Tutorial:
Characteristics & Requirements of Physical Networks in the Process Industry

IEEE802.3cg 10 Mb/s Single Twisted Pair Ethernet Task Force

Brian Franchuk
Martin Zielinski

EMERSON

Introduction

Pertinent Objectives

8) Support 10 Mb/s operation in industrial environments (e.g. EMC, temperature) over single balanced twisted-pair cabling

9) Do not preclude the ability to survive automotive and industrial fault conditions (e.g. shorts, over voltage, EMC, ISO16750)

10) Do not preclude working within an Intrinsically Safe device and system as defined in IEC 60079

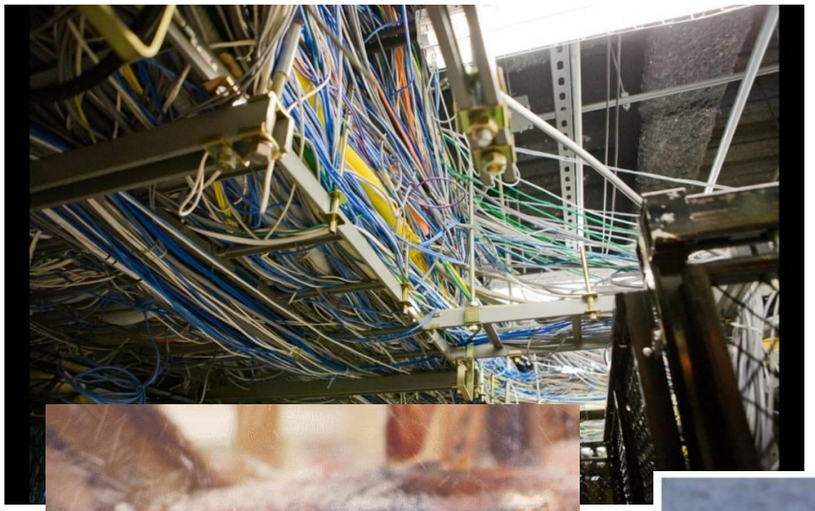
12) Define the performance characteristics of a link segment and a PHY to support point-to-point operation over this link segment with single twisted pair supporting up to 10 inline connectors using balanced cabling for up to at least 1 km reach

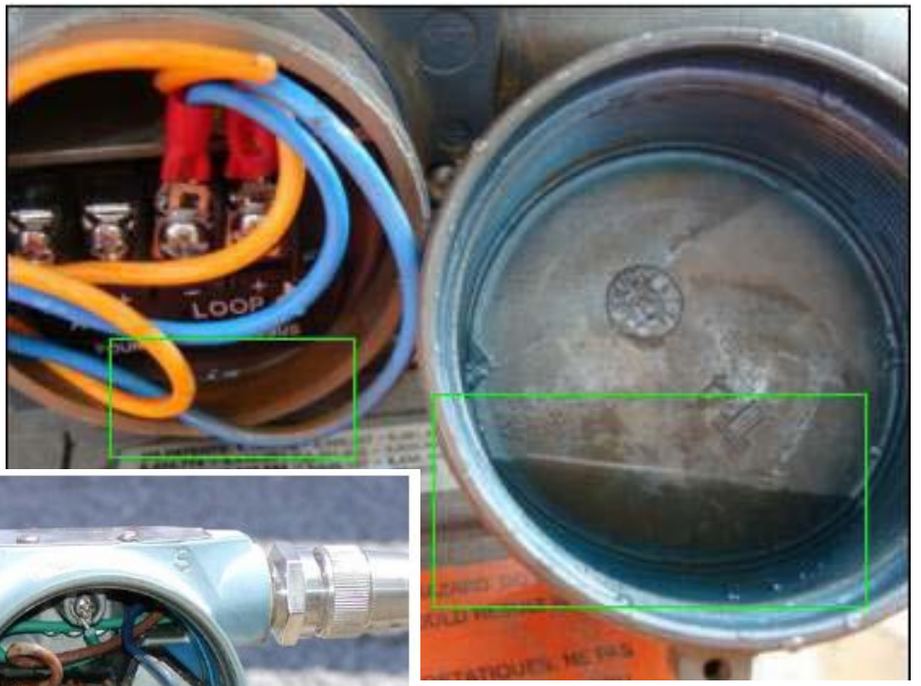
14) Maintain a bit error ratio (BER) at the MAC/PLS service interface of less than or equal to 10^{-10} on link segments up to at least 15m, and 10^{-9} on link segments up to at least 1km

15) Specify one or more optional power distribution techniques for use over the 10 Mb/s single balanced twisted-pair link segments, in conjunction with 10 Mb/s single balanced twisted-pair PHYs, in the automotive and industrial environments

