Back to Basics: Realizing Cabling Determines Design

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Direct Supply - Aptura

Back to Basics: Realizing Cabling Determines Design

Cabling distribution design

implementation

for

installation,

moves, adds and changes.

Back to Basics: Realizing Cabling Determines Design

Agenda

- Pathway fill
- 40% fill?
- NEC Chapter 8
- Firestop % fill
- Firestop Assemblies
- Examples
- Fill Ratio - <u>NO Math </u>stay in room
- Examples
- TDMM tables
- Cable Pull Force

Pathways Uuuugh!

What is the fill ratio?

What size conduit do I need?

Why didn't my cables fit!

Can I save money with smaller conduits?

Fill Ratio

- Old ANSI/EIA/TIA-569 standards "Commercial Building Standard for Telecommunications Pathways and Spaces"
- Conduit-fill table
  – from Chapter 9 of the
  1990 National Electrical Code (NEC).

NEC Conduit-fill Limits

Number of Conductors	All Conductor Types
One	53%
Two	31%
More than two	40%

Fill Ratio

- Conduit fill in the NEC is based on:
  – Safe dissipation of heat from current-carrying conductors
  – Safety considerations while pulling cable

Fill Ratio

- NEC
- Chapter 9
  - Table 1
    - Over 2 conductors

40% of Cross Section of Conduit and tubing for Conductors

Fill Ratio

- Informational Note: *"Table 1 is based on common conditions of proper cabling and alignment of conductors, where the length of the pull and number of bends are within reasonable limits. It should be recognized that, for certain conditions, a larger size conduit, or lesser conduit fill should be considered."*

Fill Ratio

- Other electrical conductor considerations:
  - Ampacity Adjustment
    - Table 310.15(B)(2)(a)
  - Ambient Temperature
    - bottom of each table
  - Conduit Bending
    - Radius of the curve of the inner edge of bend shall not be less

    than shown in Table 344.24

Derating

Fill Ratio

- **CODES & STANDARDS**
- **NFPA 70 National Electrical Code®**
  - Code: A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.(Regulations, 3.3.6.1)

NATIONAL FIRE PROTECTION ASSOCIATION
The leading information and knowledge resource on fire, electrical and related hazards

Fill Ratio

- **CODES & STANDARDS**
- **ANSI STANDARD**
  - A standard is a document, established by consensus that provides rules, guidelines or characteristics for activities or their results.
    - *As defined in ISO/IEC Guide 2:2004*

Fill Ratio

- NFPA 70 90.3 Code Arrangement
  - "Chapter 8 covers communications systems and is not subject to the requirements of Chapters 1 – 7 except where the requirements are specifically referenced in Chapter 8."

Fill Ratio

- Communications Cable Considerations
  - Tension imposed on cabling
  - Firestopping

Fill Ratio - Firestop

- 800.26 Spread of Fire or Products of Combustion
  - "Installations of communications cables and communications raceways in hollow spaces, vertical shafts, and ventilation or air handling ducts shall be made so **the possible spread of fire or products of combustion will not be substantially increased.**"

Fill Ratio - Firestop

- 800.26 Spread of Fire or Products of Combustion
  - "Openings around penetrations of communications cables and communications raceways through fire-resistant-rated walls, partitions, floors or ceilings shall be firestopped using approved methods to maintain the fire resistance rating."

Fill Ratio - Firestop

Firestop? I only want to know what size conduit so I can go.

Fill Ratio - Firestop

- Firestop System “F” rating:
- Firestop material must occupy a defined amount of space around the penetrating item.

