# Cost and Analysis Cable Study using FOUNDATION Fieldbus Instruments

The information contained herein is available courtesy of Brown & Root Energy Services from a study entitled *Principal Instrument Cable Routing Study* for the Shell Malampaya Platform FEED Plant.

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# Contents

## Introduction

FOUNDATION fieldbus (Ff) instruments are envisioned for offshore oil and gas production platforms. Ff instruments have valuable features, such as bus technology and digital communication that are not available with traditional instruments. Because Ff instruments use bus technology, a reduction in wiring is imminent. This, in turn, will reduce wiring costs.

The following study was performed in order to analyze the available wiring options using FOUNDATION fieldbus instruments and to determine the relative costs associated with the various cable routing options. In addition, an estimate of the costs associated with instrument commissioning was included in order that a complete view could be taken of the total costs incurred in instrument wiring installation.

Traditional analog instruments require that each instrument be connected to host equipment via its own dedicated wire pair. On the other hand, FOUNDATION fieldbus instruments use digital data transmission technology that allows multiple instruments to share a single-pair of wires for: (1) distribution of power to the instruments and (2) transmission of data to and from host equipment. Thus, the use of Ff instruments warrants a review of wiring methods so that cable routing and wiring design may be optimized.

FOUNDATION fieldbus instruments have capabilities far beyond the basic function of providing a measurement signal. In addition, the digital data transmission technology allows each instrument to be self-identifying and provides for the remote scaling and testing of the field instruments from the host equipment. This feature significantly reduces the time required to test field wiring and to place an instrument into operation.

The results of this study will be used to set the wiring design criteria for the project.

## References

ISA S50.02-1992 Fieldbus Standard for Use in Industrial Control System – Physical Layer Specification

Oil and Gas Platform Feed P&ID’s 01-OPI-3100-01 through 01-OPI-3940-01 dated October 13 1997

Oil and Gas Platform Feed Plot Plan drawings PSK-00-11 through PSK-00-17 (revision A1) dated October 10 1997.

## Study Description

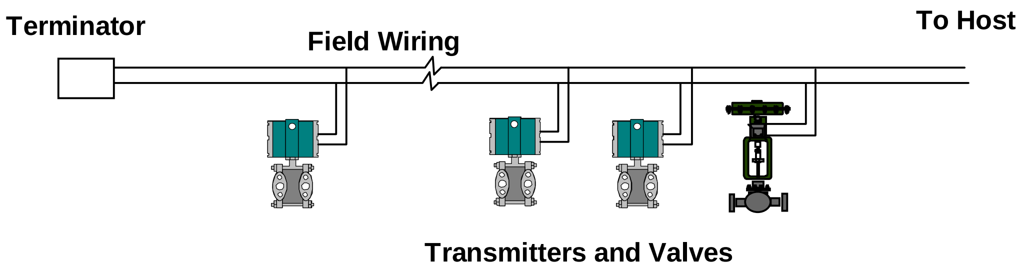
The study included the analysis of a traditional analog and discrete wiring scenario in addition to three Ff alternative wiring scenarios. The material, installation labor, and commissioning costs were estimated for each case and are summarized as part of the study results. The analysis of the traditional analog and discrete wiring scenario is included for two reasons. First, there will be a significant number of traditional analog and discrete instruments. Thus, necessity dictates the analysis in order to make proper provision for these instruments in the cable routing plans. Second, by analyzing the traditional scenario we will be able to use its cost as the baseline cost for making comparisons with Ff wiring scenarios.

The basis for the study included the P&ID's (Reference 1) and Equipment Layout Plans (Reference 2) which were available in October. Although the P&ID's and Equipment Layout Plans have undergone several revisions during the life of the study, there has been no attempt to revise the study basis, since to do so would add no value to the study results. The referenced P&ID's and Plans represent a good example of industrial systems and equipment layout for the purpose of this study.

Identifying the instruments associated with each major equipment item shown on the P&ID’s started the layout of the wiring scenarios. The assumption was made that field instruments will be installed in the immediate vicinity of the associated equipment. Thus, the Equipment Layout Plans were hand marked to indicate the number of instruments, by type, to be installed near each major equipment item. These plans were then used to determine the number and location of field junction boxes for each wiring scenario studied. These quantities and locations were then used to estimate individual cable lengths so that wiring costs could be estimated.

The traditional analog and discrete wiring scenario is shown in Appendix A, Scenario 1. In this scenario, junction boxes are provided with terminal strips for 24 analog signals and 36 digital signals. Each instrument is wired to the junction box via a single-pair cable. Using the terminal strips as an intermediate point, a transition to multi-pair cable is made for the cable run between the junction box and the Process Automation System (PAS) I/O cabinet. The junction boxes are located in the process area so that the length of cable required between an individual instrument and the junction box is limited to a length of 70 feet. On the other hand, the multi-pair cables installed between the junction box and I/O cabinet are much longer (approximately 280 feet on average.) The multi-pair cables are termed "homerun cables." This is a popular wiring method in the oil and gas industry since it allows individual instrument cables to be field routed and provides for economy of scale by using multi-pair cable for the longer cable runs. The junction box shown for this scenario is typical in size of offshore applications.

FOUNDATION fieldbus standard H1 will be used for the Oil and Gas Project. The H1 standard provides data transmission at 31.25-kbit/sec and power distribution to instruments at a nominal 24 VDC. Data and power signals coexist on the same wire pair. The wiring connection scheme for Ff instruments is quite simple. All instruments have only two terminals and are wired in parallel. The H1 standard allows up to 32 instruments to be connected to a single wire pair. In the case of intrinsically safe (IS) instruments that are installed in a hazardous area, the H1 standard limits the number of instruments on a wire pair to four instruments in order to limit the total current to a safe value. Another H1 IS requirement is that the wire pair be provided with a "terminator" at each end in order to prevent data signal reflections. The wire pair used for connecting the instruments in parallel is termed a "segment". An example of an H1 segment is illustrated below:




Although the schematic shown above is quite proper, it does not represent a wiring diagram which could be implemented using traditional industrial wiring materials such as CLX cable and cable fittings. A more traditional approach is to use a junction box with terminal strips to make up the instrument connections. Scenario 2 in Appendix A was chosen as the base scenario for the Ff wiring. As shown, up to four instruments are connected to a small junction box with a single-pair cable being used for the homerun cable. The limit of four instruments per junction box is used since the instrument philosophy calls for instruments installed in hazardous areas to be intrinsically safe. This configuration has been identified in Ff literature as a "tree" or "chicken foot" topology and has been used in most Ff installations.

In order to explore the effect of using multi-pair cable for the homerun Ff cables, the wiring system shown in Scenario 3 was analyzed. In this case, the Ff segment cables for four segments are wired to a common junction box in the process area and a four-pair cable is used for the long homerun from the process area to the PAS I/O cabinet.

Scenario 4 was chosen in order to investigate the use of wiring technology other than traditional junction boxes, terminal strips, and cable fittings. This scenario employs quick disconnect connectors and other wiring devices that have been designed specifically for instrument systems using network technology. These devices are used in the automobile and machinery manufacturing arenas where the basic manufacturing process must be very flexible in order to cope with yearly model changes. Emerson Process Management promotes this wiring technology as part of their Ff offering. Indeed, this wiring method was used in a Ff installation in Canada. It was reported that 100 Ff transmitters were physically installed and commissioned in five hours' time with a three-person crew.