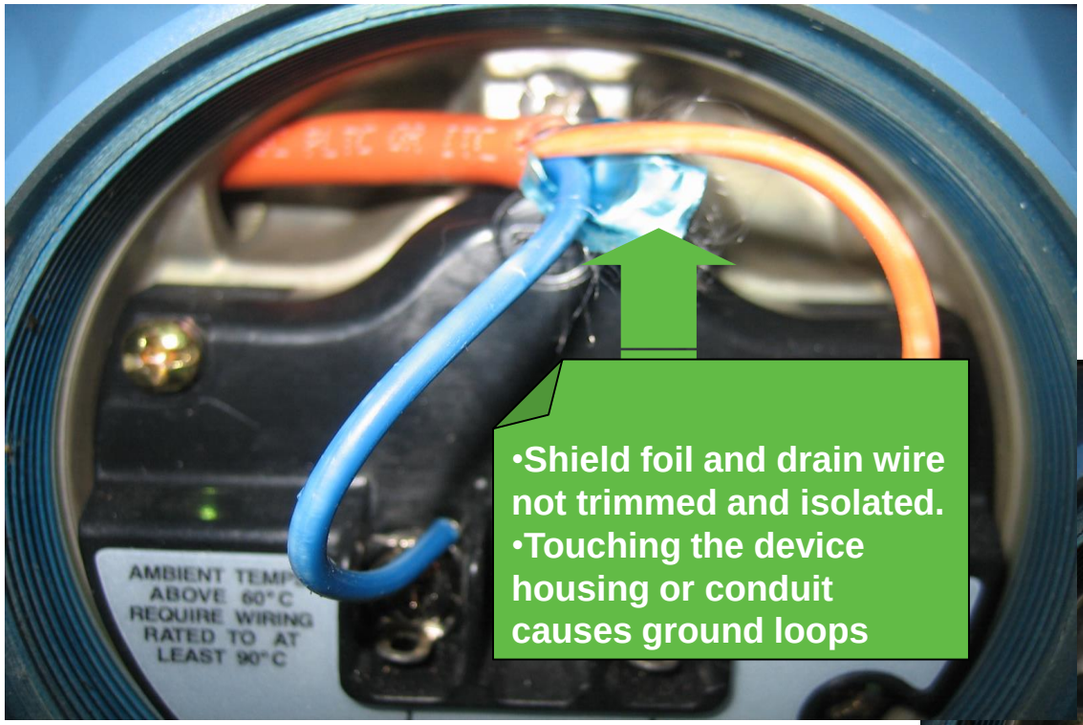
Environment

This is Not an Office Environment

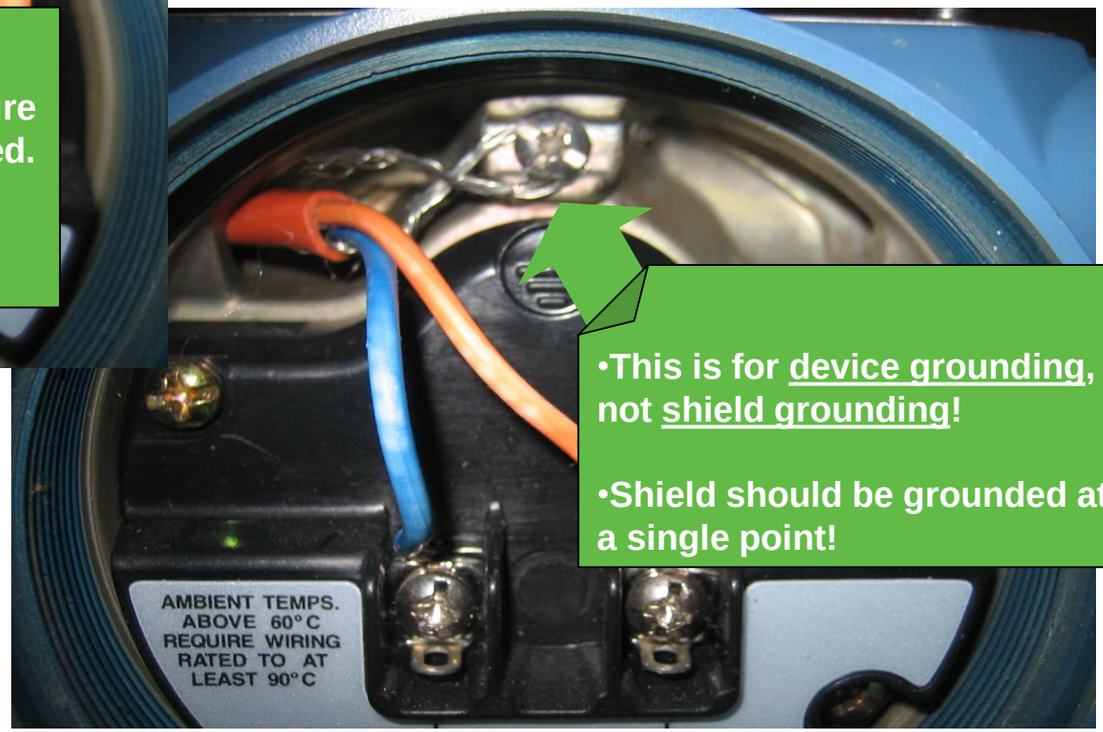




Cabling



•Shield foil and drain wire not trimmed and isolated.
•Touching the device housing or conduit causes ground loops



•This is for device grounding, not shield grounding!

