9 and 32 volts. Any network / segment designed to operate below 15V shall carry a warning about additional loads in the network documentation. The minimum network / segment voltage shall always be shown in the network documentation.

The total current draw from all the Fieldbus devices shall not exceed the rating of the Fieldbus power supply. The network / segment design shall take into account :-

- Total device quiescent current draw
- One spur short circuit fault i.e. 10 mA additional current draw
- 25% additional current load, on top of the above two requirements

The number of bus-powered devices on the segment is limited by the following factors :-

- Output voltage of the power supply
- Current consumption of each device
- Location of device on the network / segment i.e. voltage drop
- Resistance of each section of the cable i.e. cable type
- Minimum operating voltage of each device
- Additional current consumption due to one spur short-circuit fault of 10 mA

The total power distribution and consumption for the network / segment shall be calculated and documented.

3.8 GROUNDING

The instrument signal conductors shall not be used for grounding. Instrument safety ground shall be made thorough a separate conductor outside of the signal cable. The conductor may be in the same cable as the instrument signal conductor and shield but shall be located outside of the shield within this cable. None of the Fieldbus device twisted pair cables shall be grounded at any part of the network.

The network cable shield shall be earthed / grounded at one location only, at the field termination assembly (host) end. At the field device, the cable shield shall not be connected to the instrument earth / ground or chassis.

Earthing / grounding of the Fieldbus conductor will likely cause the all the devices in the bus network / segment to lose communications.

3.9 SHIELDING

The purpose of shielding is to prevent noise interferences with the network / segment communication signals.

The instrument shield shall be terminated at the host end of the network in the marshalling cabinet and shall not be connected to ground at any other place. If a multiple **trunk** cable goes through a field junction box, the cable shield wires from the different networks / segments shall not be connected together, as this will cause ground loops and noise onto the networks / segments.

3.10 LIGHTNING / SURGE PROTECTION

In areas of high lightning activity or where large inductive loads, e.g. motors, are started and stopped, lightning / surge protection shall be provided. The surge suppression device shall consist of low capacitance silicon avalanche diodes or spark gaps, wired for normal and common-mode protection, and connected to the electrical safety ground grid. Avalanche diodes normally fail to short-circuit. Where this is a concern, the surge suppression device may be connected with a series fuse. Typical installations are on field devices installed in remote tank farms and on top of tall columns and vessels.

If used, lightning / surge protection devices shall be located at the host end. For locations prone to high lightning activity, multiple lightning / surge protection devices may be considered for the individual loops.

It is important that the surge suppression device does not significantly attenuate the Fieldbus signals.

3.11 SEGMENT RISK MANAGEMENT

Each OPU / facility shall have a documented risk criticality assessment philosophy / methodology with which the risk and criticality of each Fieldbus device on the network / segment has been identified. The existing risk criticality assessment philosophy / methodology in use by the OPU / facility may be used. The philosophy shall consider the network / segment segregation, multiple segments per H1 port, etc. The risk criticality assessment shall be shown on the network / segment drawings. The topology design should minimize single point failures.

The following risk management shall be followed for Fieldbus topologies that are used for control purposes :-

Risk Management Selection	
Redundant Controller	Required
Redundant H1 Interface	Required
Redundant Power Supplies	Required
DC Power Supply Battery Capacity	Required – 30 minutes minimum
Redundant Power Conditioners	Required
Field Back-up LAS	Required
Control in Valve Positioner	Preferred for simple loops
Control in Transmitter	Only for the Primary device in the cascade loop
Control in Host	Required for complex loops
Valve / Segment Criticality Ranking	Required
Maximum Devices per Segment	12 (default)
Maximum Valves per Segment	4 (default)
Repeaters	Requires Principal Engineer approval

Multi-input and multi-variable Fieldbus transmitters Analog Input (AI) function block may be used for both monitoring and control purposes. However, such transmitter inputs should be used in one control loop only. All other variables shall be used for monitoring application only.

Multi-input Fieldbus device having Multiple Analog Input (MAI) function blocks shall be used for monitoring application only, and not for control purposes.

Discrete Fieldbus devices, using DI/DO function blocks may be used on the same network / segment as regulatory control and monitoring devices.

The following guideline should be used in the risk criticality assessment of the network / segment devices:-

Valve criticality level

The valve and associated measurement criticality shall be defined for prudent loading of Fieldbus segment. Valve criticality levels shall be defined as below:

a) Level 1 Valve and H1 Segments

Definition:

Failure of level 1 valve will result in causing a shutdown of the entire unit or plant.

Application:

Level 1 Valves and their associated measurement device(s) (transmitter) shall reside on H1 segments that are only used for Level 1 control. Only one Level 1 valve and its associated measurement devices shall be installed per segment

b) Level 2 Valves and H1 Segments

Definition:

Failure of a level 2 valve can be tolerated by operations with difficulties and may lead to production slowdown or reduction.

Application:

Maximum allowable is 10 devices with additional of 2 spares subject to segment loading calculation. Segment will consist of one level 2 control loop with monitoring devices

c) Level 3 Valves and H1 segments

Definition:

Loss of control can be tolerated until rectification with no impact on production.

Application:

Maximum allowable is 10 devices with additional of 2 spares subject to segment loading calculation. Segment shall consist maximum of three level 3 control valves loop with monitoring devices.

d) Level 4 H1 Segments: No control

Definition:

Level 4 Devices are measurement only devices that shall not be used for control and may be configured in a way that could interrupt control on a H1 segment. Devices in this class contain Multiple I/O blocks.

Application:

Level 4 Devices can reside on H1 segments with up to 12 Level 4 devices only (no control).

3.11.1 Network / Segment Shorting

A shorted network / segment or power supply failure shall result in the valves going to fail-safe mode, regardless of the device hosting the PID algorithm.

3.11.2 Transmitter Assignment

For controls, the primary process variable transmitter shall be on the same segment as the valve to enable field-based controls.

3.11.3 Multiple Process Variables

Multiple measurement devices for simple calculations, such as, differentials, shall be assigned to a common segment with the simple calculations performed in one of the transmitters, rather than in an output device. Transmitters typically have a lower load than an output device.

3.12 INTRINSICALLY SAFE (IS) INSTALLATIONS

Field Barriers

Intrinsically safe installation shall be used in hazardous locations of EEx-ia, EEx-ib or EEx-ic. Use of Ex-d equipment shall be avoided. Use of Ex-d equipment for Fieldbus installations shall require the approval of the Principal Engineer or Plant Owner.

Field barrier or "high energy trunk" concept shall be used for the intrinsically safe installation. The use of Fieldbus Non-Incendive Concept (FNICO) and Fieldbus Intrinsically Safe Concept (FISCO) installations shall not be used.

The Field Barrier shall be mounted in stainless steel junction box with Ingress Protection rating of at least IP65 and suitable to be mounted in Zone 1 areas. The design of the field barrier connections in the junction box shall include the provision of isolator switches which shall enable for any field barrier to be taken out for maintenance without interrupting the operation of the field barriers. Up to three field barriers may be installed in a single junction box. Each spur connection on the field barrier shall be provided with short-circuit and overload protection such that a fault in one spur will not have any negative influence on the trunk or on other spurs. Faults shall be indicated by LED on the field barrier.

3.13 FIELDBUS LOADING AND CALCULATIONS

The allowable network and segment loading is determined by the lower value of the following four parameters:-

- Segment Risk Management criteria, as per section 3.11
- 20% spare capacity requirement, as per section 3.13.1
- Free time in the network macrocycle, as per section 3.13.2
- Voltage drop and current supply limitation, as per section 3.13.3

3.13.1 Spare Capacity

Networks / segments shall be designed for a minimum of 20% wired spare capacity. For control network / segments, the spare capacity shall include the ability for future addition of a minimum of one control loop or at least one transmitter and one control valve.

Segment current	- o For new project, there shall be spare segment current for at least 2 field devices (2 X 20 mA) per segment. - o For retrofit project, this may be waived if no future addition is anticipated.
Function blocks	- o For new project, 20% of vendor stated max or 6 FBs whichever is higher. - o For retrofit project, 10% of vendor stated max or 3 FBs whichever is higher.
Virtual communication relationship	- o For new project, 20% of vendor stated max or 12 VCRs whichever is higher. - o For retrofit project, 10% of vendor stated max or 6 VCRs whichever is higher.
Available time for unscheduled communication	- o For new project, shall not be less than 70% of macrocycle. - o For retrofit project, shall not be less than 60% of macrocycle.
Free termination point	At least 3 (2 for future field devices + 1 for field configurator) free termination points on the wiring block/brick
FF module	At least 5 free ports (segments) or 20 % of total segment, whichever is higher. The free ports maybe spread across existing FF modules or concentrated onto spare FF module(s).
Bulk power supply	The necessary number to pre-wire the free segments above.
IS isolator/power conditioner	5 units or 20 % of installed total, whichever is higher. These must be pre-wired to above free FF ports and spare power supply unit. If field-barrier is used, assume 4 field-barriers per segment. These are to be supplied loose.
Trunk cable	1 spare pair for every j/box that housed more than 1 trunk cable. This is not required for field-barrier or water-proof wiring block/brick.
Wiring block/brick	5 units or 10 % of installed total, whichever is higher. To be supplied loose. Not applicable to installation with field-barrier.
Terminator	10 units or 2 % of installed total, whichever is higher. To be supplied loose.