The connector technology shown in Scenario 4 takes advantage of the very simple nature of a bus network; i.e., all devices are wired in parallel as illustrated in the schematic included above in Section 2. Each "brick", a device similar in size to a common masonry brick, allows for up to 6 separate Ff devices to be connected. Further, connections are provided so that a main trunk cable can be used to tie a number of bricks together. In the case of Scenario 4, each brick is limited to providing connections for a maximum of four Ff devices in order to meet the IS design criteria. Thus, the brick takes the place of the small junction box concept presented in Scenarios 2 and 3.

One important consideration in the use of Ff is the integrity of each Ff wiring segment. Since multiple devices use the same wire pair, any wiring fault on the segment will result in the loss of all data provided by the devices wired to the segment. Once wiring is installed, it very rarely fails except when physically broken. Seemingly, the greatest peril to the Ff segment wiring integrity is faults resulting from instrument maintenance requiring that an instrument be disconnected from the segment. If conventional wire and terminal strip connections are used for the Ff instruments, there is the distinct possibility of accidental shorting of the segment wiring during the maintenance process. The connector technology is designed to prevent the accidental shorting of the segment wiring. In addition, the use of connector technology helps to prevent wiring errors during installation and maintenance.

One drawback is that, at this time the technology is not available as an armored cable construction such as CLX. Thus, use of this technology would require that the instrument cables be placed in mechanical channel in order to provide a degree of mechanical protection for the cables. It can be argued that this is not a great disadvantage since individual-pair CLX cable is often placed in mechanical channel for this very reason. However, the perception that the non-armored cable is not as robust as CLX cable will always persist. We've been advised that other end users have these same concerns. As a result, the manufacturer of the connector technology is planning to develop an armored cable option.

The material and labor costs used in this study are included in Appendix B. The costs associated with traditional CLX cable were developed from data provided by the BRES estimating group. The costs for the junction boxes were obtained from local suppliers using the bills of material shown in Appendix B. The costs related to the connector technology considered in Scenario 4 were obtained from InterlinkBT / Turck Inc. using the bills of material also shown in Appendix B.

The costs attributed to commissioning instruments are documented in Appendix C. As shown, we prepared a flow chart of activities for commissioning traditional instruments and assigned nominal work-hour allocations for each major activity. This flow chart is based on past experience and represents the commissioning activities common to most projects. As a final step, a separate estimate was made of the work hour allocation expected to be experienced with Ff devices. As can be seen, the estimate of commissioning labor per traditional device is 300 minutes,l while the estimate of commissioning labor per Ff device is 70 minutes.

The costs associated with each wiring scenario were developed as described above and as documented in the spreadsheets included in Appendix D. Please note that the spreadsheets are organized by major equipment number. The corresponding locations of the major equipment items and the junction boxes assumed for the wiring scenarios are documented in the marked-up location plans included as Appendix E.

## Study Results

The wiring and commissioning costs for each scenario were evaluated on a per device basis as listed below:

| | | |
|---|---|---|
| Scenario 1: | Traditional field instruments | $890 |
| Scenario 2: | Ff devices w/ single-pair homerun | $672 |
| Scenario 3: | Ff devices w/ multi-pair homerun | $652 |
| Scenario 4: | Ff devices w/ connectors | $567 |

For a breakdown of the costs associated with each scenario, please refer to the spreadsheet and pie charts contained in Appendix F.

In reviewing the above results, we find that Ff offers reduced wiring and commissioning costs over traditional instruments, as expected. These savings are listed below:

| | |
|---|---|
| Scenario 2: | 24 % cost saving |
| Scenario 3: | 26 % cost saving |
| Scenario 4: | 36 % cost saving. |

Current Ff literature contains several similar cost comparisons. However, these cost comparisons usually claim cost savings on the order of 30 to 40 percent. The discrepancy between this study and these projections may be accounted for by the fact that the projections are based on a larger number of instruments per segment than the four instruments per segment which has been used for the IS case assumed in Scenarios 2, 3, and 4. In the case of the Oil and Gas Project, there may be several equipment areas that are non-hazardous areas not requiring intrinsically safe circuits. Thus, an additional Non-Intrinsically Safe Scenario, wherein sixteen devices were connected to a segment, was evaluated as part of this study. As shown in Appendix G, the wiring and commissioning costs drop to $371 per device for the non IS scenario of sixteen devices per segment. When compared to the traditional wiring scheme, the cost savings increase to 58 percent, well above the aforementioned projections.

## Recommendations

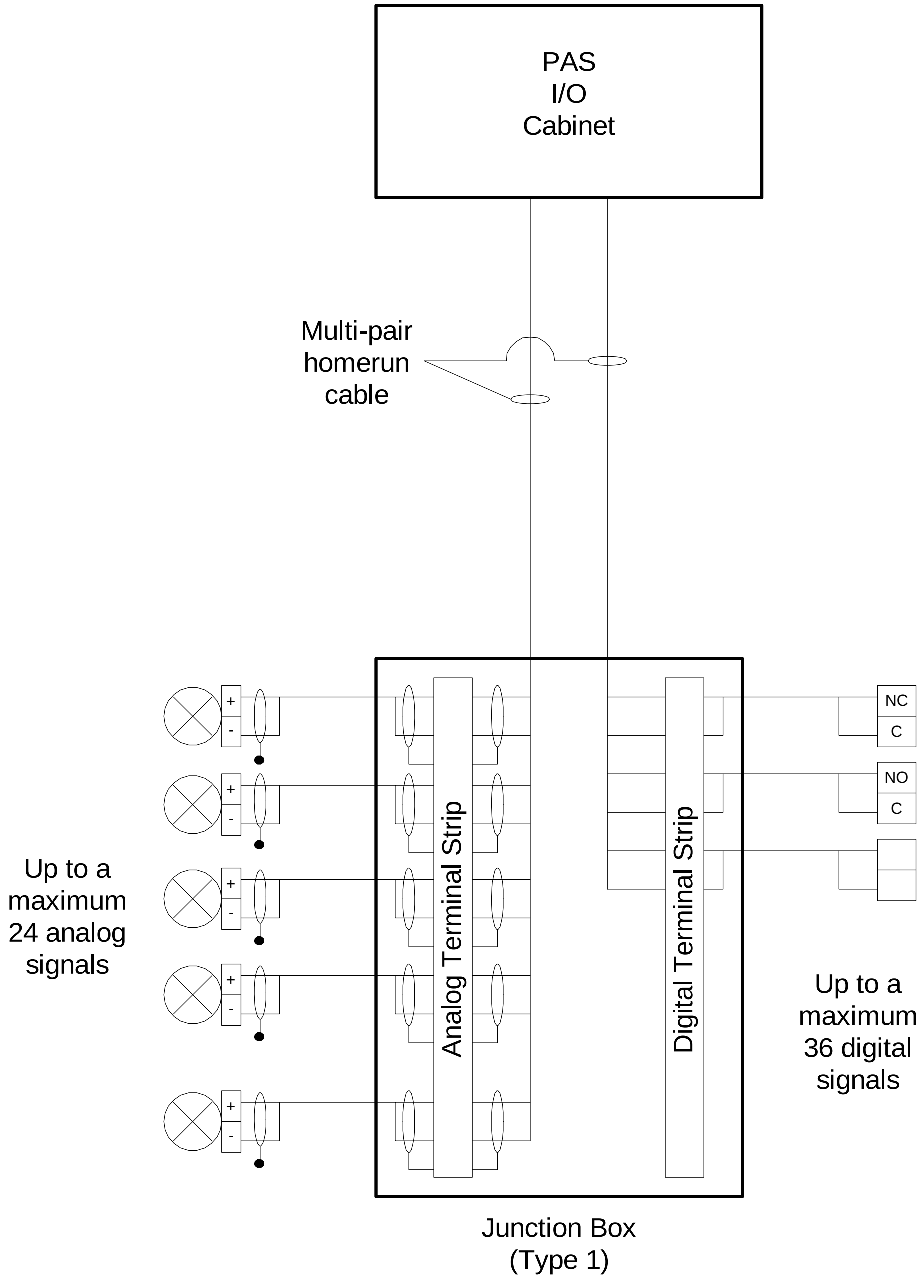
Of the three Ff wiring scenarios examined, Scenario 4 is recommended over Scenarios 2 and 3 for Ff instruments. Scenario 4 proved to show an economical choice and to provide a degree of protection against segment faults caused by human error.