Fill Ratio - Firestop

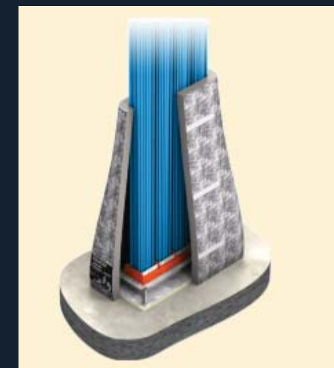
Fill Ratio - Firestop

- Firestop Systems
  - F rating
  - T rating
  - L rating
  - W rating

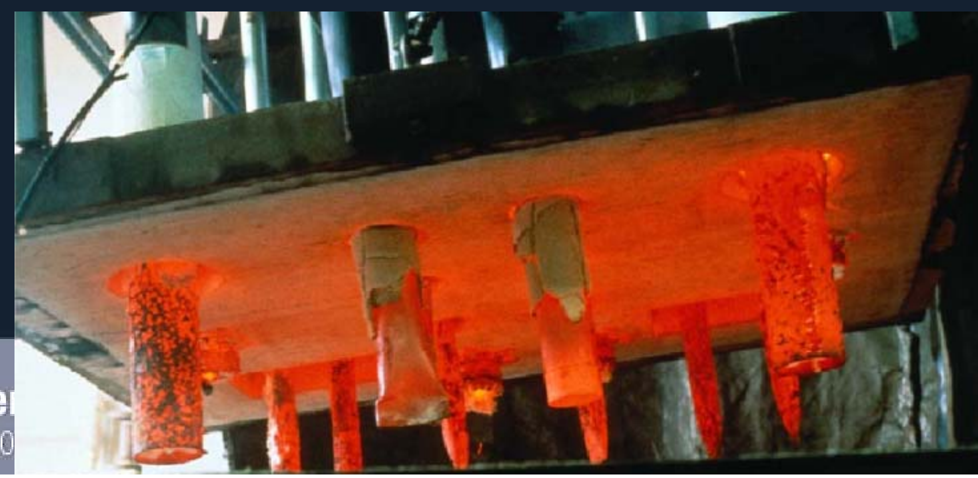
Fill Ratio

- “F” rating is for flame
- Specific length of time the firestopping system prevents flames from passing through the opening.
- Hose stream test
- Expressed in hours

Fill Ratio



- "T" rating is for temperature
  - Length of time a firestopping system keeps the temperature on the non-fire side from increasing more than 325° F plus the ambient air temperature.



Fill Ratio

- “L” rating is for smoke leakage
  - Measurement of air or cold smoke passing through a firestop barrier in cubic feet per minute.
  - Other reasons:
    - Germs
    - Sound

Fill Ratio

- "W" rating is for water
  - firestop assembly must withstand a 3-ft head of water for 72 hours with no leakage.
  - W Rating provides protection against water from floor to floor.

Fill Ratio - Firestop

- "If there is too little space (i.e., the gap is less than the minimum annular space identified in the listing), there may be insufficient firestop material to perform its intended duty, such as swelling up ("intumescing") to fill the gap left behind by a plastic pipe or plastic cable jacketing that has melted or burned away in the fire. "
  - Journal of ASTM International, April 2006, Vol.3, No. 4, Paper ID JAI13027, available online at www.astm.org

Fill Ratio - Firestop

What is "intumescing"?

Fill Ratio - Firestop

- Fire Resistance Directory Numbering System
- Alpha – Alpha – Numeric
- Alpha – Alpha/Alpha – Numeric