3.13.2 Segment Execution Time

The default segment execution time shall be one (1) second or less, unless otherwise approved by the Principal or Plant Owner. Further guidance on segment times is given in Sections 5.6.2 and 5.6.3.

The maximum number of devices per segment for the listed execution times shall be as follows:-

- For segments with monitoring loops only, the segment shall be limited to a maximum of twelve (12) devices.
- For control loops where the 1 second execution time is sufficient, the segment shall be limited to twelve (12) devices, with a maximum of four (4) valves.
- For control loops requiring a 0.5 seconds execution time, the segment shall be limited to six (6) devices, with a maximum of two (2) valves.
- For control loops requiring 0.25 seconds execution, the segment shall be limited to three (3) devices, with a maximum of one (1) valve.

3.13.3 Voltage Drop Calculations

Circuit analysis shall be carried out for each Fieldbus segment to determine the operating voltage for each device. The calculated voltage at the device shall exceed the device minimum voltage rating by 1 volt. For example, when the normal minimum voltage of a device is 9 VDC, the calculated minimum voltage at the device shall be taken as 10 VDC. The 1 volts margin is required for future device addition to the segment. Specific minimum voltage and current requirements shall be contained in the product specification for each device.

For purposes of estimating the required minimum supply voltage, the following rules of thumb may be used :-

- No input device is allowed to consume more than 16.5mA
- No output device is allowed to consume more than 32mA
- No network can have more than 12 devices
- No network can be more than 1900m long
- Assume the worst case of all 12 devices are at the far end of the bus
 - o Total power consumption = 16 X 15mA = 240mA
 - o 1.9 km loop of #18 AWG cable has estimated resistance of 44 ohm/km
 - o Voltage drop = 83.6 ohm X 240 mA = 20.06 V
 - o Hence, minimum supply voltage = 9V + 20.06 V = 29.06 V

The calculated voltage for each device shall be shown on the network / segment drawing.

3.13.4 Voltage Drop Calculations

The maximum of 1900m recommended by ISA 50 is a good practical limit for field installations. The Principal or Plant Owner shall approve for any requirements longer than 1900m.

The cable attenuation is calculated as follows :-

$$\text{dB} = 20 \log \frac{\text{transmitted signal amplitude}}{\text{received signal strength}}$$

Cable attenuation is dependent on frequency. The Fieldbus frequency is 39kHz. Standard Fieldbus cables have an attenuation of 3dB/km or about 70% of the original signal after 1km. If a 500m standard Fieldbus cable is used, the attenuation is about 1.5dB.

A Fieldbus transmitter can have a signal as low as 0.75 volts peak-to-peak. The Fieldbus receiver shall be able to detect signals as low as 0.15 volts peak-to-peak. Hence, the cable can attenuate the signal by 14dB, as per the following calculations :-

$$20 \log \frac{0.75}{0.15} = 14\text{dB}$$

Since the standard Fieldbus cable has an attenuation of 3 dB/km, this indicates that the segment can be as long as 4.6km, as indicated by the following calculations :-

$$\frac{14 \text{ dB}}{3 \text{ dB/km}} = 4.6 \text{ km}$$

However, though the distance may be theoretically possible, there are other factors to be considered, such as, signal distortion, voltage drops, etc. Hence, the maximum cable length shall be 1900m.

3.14 FIELDBUS NAMING CONVENTIONS

Device tagging shall comply with PTS 32.31.00.32 Instrument for Measurement and Control, Section 2.7 Instrument Name Plates and Warning Plates. However, Fieldbus hardware shall be tagged appropriately to indicate that they are part of the Fieldbus network / segment.

Tagging may be as follows:

- Junction Box JB-FF-XXX
- Cable FF-XXX

Spurs shall be labeled with the instrument tag name.

For software block naming convention, the following shall be used:

E.g. FF-FT-1301-AI, FF-TIC-2044B-PID

The minimum documents that shall be amended or updated to reflect Fieldbus implementation are :-

- P&ID
- Instrument Network and Segment Diagrams
- Instrument Data Sheets
- Instrument Index
- Control and Data Acquisition

3.14.1.1 Piping & Instrumentation Diagrams (P&ID)

The P&ID must indicate that the installed instrument is a Fieldbus instrument. The drawing must differentiate between Fieldbus instruments and other instrument by, for example, the insertion of "FF" into the instrument tag name. The electrical signal shall be as per draft ISA S20.01 standard.

3.14.2 Instrument Network / Segment Diagrams

The Instrument Segment Diagrams or the Network Drawings shall complement the normal loop drawings associated with 4-20 mA field devices. The new network drawing may also include Master LAS, backup LAS, P&ID FB location, location of terminators, trunk and spur length, tagging (model no., inst tag no. and cable no).

The FOUNDATION Fieldbus system network should follow a consistent naming convention as follows :-

NN MM P

where :

= Plant / Unit / Area number to which the segment is connected to

NN = Node number / controller name

MM = Module / card number

P = segment or port number

3.14.3 Instrument Data Sheets

Data sheet updates shall include some of important Fieldbus parameters, as listed below:

- quiescent current consumption
- supplied FB
- max nos. of FBs
- max nos. of VCRs
- min operating voltage
- device capacitance
- polarity sensitive
- support online instantiation (power-up)
- firmware version no
- online firmware update
- link master capable

3.14.4 Instrument Index

To include Instrument Function Blocks used for the instrument and network which the instrument is associated with.

3.14.5 Control and Data Acquisition

The Fieldbus system drawing and data acquisition shall also be compiled. This includes all controllers, bridges, Fieldbus modules and associated networks.

4 HOST SYSTEM REQUIREMENTS

4.1 USE OF STANDARD PRODUCTS

The system shall be composed of manufacturer's standard hardware, system software and firmware that can be configured to meet the stated requirements. The vendor's standard operating software shall not be modified to meet any of the user's requirements

The application software shall be designed in a manner that requires no modifications to the system operating software. The software design shall be such that the future revisions or updates of the system operating system will not affect the successful operation of the system.

The information from the Fieldbus devices shall not be mapped into the system as I/O channel. The function blocks resident in the device shall be employed directly in the control strategy.

4.2 SPARE CAPACITY EXPANSION

Each system shall be supplied with a minimum of 20% spare capacity for all elements of the system configuration, including application software, graphics, reports and trends. A spare capacity of 20% for each I/O shall be installed in the base system, covering also marshalling terminals. The base system is defined as the quantity of hardware and software required to meet the project requirements.

The communication networks within the system shall include 20% unused node addresses. System expansion shall be achievable without shutting down the regulatory controls that are not directly involved in the expansion. The communication network shall utilize automatic network self-addressing technology (plug and play), which automatically assigns unique device address when a new device is connected to the Fieldbus. Each H1 module shall be able to support a minimum of two segments. Each segment shall be able to support a minimum of 16 Fieldbus devices.

4.3 INTEROPERABILITY

All Fieldbus host system shall have completed the Host Interoperability Support Test (HIST) that are based on the HIST Procedures Document FF-569. A letter of conformance to the HIST and the vendor's HIST report shall be provided to verify test completion and feature support.

All supported FF HIST features shall be integrated seamlessly into the existing control system's engineering, configuration, maintenance and operations system. The host shall use the registered device description as found on the FOUNDATION Fieldbus website and defined in Fieldbus FOUNDATION Document FF-940.

No third-party files shall be required for device configuration.

4.4 HOST SYSTEM DCS FIELDBUS FUNCTIONALITY

The host system functionality shall be designed to integrate the features of FOUNDATION Fieldbus as follows :-

- Automatic node addressing
- Interoperability
- Direct configuration of devices using standard Device Description Language (DDL) such as EDDL
- Direct integration of FF device operating, maintenance and diagnostic data
- Tuning parameters, modes alarm and quality data
- Field devices shall be configurable while the host system is operating, without shutting down the network
- The host system shall have the capability to add and fully configure new field devices to an existing network / segment (Device Tag / Placeholder) without commissioning and start-up delays.
- The host system shall be provided with device capability files
- Firmware revisions of Fieldbus devices shall not impact upgrades to the host system software and vice-versa
- Host shall have redundant field-level network interface in different backplane
- More than 50 Virtual Communication Relationships (VCR) per port
- OPC data access version 2.0 or better, compliance tested. All OPC products used in the Fieldbus system shall be OPC compliance tested. Vendors shall provide the OPC compliance test report.
- Integrated redundant power supply
- Minimum 4 field level ports
- Publisher / subscriber communication of process I/O
- FOUNDATION Fieldbus language function block execution : PID, Arithmetic, Signal Characterizer, Integrator, Analog Alarm, Input Selector, Timer and Lead-Lag.

- Conventional I/O represented by regular input and output function blocks : Analog Input, Discrete Input, Analog Output, Discrete Output.
- Shall have configuration tool capable of off-line and on-line configuration. The configuration tool shall have multi-user and multi-device capabilities.

The following criteria should be used to evaluate a FOUNDATION Fieldbus host :-

- Comparison of features supported by the host system against the requirements specified by the HIST description
- Function block limitations per network
- Limitations on VCRs
- Schedule communication between networks
- Limitation on the number of “writes”, such as, unscheduled communication. Note also that set-point changes are “writes”.

