Welcome to

Energy Production Systems Engineering

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UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC

Session 8: Electrical Systems & Instrumentation

Spring 2012

Session 8: Electrical Systems & Instrumentation

- **Electrical Systems**
- **Instrumentation**

Electrical Systems

Electrical Systems

Busway Applications:
Busway is electric conductor system the uses rigid bars or tubes of CU or AL supported and enclosed in metal housing (may or may not be insulated bus)

Feeder Busway - Used to transmit large amounts of power

Plug-in Busway – Used to make changeable load connections

Electrical Systems

Standards –
IEEE C37.23 IEEE Standard for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus
NEC article 64B
IEEE 141 IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book),

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Electrical Systems

Three types –
Nonsegregated phase bus duct

Segregated phase bus duct

Isolated phase bus duct

Reliability vs. cost

Electrical Systems

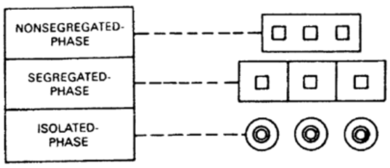

FIGURE 4.6.1 Types of MV busway.

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Segregated phase bus duct

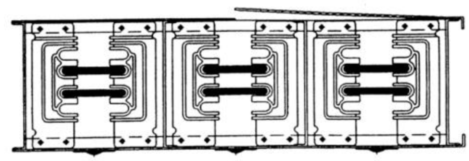

FIGURE 4.6.2 Segregated-phase busway cross section.

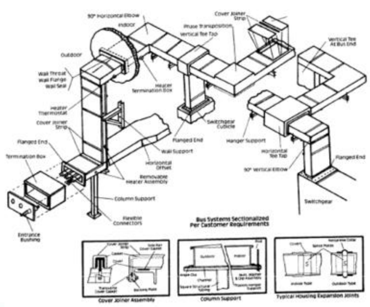

FIGURE 4.6.3 Typical MV busway routing and details.

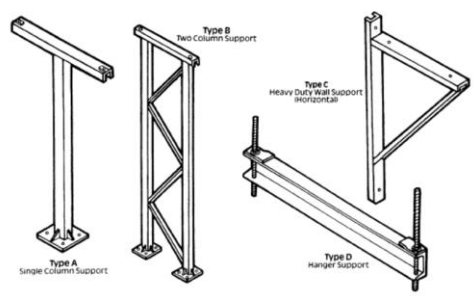

FIGURE 4.6.4 Typical busway supports. (*Courtesy of Unibus, Inc.*)

Electrical Systems

Flexible joints every 50ft – supports every 5 feet

Barriers around generators to seal hydrogen (or purge)

Fire barriers / vapor seals / space heaters

Ratings of 1200A, 2000A, 3000A, 4000A, and 5000A

Short ckt withstand ratings & voltage ratings

Electrical Systems

Segregated phase bus duct testing

TABLE 4.6.1 Segregated- and Nonsegregated-Phase Bus Rated Short-Circuit Withstand Current (kA Asymmetric) 167-ms Duration

Nominal voltage, kV	Nonsegregated	Segregated
0.635 ac and all dc	75; 100; 150	—
4.76	39; 58; 78	—
13.8	37; 58; 77	—
14.4	—	60; 80; 100
23.0	32; 56; 64	60; 80; 100
34.5	32; 56; 64	60; 80; 100

Note: The power factor of the test circuit shall be 4 to 5 percent lagging (X/R ratio of 25 to 6.6) with X and R in series connection.

Electrical Systems

TABLE 4.6.2 Bus Voltage Ratings

Maximum operating voltage, kV rms	Insulation level, kV: Rated frequency withstand, rms — Dry (1 min)	Insulation level, kV: Rated frequency withstand, rms — Dew (10 s)	DC withstand dry	Impulse withstand
Nonsegregated phase				
0.635	2.2	—	3.1	—
4.760	19.0	15.0	27.0	60
15.000	36.0	24.0	50.0	95
25.800	60.0	40.0	85.0	125
38.000	80.0	70.0	—	150
Segregated phase				
15.5	50	30	70	110
25.8	60	40	85	125
38.0	80	70	—	150

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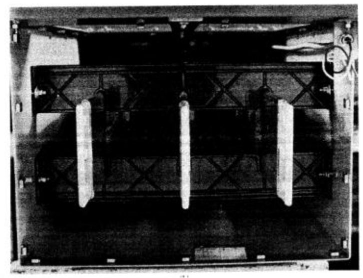