Fill Ratio - Firestop

- First Alpha designator – Penetrated item

Letter	Description
F	Floors
W	Walls
C	Combination of Floors and Walls

Fill Ratio - Firestop

- Second Alpha designator – Construction Type

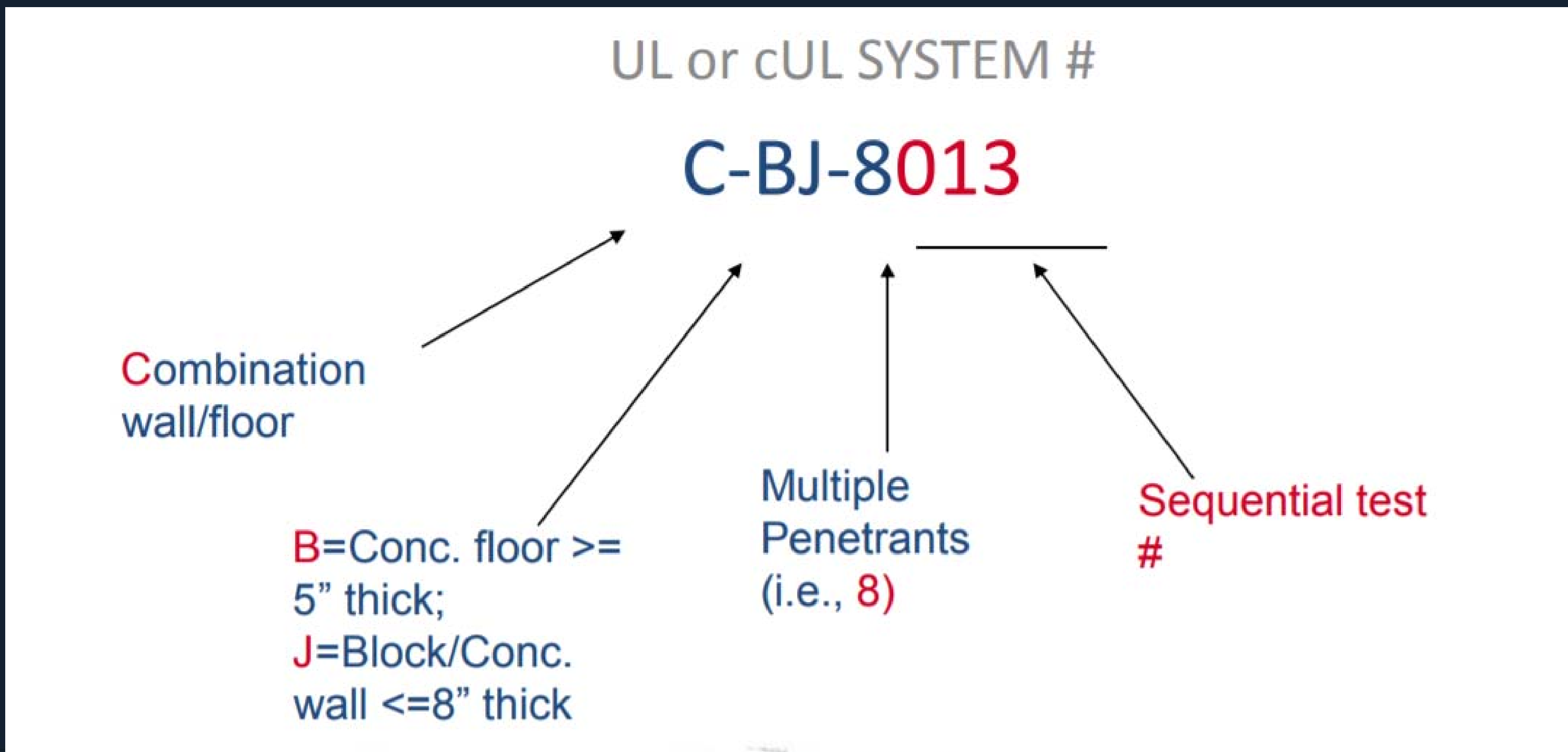
Letter	Description
A	Concrete floors with a minimum thickness less than or equal to 5 in.
B	Concrete floors with a minimum thickness greater than 5 in.
C	Framed floors
E	Floor-ceiling assemblies consisting of concrete with membrane protection
J	Concrete or masonry walls with a minimum thickness less than or equal to 8 in.
K	Concrete or masonry walls with a minimum thickness greater than 8 in.
L	Framed walls
N	Composite panel walls