4.5 HOST SYSTEM INTEGRATION

All host Fieldbus functions, including engineering, configuration, maintenance and operational display functions shall be integrated into a single seamless host system. Engineering, configuration, maintenance and operational features should apply consistently to conventional analog or discrete I/O, smart HART and propriety I/O, bus-based systems and FOUNDATION Fieldbus system. The use of separate software tools, displays or procedures for FOUNDATION Fieldbus and other conventional should be avoided.

4.6 HOST SYSTEM FEATURES

Internal mirror or shadow function blocks used by the control system to map the Fieldbus function blocks to internal propriety function blocks shall be completely transparent to the configuration and maintenance engineer. A single unique and independent function block and parameter tag name shall be used for both configuration and operation. Duplicate shadow blocks / parameters with parameter names different from the Fieldbus block / parameters shall not be used.

The host Fieldbus configuration tool shall seamlessly and transparently integrate with and maintain the master configuration database. Saves, restores and partial downloads of the master control system database shall seamlessly and transparently be accomplished by the Fieldbus configuration tool.

4.7 HOST SYSTEM CAPABILITIES

The host system shall be capable of to execute off-line Fieldbus configuration i.e. to configure the Fieldbus strategies without network /segment or Fieldbus devices connected. The host shall be capable of configuring all the Fieldbus function blocks, parameters, support Device Description (DD) services and Common File Format (CFF) specifications.

Additionally, the host system shall be capable of :-

- Soft simulating and testing any and all Fieldbus control strategies
- Importing non-native, bulk configuration data for developing large project databases
- Simple or complex on-line Fieldbus control strategy creation or modification

- Transparently managing the macrocycle schedule, including maintaining the minimum unscheduled acyclic time of 50%. For new installations, a minimum of 70% unscheduled acyclic time shall be maintained to allow for future system expansion, future addition of new devices or future modification of configuration.
- Partial or incremental downloads to the target function blocks and link schedulers without interrupting the operating network / segment strategies.
- Master databases Saves and Restores of targeted strategies or Fieldbus networks / segments.
- Support EDDL technology.

4.8 REQUIRED FUNCTION BLOCKS

The host system shall support the implementation of the following Fieldbus function blocks in the field devices :-

- Analog input (AI)
- Analog output (AO)
- Discrete input (DI)
- Discrete output (DO)
- Multiplexed analog input (MAI)
- Multiplexed analog output (MAO)
- Multiplexed discrete input (MDI)
- Multiplexed discrete output (MDO)
- Proportional Integral Derivative (PID)
- Input selector

4.9 OPTIONAL ADDITIONAL FUNCTION BLOCKS

The following optional additional function blocks may be required to be implement control schemes at the host and network / segment level :-

- Arithmetic / Logic / Flexible function block
- Signal characterizer
- Integrator

Logical block should be applied with caution in field devices as they not yet uniformly applied by all manufacturers.

4.10 REDUNDANCY

For applications requiring high availability, the following redundant components shall be used :-

- Redundant power feeds
- Redundant bulk power supplies with 30 minutes battery back-up
- Redundant system controller power supplies
- Redundant system controllers
- Redundant FOUNDATION Fieldbus H1 cards
- Redundant Fieldbus power conditioners

4.11 HOST SYSTEM ROBUSTNESS

For processes that require high availability, the host system used shall be robust enough to handle bumpless switchovers of failed redundant components so as not to cause a process upset.

There shall be a minimum potential for single point failures in the host system.

The host must provide for online software upgrades for all nodes where redundancy is specified.

A single failure anywhere in the system shall not result in the loss of regulatory controls to more control loops than those associated with a single process input/output/H1 card. Failure of any device shall not affect the ability of the system to communicate with other devices in the system. Switchovers shall not disrupt any system functions.

Redundant equipment and software shall be continuously monitored for errors. All modules shall be diagnosed online. Errors shall be alarmed with an error message identifying the failed module.

I/O terminations shall be on pluggable connectors to facilitate quick change-out of all parts of the network, including interface cards.

4.12 ENVIRONMENT

For indoor installation in an air conditioned building, the equipment shall be designed for :-

- Temperature range : 0 degC to 60 degC
- Relative humidity : 5% to 95%

If required for outdoor installation, it shall be possible to install the system controllers and I/O system in outdoor enclosures in a Zone 2 environment.

It shall be possible to store the equipment for up to six (6) months, if the equipment is packed in a moisture proof container in an air conditioned building that is designed for :-

- Temperature range : -40 degC to 85 degC
- Relative humidity (outside the moisture proof container) : 5% to 95%

5 SOFTWARE CONFIGURATION GUIDELINES

All modifications or reconstruction of control system graphics shall comply to the project standards. The FOUNDATION Fieldbus provides an abundance of information to the host system, The Principal and /or Plant Owner shall indicate to the control system integrator or vendor which of the following parameters shall be included as part of the Operator console and how the graphical representation shall be done :-

- Device status alarms
- FOUNDATION Fieldbus trends
- Alerts

The Principal and / or the Plant Owner shall ensure the effective usage of the alarm management system to ensure that the panel Operator is not overloaded with information.

All device status alarms shall be transmitted to the intelligent device management system for repair by the maintenance personnel, as per Section 9.2.

5.1 NODE ADDRESSING

Each FOUNDATION Fieldbus node shall have a unique Node Address. The Node Address is the address that the segment is using for the device.

Each Fieldbus device shall have a unique physical device tag and corresponding network address. The device tag is usually assigned when the device is commissioned and retains the tag in memory when it is disconnected from the network.

Specifications for node addressing shall as per FOUNDATION Fieldbus System Engineering Guidelines latest version.

5.2 DEVICE TAG NAMING CONVENTIONS

Each Fieldbus device shall have a unique physical tag, as provided by the Plant Owner. The device tag is assigned to the device when it is commissioned and retains this tag in its memory when it is disconnected from the network. The device tag shall be shown on the P&ID.

The device tag shall be used for the device diagnostic alarm faceplate.

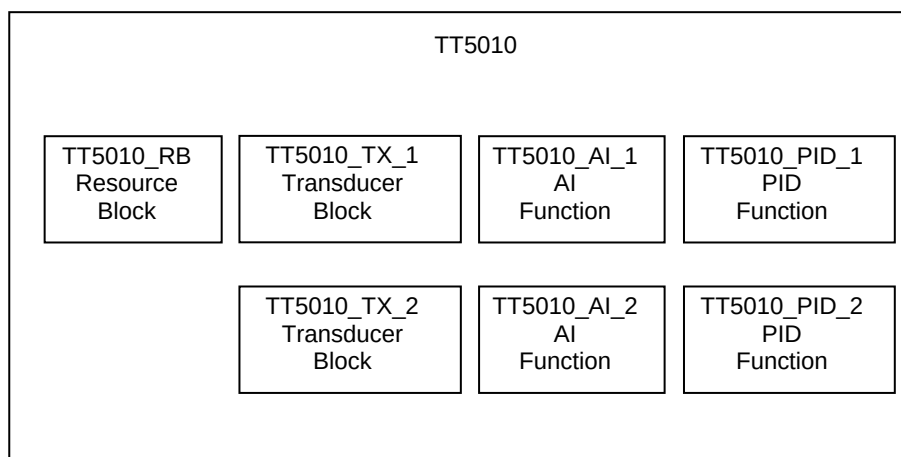
The device tag shall be permanently available in the Fieldbus device.

5.3 CONTROL STRATEGY / MODULE NAMING CONVENTION

Each Fieldbus control strategy or module shall be named as shown on the P&ID. The primary function block used for the Operator interface (AI or PID) shall share the module name.

Each field device contains a number of function blocks. Each block shall include, as a suffix, information relative to the function or block type for which it is defined. Examples are as follows :-

- FT5010_AI : Analog Input block for flow transmitter 5010
- FT5010_PID : PID block for flow transmitter 5010



5.4 CONTROL FUNCTIONALITY LOCATION

Control is contained in software entities called modules. The control blocks inside the modules can be assigned to run in field devices or the host controller. The module is named by the tag shown in the P&ID and is displayed by a faceplate with the same tag.

Configuration details, such as analog input block parameters of range, span, alarms, etc., shall be stored in the host system for download to the field devices as they are connected to the network.

Control blocks should be configured in the field device, with host system as back-up.

5.4.1 Field-based Control

Field devices using PID control algorithm shall be shown on the network / segment drawing with a bold letter P.

5.4.2 Single Loop PID Control in the Segment

For single PID control in the field device, all function blocks that make up that control loop shall reside in the same segment.

If all function blocks cannot be placed in the same segment, considerations shall be made to place the function blocks in the host system.

When a single loop PID control is implemented in the field device, the PID function block shall be located in the final control element. As with conventional control loops, the Fieldbus device failure modes shall be determined and the correct fail action shall be identified for each loop.

5.4.3 Cascade Control

The preferred cascade configuration is to locate each of the cascade loop function blocks and devices on the same network / segment. The primary PID controller shall reside in the primary measurement transmitter and the secondary PID controller shall reside in the final element.

If the primary and secondary loops have function blocks on separate segments, the primary PID control shall reside in the host controller. In this case, if all the secondary loop function blocks reside in the same segment, the secondary loop PID shall reside in the secondary final control element.

5.4.4 Split range control

Split range configuration shall be located in the host controller.