•Shield should be grounded at a single point!

- Installers often get it wrong
- Installer skill level is dropping over time

Cabling and Connectors Need to be Foolproof and Robust

Process Industry Environment

- A large percentage of products are directly used in hazardous locations; areas made hazardous by the presence of flammable or explosive concentrations of gases, vapors, or dusts.
  - Chemical
  - Petroleum
  - Food
  - Pharmaceuticals

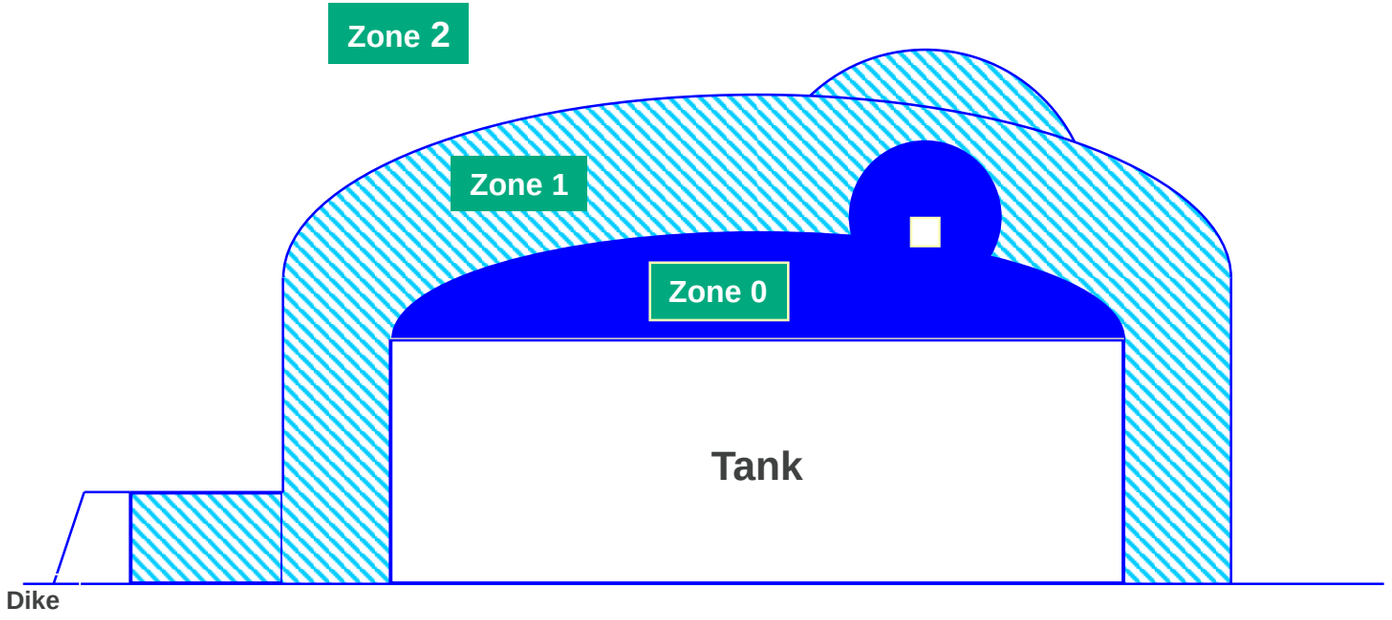
Area Classification

Classification by degree of hazard present (Ignition Risk)