Fill Ratio - Firestop

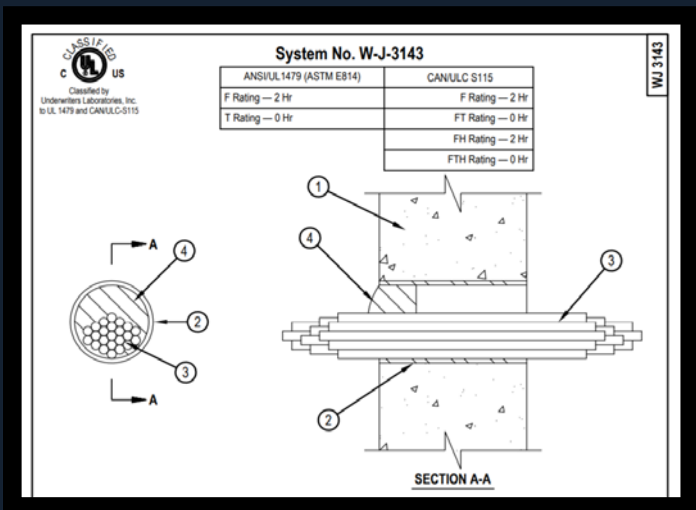
- Third Numeric designator – Penetrant Type

No. Range	Description
0000-0999	No penetrating items
1000-1999	Metallic pipe, conduit or tubing
2000-2999	Nonmetallic pipe, conduit or tubing
3000-3999	Electrical cable
4000-4999	Cable trays with electrical cable
5000-5999	Insulated pipe
6000-6999	Miscellaneous electrical penetrants, such as busducts
7000-7999	Miscellaneous mechanical penetrants, such as air ducts
8000-8999	Groupings of penetrations, including any combination of items listed above

Fill Ratio - Firestop



Fill Ratio - Firestop



1. Wall Assembly — Min 6 in. (152 mm) thick reinforced lightweight or normal weight (100-150 pcf or 1600-2400 kg/m3) concrete. Wall may also be constructed of any UL Classified Concrete Blocks*. Max diam of opening is 4 in. (102 mm).
   See Concrete Blocks (CAZT) category in the Fire Resistance Directory for names of manufacturers.
2. Steel Sleeve — (Optional) - Nom 4 in. (102 mm) diam (or smaller) Schedule 5 (or heavier) steel pipe sleeve cast or grouted into wall assembly. Sleeve to be flush with wall surfaces or may extend up to 12 in. (305 mm) beyond either or both wall surfaces. Where sleeve extends more than 6 in. (152 mm) beyond wall surface it shall be rigidly supported. When wall is constructed of concrete blocks, steel sleeve is required.
3. Cables — Aggregate cross-sectional area of bundled cables in opening to be max 50 percent of the cross-sectional area of the opening. The annular space between the cable bundle and the periphery of the opening or sleeve to be min 0 in. (point contact) to max 1 in. (25 mm). Cables to be rigidly supported on both sides of wall assembly. Any combination of the following types and sizes of cables may be used:
   A. Max 300 pair No. 24 AWG telephone cable with polyvinyl chloride (PVC) insulation and jacket.
   B. Max 750 kcmil single copper connector power cable with thermoplastic insulation and PVC jacket.
   C. Max 7/C No. 12 AWG multiconductor power and control cable with PVC or cross-linked polyethylene (XLPE) insulation and PVC jacket.
   D. Multiple fiber optical communication cable jacketed with PVC and having a max outside diameter of 1/2 in. (13 mm).
   E. Max 3/C No. 12 AWG with bare aluminum ground, PVC insulated steel Metal-Clad cable.
   F. Max 1 in. (25 mm) diam metal clad TEK cable with PVC jacket.
4. Fill, Void or Cavity Materials* - Plug — Plug sized for the steel sleeve/wall opening friction-fitted within the sleeve or wall opening such that the outer circumference of the dome-shaped plug is flush with either end of sleeve or either side of wall. Plug cut to fit around the cable bundle and installed tightly within the sleeve/wall opening.
   HILTI CONSTRUCTION CHEMICALS, DIV OF HILTI INC — CP 658T Firestop Plug or CFS-PL Firestop Plug

*Bearing the UL Classification Mark

Hilti Firestop Systems

Reproduced by HILTI, Inc. Courtesy of Underwriters Laboratories, Inc.
April 05, 2012