5.5 ALARMS & ALERTS

5.5.1 Alarms

Fieldbus contains fifteen (15) alarms that must be mapped to the host system. These alarm priorities are shown in the following table, along with how they map to the DCS.

Alarm	Fieldbus Alert Priority	Host Alarm Priority
15	Critical	Emergency
14	Critical	Emergency
13	Critical	Emergency
12	Critical	Emergency
11	Critical	High
10	Critical	High
9	Critical	High
8	Critical	High
7	Advisory	Low
6	Advisory	Low
5	Advisory	Low
4	Advisory	Journal
3	Advisory	Journal
2	Low - fixed	Journal
1	No notification	No action

Alarms shall be managed as part of the overall alarm management philosophy.

The host shall support time synchronization and alarm time stamping in field devices.

5.5.2 Alerts

Field devices generate diagnostic alerts due to miscommunication, disoperation and failures. Alerts are important for the system integrity and are needed to take advantage of the diagnostic capabilities of field devices. Alerts are not the same as alarms, as alerts are used to notify the users of the various status conditions of the device.

5.5.3 Trend Collection

The Fieldbus can trend up to sixteen (16) of the most recent process values and status points, with time stamp for each network / segment. Trends can be supported in various ways.

The preferred way of collected trends should be by using the Fieldbus trend object to gather high speed data based on a single event. The trend object uses the client / server services to read sixteen (16) trend variables in a single call.

5.6 NETWORK COMMUNICATION AND SCHEDULING

5.6.1 Link Active Scheduler (LAS)

The LAS is a deterministic, centralized bus scheduler that maintains a list of transmission times for all data buffers in all devices that needs to be cyclically transmitted. The LAS is responsible for coordinating all the communication on the Fieldbus

The Master and Primary Back-up LAS shall reside in the host system in redundant H1 network interface cards.

An additional back-up LAS shall be configured for all networks and shall reside in the network device with the lowest address. The device shall not have controlling functions.

Each network shall be configured for automatic fail-over to the back-up LAS, in the event of Master LAS failure.

There can be on or more back-up LAS on the Fieldbus network. If the active LAS fails one of the back-up LAS automatically takes charge of the bus. Only one LAS is active on an H1 Fieldbus network.

Failure modes shall be considered for final placement of LAS and back-up LAS.

5.6.2 Network / Segment Execution Time

See also Section 3.13.2.

The network / segment macrocycles shall match the module execution times. Each network / segment shall operate within a single specified macrocycle execution time. Multiple macrocycles shall not be used on a single network / segment. Hence, devices with different macrocycles times (e.g. 1 sec Vs. 0.25 sec) shall not reside on the same network / segment.

Further, having different macrocycles on the same network are likely to make it difficult to diagnose communication problems, should they occur in the future, especially if they are sporadic in nature.

If a faster control loop is added to a network / segment containing slower loops, then the macrocycles times of all the devices residing on that network / segment shall be adjusted to accommodate the faster execution time.

Care shall be taken to ensure the network does not become overloaded due to fast macrocycle times.

5.6.3 Macrocycles

The macrocycle contains unscheduled time which is required for non-deterministic bus communications, such as, alarm transmission, set point changes, etc.

The macrocycles shall have a minimum of 50% unscheduled (free asynchronous) time. The unscheduled time calculation shall include spare capacity requirements. Hence, a newly commissioned segment shall have a minimum of 70% unscheduled time. Loops can be moved to another segment or macrocycles can be slowed if a segment has insufficient unscheduled time.

Specifications for macrocycles shall as per FOUNDATION Fieldbus System Engineering Guidelines latest version.

5.6.4 Network / Segment Scheduling

The engineer shall design the scheduling requirements and develop the timing cycle map. Each host has a limit on how many parameters it can transmit during a single cycle. The timing cycle map and its associated calculations shall be documented. The timing cycle map and its calculation shall be updated each time there is a change of point / block on the network / segment. Sufficient unscheduled time shall remain in each cycle to transmit acyclic (maintenance and configuration) information.

5.6.5 Function Block Considerations

Specifications for function block consideration shall as per FOUNDATION Fieldbus System Engineering Guidelines latest version.

5.6.6 Virtual Communication Relationships (VCR)

The field device shall have a minimum number of VCRs to meet the required control strategy and communication requirements. It is recommended to have sufficient numbers of VCR to avoid the need to execute detail calculation. The configuration tool shall be used to verify the number of VCRs has not exceeded.

5.7 DATA IMPORT AND EXPORT

The host configuration tool and databases shall have import/export capability for all function blocks and modules. Formats for import/export includes :-

- Comma delimited
- MS Excel
- Text
- MS Access
- SQL

The host shall be able to download all Fieldbus function blocks with imported data. The host shall be able to export updates and changes to an external database. The host download function shall include control functionality, scheduling and initialization.

The original field device data shall be verified, before execution of download from host to field device.

The latest configuration database shall be back-up in a storage media after each data import / export.

5.8 OPERATOR DISPLAY

The Operator display for FOUNDATION Fieldbus shall be as per as per FOUNDATION Fieldbus System Engineering guidelines. Device common alarms shall be triggered through the engineering diagnostic tools located at the intelligent device management system, as described in Section 9.2. The HMI general guidelines shall also be as per PTS 32.00.00.11, HMI in the Control Room.

5.8.1 Field Device Alarms

Any Field device failures shall be alarmed to the operator display. Detailed analysis shall be available through the engineering diagnostic tools located at the intelligent device management system, as described in Section 9.2.

The conventional and Fieldbus graphics shall be consistent by having the same look and feel.

5.8.2 Conditioned Based Maintenance Management

Condition based maintenance functions shall be carried from a separate intelligent device management system, as described in Section 9.2

5.9 SOFTWARE REVISION

All software, exclusive of application software, shall be the most recent revision that is applicable to the system hardware at the time of the hardware freeze date as defined in the contract or purchase order.

The system shall allow for upgrading of system operating software on all redundant modules of the system without the necessity of shutting down the process, without losing Operator display and without loss of access to any control function.

Application software shall not require modifications in order to be able to run under new releases of the system operating software. Any new system software release shall be backward compatible with the files created using the previous software releases.

5.10 SYSTEM MANAGEMENT

System Management (SM) synchronizes the execution of function blocks to a common time clock shared by all devices. SM also handles the communication of function blocks such as:-

- Publication of time of day to all devices, including automatic switch-over to a redundant time publisher.
- Searching for parameter names or tags on the Fieldbus.
- Automatic assignment of device addresses.

5.11 CONTROL AND DATA HANDLING

No propriety programming languages shall be used for regulatory control.

5.11.1 Fault Handling

Fault detection and processing shall conform to FOUNDATION Fieldbus standards and guidelines.

Detailed fault detection and processing shall be executed in the intelligent device management system. The Operator display shall only handled critical alarms, as per the alarm management guidelines.

5.11.2 Control Modes

Control modes shall conform to FOUNDATION Fieldbus standards and guidelines.

5.11.3 Initialization

Initialization is the process by which the initial values of the mode, setpoint and output of a control block is set. Initialization shall conform to FOUNDATION Fieldbus standards and guidelines.

5.11.4 Calculations

Algorithm calculations shall be performed in floating point engineering units or other equivalent methods that do not require scaling.

5.11.5 Regulatory Control

5.11.5.1 Algorithms

Standard FOUNDATION Fieldbus software algorithms shall be available to perform regulatory control functions. These process control functions shall be performed by predefined algorithms with configurable parameters.

Standard FOUNDATION Fieldbus control algorithms shall be identical regardless of whether they reside in system controllers or the H1 field devices.

5.11.5.2 Setpoint Clamps

Upper and lower setpoint clamps for all setpoints shall be available.

5.11.5.3 Windup Protection

Control functions that include integral action shall be provided with windup protection. Windup protection shall inhibit the integral action when the control block output is constrained by conditions such as :-

- Output at high or low limits of span.
- Output at high or low clamps.
- Output is connected to the setpoint of a secondary controller which is clamped.
- Output is not connected to any valid device or algorithm
- Output tracking is active

When the windup protection is active, this status shall be clearly visible to the Operator on the faceplate display.

Control functions and computational functions shall include the ability to propagate the windup parameter through multi-level control strategies.

5.11.6 Control and Execution Monitoring

The system shall provide a mechanism to view control strategies as defined in the configuration while they execute in real-time, as well as, real time input and output values. When a tag is selected, the Operator shall be able to press a single button to view the control strategies. No additional configuration shall be necessary to provide this functionality.

5.11.7 Loop Performance Monitoring

The automation system shall monitor all active control loops and set a flag upon degradation in any loop performance or upon detecting an abnormal condition in measurement, actuator or control block. The following conditions shall be flagged :-

- Bad I/O – the block process variable is bad, uncertain or limited
- Limited control action – a downstream action condition exists that limits the control action taken by the block
- Mode not normal – the actual mode of the block does not match the normal configured mode for the block.

A variability index can be calculated for each loop. This index shall be used to quantify the following and present the results graphically :-

- Loop utilization
- Bad, uncertain and limited measurement status
- Control action limitation
- Process variability

Excessive variability shall be flagged.

This capability shall be a standard feature of the system. No additional configuration shall be required. The system shall automatically detect when new control modules are added or deleted in the configuration, and when used, shall automatically active loop performance monitoring.