Non segregated phase bus duct

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Cable Application -

The selection of conductor size requires consideration of;
- load current
- loading cycle
- emergency overloading
- fault clearing time
- voltage drop
- routing
- ambient temperatures

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Copper vs. Aluminum

Aluminum requires larger conductor sizes to carry the same current as copper.
For equivalent ampacity, aluminum cable is lighter in weight and larger in diameter than copper cable.
Coefficient of thermal expansion of AL 36% > CU
NEC - #8 AWG and larger stranded conductor

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Insulation –
Thermosetting compounds
Thermoplastic compounds
Paper-laminated tapes
Varnished cloth, laminated tapes
Mineral insulation

Tapes long history, but susceptible to moisture intrusion – replaced by thermosetting / thermoplastic compounds

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Comparison of thermosetting vs. thermoplastic insulation

Common name	Properties of insulation: Electrical	Properties of insulation: Physical
Thermosetting		
Cross-linked polyethylene	Excellent	Excellent
EPR	Excellent	Excellent
Butyl	Excellent	Good
SBR	Excellent	Good
Oil base	Excellent	Good
Silicone	Good	Good
TFE*	Excellent	Good
ETFE†	Excellent	Excellent
Neoprene	Fair	Good
Class CP rubber‡	Good	Good
Thermoplastic		
Polyethylene	Excellent	Good
Polyvinyl chloride	Good	Good
Nylon	Fair	Excellent

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Thermoplastic soften to a liquid state with increasing temperature and return to their solid state unchanged on cooling
Thermoset retains dimensions with increasing temperature to decomposition temperature

Electrical Systems

Insulation hardness vs. temperature

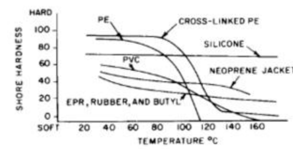

Figure 12-2—Typical values for hardness versus temperature

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NEC Classifications -

EPR or XLPE insulated, with or without a jacket
Type RHW for 75 C max temp in wet or dry locations
Type RHH for 90 C max temp in dry locations only
Type RHW-2 for 90 C max temp in wet and dry locations.

XLPE or EPR insulated, without jacket
Type XHHW for 75 C max temp in wet locations and 90 C in dry locations only
Type XHHW-2 for 90 C max temp in wet and dry locations.
(above restricted to conduit)

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NEC Classifications -

PVC insulated, nylon jacketed
Type THWN for 75 C max temp in wet or dry locations
Type THHN for 90 C in dry locations only

PVC insulated, without jacket
Type THW for 75 C max temp in wet or dry locations.
(above restricted to conduit)

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NEC Classifications -

Metal-clad cable, Type MC
Cable using metallic sheath or tape armor. Usually Type XHHW, XHHW-2, RHH/RHW, or RHW-2.

Type MC cable may be installed in any raceway, in cable tray, as open runs of cable, direct buried, or as aerial cable on a messenger.

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NEC Classifications -

Power and control tray cable, Type TC
Cable with flame-retardant nonmetallic jacket.

Type TC may be installed in cable trays, raceways, or where supported in outdoor locations by a messenger wire.

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NEC Classifications -

PVC insulated, nylon jacketed
Type THWN for 75 C max temp in wet or dry locations
Type THHN for 90 C in dry locations only

PVC insulated, without jacket
Type THW for 75 C max temp in wet or dry locations.
(above restricted to conduit and tray)

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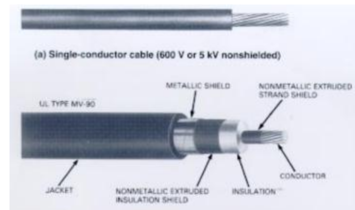
Cable Construction



(a) Single-conductor cable (600 V or 5 kV nonshielded)
(b) Type MV medium-voltage single-conductor cable (5–35 kV)

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Cable Construction


(c) Type TC power and control tray cable (600 V)
(d) Type MC metal-clad power and control cable (600 V–35 kV)

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Protection of insulation – Jacket or sheath
Typical
Polyvinyl chloride
Polychloroprene (Neoprene)
Chlorosulfonated polyethylene (Hypalon)