Fill Ratio - Firestop

XHEZ - Through-penetration Firestop Systems

XHEZ7 - Through-penetration Firestop Systems Certified for Canada

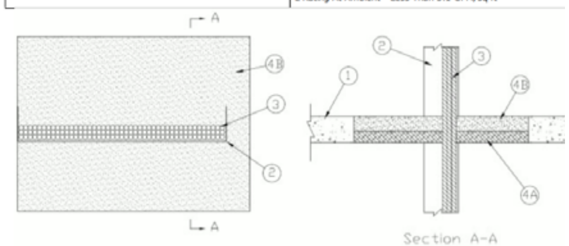
See General Information for Through-penetration Firestop Systems

See General Information for Through-penetration Firestop Systems Certified for Canada

System No. F-A-4008

October 27, 2015

ANSI/UL1479 (ASTM E814)	CAN/ULC S115
F Rating - 2 Hr	F Rating - 2 Hr
T Rating - 1 Hr	FT Rating - 1 Hr
L Rating At Ambient - Less Than 1 CFM/sq ft	FH Rating - 2 Hr
	FTH Rating - 1 Hr
	L Rating At Ambient - Less Than 5.1 CFM/sq ft



1. **Floor Assembly —** Min 114 mm (4-1/2 in.) thick reinforced lightweight or normal weight (1600-2400 kg/m^3 or 100-150 pcf) concrete. Max area of opening is 7742 cm^2 (1200 in.^{2}) with a max dimension of 1016 mm (40 in.).

2. **Cable Tray —** Max 914 mm (36 in.) wide by max 152 mm (6 in.) deep open-ladder steel cable tray. The annular space between the cable tray sides and the periphery of the opening shall be min 0 in. (point contact) to max 102 mm (4 in.). The annular space between the cable tray back and front and the periphery of the opening shall be a nom 305 mm (12 in.) Cable tray to be supported on both sides of the floor assembly.

3. **Cables —** Aggregate cross-sectional area of max 6/C No. 10 AWG cables with PVC insulation and jacket to be max 30 percent of the aggregate cross-sectional area within the cable tray based on a 152 mm (6 in.) loading depth within the cable tray.

4. **Firestop System —** The firestop system shall consist of the following:

   A. **Packing Material —** Nom 51 mm (2 in.) thickness of nom 120 kg/m^3 (8 pcf) mineral wool batt insulation cut to tightly fit the contour the penetrant and firmly packed into opening as a permanent form. Packing material to be installed flush with the bottom surface of the floor.

   B. **Fill, Void or Cavity Material* - Mortar —** Min 64 mm (2-1/2 in.) of mortar installed within annulus, flush with top surface floor. Mortar to be mixed at a ratio of 0.85 part water to 1.0 parts of dry mixture, by weight, as specified in the manufacturer's installation instructions.

   INTERNATIONAL CARBIDE TECHNOLOGY CO LTD — CFS01 Mortar

   INTERNATIONAL FIREPROOF TECHNOLOGY INC — CFS01 Mortar

   C. **Forms —** (Not Shown) - Nom 10 mm (3/8 in.) thick (or thicker) plywood sheets cut to fit the contour of the penetrating item and fastened to the bottom surface of the floor. Forms to be removed after the fill material (Item 4B) is cured.

*** Indicates such products shall bear the UL or cUL Certification Mark for jurisdictions employing the UL or cUL Certification (such as Canada), respectively.**

Last Updated on 2015-10-27

Fill Ratio - Firestop

- Average fill for sleeves based on systems in the UL Fire Resistance Directory is 28%!
- Spacing between the sleeves is typically 2 to 4 inches.