5.12 SYSTEM CONFIGURATION TOOLS

5.12.1 Configuration Tool

A configuration tool shall be provided to generate or modify databases and configuration data. The configuration tool shall employ fill-in-the-blanks or graphical block connecting format. It shall have step-by-step prompts to guide sequential actions followed by validation responses on completion of actions.

A common configuration tool shall be used for both conventional and FOUNDATION Fieldbus control. It shall allow for selecting the location of the control in the system controller or the field device. Configuration of the control module shall be the same regardless of where the control is located.

The configuration tools shall allow drag-and-drop functionality to move or copy configuration data from one location or the other.

It shall be possible to stop the execution of a configured module, execute a single block, set break points that stop execution at a particular point or force specific values to override the actual signal, all without affecting the other modules that may be running in the same controller.

The configuration tool shall include a help facility to provide configuration guidance.

5.12.2 Configuration Displays

Configuration displays shall be provided to aid in system configuration. All displays and tags shall reside in one global database, shared by the entire system. No data mapping between systems shall be required. It shall be possible to show :-

- All tags in the system.

- All parameters for each tag, including, where applicable, tag ID, tag descriptor, the hardware address, tuning constants, mnemonics associated with the tag, algorithm relating to the tag and input / output details.
- All configurable or soft keys and their functions.
- All hardware modules in the system and the configuration parameters for each of them.

A facility such as copy/paste or a template shall be provided to facilitate creating multiple tags that have common parameters. This template shall be defined once and then used as a basis for each tag. It shall be possible to define and store multiple templates. An easy method for recalling each template shall be available.

It shall be possible to configure a series of keystrokes that can be initiated by a single Operator action.

Configuration additions, changes and deletion shall automatically update all the modules and tags affected by the change. Configuration changes shall follow a prompt-validation sequence requiring final acknowledgement before the change is downloaded to the online automation system.

When configuration data are downloaded to the automation system, invalid configuration entries shall be identified and the affected parameters shall be indicated.

It shall be possible to save all databases and configuration data on removable and non-removable media for back-up purposes, without taking the system off-line.

It shall be possible to change, delete and add any independent loop of a multiple loop process controller module, without affecting the other loops in that controller.

The addition of a new H1 field device shall be auto sensing without manual intervention. New devices shall automatically report to the configuration database as unassigned devices. Device addresses shall be integer numbers. Hexadecimal code addresses shall not be used.

5.12.3 Tag Parameters

All tags shall be defined with at least the following parameters :-

- Tag ID
- Tag descriptor
- Tag type
- Alarm requirements

Tag IDs shall be unique throughout the system and access to all tag parameters for configuration shall be available directly by the tag ID. The system shall provide the capability to define free-format alphanumeric descriptors for each state of a multi-state device.

5.12.4 Engineering Units

Each analog input, output and control block shall be assigned an engineering unit designation. It shall be possible to automatically display this designation with the value when the input, output or algorithm is accessed.

5.12.5 Engineering Workstation

It shall be possible to install more than one engineering workstation in the system. Only one engineering workstation shall be necessary to perform all conventional and FOUNDATION Fieldbus configuration, database generation and editing. However, it shall also be possible to use multiple engineering workstations simultaneously for configuration, database generation and editing. The automation system shall use a single global configuration database to be shared by all components in the system. Users shall not be required to enter the same data or configuration more than once.

5.12.6 System Access

Security access to the system functions shall be restricted by passwords or other unique identifiers. It shall be possible to define single users with selectable access privileges. It shall also be possible to limit a user to a particular area of the plant.

As a minimum, the following security access levels shall be available :-

- Operator level
- Supervisor (function : setting changes, etc.)
- Engineer (function : tuning, download, configuration, graphic changes, etc)
- System administrator (global access)

5.13 DISPLAYS

5.13.1 Faceplates

The faceplate displays shall as per FOUNDATION Fieldbus System Engineering guidelines.

5.13.2 Communication System Status Displays

Standard displays shall show the operational status of the communication system. The communication parameters of each module connected to the communication system (online, offline, failed, primary failed, backup failed) shall be shown.

The display status shall be as per Fieldbus FOUNDATION System Engineering guidelines.

6 DOCUMENTATION REQUIREMENTS

There shall be an integrated design and documentation system for the initial and design and maintenance support of the Fieldbus installations. The system shall include database with import and export provisions, design calculations for the project support and a CAD system that can use data in the project database. Management of Change (MOC) tools and equipment history features shall be included.

FOUNDATION Fieldbus system design requires the same type of documentation as conventional control system designs, as per PTS 32.31.00.34 and as per FOUNDATION Fieldbus System Engineering Guidelines. However, some documents must be altered to meet the Fieldbus architecture. The minimum document, data and drawing requirements for Fieldbus installation shall include, but not limited to, the following :-

- System drawings
- Network / Segment drawings, including calculated minimum supply voltage for each device
- Fieldbus network loading and calculations

- Total power distribution and consumption for the total network / segment, including all calculations.
- Timing cycle map and calculations
- Network / Segment / Spur termination drawings
- Junction box termination drawings
- Location drawings
- Building layouts
- Installation / hook-up drawings
- Process & Instrument drawings (P&ID)
- Instrument index / database, complete with device assignment / addresses
- Instrument data sheets
- Material requisitions
- Spares requirements, including Spares Interchangeability Replacement (SPIR) list and SAP material numbers
- Manufacturer documentation
- Network / segment check-out forms
- Instrument criticality list
- Logic diagrams
- Functional description / control narratives
- Maintenance manuals

All documentation shall be available in electronic format. The drawings shall be continuously kept updated throughout the lifecycle of the Fieldbus system.

7 ACCEPTANCE TESTING REQUIREMENTS

7.1 INTRODUCTION

It is not practical to test all the field devices in a Factory Acceptance Test (FAT). However, at least one of each type of Fieldbus device shall be tested during the FAT.

The FAT shall focus on graphics verifications, database, power, communications and other system integration and functions.

Rigorous Fieldbus testing shall be performed during Site Integration Tests, which shall include all the Fieldbus devices. Site Integration Tests are described in Section 8.

7.2 FACTORY STAGING

A factory staging test plan shall be written by the vendor and approved by all parties. One of each type of Fieldbus device shall be available at the staging facility. Suggested test activities are as follows :-

- Interoperability test – the ability to test at least one example of each configuration in the system.
- Control strategy and/or control philosophy configuration verification
- Backup LAS function
- Third party communications i.e. OPC communications
- Moving devices from one network to another

7.3 ASSUMPTIONS

The FAT assumes that the following shall be done :-

- Any deficiencies in the FAT shall be resolved at the vendor premises before shipment to site.
- The vendor has already conducted pre-testing of the all the types of Fieldbus devices with the host system before commencement of the FAT. The pre-testing documentation (procedures and results) shall form part of the FAT documentation.
- The FAT shall be conducted at the vendor premises and witnessed by the end-user, who shall include the Operations and Maintenance personnel, to ensure knowledge transfer of expertise to the end-user. The end-user shall also witness and verify that all corrective actions are carried out by the vendor.
- The host configuration and graphics have been completed as per end-users specifications with the appropriate Fieldbus function blocks assigned to the appropriate devices.
- The Fieldbus device tags corresponding to the host configuration have been configured for each of the redundant ports of each of the H1 interface cards.
- Sufficient devices are available to configure all typical networks and selections of segments are available. The end-user shall verify that the selected segments are representative of the networks being installed.
- The selected Fieldbus networks / segments are prepared, with no Fieldbus devices connected, for the corresponding H1 cards and ports with the power and grounding checks successfully performed.
- Simulations of Fieldbus parameters shall be carried out to simulate the process conditions and to evaluate alarm settings.
- The final cabling and junction boxes are not used. Representative connections shall be made. The final infrastructure shall be tested during commissioning.

7.4 FACTORY ACCEPTANCE TEST (FAT) REQUIREMENTS

FAT is an essential quality assurance check to verify that all components of the host are working properly. Since a substantial part of the control strategy is executed in the field devices, it is not possible to test the control strategy.

The Fieldbus system vendor shall develop a written test plan and procedure, approved by all parties, for the FAT.

The FAT shall be performed on the host system which shall include the following :-

- **Functionality test**
A complete functionality test shall be carried out for one of each Fieldbus device, including third-party devices. This test shall include, but not limited to, plug-and-play connectivity to the host, verify access to all function blocks, actual device operation e.g. stroke valves/MOVs, simulate process inputs to transmitters, etc.
- **Calibration test**
The test shall include a calibration and set-up of each type of Fieldbus device. Examples are :-
 - o Temperature transmitters
Changing the RTD/thermocouple types and downloading transmitter span
 - o Pressure transmitters
Zeroing pressure and DP transmitters
Zeroing elevation on DP level transmitters
 - o Valve positioners
Set-up and calibration of a new positioner on a control valve. The intent here is to verify ease of access to the calibration wizards and set-up procedures via the host system.
- **Calibration and set-up procedures**
All calibration and set-up procedures shall be documented in detail by the vendor and approved by the end-user.
- **Redundancy switch-over test procedure**
The vendor shall develop a redundancy fail-over test procedure, approved by all parties, for all the H1 interface cards and Fieldbus power conditioners. The test shall verify that automatic fail-over shall not cause any upsets i.e. signal bumps, loss of Operator view, mode changes, etc. All the power supply and conditioner failure alarms shall be tested and signed off.
- **Network test procedure**
Each network port, including spares shall be operationally tested by live connection of at least one Fieldbus device. The Fieldbus device shall be connected to the terminal block designated for field wiring or the system cable downstream of the Fieldbus power conditioner. This procedure shall be developed by the vendor and approved by all parties.