The recommendation to the use of connector technology is qualified in two respects. First, the development of the armored cable option should be closely followed and adopted if developed in a time period supportive of the project schedule. If the armored cable option is not developed or available, the development of installation details that include provisions for mechanical protection of the cables should be included in the detail design of the project. Secondly, use of the connector technology may be a new experience for the electrical craftsmen in the fabrication yard. The fabricator must be required to train the electrical craftsmen in proper connector installation techniques.

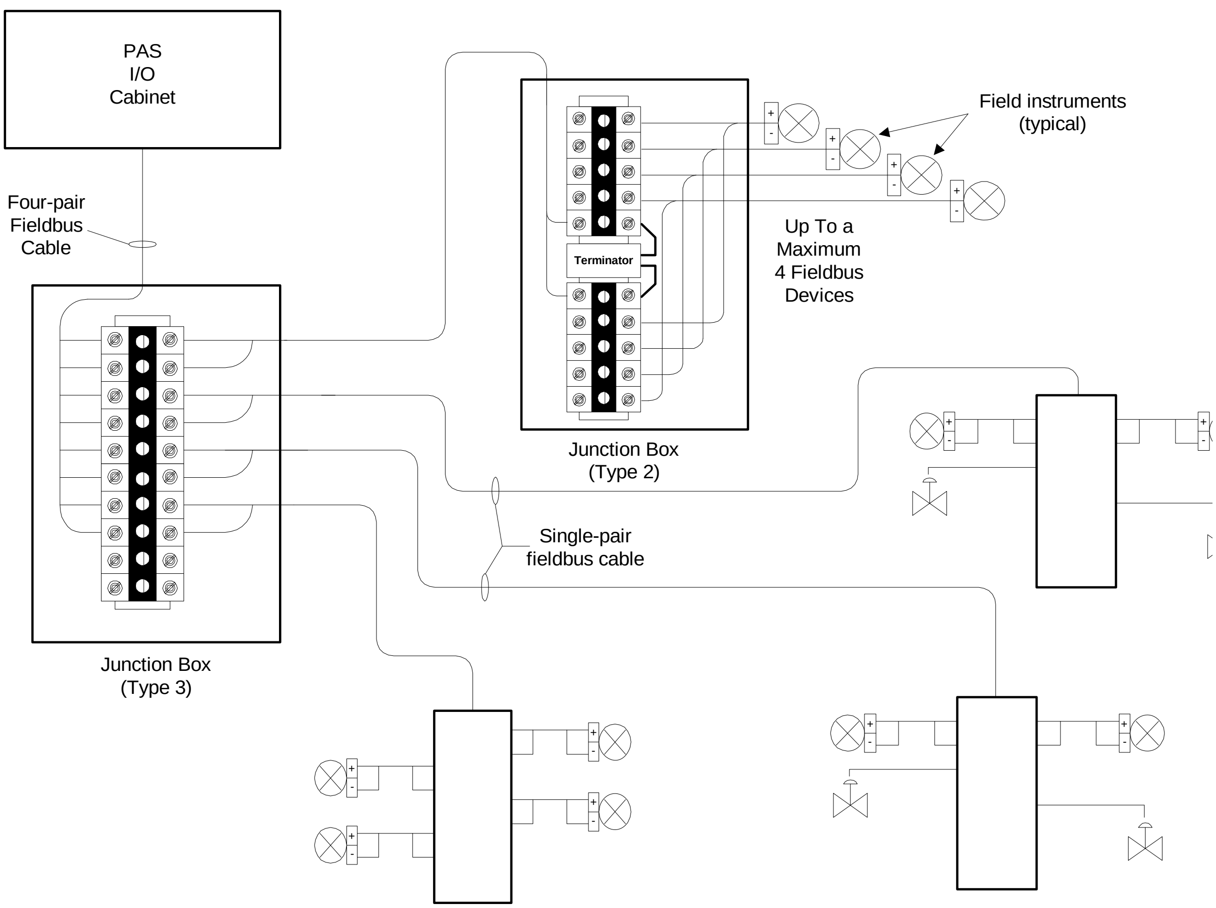
In the case of non-intrinsically safe instruments, it is recommended that the number of devices per segment be increased to sixteen to take advantage of the lower per-device wiring costs.