Fill Ratio - Firestop

Fill Ratio - Firestop

- Best engineering practices recommend raceways are oversized to accommodate moves, adds and changes.
- Over life of the building additional cables must remain within the percentage-of-fill.
- May consider spare conduits

Fill Ratio

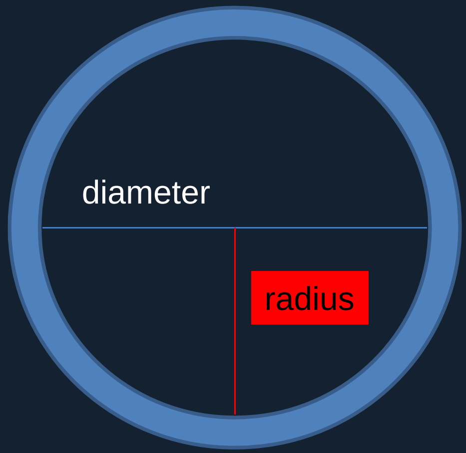
- Area of a conduit (circular)
- $A = \pi \times r^2$
  - A = Area in square inches
  - π = 3.1416
  - r = radius

Fill Ratio

- I failed geometry!?!

Fill Ratio

- Radius



Fill Ratio

- Which pizza has more "Pizza"?
- One 18 inch pizza
- Two 12 inch pizzas

Fill Ratio

- Area of a Pizza
  - $A = \pi \times r^2$
- ○ 18" Pizza
- ○ $A = 3.1416 \times (18" \div 2)^2 =$
- Two 12" Pizzas
- $A = 2 \times 3.1416 \times (12" \div 2)^2 =$

Fill Ratio

- Which pizza has more "Pizza"
- One 18 inch pizza
  - 254 in^2
- Two 12 inch pizzas
  - 226 in^2

Fill Ratio

- What space is available in 2” EMT at 30% fill?
- Find diameter of conduit
  - NEC Chapter 9 Table 4
- r = D ÷ 2
- r = 2.067” ÷ 2 =

1.0335”

Fill Ratio

Fill Ratio

- What space is available in 2” EMT at 30% fill?
  - Change percentage to decimal
  - 30% = 30 ÷ 100 = .3

Fill Ratio

- What space is available in 2” EMT at 30% fill?
- Find area of the conduit
- $A = \pi \times r^2$
- A = 3.1416 x 1.0335” x 1.0335”
- A = 3.35561286 sq. in

Fill Ratio

Fill Ratio

- What space is available in 2” EMT at 30% fill?
- Find space allowed by fill percentage
- Area Available = A x %
- Area Available = 3.3556 sq. in x .3 = 1.00 sq. in

Fill Ratio

- How many CAT6A cables fit in a 2” EMT at 30% fill?
- Find diameter of cable:

SENDING ALL THE RIGHT SIGNALS

Part Number: 10GX12

CAT6A 10GX, 4pr, UTP, PVC Jkt, CMR

Product Description

CAT6A (625MHz), 4-Pair, U/UTP-unshielded, Riser-CMR 90C OR CMR-LP (0.5A) OR CL3R-LP (0.5A), Premise Horizontal cable, 23 AWG solid bare copper conductors, polyolefin insulation, patented Double-H spline, ripcord, PVC jacket

Technical Specifications

Product Overview

Environmental Space:	Riser
Suitable Applications:	Premise Horizontal Cable, 10 Gigabit Ethernet, 100BaseTX, 100BaseVG ANYLAN, 155ATM, 622ATM, NTSC/PAL Component or Composite Video, AES/EBU Digital Audio, AES51, RS-422, Noisy Environments, PoE

Physical Characteristics (Overall)

Conductor

AWG	Stranding	Material	No. of Pairs
23	Solid	BC - Bare Copper	4

Conductor Count:	8
Total Number of Pairs:	4
Conductor Size:	23 AWG

Insulation

Material
PO - Polyolefin

Color Chart

Number	Color
1	White & Blue
2	White & Orange
3	White & Green
4	White & Brown

Outer Jacket Material

Material	Nominal Diameter	Ripcord	Separator Material
PVC - Polyvinyl Chloride	0.295 in	Yes	Patented RoundFleX - Double H Cross-Web