7.5 FAT PROCEDURE

The FAT procedure comprises of three subsections :-

7.5.1 Network / Segment Checks

All segments shall be tested during FAT. For each segment, the following steps shall be carried out :-

- The complete network / segment test shall be simulated as per Section 8.
- Test and confirm that the host and devices have the same firmware/software revisions.
- Test and confirm that all H1 interface cards used in the host are of the same firmware/software revisions.

- Check that the relevant network / segment communication parameters are correct and that the macrocycle duration has been set for each network.
- Check that the power conditioner module operates correctly, including redundancy checks, and that a failure is communicated to the host system.
- Check that the network / segment is not affected from a short circuit.
- Measure the overall current consumption.
- Check that the Fieldbus interface module operates correctly and that a failure is identified by the host system.
- Check that the Back-up LAS is functioning and is executing in the correct schedule.
- Use a bus monitor to check that the communication load is stable, under no download condition. Verify that a load of less than 70% is achieved. The actual bus load result shall be recorded as part of the FAT documentation.
- Ensure sufficient spare capacity in the bus by connecting two additional field devices and observing the bandwidth on the bus monitor.

In addition to the above, the following shall be tested :-

- all segment ports in the host
- execution of redundancy checks for all components
- load heaviest segment to maximum, including spares, and, with the bus monitor, ensure stable operation of the bus for at least 12 hours i.e. no unexplained errors observed or detected.
- intelligent device management system capability to display the full device diagnostics features

7.5.2 Device Check

For each device to be tested as part of the network / segment under test as described in Section 7.5.1, the following steps shall be carried out :-

- Check that the database for this device is correctly populated. It is assumed that the database is populated by an upload, followed by modifying the relevant ranges, alarms, units, etc. The correct database population is checked by comparing against the documentation.
- Perform a download to the Fieldbus device and observe that both the configurator and the bus monitor do not raise any unexplained errors.

7.5.3 Data Reconciliation

For each parameter that resides in the Fieldbus device i.e. AI, PID or AO block, the following steps shall be carried out :-

- Verify that the appropriate scale and engineering units are configured in both the function block and the transducer block.

- Verify that the scale and engineering units are correct and consistent for the Fieldbus device and its associated faceplate, graphics and trends.
- Simulate a process variable equal to half the scale and verify.
- The process variable appears correctly within the PV parameter of the block.
- The same value appears where the PV parameter is configured on the process graphics.
- The same value appears where the PV parameter is configured on the historical trend.

For the same device, generate a process variable that exceeds the alarm limits and verify that the pre-configured alarms appear in the Operator and maintenance workstations.

If the device is a valve positioner, the following steps shall be carried out :-

- Verify that the AO block is in CAS mode.
- Verify that the PID block is in MAN mode.
- Manually enter the controller output on the controller faceplate.
- Verify that the positioner maintains the same output as the controller faceplate.

8 SITE INSTALLATION GUIDELINES

8.1 INTRODUCTION

Configuration of the Fieldbus system shall be carried out from the host system to build up the database as the commissioning proceeds. The procedures for commissioning the Fieldbus includes :-

- Cable, junction box continuity, grounding and insulation tests.
- Field device connection and signal analysis.
- Device download /software checks
- Bus monitor capture / waveform capture
- Process connection pressure testing and inspection.
- Physical installation of field devices
- Calibration
- Loop tuning

8.2 NETWORK INSTALLATION

Care must be taken when carrying out the network wiring and spurious failures can occur throughout the lifecycle of the Fieldbus system, with poorly executed wiring connections and terminations. The following are steps to be taken during installation :-

- The trunk cable (longest cable) shall be installed first.

- Terminators shall be installed at both ends of the trunk cable. The terminators shall not be installed in any field device. Terminators shall be installed in junction boxes. The terminators shall be clearly marked.
- Install the spur cables to the trunk.
- Perform cable resistance and grounding checks as per Section 8.3.
- Connect power supply, power conditioner, grounds and H1 interface to the trunk cable.
- Perform the Fieldbus network / segment test as per Section 8.4.
- After testing the network wiring system, the devices can be connected and commissioning of the loops can proceed.

8.3 CABLE TEST PROCEDURE

Disconnect terminals should be installed in the marshalling panel as a means to isolate the home run cable until it is ready to be tested and commissioned.

The tools needed to perform the network / segment checkout are :-

- Digital multimeter with resistance, DC voltage and capacitance measurement capability.
- Fieldbus network / segment check-out form.

Before performing the check-out :-

- Ensure that the field wiring are all properly terminated and that all field spurs are attached, but not the devices.
- Remove the Fieldbus network cable (+, - and shield) at the power conditioner terminal block.

8.3.1 Step 1: Resistance Checks

Measure the resistance on the H1 network / segment conductors at the removed terminal block connector coming from the field.

Measure resistance from the :-	Expected Results
+ signal conductor to the – signal conductor	> 50 kohm (increasing)
+ signal conductor to the drain / shield wire	Open circuit > 20 Mohm
- signal conductor to the drain / shield wire	Open circuit > 20 Mohm
+ signal conductor to instrument ground bar	Open circuit > 20 Mohm
- signal conductor to instrument ground bar	Open circuit > 20 Mohm
Drain / shield wire to instrument ground bar	Open circuit > 20 Mohm

8.3.2 Step 2: Capacitance Checks

Measure the capacitance on the H1 network / segment conductors at the removed terminal block connector coming from the field.

Measure capacitance from the :-	Expected Results
+ signal conductor to the – signal conductor	1μF (0.8 to 1.2 μF acceptable)
+ signal conductor to the drain / shield wire	< 300 nF
- signal conductor to the drain / shield wire	< 300 nF
+ signal conductor to instrument ground bar	< 300 nF (> 1μF indicates poor quality ground noise, which must be corrected to prevent communication errors)
- signal conductor to instrument ground bar	< 300 nF (> 1μF indicates poor quality ground noise, which must be corrected to prevent communication errors)
Drain / shield wire to instrument ground bar	< 300 nF (> 1μF indicates poor quality ground noise, which must be corrected to prevent communication errors)

8.3.3 Step 3: DC Voltage Checks

Reconnect the terminal block connectors to the power supply and measure the DC voltage going to the field.

8.4 NETWORK / SEGMENT CHECKOUT PROCEDURE

The FOUNDATION Fieldbus shall be tested using a proven Fieldbus Wiring Monitor that can test the voltage, signal levels and wiring noise. The test shall comply as per FOUNDATION Fieldbus System Engineering Guidelines.

8.5 LOOP CHECKOUT / SITE INTEGRATION TEST

Once devices are proven to work electrically, additional software checks are necessary to assure all graphics and other functions, that are dependent on the field devices, are correctly configured.

All devices on the network shall be fully functional and all software integration tests completed before any of the devices on the segment are placed in service i.e. connected to the process. All transmitters shall be checked for :-

- Correct range
- Alarms
- Failure modes

All control valves shall be checked from the host for :-

- Correct operation
- Limits / feedback
- Failure modes

Site specific Field Installation, Testing and Commissioning procedures shall be developed to provide details of loop check outs and commissioning. To ensure efficient testing and pre-commissioning work, a simple configuration guide shall be developed. This document shall have the minimum of the following procedures :-

- Adding a new instrument to the network
- Removing an instrument from the network
- Substituting instruments on the network
- Modifying instrument variables and parameters such as :
 - o Changing tag names
 - o Changing the measuring range
 - o Changing the device descriptor
 - o Changing the engineering units
 - o Changing instrument display settings

At the end of all configuration and site commissioning activities the network / segment bus shall be checked for errors with the bus monitor. Any errors shall be corrected before the Fieldbus system is handed over to Operations. The bus load shall also be documented with the use of the bus monitor.

9 MAINTENANCE REQUIREMENTS

9.1 HOST SYSTEM REQUIREMENTS

The host system shall be capable of commissioning, set-up and maintaining all Fieldbus devices. The functions shall be available from the host workstations. The following functions shall be supported :-

- Report of load on all the busses
- Error counters for all the busses
- A schedule (time chart) report for H1 network / segments
- An online reconcile function to allow change management when replacing field devices
- Ability to report, alarm and acknowledge all device alarms
- Add a new Fieldbus device to a network / segment. Add future Fieldbus device to a network / segment through the use of placeholder templates.
- Move Fieldbus devices from and between offline, spare, standby, commissioned and mismatch states and manage all address changes transparently. Manual address changes shall not be required.
- Simple and complex commissioning functions including transmitter range changes, zeroing and control valve positioner set-up.
- Support for DD methods and menus (wizards) for all maintenance functions to walk the maintenance engineers and technicians through the necessary procedures.

- Provide specific maintenance displays, organized in a logical manner, for all Fieldbus devices using specified language descriptors and definitions with access to all parameters.
- Ability to mirror existing Fieldbus device configuration (all function blocks and parameters) onto a new Fieldbus device to allow quick device replacements.
- Display of commissioning and maintenance screens shall be possible from the operator and engineering workstations

9.2 INTELLIGENT DEVICE MANAGEMENT SYSTEM

The primary benefit of installing a FOUNDATION Fieldbus network is to get more information about the process and devices controlling the process itself. The intelligent Fieldbus device can make available to the Operator, Engineers, Technicians, Inspectors and Plant Management hundreds of different parameters, including device diagnostic parameters, about the process or instrument from a single smart device. To manage, in real-time, all the device diagnostic parameters, a separate intelligent device management system is required.