Neoprene avoid contact with creosote treated material – softens jacket

Table 12-4—Properties of jackets and braids

Material	Abrasion resistance	Flexibility	Low temperature	Heat resistance	Fire resistance
Neoprene	Good	Good	Good	Good	Good
Class CP rubber*	Good	Good	Fair	Excellent	Good
Cross-linked polyethylene	Good	Poor	Poor	Excellent	Poor
Polyvinyl chloride	Fair	Good	Fair	Good	Fair
Polyurethane	Excellent	Good	Good	Good	Poor
Glass braid	Fair	Good	Good	Excellent	Excellent
Nylon	Excellent	Fair	Good	Good	Fair
ETFE	Excellent	Poor	Excellent	Good	Fair

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Wiring methods
Conduit – best known – higher possibility of cable damage during pulling – verify maximum pull tensions and jam ratios for installation
IMC (intermediate metal conduit) – ½ thickness wall
EMT (electric metallic tubing) – thinner walls

Not recommended for power plant use.

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Cable tray – maximum tray fill defined by NEC
Supported every 10-20 feet
When approved for use, can use as equipment grounding.
Better than single ground conductor.
Fault conditions, without grounded tray, cable tends to jump out.
Grounded tray reduced fault force on phase cable

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Table 12-7—Wiring methods for hazardous locations

Wiring method	Class I division 1	Class I division 2	Class II division 1	Class II division 2	Class III division 1 or 2
Threaded rigid metal conduit	X	X	X	X	X
Threaded steel intermediate metal conduit	X	X	X	X	X
Rigid metal conduit				X	X
Intermediate metal conduit				X	X
Electrical metallic tubing				X	X
Rigid nonmetallic conduit					X
Type MI mineral insulated cable	X	X	X	X	X
Type MC metal-clad cable		X		X	X
Type SNM shielded nonmetallic cable		X		X	X

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Table 12-7—Wiring methods for hazardous locations

Wiring method	Class I division 1	Class I division 2	Class II division 1	Class II division 2	Class III division 1 or 2
Type MV medium-voltage cable		X			
Type TC power and control tray cable		X			
Type PLTC power-limited tray cable		X			
Enclosed gasketed busways or wireways		X			
Dust-tight wireways				X	X

Source: Based on the NEC.

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Underground cables operated < 69C regardless of insulation rating – soil dryout – thermal runaway.

Ampacity – NEC tables or IEEE S-135 tables

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Cable applications above 2KV must use shielded cable (exception in NEC for up to 8KV removed in 2005)

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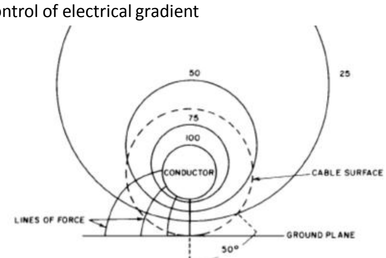
Control of electrical gradient



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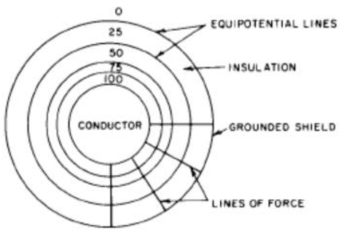
Control of electrical gradient



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Terminations –
600v strip and either mechanical lug or compression lug (compression preferred)

MV termination kits
Three classes
Class 1: Seals factory cable from pressure, moisture, and contamination and provide stress control
Class 2: Similar to class 1, but no pressure seal
Class 3: Provides only stress control and only for clean dry location

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Cable Splicing

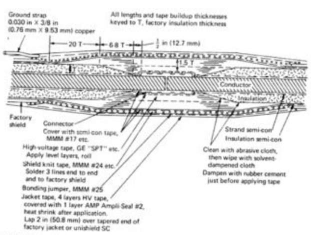

FIGURE 4.7.1 Straight splice, solid dielectric cable.

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Cable Termination Kit

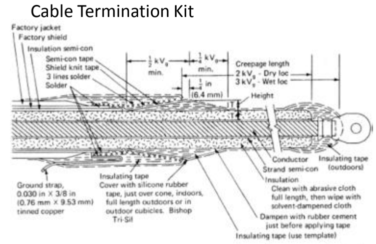

FIGURE 4.7.2 Taped termination, solid dielectric cable. Note: $\frac{1}{4}$ kV$_g$, $\frac{1}{2}$ kV$_g$, 2 kV$_g$, and 3 kV$_g$ = $\frac{1}{4}$ in (6.4 mm), $\frac{1}{2}$ in (12.7 mm), 2 in (50.8 mm), and 3 in (76.2 mm) per kilovolt to cable ground, respectively.