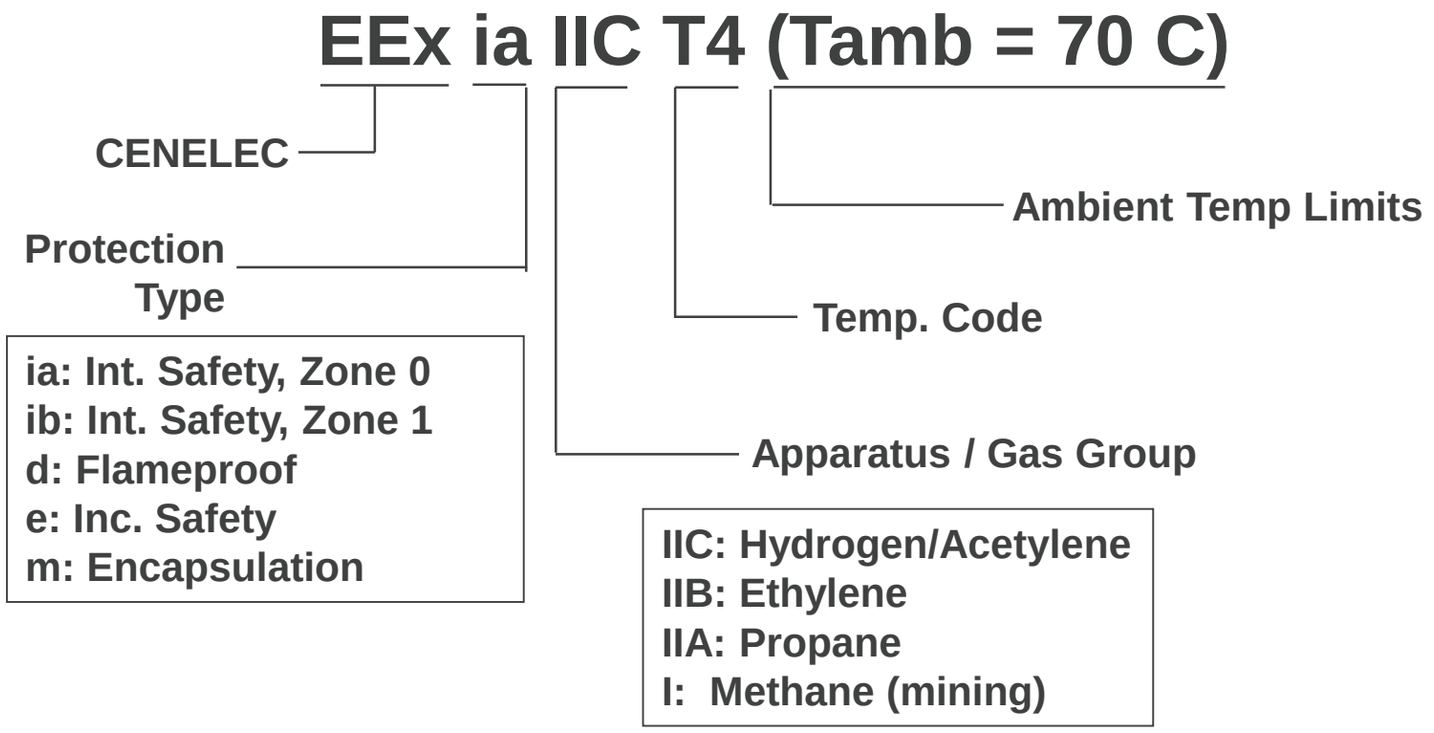
North American	IEC	Definition
Division 1	Zone 0	Ignitable concentrations present most of the time under normal conditions
	Zone 1	Ignitable concentrations present under normal conditions for short periods
Division 2	Zone 2	Ignitable concentrations present only under fault conditions

Area Classification Example – IEC (World Wide)

- Example: Mass Storage Tank



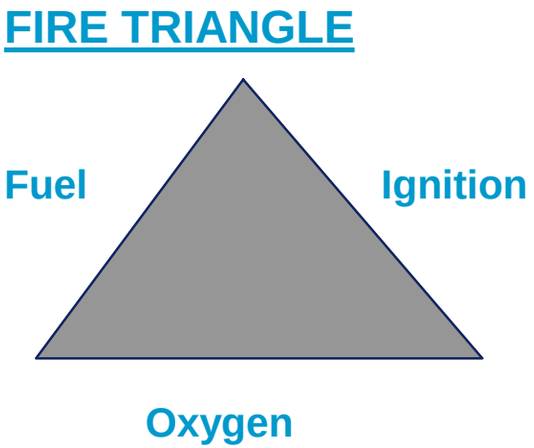
Equipment Selection – IEC (World Wide)



Approvals are Complex and Vary from Country to Country

Methods of Hazard Reduction

- Enclose potential explosion
  - Explosion proof / Flameproof



- Prevent potential explosion
  - Remove one of the necessary components
    - Intrinsic Safety: Removes ignition source
    - Non incendive: Removes ignition source
    - Purging: Removes fuel