An intelligent device management system, separate from the host operator and engineering workstation shall be provided to manage and display real-time and historical diagnostic and maintenance information. It shall not replace the commissioning and maintenance function integrated into the host as described in Section 4.5.

For security reasons, the intelligent device management station and functions shall be maintained on a separate server, with access only from a controlled maintenance area, preferably within the vicinity of the SAP workstation. This will prevent changes being made to the network, without proper control and management of change in place. However, for critical devices, it shall be possible to configure the device failures to be alerted in the operator workstations for operator awareness. It shall be possible for the operators to click on the device failure alerts captured in the operator workstations to see the “ranked” device diagnostics to aid in decision making.

The intelligent device software solutions shall have the capability to manage and protect industrial assets, by maximizing the effectiveness of plant operations (by decreasing downtime) equipment and human assets (reduced incidents) to help achieve superior business performance.

The requirements for the intelligent device management system are :-

- Ability to streamline routine maintenance tasks such as loop check-out, configuration and calibration.
- Ability to establish a predictive maintenance capability with reliable diagnostics to allow maintenance before failure.
- Ability to provide automatic documentation of diagnostics and maintenance activities.
- The H1 module shall have pass-through capability to transfer non-control data to the field device asset management applications.
- Ability to compare and reconcile between current and previous configurations.
- Have audit trail capability for all devices
- Device alert monitoring to facilitate early warning of developing problems.

- As found / as left device test capability
- Device template creation
- Device signal tag and device search capability
- Online help
- Database import / export capability
- Diagnostic add-on capability
- OPC, to access data from any device, and third-party database
- Device configuration export from any device to MS Excel
- Graphics and menu rendering as per IEC 61804-3, including waveform graph, trend chart, gauge, table grid and image
- Execution of methods (snap-on wizards)
- Handling of conditionals

9.3 MINIMUM DIAGNOSTIC REQUIREMENTS

As a minimum, diagnostic capabilities shall report critical failures of devices. Diagnostics shall be reported to the host by alarms and alerts. Polling schemes for diagnostics are not acceptable. General diagnostics shall be alerted to the Operator, with parallel detailed diagnostics reported to the intelligent device management system.

9.4 MAINTENANCE TOOLS

All Fieldbus maintenance tools shall be compliant to FOUNDATION Fieldbus. The following tools shall be provided as minimum:

1. Fieldbus Handheld Communicator (Emerson 375 or equivalent)
2. Portable Fieldbus Tester (Relcom FBT 6 or equivalent)
3. Portable Fieldbus Signal Injector (Relcom FBT 5 or equivalent)
4. Advanced diagnostic module on the power conditioner

9.5 MAINTENANCE PRACTICES

Field maintenance on Fieldbus devices should generally be :-

- Daily review of the intelligent device management system to check for system health, alerts and alarms by the maintenance personnel.
- Inspection of cabling and enclosures to ensure they meet hazardous area requirements.
- Replacement of faulty items and equipment.
- Zeroing of instruments, as required
- Proof testing for critical devices.
- 6 monthly verification, trending & analysis of each segment signal noise levels

- 6 monthly verification & analysis of network loading
- Yearly verification & analysis of system health checks
- 6 monthly trending and analysis of all device diagnostics
- Automated, scheduled 3 monthly routine back-up of configuration files and device parameters

All Fieldbus sites shall have a Fieldbus maintenance methodology established, with the following minimum procedures in place :-

- Calibration procedures
- Removal and replacement of a field device
- Preventive and predictive maintenance activities
- Testing of critical devices
- Management of change procedures, such as for software revisions
- Documentation of software revisions
- Spares handling

10 REFERENCES

In this specification reference is made to the following publications.

Note:

Unless specifically designated by date, the latest issue of each publication shall be used (together with any amendments/supplements/ revisions thereof)

In the situation where the latest issue is required to be applied, it is particularly important that the effect of revisions to such publications shall be considered when they are used in conjunction with this manual.

PETRONAS STANDARDS

Instrument for Measurement and Control	PTS 32.31.00.32
Human Machine Interface in a Control Room	PTS 32.00.00.11
Instrumentation Documents and Drawings	PTS 32.31.00.34

AMERICANS STANDARDS

Fieldbus Standard for Use in Industrial Control Systems	ISA S50.02
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INTERNATIONAL STANDARDS ORGANISATION

Open System Interconnection Model	ISO 7498
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INTERNATIONAL ELECTROTECHNICAL COMMITTEE

Digital data communications for measurement and control - Fieldbus for use in industrial control systems	IEC 61158
Electrical apparatus for explosive gas atmospheres Part 27: Fieldbus intrinsically safe concept (FISCO) and Fieldbus non- incendive concept (FNICO)	IEC 60079-27

DOCUMENTS & BOOKS

FOUNDATION™ Fieldbus System Engineering Guidelines (AG-181) Revision 2.0	
Fieldbuses for Process Control: Engineering, Operation and Maintenance, by Jonas Berge, ISA	

11 STANDARD DRAWINGS

In this manual reference is made to the following standard drawings, the latest issue of which shall be used.

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12 LIST OF APPENDICES

Appendix 1: Advantage of Using Fieldbus
Appendix 2: Fieldbus Overview

Appendix 1 **Advantage of using Fieldbus**

Why use Fieldbus? The advantages of using Fieldbus are listed below :-

The Fieldbus system is fully digital allowing for more information to be accessed on a single cable.

The digital system has the capacity to connect several instrumentation devices on the same single pair of wires to form a multi-drop network.

Digital system has a very robust signal with only two states of either one or zero. Hence, it is less sensitive to distortion compared to the standard 4 – 20 mA analog signals. Therefore, digital system is more accurate compared to the analog system.

The digital system enables interoperability between various vendor devices, provided the same digital protocol is used.

- Installation, cable pulling, termination and wiring savings
- Hardwire savings (fewer devices, elimination of I/O cards with minimal field interface cards, cable trays conduits safety barriers and equipment room foot print)
- Multifunctional field devices hence less process connections
- Reduced commissioning and start up costs due to faster loop checks and commissioning.
- Reduced downtime due to smart diagnostics and trouble shooting, leading to a reduction in unplanned trips, shutdowns and maintenance costs
- DCS future capacity savings
- Signal distortion is detected and managed. Signal is not limited to a set range. Works in engineering unit, thereby, avoiding scaling mismatch problems.

Some of the advantages of using FOUNDATION Fieldbus (FF) are listed below:

- Control in field with improved process control flexibility and availability of field based control algorithms
- Device plug and play
- On line configuration of instruments
- Time stamping and clock synchronization
- Obsolescence robustness
- Status information
- Tag search capability
- Interface to high speed Ethernet
- Trend storage in the field device
- Automated data collection for asset management
- Predictive maintenance, rather than using corrective and preventive maintenance utilizing true predictive and condition based maintenance strategies
- Isochronous (precisely periodic) synchronized communication and control execution enabling PID control and other time based functions such as integration function (totalization)

- Automated firmware download
- Plug-and-play, due to automatic addressing
- Separate real-time and non-real-time communication channels
- Improved diagnostics

Difference between Profibus and FF

- Profibus is a polling system, FF utilizes cyclic transmission thus have scheduled times to transmit information. Link Active Scheduler (LAS) in FF has a timetable to determine when devices communicate on the segment. PA submits data at random times (not isochronous: no scheduling and synchronization with control or separation of real-time and non-real-time). In PA, slave polling involves bus master asking for information from devices.
- Address allocation in PA has to be done by communication with each device individually (manually offline). FF devices announce themselves to the bus master (addressed automatically online).
- PA devices go back to bus master with the info, which will then transmit to other devices the relevant data. FF utilizes peer-to-peer communication.
- FF has built-in function blocks that allows peer-to-peer communication, perform control functions and continue to operate if communications are lost to the control system. Control in the field results in faster loop execution time. Profibus no function block capability reports and takes direction from PA master. If communications to master are lost, all instruments must go to fail-safe positions or maintain their last settings.
- Profibus has no handheld communicator
- Profibus has no report-distribution (alerts), so status must be regularly polled.

Appendix 2 **Fieldbus overview**

App 2.1 Fieldbus Overview

Fieldbus is an all digital, two-way multi-drop communications link among intelligent smart field devices and automation systems. The Fieldbus is the Local Area Network (LAN) for instruments used in process automation with built-in capability to distribute the control application across multiple devices. The Fieldbus system is based on the concept of the Manchester encoded bus powered signals designed in accordance to IEC 61158. Unlike a traditional 4 to 20 mA instrumentation devices that requires individual set of wires for each device, several Fieldbus devices can be connected on one set of wires. Fieldbus supports digital encoding of data and many other types of messages, such as individual device diagnostics messages.

In view of the technical complexity of Fieldbus over conventional 4-20mA instrumentation system, the use of Fieldbus technology shall be justified based on the business needs and shall be approved in writing by the Principal or Plant Owner.