# Appendix A: Wiring Scenarios

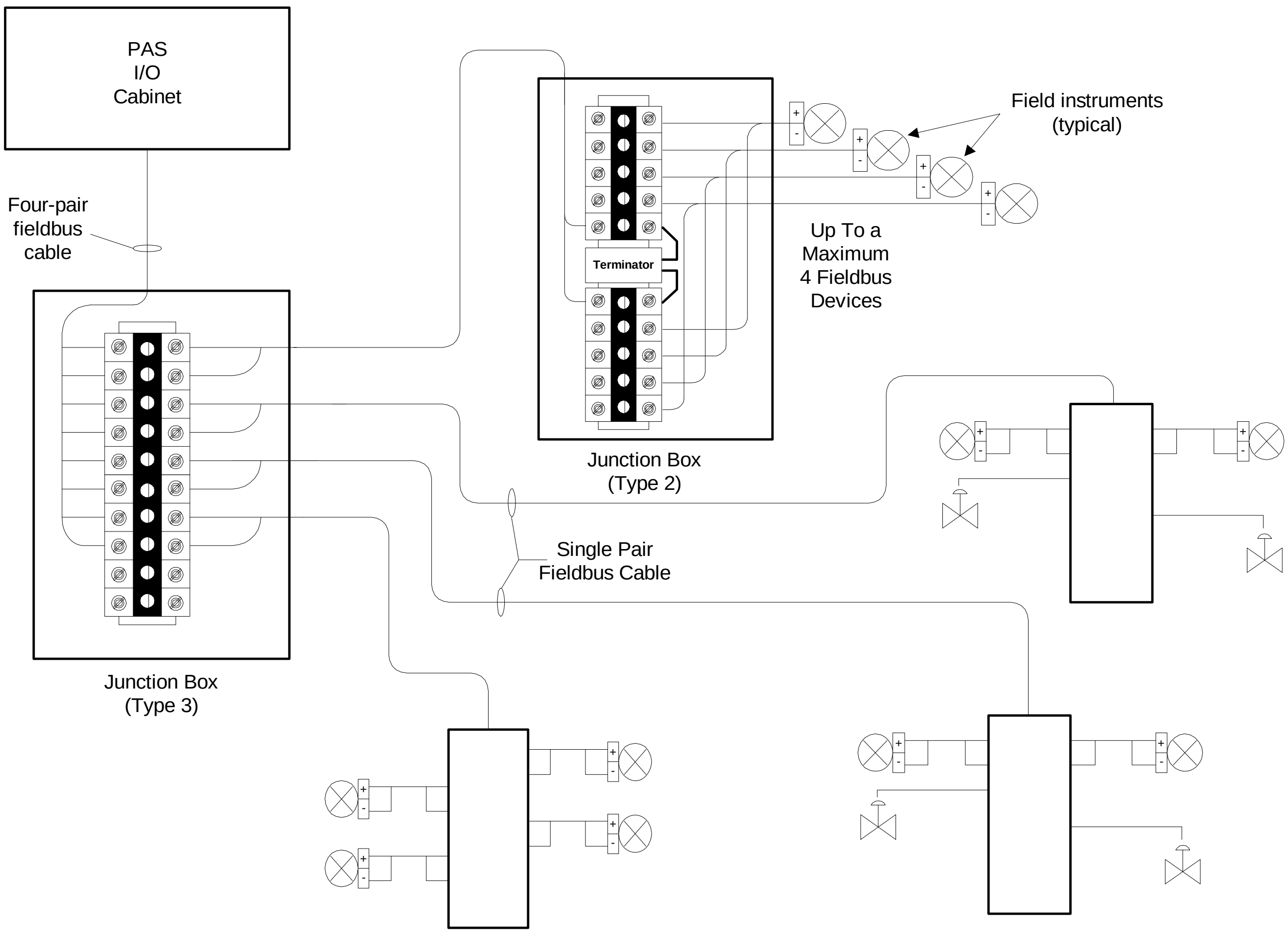
Scenario 1: Conventional Wiring for Analog and Digital Signals



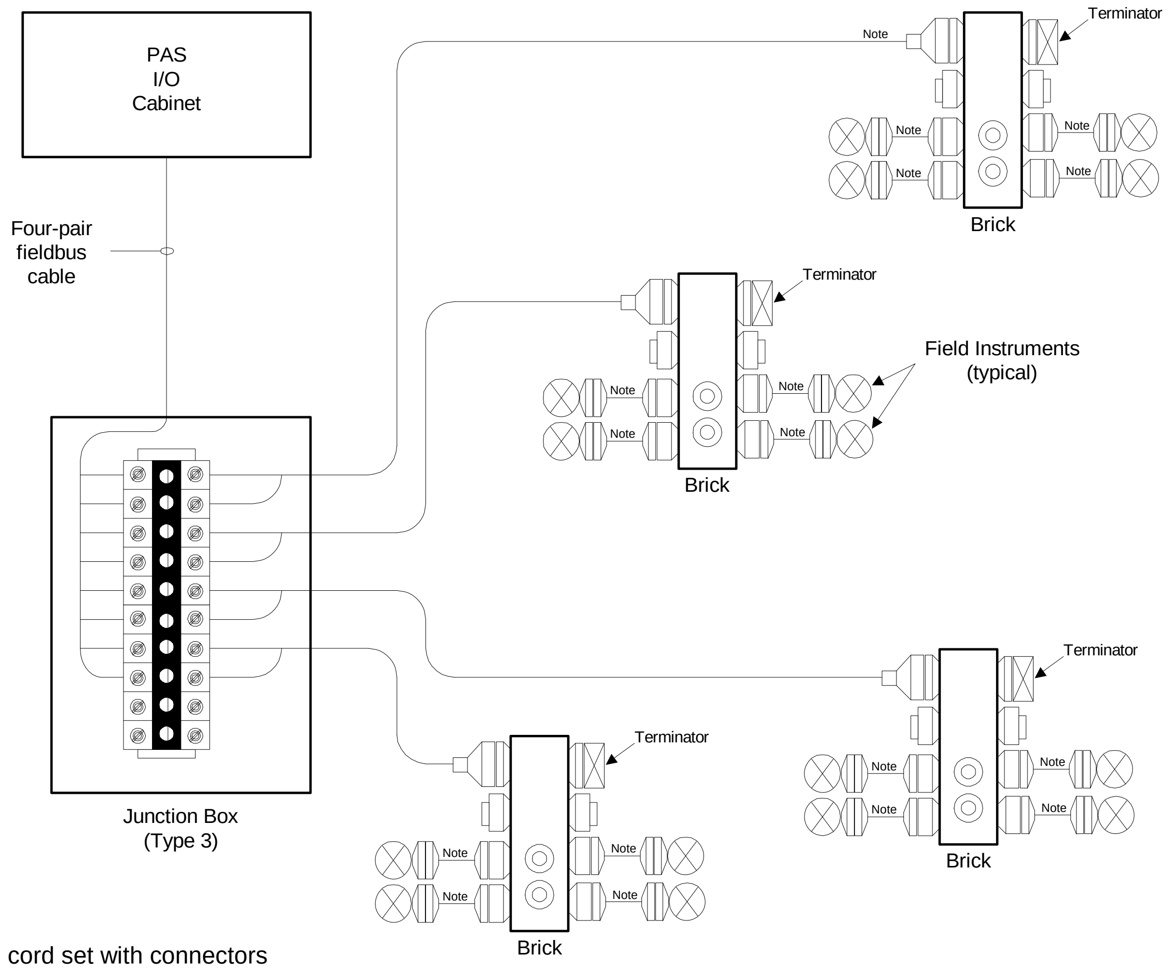
Scenario 2: Fieldbus Junction Box with Single-pair Fieldbus Homerun Cable



Scenario 3: Fieldbus Junction Boxes with Multi-pair Homerun Cable



Scenario 4: Fieldbus "Brick" with Multi-pair Homerun Cable




Note:
(1) Pre-constructed cord set with connectors

# Appendix B: Material and Labor Costs

*Wiring (Material & Labor) Cost Basis*

| Summary Wiring & Labor Cost | | | | | | |
|---|---|---|---|---|---|---|
| Instr. Wire & Cable | Qty. | Unit | Labor Cost | Material Cost | Total Cost | Total Cost/LF |
| 1-PR #16 shield CLX | 53 | LF | $ 107.00 | $ 68.00 | $ 175.00 | $ 3.30 |
| 4-PR #16 shield CLX | 102 | LF | $ 341.00 | $ 247.00 | $ 588.00 | $ 5.76 |
| 8-PR #16 shield CLX | 102 | LF | $ 694.00 | $ 370.00 | $ 1,064.00 | $ 10.43 |
| 12-PR #16 CLX | 102 | LF | $ 763.00 | $ 471.00 | $ 1,234.00 | $ 12.10 |
| 24-PR #16 CLX | 102 | LF | $ 1,559.00 | $ 794.00 | $ 2,353.00 | $ 23.07 |