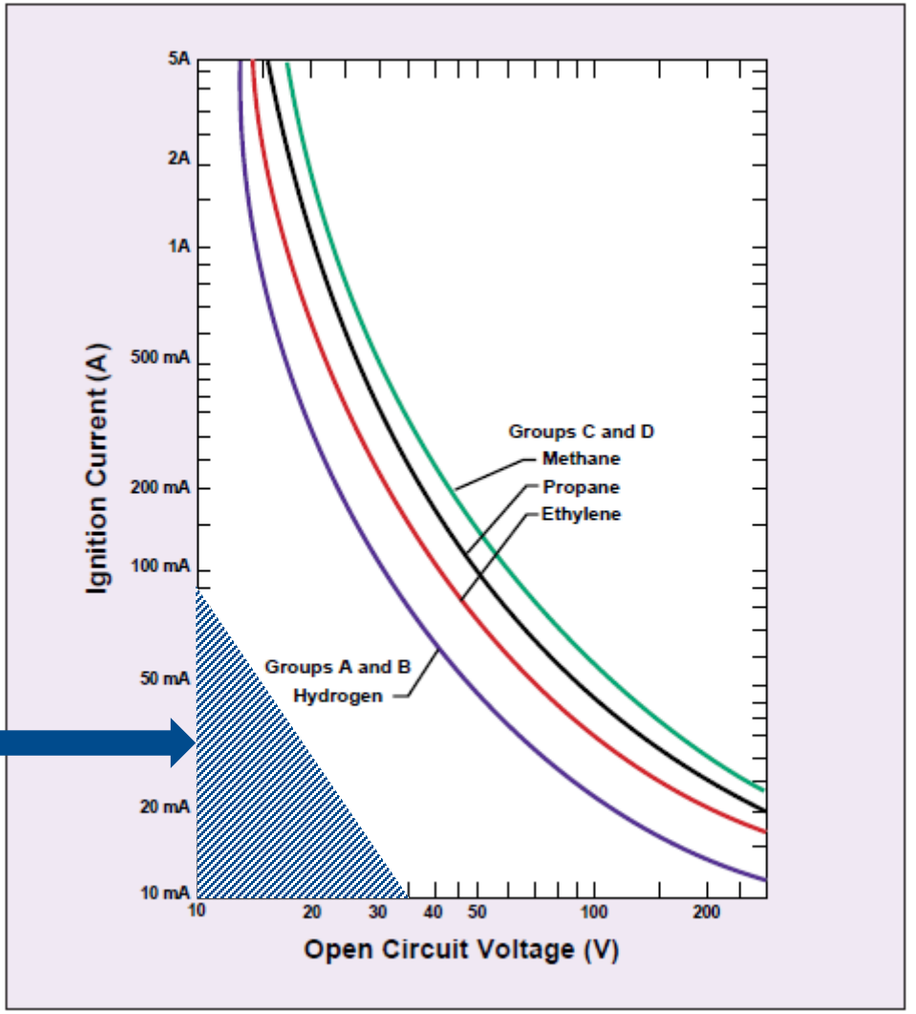
For 802.3cg in Industrial Environments, Intrinsic Safety is Key

Intrinsic Safety (IS)

- Device installation and fault conditions will not ignite a flammable atmosphere
- Protection is achieved by limiting the available energy both into and out of the device
  - Energy both as electrical sparks as well as component surface temperature
  - Non-stored energy (power supply)
  - Stored energy in the device and/or the cable
- Classification examples
  - EExia
    - Zone 0, 1, and 2
    - Safe with two faults in the device
  - EExib
    - Zone 1 and 2
    - Safe with one fault in the device