There are a wide range of Fieldbus technologies available in the market. The governing international standards for Fieldbus are the IEC 61158, which is in eight parts. The IEC 61158 standard acknowledges the diversities of the various types of Fieldbus technologies available in the market and has provided eight designations of Type 1 to Type 8. The list of the protocols is set as below:

- Type 1 : FOUNDATION Fieldbus H1 (31.25kbits/s)
- Type 2 : ControlNet
- Type 3 : Profibus DP and PA
- Type 4 : P-Net
- Type 5 : FOUNDATION Fieldbus HSE (High Speed Ethernet) (100 Mbits/s)
- Type 6 : SwiftNet
- Type 7 : World FIP
- Type 8 : Interbus S

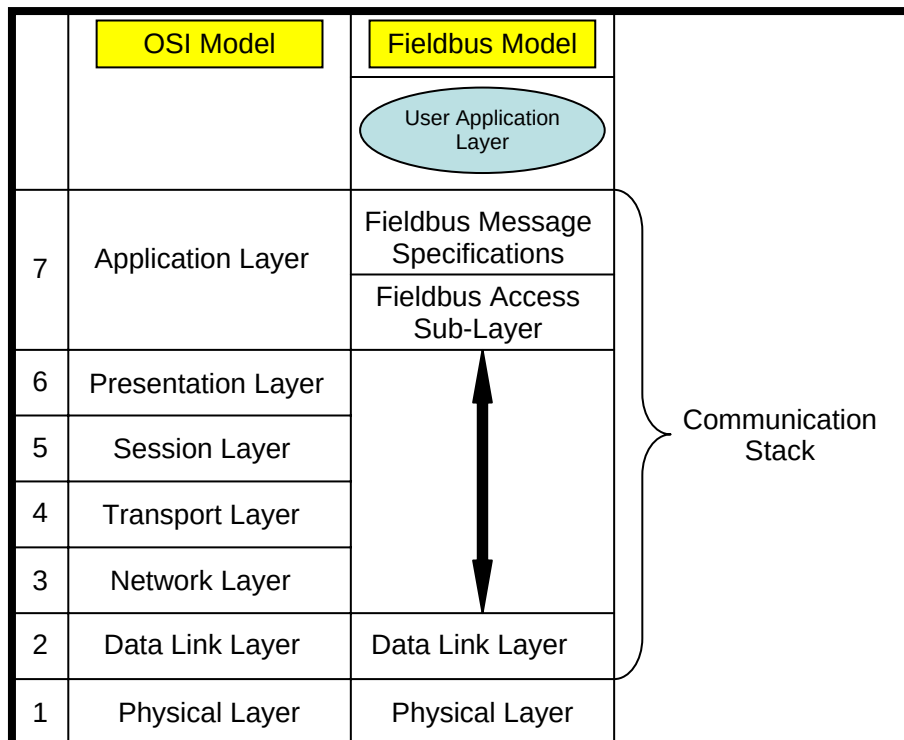
However, the different types of Fieldbus technologies are NOT compatible to each other. Once the Fieldbus system technology has been chosen, it cannot be easily changed over the lifecycle of the plant.

The use of any other Fieldbus technologies shall require Custodian approval.

Fieldbus FOUNDATION is an international, not-for-profit, organization of over 180 manufacturers and users of automation equipment that was formed for the purpose of developing an open and integrated Fieldbus architecture.

All references to Fieldbus, in this document onwards, shall refer to FOUNDATION Fieldbus, unless specifically stated otherwise.

The FOUNDATION Fieldbus is based on the internationally accepted standards of Open Systems Interconnection (OSI) model as defined in ISO 7498. The relationship between the OSI and Fieldbus models are as follows:-

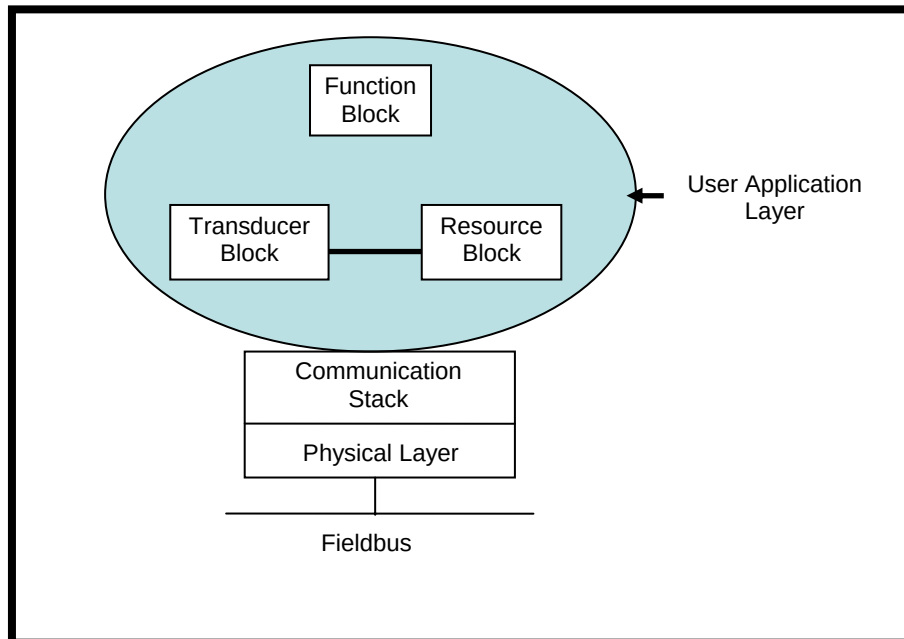


Layer 1 is the physical media of data communication, e.g. by wires. Above Layer 7, is the device function, called the User Layer. The User Layer is not defined by the OSI Model and is defined by the Fieldbus FOUNDATION. The User Layer will have functions, such as, measurement, actuation, control or operator interface in a host. The User Layer is where data formats and semantics are defined to allow devices understand and act intelligently on data, thereby, achieving real interoperability. Fieldbus does not use OSI Layers 3, 4, 5, and 6. The Fieldbus Access Sub-Layer (FAS) maps the Fieldbus Message Specifications (FMS) onto the Data Link Layer (DLL).

For devices to interoperate with each other on the same network, all the seven OSI and User Layers must be the same.

App 2.2 FIELDBUS User Application Layer Blocks

The Fieldbus FOUNDATION has defined a standard User Application Layer based on “blocks”. The blocks represent the different types of application functions, as follows :-



Devices are configured using the Resource Blocks and the Transducer Blocks. Control strategies are built using the Function Blocks.

Resource Block (RB)

The RB describes the characteristics of the Fieldbus devices such as the device name, manufacturer and serial number. There is only one RB per device.

Transducer Block (TB)

The TB contains information such as calibration date and sensor type. The TB decouples the Function Block (FB) from the local Input / Output (I/O) functions required to read the sensors and command output hardware. This is where parameterization, calibration and diagnostics for the device is done. There is typically one TB channel for each input or output channel of a device.

Function blocks (FB)

FBs provide the control strategies of the devices. The FB applications are used to provide the various functions required in a control system such as input, output, signal selection and other control actions. The execution of each FB is precisely scheduled. There can be many FBs in a single User Application.

Fieldbus FOUNDATION has defined sets of standard FBs. Ten standard FB for basic controls are defined by FF-891 Function Block Application Process – Part 2 specifications. These are :-

AI	-	Analog Input
AO	-	Analog Output
B	-	Bias
CS	-	Control Selector
DI	-	Discrete Input
DO	-	Discrete Output
ML	-	Manual Loader
PD	-	Proportional / Derivative Control
PID	-	Proportional / Integral / Derivative Control

RA - Ratio

The following eleven standard FBs are defined by FF-892 Function Block Application Process – Part 3 specifications. These are :-

DC	-	Device Control
OS	-	Output Splitter
SC	-	Signal Characteristics
LL	-	Lead Lag
DT	-	Dead Time
IT	-	Integrator (Totaliser)
SPG	-	Setpoint Ramp Generator
IS	-	Input Selector
AR	-	Arithmetic
TMR	-	Timer
AAL	-	Analog Alarm

The following four standard FBs are defined by FF-893 Function Block Application Process – Part 4 specifications. These are :-

MAI	-	Multiple Analog Inputs
MAO	-	Multiple Analog Outputs
MDI	-	Multiple Discrete Inputs
MDO	-	Multiple Discrete Outputs

The Flexible Function Block (FFB) is defined by FF- Function Block Application Process – Part 5 specifications. The FFB is a user defined block. The FFB allows manufacturers and users to define the block parameters and algorithms to suit an application that interoperates with standard FBs and the host system.

From the list of FBs above, it should be seen that not all FBs are suitable or available for all instruments. End-users shall verify with the manufacturer that the required FBs are available for the devices purchased. It is recommended that only standard FBs be used in the control strategies. Enhanced FBs (standard blocks with additional parameters) should only be used if absolutely required for a specialized requirements. Use of standard FBs ensures the ease of maintenance replacement of the device, during normal operation and ensures device interchangeability over the system lifecycle in the plant.

The FOUNDATION Fieldbus test of FBs only verifies the presence of the FB and that it is able to interface externally, but not how well they work internally. Each manufacturer will configure their internal operation of the FBs to give them the best competitive advantage. Hence, end-users should verify with the manufacturer on the internal macrocycle efficiencies of their FBs to ensure it meets the process needs.