The unit cost for wiring labor and material cost shown in the summary Wiring and Labor Cost table was developed from the data shown in the detailed Wiring Labor Cost estimate. The data shown in the detailed table was provided by BRES estimating.

| Detail Wiring & Labor Cost Estimate | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Labor Cost | | | | Material Cost | | Total |
| Instr. Wire & Cable | Qty. | Unit | Workhrs Unit | Workhrs Tot. | Wage Rate | Total | Unit | Total | Cost |
| 1-PR #16 Shield CLX | 52 | LF | 0.03 | 2 | 36 | 57 | 0.78 | 41 | 98 |
| 1-PR #16 Shield CLX Term. | 7 | ea. | 0.21 | 1 | 36 | 50 | 4.08 | 27 | 77 |
| 4-PR #16 Shield CLX | 102 | LF | 0.04 | 4 | 36 | 154 | 1.6 | 163 | 317 |
| 4-PR #16 Shield CLX Term. | 7 | ea. | 0.79 | 5 | 36 | 187 | 12.84 | 84 | 271 |
| 8-PR #16 Shield CLX | 102 | LF | 0.05 | 5 | 36 | 175 | 2.27 | 231 | 406 |
| 8-PR #16 Shield CLX Term. | 7 | ea. | 2.19 | 14 | 36 | 518 | 21.25 | 139 | 658 |
| 12-PR #16 CLX | 102 | LF | 0.05 | 6 | 36 | 201 | 3.19 | 324 | 525 |
| 12-PR #16 CLX Term. | 7 | ea. | 2.38 | 16 | 36 | 562 | 22.47 | 147 | 709 |
| 24-PR #16 CLX | 102 | LF | 0.12 | 12 | 36 | 436 | 5.06 | 514 | 950 |
| 24-PR #16 CLX Term. | 7 | ea. | 4.75 | 31 | 36 | 1123 | 42.72 | 280 | 1404 |

| Fieldbus Foundation Cordset for Wiring Scenario #4 * | | | | | |
|---|---|---|---|---|---|
| Instr. Wire & Cable | Qty. | Unit | Labor Cost | Material Cost | Total Cost |
| FF Cable Cordset Outdoor (w/ connectors @ both ends) | 70 | LF | $ 105.00 | $ 121.65 | $ 226.65 |
| FF Cable Cordset Outdoor (w/ connector @ one end) | 70 | LF | $ 105.00 | $ 142.65 | $ 247.65 |

* Material cost from Turck / Interlink BT

**Detail Pricing for Fieldbus Foundation Cordset - Wiring Scenario #4 ***

(1) Cable set from instrument device to bus box (brick) - connectors at both ends:

| | |
|---|---|
| cable: | 63.5 ft. * $1.10/ft. = $69.85 |
| connectors: | $51.80 |
| material total: | $121.65 |
| labor: | $1.5/ft * 70ft= $105 |
| total (70ft.): | $226.65 |

(2) Cable set from brick to junction box - connector at one end:

| | |
|---|---|
| cable: | 63.5 ft. * $1.10/ft = $69.85 |
| connectors: | $51.80 |
| receptacle: | $21.00 |
| material total: | $142.65 |
| labor: | $1.5/ft * 70 ft. = $105 |
| total (70ft.): | $247.65 |

### *Junction Box (Type 1)*

| Item | Qty. | Unit | Description | Manufacturer | Model No. | Unit Price | Net Price |
|---|---|---|---|---|---|---|---|
| 1 | 1 | ea. | 24" x 20" x 8" Enclosure, Nema 4X, 316L SS | Hoffman | A-24H2008SS6LP | $ 577.04 | $ 577.04 |
| 2 | 1 | ea. | 21" x 17" panel, 316L SS | Hoffman | A-24P20SS6 | $ 62.08 | $ 62.08 |
| 3 | 144 | ea. | Terminal blocks WDU 2.5 CUN | Weidmuller | 102500 | $ 1.40 | $ 201.60 |
| 4 | 1 | ea. | Mounting rail, TS 35 x 7.5, length 2 M, aluminum | Weidmuller | 33080 | $ 13.42 | $ 13.42 |
| 5 | 2 | ea. | End plate, WAP 2.5-10 | Weidmuller | 105000 | $ 0.36 | $ 0.72 |
| 6 | 4 | ea. | End bracket, EW 35 for TS 35 | Weidmuller | 38356 | $ 0.55 | $ 2.20 |
| 7 | 12 | ea. | Screws for mounting rail - #10-32, sheet metal, 304 SS | --- | --- | | $ - |
| 8 | 3 | ea. | Tie-rap mounting base w/#10 mounting screw | T&B | TC5356 | $ 0.65 | $ 1.95 |
| 9 | 1 | ea. | One hole compression lug | Burndy | YA4C-L | $ 1.22 | $ 1.22 |
| 10 | 1 | ea. | Combination drain and breather | Crouse-Hinds | ECD18 | $ 47.17 | $ 47.17 |
| | | | | | | **Total** | **$ 907.40** |

### *Junction Box (Type 2)*

| Item | Qty. | Unit | Description | Manufacturer | Model No. | Unit Price | Net Price |
|---|---|---|---|---|---|---|---|
| 1 | 1 | ea. | 16" x 12" x 8" Enclosure, Nema 4X, 316L SS | Hoffman | A-16H1208SS6LP | $ 415.59 | $ 415.59 |
| 2 | 1 | ea. | 13" x 9" panel, 316L SS | Hoffman | A-16P12SS6 | $ 26.99 | $ 26.99 |
| 3 | 10 | ea. | Terminal blocks WDU 2.5 CUN | Weidmuller | 102500 | $ 1.40 | $ 14.00 |
| 4 | 1 | ea. | Mounting rail, TS 35 x 7.5, length 2 M, aluminum | Weidmuller | 33080 | $ 13.42 | $ 13.42 |
| 5 | 2 | ea. | End plate, WAP 2.5-10 | Weidmuller | 105000 | $ 0.36 | $ 0.72 |
| 6 | 4 | ea. | End bracket, EW 35 for TS 35 | Weidmuller | 38356 | $ 0.55 | $ 2.20 |
| 7 | 6 | ea. | Screws for mounting rail - #10-32, sheet metal, 304 SS | --- | --- | | $ - |
| 8 | 2 | ea. | Tie-rap mounting base w/#10 mounting screw | T&B | TC5356 | $ 0.65 | $ 1.30 |
| 9 | 1 | ea. | One hole compression lug | Burndy | YA4C-L | $ 1.22 | $ 1.22 |
| 10 | 1 | ea. | Combination drain and breather | Crouse-Hinds | ECD18 | $ 47.17 | $ 47.17 |
| 12 | 1 | ea. | Fieldbus terminator | MTL | FBT1 | $ 84.00 | $ 84.00 |
| | | | | | | **Total** | **$ 606.61** |