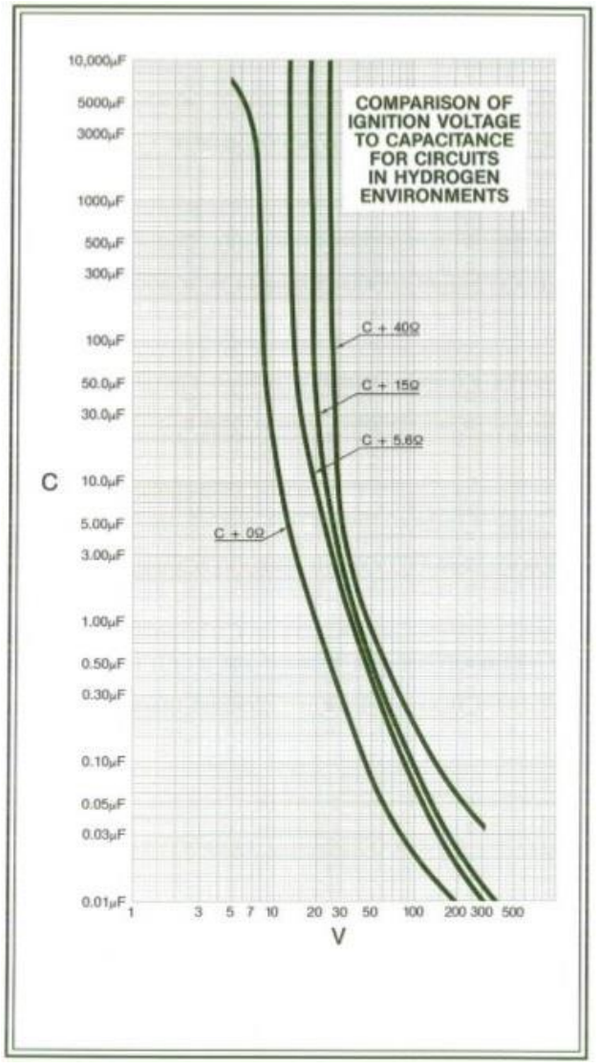
Intrinsic Safety – Ignition Curves

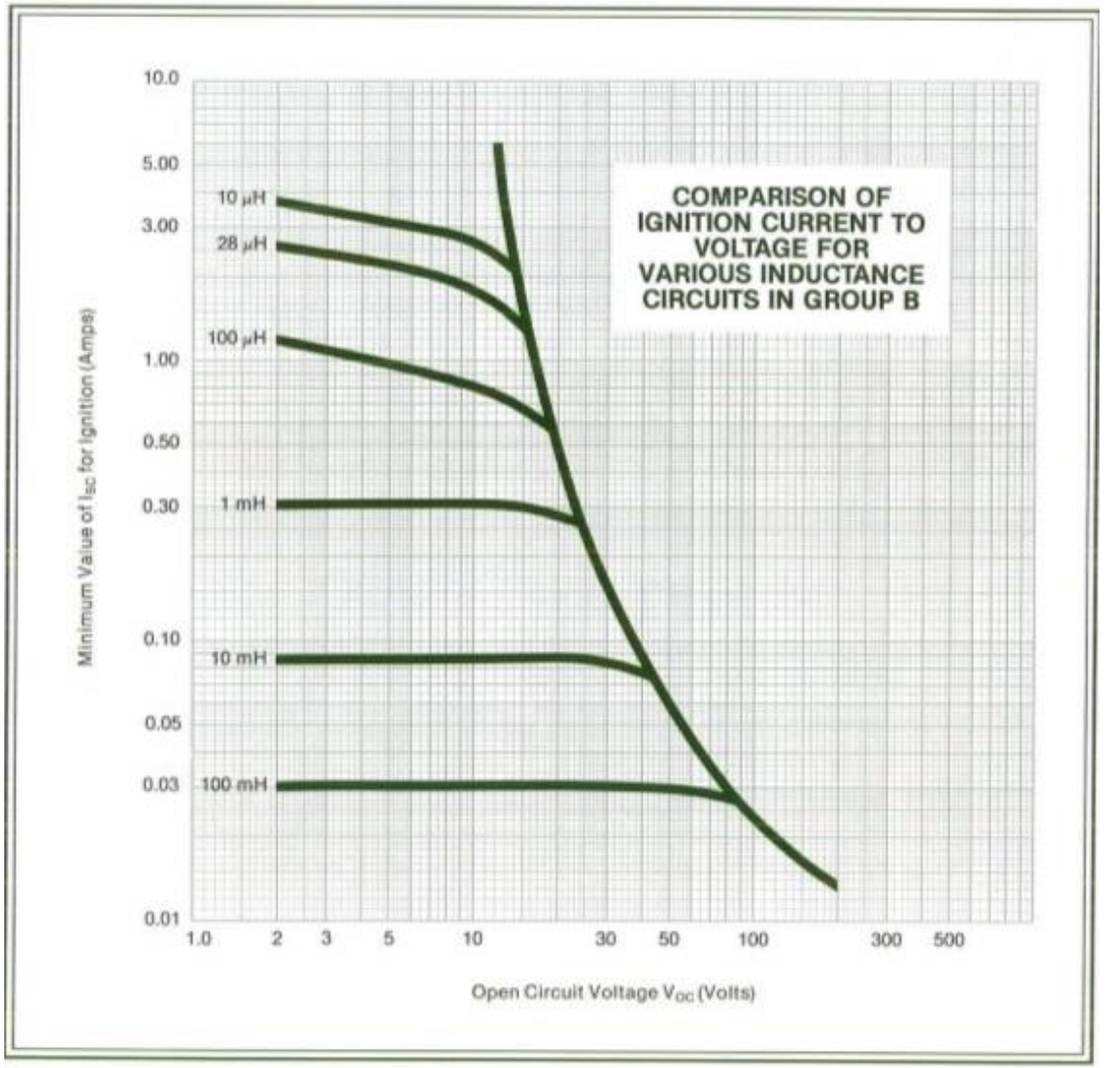
- Must operate under the ignition curve for a given group.
- Typically, a safety factor of 1.5 to 2 is used.