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Class 2 termination

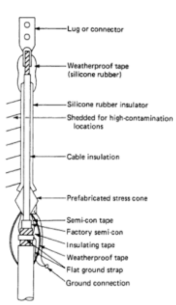

FIGURE 4.7.3 Class 2 terminator.

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Class 3 termination

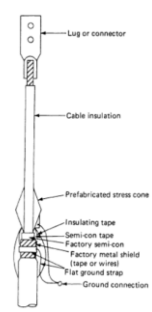

FIGURE 4.7.4 Class 3 terminator.

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Bend radius

TABLE 4.7.3 Minimum Bending Radius Times the Outside Diameter of Unshielded Cable

Insulation thickness, in*	Outside diameter, in 1.00−	1.001–2	2.001+
0–0.155	4	5	6
0.170–0.310	5	6	7†
0.325 or more	—	7†	8†

*In × 25.4 = mm.
†Armored.

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Information from IEEE 1185 – Recommended Practices for Cable Installation at Generating Stations

To determine the max pulling length, must determine the max allowable pull tension and sidewall pressure.

Maintain Minimum bend radius (may be larger to minimize side wall pressure)

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Bend radius

Table 1 – Minimum trained bend radius for non-shielded or non-armored cable

Non-Shielded, Non-Armored Cable	Minimum Cable Bend Radius = Multiplier × OD of Cable		
	OD of Cable in inches (mm)		
Thickness of Insulation [mils (mm)]	Less than 1in (25.4 mm)	1in to 2in (25.5 to 51 mm)	Above 2in (Over 51 mm)
155 mils (3.9 mm) or smaller	4	5	6
157 mils (4.0 mm) to 310 mils (12.2 mm)	5	6	7
Over 310 mils (12.2 mm)	-	7	8

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Bend radius

Table 2 – Minimum trained bend radius for shielded or armored cable

Shielded or Armored Power & Control Cable	Minimum Cable Bend Radius = Multiplier × OD of Cable
Type of Shield or Armor	Multiplier
Tape Shield	12
Wire Shield	8
Interlocked Armor	7
Corrugated, Welded Armor	12
Smooth Welded Armor	10 to 15
Extruded Aluminum Armor	10 to 15

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Max allowable pull tension – conductor pull

Pull tension based on pulling by conductor such as with pulling eye:

$$T_{max} = K \times n \times A_c \qquad (1)$$

Where:

T_{max} = maximum pulling tension in lbf (N)
A_c = conductor area in circular mils (square mm)
n = number of conductors
K = 0.008 lbf/cmil (70.27 N/mm^2) for soft annealed copper
K = 0.006 lbf/cmil (52.71 N/mm^2) for 3/4 hard aluminum (alloy 1350-H16)

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Installation –
Pull on both conductor & jacket
Pull from the longest straightest section
Pull Tension Calculation:

For straight length pull tension is

T = W * 0.5 where
T = Tension required for straight length, lb
W = weight of cable total, lb
(W = Weight of cable (lb/ft) * Length of section (ft))
0.5 = estimate of friction coefficient (with lube)

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Example 16: for a straight pull of 100', pulling a cable weighing 2 lb/ft, what is the pulling tension?

T = (2 lb/ft) * (100ft) * 0.5

T = 100 lb

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For curves, the pull tension is

Tc = T1 * exp (0.5 * a) where

Tc = Tension required for curve bend, lb
T1 = Tension at entering end of bend or curve, lb
exp = 2.72
A= angle of bend, rad (degree / 57.3)
0.5 = estimate of friction coefficient (with lube)

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Example 17: What is the pull tension for a cable pull through a 90 degree bend where the tension at the bend inlet is 100 lb

Tc = 100lb * exp (0.5 * (90/57.3))

Tc = 219 lb

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Jam Ratio Calculation:

JR = ID conduit / OD cable

JR > 3 recommended. Avoid 2.8 < JR < 3.0

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Use of Cable Pulling Charts

$$SAF = \frac{\sin\theta + K'\cos\theta}{K'}$$

Where:

SAF = the slope adjustment factor, used in Table 3

θ = the angle (in degrees) of the slope from horizontal

K' = the effective coefficient of friction

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"Effective" conduit length determination