### *Junction Box (Type 3)*

| Item | Qty. | Unit | Description | Manufacturer | Model No. | Unit Price | Net Price |
|---|---|---|---|---|---|---|---|
| 1 | 1 | ea. | 16" x 12" x 8" Enclosure, Nema 4X, 316L SS | Hoffman | A-16H1208SS6LP | $ 415.59 | $ 415.59 |
| 2 | 1 | ea. | 13" x 9" panel, 316L SS | Hoffman | A-16P12SS6 | $ 26.99 | $ 26.99 |
| 3 | 10 | ea. | Terminal blocks WDU 2.5 CUN | Weidmuller | 102500 | $ 1.40 | $ 14.00 |
| 4 | 1 | ea. | Mounting rail, TS 35 x 7.5, length 2 M, aluminum | Weidmuller | 33080 | $ 13.42 | $ 13.42 |
| 5 | 2 | ea. | End plate, WAP 2.5-10 | Weidmuller | 105000 | $ 0.36 | $ 0.72 |
| 6 | 4 | ea. | End bracket, EW 35 for TS 35 | Weidmuller | 38356 | $ 0.55 | $ 2.20 |
| 7 | 6 | ea. | Screws for mounting rail - #10-32, sheet metal, 304 SS | --- | --- | | $ - |
| 8 | 2 | ea. | Tie-rap mounting base w/#10 mounting screw | T&B | TC5356 | $ 0.65 | $ 1.30 |
| 9 | 1 | ea. | One hole compression lug | Burndy | YA4C-L | $ 1.22 | $ 1.22 |
| 10 | 1 | ea. | Combination drain and breather | Crouse-Hinds | ECD18 | $ 47.17 | $ 47.17 |
| | | | | | | **Total** | **$ 522.61** |

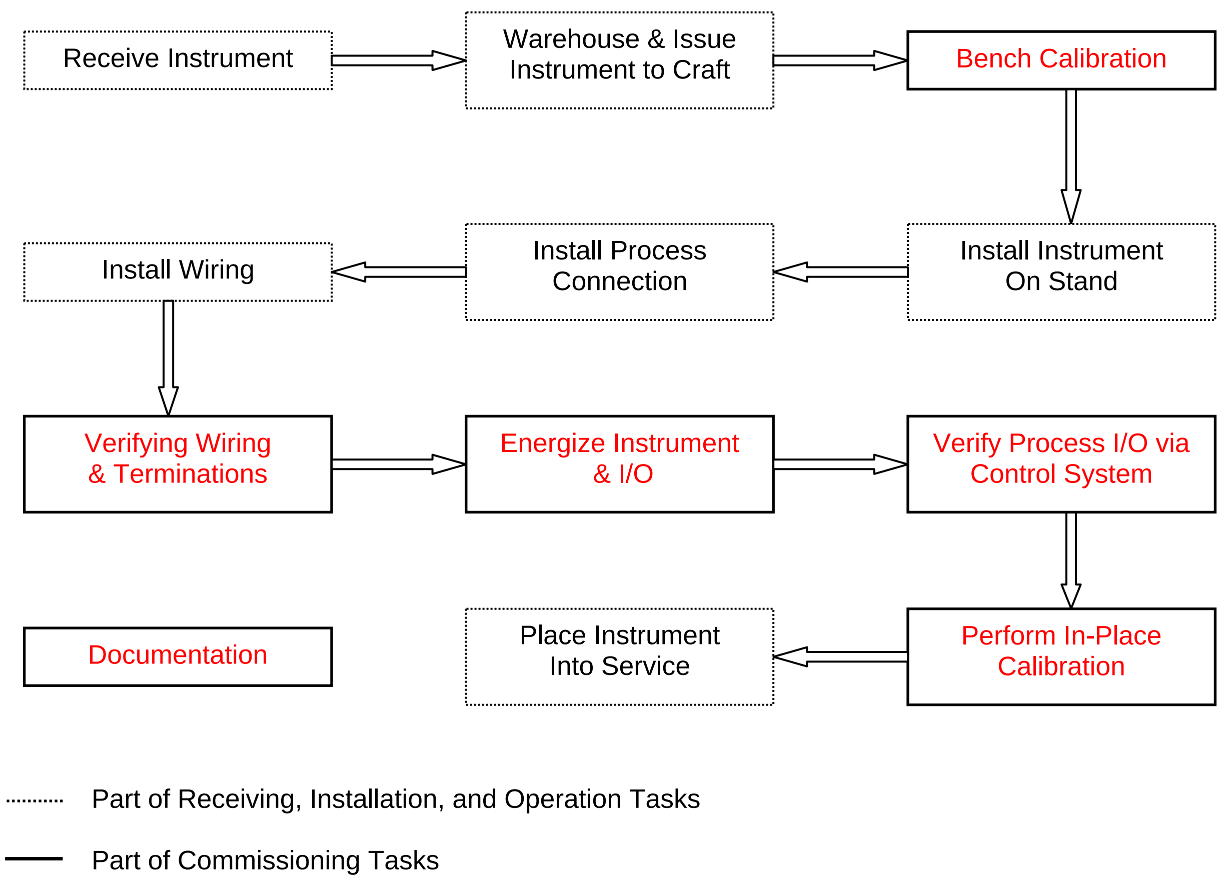
### *InterlinkBT/Turck Bus Module "Brick"*

| Item | Qty. | Unit | Description | Manufacturer | Model No. | Unit Price | Net Price |
|---|---|---|---|---|---|---|---|
| 1 | 1 | ea. | FF Junction Box, 6 MiniFast Spurs, GND stud, SS | Turck | JBBS-49-M613 | $ 258.00 | $ 258.00 |
| 1 | 1 | ea. | FF MiniFast Terminator, SS | Turck | RSM 49 TR | $ 24.50 | $ 24.50 |
| | | | | | | **Total** | **$ 282.50** |

# Appendix C: Commissioning Instrument Costs

## LOOP COMMISSIONING ACTIVITIES

## Conventional Instrument Receiving, Installation, and Commissioning Process



## Commissioning Tasks Identifications

***Bench Calibration***

Calibration of instrument on test stand to verify that the device operates properly before physical installation.

***Verify Field Wiring***

Visual inspection of wiring to verify that wiring and terminations are installed properly and as shown on drawings.

***Energize Instrument and I/O***

Apply power to instrument.

***Verify Proper I/O via Control System***

Verify that control system I/O responds directly to changes applied to instrument (five-point check). Verify that values are displayed properly on control system graphics.

***Perform In-place Calibration***

Perform final calibration of instrument using installed manifolds and process connections.

***Documentation***

Document the steps above, along with wiring drawings and instrument data sheets.

## Commissioning Work Hours Allotted for Conventional versus Fieldbus Devices

| | Conventional Analog Device | Fieldbus Device |
|---|---|---|
| Bench Calibration | 30 minutes | - - - |
| Verify Field Wiring | 30 minutes | 15 minutes |
| Energize Instrument I/O | 30 minutes | 5 minutes |
| Verify Proper I/O via Control System | 30 minutes | 5 minutes |
| Perform In-Place Calibration | 60 minutes | 15 minutes |
| Documentation | 120 minutes | 30 minutes |
| **Total Work Time per Device** | **300 minutes (5 hours)** | **70 minutes (1 hour & 10 minutes)** |

***Perform In-place Calibration***

Perform final calibration of instrument using installed manifolds and process connections.