Ignition curves – resistance

Intrinsic Safety – Ignition Curves





Evolution of Foundation Fieldbus Network Topologies

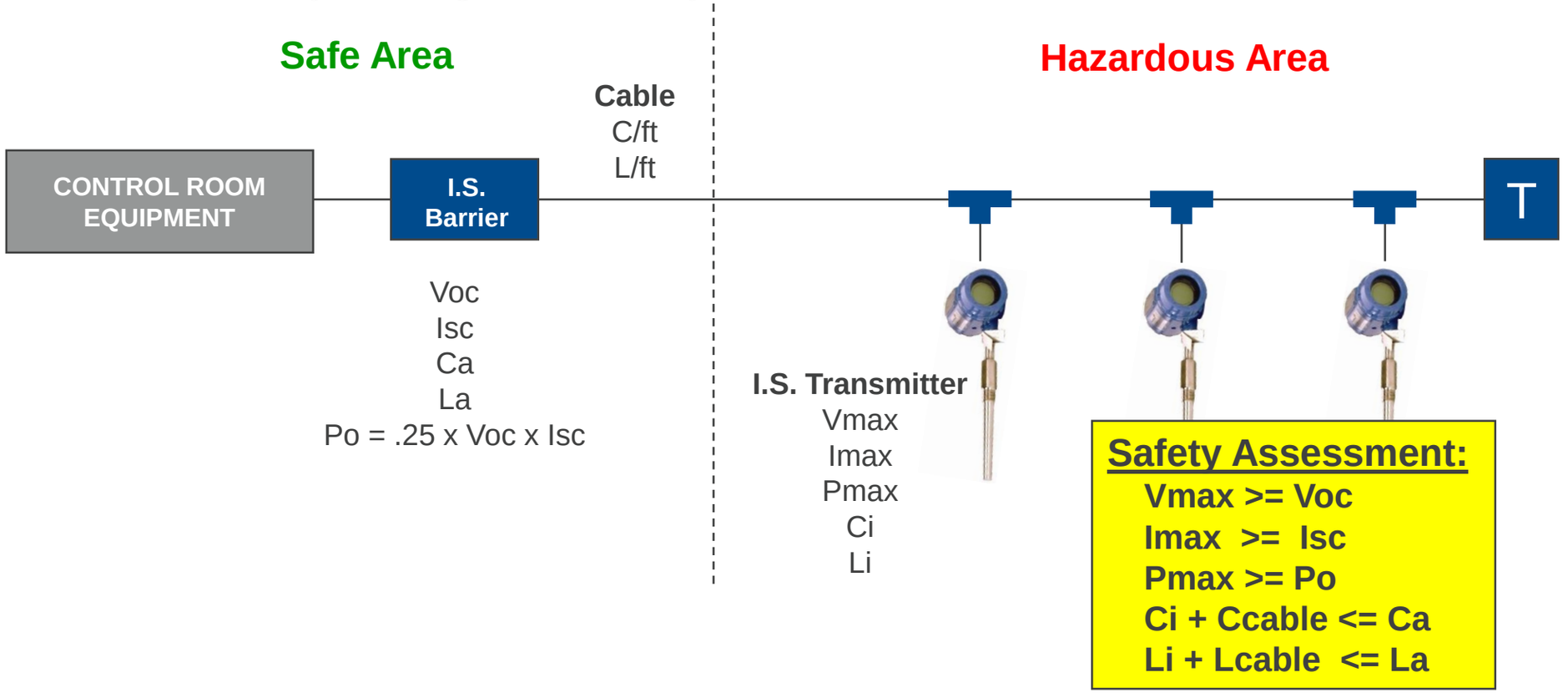
Foundation Fieldbus (FF) H1

- All digital, bi-directional communication protocol
  - Real-time process control (multicast)
  - Process monitoring (peer-to-peer)
  - Alarms

- Physical Layer
  - Multi-drop, digital-only, Manchester encoding, 31.25kbps
  - 2 Wire, power and signal, up to 1900m using 18 AWG cable
  - Same as PROFIBUS PA

Early FF Installations (mid to late 1990s)

- Characteristics
  - Multi-drop using Bus + Tap topology
  - Intrinsic safety using the Entity Model



Early FF Installations (mid to late 1990s) - Problems

- Bus + Tap topology
  - Difficult to isolate individual devices making field replacement difficult
  - No short circuit protection

- Entity model
  - Overly conservative
    - The assumptions behind the entity model turned out to be false in real-world installations
    - Total amount of power available on the segment excessively limited
  - Complex
    - Individual device + cable calculations made plant engineering difficult and time consuming

Fieldbus Intrinsically Safe COncept (FISCO)

- IS calculation simplification resulting from research done by the PTB in Germany
  - Allowed more power to be available on the segment (approx. 2x)
  - Standardized IS parameters
  - Simplified segment design