Table 3 – Development of "effective" conduit length—chart comparison

Type of conduit section	"Effective" conduit length
Horizontal conduit	As measured
Conduit sweep	Need not be included
Vertical conduit—Up	As measured multiplied by: 2 for $K' = 0.5$ and 2.9 for $K' = 0.3$
Vertical conduit—Down	Not included; $L = 0$
Slope—Down	As measured
Slope—Up	As measured multiplied by SAF from Equation (13) or Table 4

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Table of Slope Adjustment Factor (SAF)

Table 4 – Slope adjustment factor (SAF)

Slope angle (°)	"Effective" coefficient of friction (K')	
	0.5	0.3
15	1.5	1.7
30	1.9	2.3
45	2.1	2.7
60	2.2	2.9
90	2.0	3.3

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Example:
Control cables are being pulled into 3" trade size conduit (See Figure B.1). Side wall bearing pressure (SWBP) of cable is 500 lbf/ft and coefficient of friction is not known but assumed to be no greater than 0.5. What is;

a. Total effective conduit length?
b. Total degrees of bend?
c. Maximum allowable effective conduit length for cable specified?
d. What is maximum pulling tension for application?

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Conduit routing;
Effective length
25'
Total degrees turns
270 degrees:

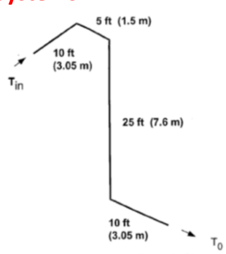

Figure B.1 – Isometric of conduit layout – Example #1

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Conduit routing;
Effective length
25'
Total degrees turns
270 degrees:

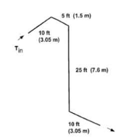

Figure B.1 – Isometric of conduit layout – Example #1

Table B.1 – Effective conduit length and degrees of bend—Example #1

Section type	Angle (°)	Measured conduit length, ft (m)	Effective conduit length, ft (m)
Straight horizontal		10 (3.05)	10 (3.05)
Horizontal bend	90		
Straight horizontal		5 (1.5)	5 (1.5)
Bend down	90		
Vertical down		25 (7.6)	0
Bend down	90		
Straight horizontal		10 (3.05)	10 (3.05)
End of pull (totals)	270		25 (7.6)

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For 3" conduit, 270 degree turn, max allowable effective length is 28' (max pulling tension of 478 lbf).

Table A1a – Conduit-cable pulling chart for control cable
SWBP = 500 lbf/ft and K' = 0.5

Conduit Trade Size	Maximum effective conduit length (ft) — Total degrees of conduit bend						Maximum allowable pulling tension (lbf)
	45°	90°	180°	270°	315°	360°	
¾	935	631	288	131	89	60	66
1	754	509	232	106	71	48	132
1 ½	483	326	149	68	46	31	310
2	327	221	101	46	31	21	353
2 ½	251	169	77	35	24	16	386
3	200	135	62	28	19	13	478
3 ½	173	117	53	24	16	11	551
4	142	96	44	20	13	9	583
5	138	93	43	19	13	9	895
6	120	81	37	17	11	8	1124
Minimum one single conductor 14 AWG or one multiple conductor 14 AWG conductor size.							

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Example:
Same application, but pull from other direction. Control cables are being pulled into 3" trade size conduit (See Figure B.1). Side wall bearing pressure (SWBP) of cable is 500 lbf/ft and coefficient of friction is not known but assumed to be no greater than 0.5. What is;

a. Total effective conduit length?
b. Total degrees of bend?
c. Maximum allowable effective conduit length for cable specified?
d. Does pull end selection make difference?

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Section Type	Angle (degree)	Measured Conduit Length, Ft	Effective conduit length, FT
Straight Horizontal		10	10
Bend up	90		
Vertical Up		25	50
Bend Down	90		
Straight Horizontal		5	5
Horizontal Bend	90		
Straight Horizontal		10	10
End of Pull Total	270	50	75

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Conduit routing;
Effective length
75'
Total degrees turns
270 degrees:

Pull from and two makes difference!!!