***Documentation***

Document the steps above, along with wiring drawings and instrument data sheets.

## Commissioning Work Hours Allotted for Conventional versus Fieldbus Devices

| | Conventional Analog Device | Fieldbus Device |
|---|---|---|
| Bench Calibration | 30 minutes | - - - |
| Verify Field Wiring | 30 minutes | 15 minutes |
| Energize Instrument I/O | 30 minutes | 5 minutes |
| Verify Proper I/O via Control System | 30 minutes | 5 minutes |
| Perform In-Place Calibration | 60 minutes | 15 minutes |
| Documentation | 120 minutes | 30 minutes |
| **Total Work Hours per Device** | **300 minutes (5 hours)** | **70 minutes (1 hour & 10 minutes)** |

## Appendix D: Wiring Scenario Cost Estimate Spreadsheets

Contains four cost estimate spreadsheets dated 11-26-97:

Scenario 1: Conventional Signal Wiring

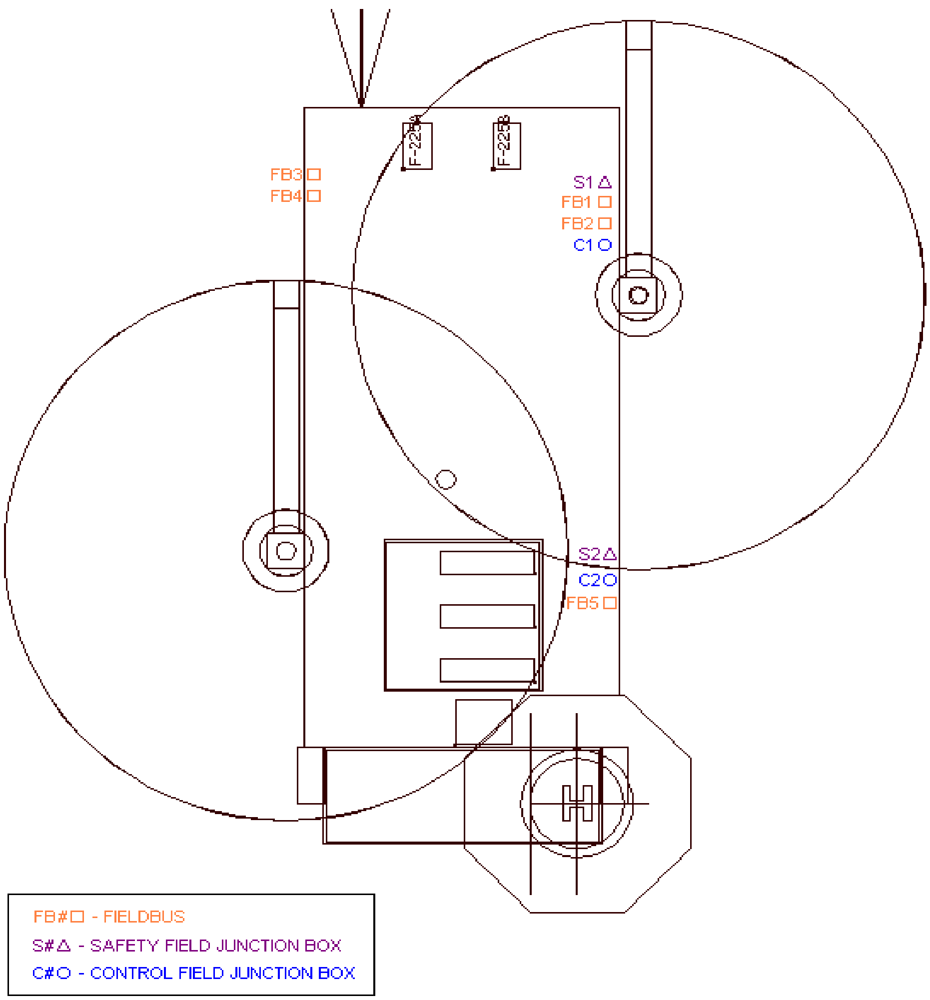
Scenario 2: Fieldbus Wiring with Single-Pair Homerun Cable

Scenario 3: Fieldbus Wiring with Multi-Pair Homerun Cable

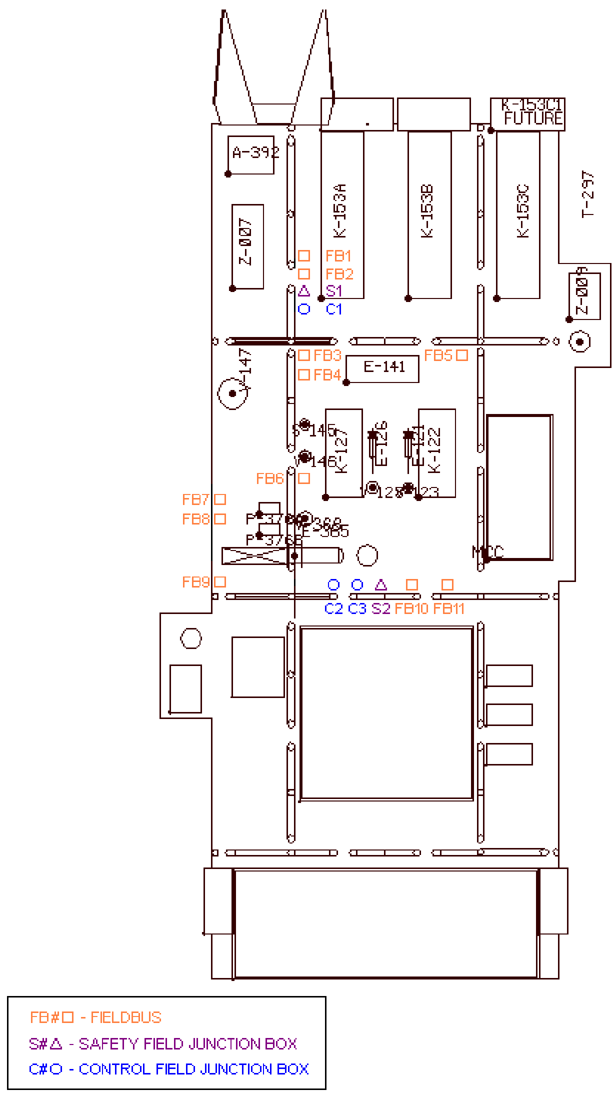
Scenario 4: Fieldbus Wiring Using InterlinkBT Fieldbus Modules and Multi-Pair Homerun Cable
http://www.easydeltav.com/repository/whitepapers/Appendix_D_Scenarios.xls