- Difficulties
  - No mixing of Safe and Hazardous areas on a single segment
  - Lack of power supply redundancy

High Power Trunk (HPT), 2002

- Trunk + Spur topology
- Limits power at the spur, rather than the trunk
- Trunk is not IS, but is protected via other means (e.g. explosion proof)

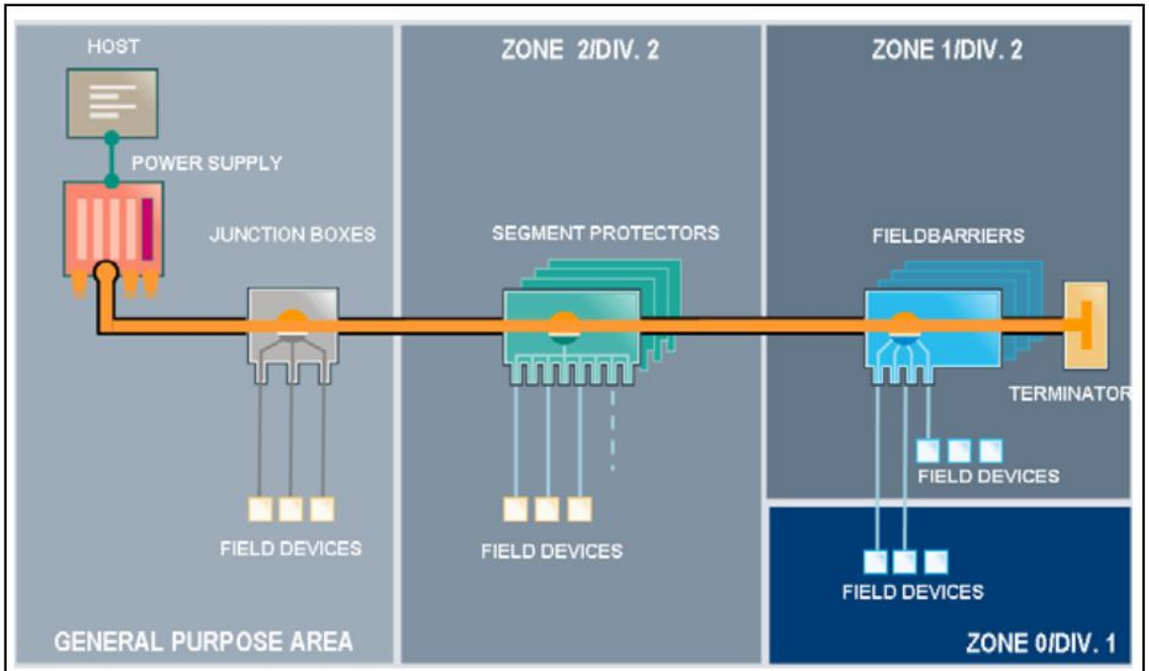


Figure 3: High-Power Trunk for any hazardous area Segment Protectors provide short-circuit protection and non-incendive energy limitation (Ex nL).. FieldBarriers provide intrinsic safety (Ex i).

Source: Technical White Paper, "INTRINSICALLY SAFE FIELDBUS IN HAZARDOUS AREAS", Pepperl & Fuchs

Present Day

- Continued use of Trunk + Spur topology

- DART (Dynamic Arc Recognition and Termination)
  - Allows even higher power levels on the trunk due to arc detection and quenching
  - Both trunk and spurs are IS, simplifying plant engineering

Present Day

- Broken Assumptions
  - Assumption:
    - The multi-drop nature of FF will provide substantial savings on installation costs due to reduced cabling
  - Finding
    - Savings were not realized due to increased costs
      - FF-qualified cable
      - Field device isolation/protection junction boxes
      - Ancillary costs such as plant work permits and process swamped the cabling costs

Other Constraints

Other Constraints

- Energy efficiency
  - Specifically, delivery efficiency from power source to device
  - Delivery efficiency is not a strong concern for industrial applications
  - IS requirements dominate
  - Minimum device voltage (lift-off) is crucial to engineering a working network
- Maximum device voltage
  - IS constraints
  - Circuit component values and parts availability

Summary

- Industrial environments present unique system challenges due to
  - IS constraints
    - Limited power
    - Restrictions on the instantaneous peak voltage (DC + signal) on the cable
    - Minimum device voltage
  - Harsh electrical environment
    - Ground loops
    - Large motors and drives (VFDs)
    - High Transients (lightning, welders, load switching)
- Bus + Tap topology is no longer used for industrial applications
  - State of the art applications use Trunk + Spur cable topologies
  - Point to point switched Ethernet model fits well with existing trunk + spur topologies

Questions ??