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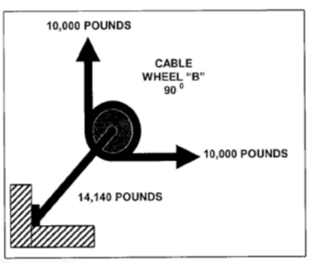
Statics – Sum of forces on object must sum to zero



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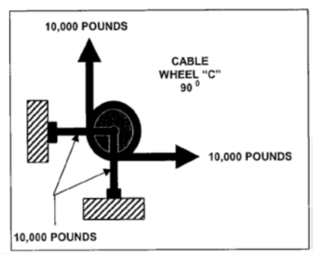
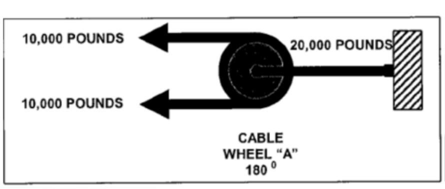
Statics – Sum of forces on object must sum to zero



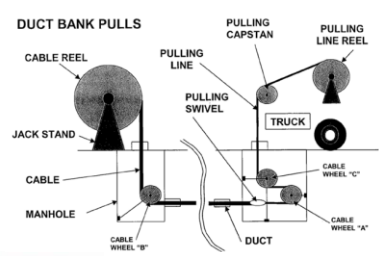
Electrical Systems

Statics – Sum of forces on object must sum to zero



Electrical Systems

Typical Equipment used in cable pulls



Electrical Systems

Fundamental Electrical Calculations:
Wye – Delta Transformation
Base value Calculations
n*p=120*f
slip=(n_s-n_{fl})*(100%)/n_s
Torque=V/f
PF=Preal(KW)/Ptotal(KVA)
KVARcorr=KW*mult
5250*P(HP)=Torque(lb ft)*speed (RPM)
Tc = Tin * 0.5 (straight pull, K=0.5)
Tc = Tin * exp (0.5 * a) (bend pull, K-0.5, a=radians angle)
Sum of forces on object must sum to zero

End of Electrical Systems

Instrumentation Systems

Instrumentation

Instrumentation function; monitor / control

Pressure
Temperature
Flow
Level

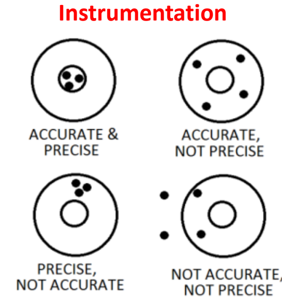
Vibration, O2, CO, NO, Opacity, PH, Conductivity

Instrumentation

Instrumentation is the use of devices for the measurement, detection, observation, computation, communication, or control of systems.

Precision & Accuracy –
Precision is the range of values of a set of measurements.
Accuracy is a statement of the limits that bound the departure of a measured value from the true quantity.

Instrumentation



Instrumentation

Temperature:
Thermometers – Bimetallic
Range: -200oF to +1000oF
Sensitivity: max of 3oF
Accuracy: 1%
Materials: 8-18 Stainless Steel
Limitations: local indication, shock change calibration,

Instrumentation

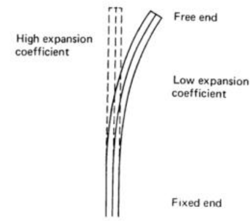


FIGURE 5.1.1 Bimetallic element bends on temperature increase. (*Courtesy J. A. Moore.*)

Instrumentation

Temperature:
Thermocouples
Dissimilar metals form current source
Function of temperature
Bare wire – Pencil
Thermowell – protect T/C from environment
Transducer – convert signal to usable level for I/O
High temp applications.

Instrumentation

Extension connection

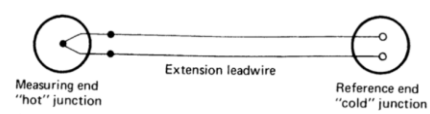


FIGURE 5.1.2 Thermocouple circuit, with extended reference junction. (*Courtesy J. A. Moore.*)

Instrumentation

Series Connection – (T1 – T2)

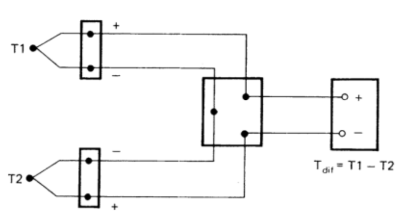


FIGURE 5.1.3 Thermocouple connected in series opposition to produce temperature-difference measurement. (*Courtesy J. A. Moore.*)