Fill Ratio

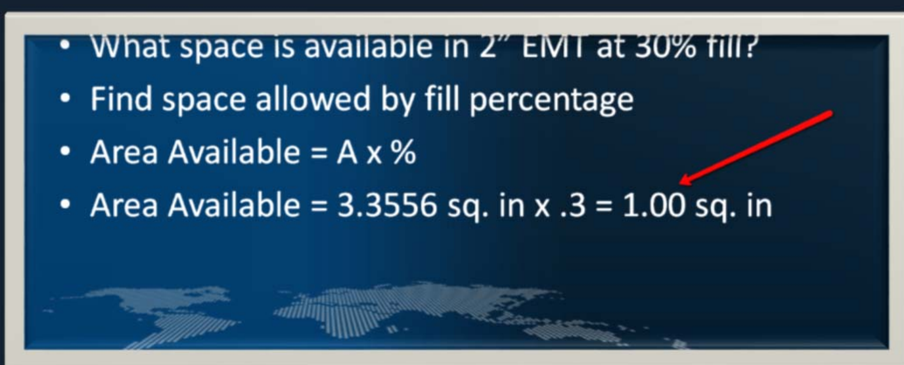
- How many CAT6A cables fit in a 2” EMT at 30% fill?
- r = D ÷ 2
- r = .295” ÷ 2 = .1475”

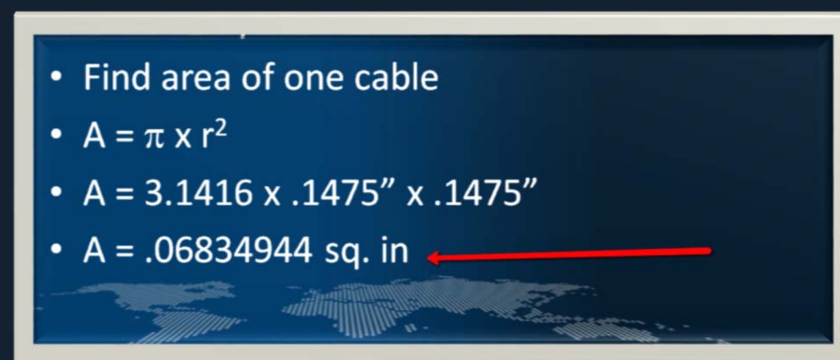
Fill Ratio

- How many CAT6A cables fit in a 2” EMT at 30% fill?
- Find area of one cable
- $A = \pi \times r^2$
- A = 3.1416 x .1475” x .1475”
- A = .06834944 sq. in

Fill Ratio

- How many CAT6A cables fit in a 2” EMT at 30% fill?
  - Number of cables =
  - Area of conduit max fill ÷ area of one cable





Fill Ratio

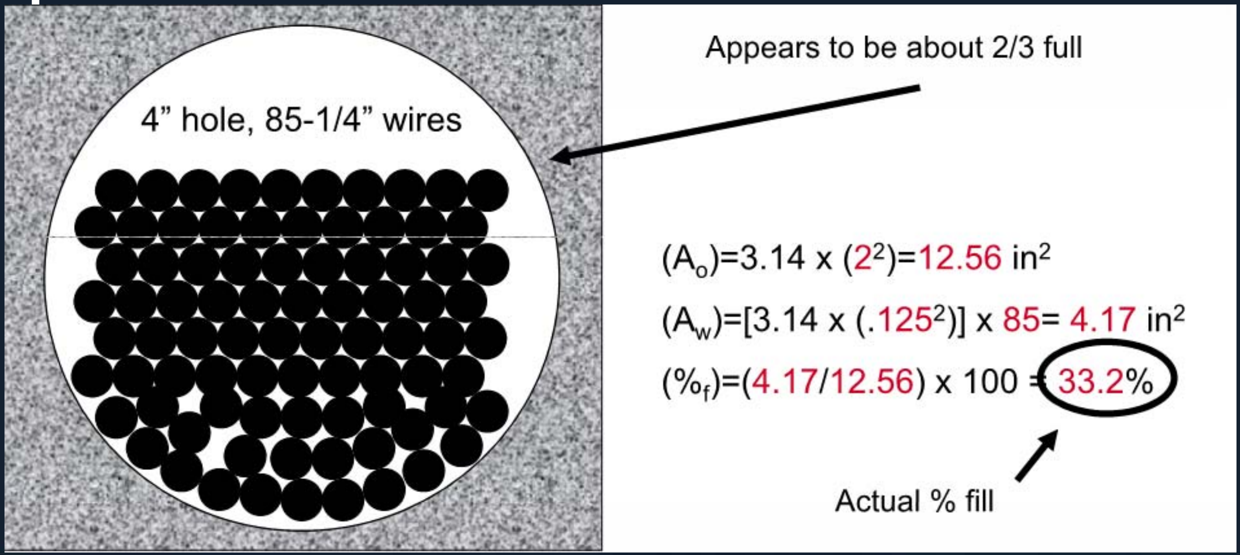
- How many CAT6A cables fit in a 2" EMT at 30% fill?
- Number of cables =