# Appendix E: Junction Box Location Plans

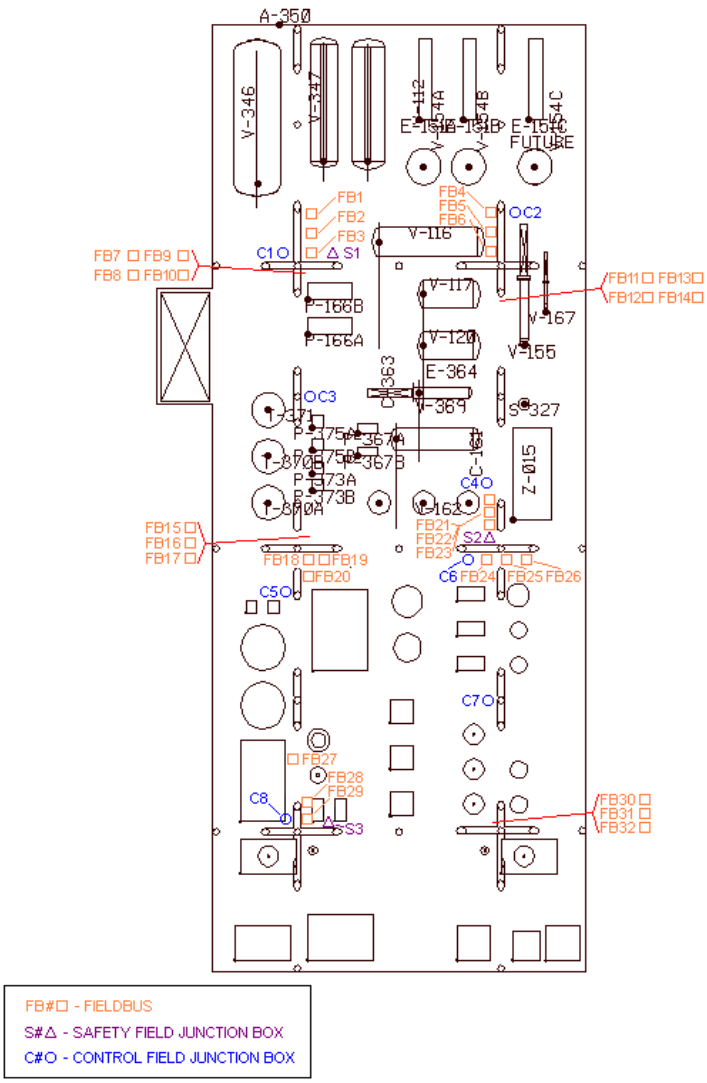
## Weather Deck



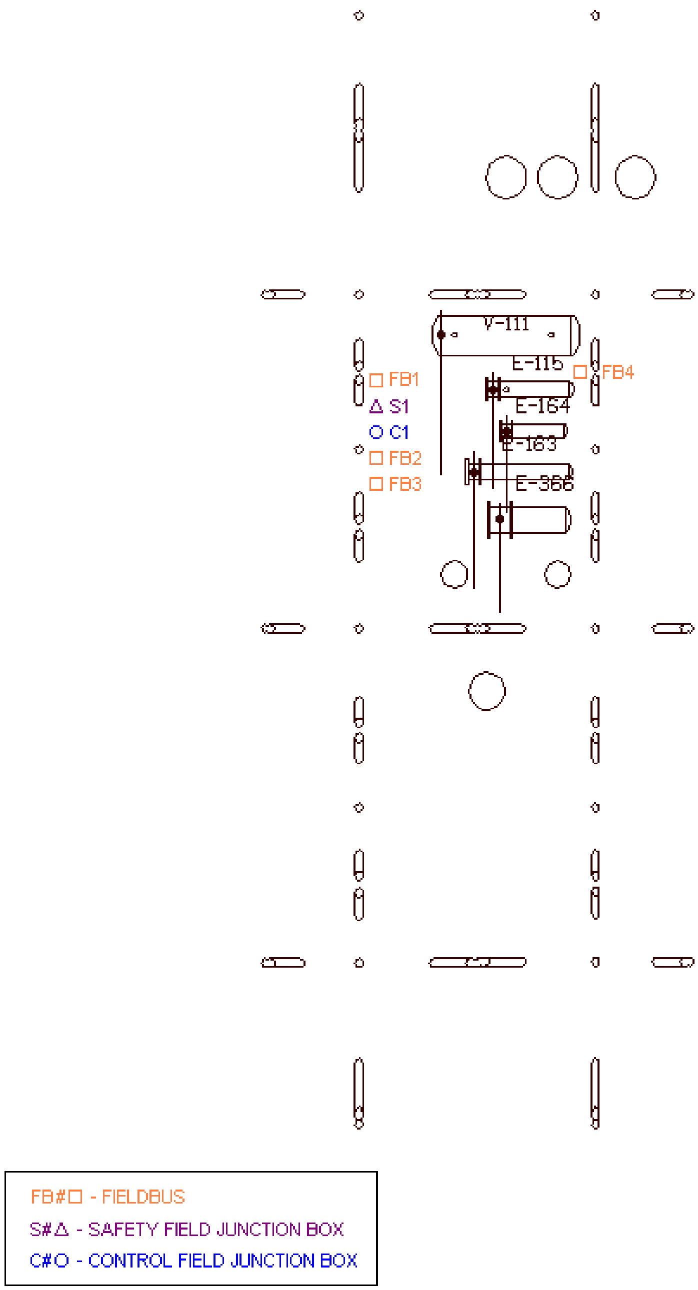
## Production Deck



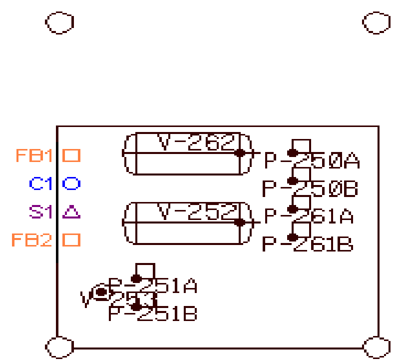
## Mezzanine Lower Deck



## Mezzanine Upper Deck


V-111
E-115
E-164
E-163
E-366
FB1
S1
C1
FB2
FB3
FB4
FB#☐ - FIELDBUS
S#△ - SAFETY FIELD JUNCTION BOX
C#○ - CONTROL FIELD JUNCTION BOX

## Cellar Deck




FB# ☐ - FIELDBUS
S# △ - SAFETY FIELD JUNCTION BOX
C# ○ - CONTROL FIELD JUNCTION BOX

## Appendix F: Wiring Scenario Cost Breakdown

The following contains information concerning the cost per device breakdown of each respective scenario. The breakdown includes graphs and a spreadsheet demonstrating both the wiring and junction box costs.

http://www.easydeltav.com/repository/whitepapers/Appendix_F_Wiring_Scenario_Cost_Bdown.xls

## Appendix G: Non-Intrinsically Safe Wiring Scenario Cost Estimate

### Non-Intrinsically Safe Wiring Scenario

**Basis of Comparison**:

Non-intrinsically safe wiring: using 16 devices per segment, vs. 4 devices per segment used in Scenario 2.

Average homerun cable length from Scenario 2 is 280 feet.

Junction box cost for non-intrinsically safe wire is $643.01

Junction box (type 2) cost = $606.61

Addition terminal blocks = $ 36.40

**Price per Device Calculation**

Field wiring = (70 ft.) x (16 devices) = 1120 feet

Material & labor rate = $3.30/ft.

Total field wiring cost = $3696.00

Junction box cost = $643.01

Homerun wiring = (280 ft.) x (1 homerun cable) = 280 feet

Material & labor rate = $3.30/ft.

Total homerun wiring cost = $924.00

Commissioning cost = ($42.00/device) x (16 devices) = $672.00

Total installation & commissioning cost for 16 devices = $5935.01

Total installation & commissioning cost per device = $370.94