Instrumentation

Thermocouple Materials

TABLE 5.1.1. Thermocouple Materials

Material	Type	Temp. range, °F (°C)	Approx. millivolt change over 1000°F (540°C)
Copper-constantan	T	−300–700 (−185–370)	27.3
Iron-constantan	J	0–1400 (18–760)	29.5
Chromel-alumel	K	0–2300 (−18–1260)	22.3
Platinum-platinum, 10% rhodium	S	0–2700 (−18–1480)	4.6
Platinum-platinum, 13% rhodium	R	0–2700 (−18–1480)	4.9

Instrumentation

ANSI-IEC T/C COLOR CODES

ANSI Code	ANSI MC 96.1 Color Coding: Thermocouple Grade	ANSI MC 96.1 Color Coding: Extension Grade	Alloy Combination: + Lead	Alloy Combination: – Lead	Comments Environment Bare Wire	Maximum T/C Grade Temp. Range	EMF (mV) Over Max. Temp. Range	IEC 584-3 Color Coding: Thermocouple Grade	IEC 584-3 Color Coding: Intrinsically Safe	IEC Code
J			IRON Fe (magnetic)	CONSTANTAN COPPER-NICKEL Cu-Ni	Reducing, Vacuum, Inert. Limited Use in Oxidizing at High Temperatures. Not Recommended for Low Temperatures.	−210 to 1200°C −346 to 2193°F	−8.095 to 69.553			J
K			CHROMEGA® NICKEL-CHROMIUM Ni-Cr	ALOMEGA® NICKEL-ALUMINUM Ni-Al (magnetic)	Clean Oxidizing and Inert. Limited Use in Vacuum or Reducing. Wide Temperature Range, Most Popular Calibration	−270 to 1372°C −454 to 2501°F	−6.458 to 54.886			K
T			COPPER Cu	CONSTANTAN COPPER-NICKEL Cu-Ni	Mild Oxidizing, Reducing Vacuum or Inert. Good Where Moisture Is Present. Low Temperature & Cryogenic Applications	−270 to 400°C −454 to 752°F	−6.258 to 20.872			T
E			CHROMEGA® NICKEL-CHROMIUM Ni-Cr	CONSTANTAN COPPER-NICKEL Cu-Ni	Oxidizing or Inert. Limited Use in Vacuum or Reducing. Highest EMF Change Per Degree	−270 to 1000°C −454 to 1832°F	−9.835 to 76.373			E
N			OMEGA-P® NICROSIL Ni-Cr-Si	OMEGA-N® NISIL Ni-Si-Mg	Alternative to Type K. More Stable at High Temps	−270 to 1300°C −450 to 2372°F	−4.345 to 47.513			N

Instrumentation

Thermowell

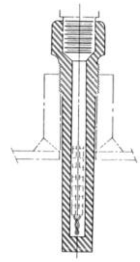


FIGURE 5.1.4 Thermocouple well. (Courtesy J. A. Moore.)

Instrumentation

Temperature RTD (Resistance Temperature Detector)
Resistance Temperature Coefficient
Material Specific
Three Leads (sometimes 4) Lead compensation
Copper (10 ohm)
Nickel (25 ohm)
Platinum (100 ohm)
More accurate – less reliable

Instrumentation

Standards for Temperature coefficient:

Temperature coefficient defined by DIN or ANSI standard

Platinum example range of 0.00385 - 0.003923 ohm/ohm/°C

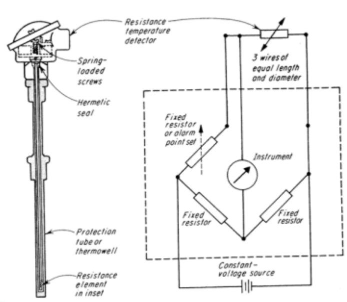


FIGURE 5.1.6 Resistance temperature detector.

Instrumentation

Flow:
Differential Pressure
Low accuracy – non linear
Moderate cost
Orifice Plate

Instrumentation

Differential Pressure = Flow * Flow

$$Q = kA\left(\frac{2ghp}{GT}\right)^{1/2}$$

where Q = flow
k = orifice coefficient
A = cross-sectional area of restriction
g = gravitational constant
h = head (differential pressure)
p = static pressure
G = specific gravity
T = absolute temperature

Instrumentation

Tab has
Tag Number
Diameter Ratio
Pipeline size

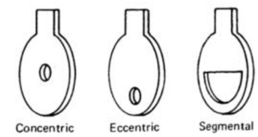


FIGURE 5.1.8 Orifice plates.

Instrumentation

Orifice Flange has pressure taps

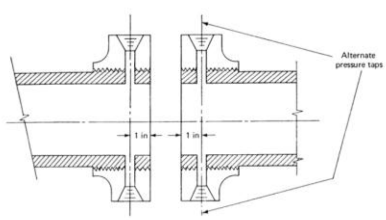


FIGURE 5.1.9 Orifice flanges. (*Courtesy J. A. Moore.*)

Instrumentation

Flow Nozzle
Reduces Turbulence
Less Pressure loss
Greater efficiency
10X more expensive

Instrumentation

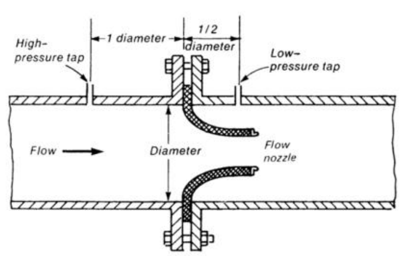


FIGURE 5.1.10 Flow nozzle.

Instrumentation

Venturi Tube
Improved efficiency – lower loss
20X more expensive
Power = Flow * Pressure
As area drops, Flow increases, Pressure Drops

Instrumentation

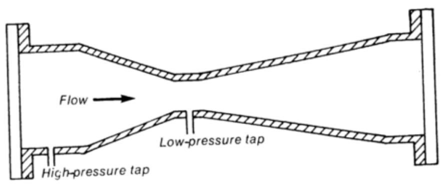


FIGURE 5.1.11 Venturi tube.

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Instrumentation

Pitot Tubes
One tap measures Static Pressure & Velocity Head
Second tap measures Static Pressure
Difference is Velocity head

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Instrumentation

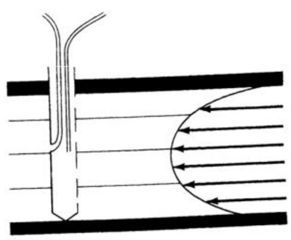

FIGURE 5.1.12 Averaging pitot tube.

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Instrumentation

Other;
Rotary Meters
Turbine Meters
Magnetic Flow Meters
Vortex Flow meters
Coriolis Meters
Ultrasonic Meters (during tour)
Positive Displacement Meters

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Instrumentation

Pressure:
Absolute Pressure
Gage Pressure (14.7 psia reference)
Vacuum – 4.7 vacuum = 10 PSIA

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Instrumentation

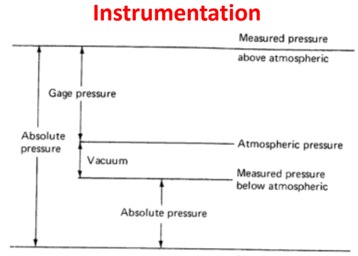

FIGURE 5.1.13 Relationships among measured (gage) pressure, absolute pressure, and atmospheric pressure. (*Courtesy J. A. Moore.*)

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Instrumentation

Pressure:
Bourdon Tubes
Flexible Metal shape formed in curve
Increased pressure attempts to straighten tube.

Instrumentation

FIGURE 5.1.14 Compound pressure-vacuum gage. (*Courtesy Perma-Cal Corp.*)

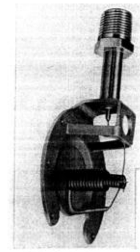

FIGURE 5.1.15 Bourdon tube. (*Courtes Perma-Cal Corp.*)

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Instrumentation

Pressure
Bellows
Spring opposes bellows movement
Force causes movement

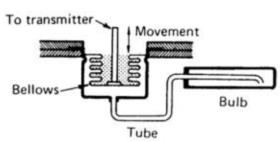

FIGURE 5.1.16 Bellows. (*Courtesy Robertshaw Controls Co.*)

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Instrumentation

Pressure
Electronic Transmitters
Capacitive sensor
(most common)
Movement changes D
C = μA/D

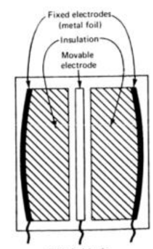

FIGURE 5.1.18 Capacitive sensor.

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Instrumentation

Pressure – Electronic Transmitter
Strain-Gage
Compression / Tension forces stretch stain wire, effectively changing resistance.
Temperature Drift, major challenge

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Instrumentation Systems

To Be Continued …

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End of Session 8: Electrical Systems & Instrumentation

Spring 2012