Area of conduit max fill ÷ area of one cable

- 1.00 sq. in ÷ . 06834944 sq. in = 14.6306988
- 14 CAT6A cables fit in a 2" EMT at 30% fill.

Fill Ratio

- Actual fill rates are roughly 50 – 60% of what they visually appear to be.



Fill Ratio


WARNING
Real Men
Don't Read the Instructions
BRADY® MS3210 BRADYID.COM Y41864

Fill Ratio

Table 5.5
Typical electrical metallic tubing conduit fill rate for varying cable diameters

Trade size (nominal diameter)	4.5 mm (0.18 in)	5 mm (0.2 in)	6 mm (0.24 in)	7 mm (0.28 in)	8 mm (0.31 in)	9 mm (0.35 in)
3/4	9	6	5	3	3	2
1	14	10	9	6	5	3
1-1/4	25	17	16	11	9	6
1-1/2	34	23	21	15	12	8
2	56	39	36	24	20	14
2-1/2	80	56	51	35	29	20
3	124	86	79	54	45	30
3-1/2	166	115	106	72	60	41
4	214	149	136	93	78	52

in = Inch
mm = Millimeter

Fill Ratio

- Why did we calculate 14 cables

yet TDMM table shows 20 cables?

Fill Ratio

2	56	39	36	24	20	14
2-1/2	80	56	51	35	29	20
3	124	86	79	54	45	30
3-1/2	166	115	106	72	60	41
4	214	149	136	93	78	52

in = Inch
mm = Millimeter

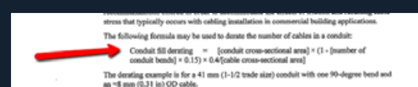
NOTE: The calculations used in Table 5.5 to determine cable fill are based on a 40 percent initial fill factor assuming straight runs with no degrees of bend. These conduit sizes are typical in the United States and Canada and may vary in other countries. The metric trade designators and imperial trade sizes are not literal conversions of metric to imperial sizes. Fire and smoke stop assemblies may require different fill ratios.

Fill Ratio

- Communications Cable Considerations
  - Tension imposed on cabling
  - Firestopping

Fill Ratio - Pull Force

Wait. There were more words on the next page?



stress that typically occurs with cabling installation in commercial building applications.

The following formula may be used to derate the number of cables in a conduit:

Conduit fill derating = [conduit cross-sectional area] × (1 - [number of conduit bends] × 0.15) × 0.4/[cable cross-sectional area]

The derating example is for a 41 mm (1-1/2 trade size) conduit with one 90-degree bend and an ~8 mm (0.31 in) OD cable.

Fill Ratio - Pull Force

- Conduit fill derating for bends
- Fill derating = conduit area x (1 – b x 0.15) x 0.4 ÷ c
  - b = number of conduit bends
  - c =cable cross sectional area

Fill Ratio - Pull Force

- Example 1-1/2” conduit with 1 bend 40% fill
- Fill derating = conduit area x (1 – b x 0.15) x 0.4 ÷ c

= 2.0358 sq. in x (1 – 1 x 0.15) x 0.4 ÷ .06834944 sq. In

= 2.0358 sq. in x (0.85) x 0.4 ÷ .06834944 sq. In

= .69218 ÷ .06834944 sq. In

= 10.1270764 cables

Fill Ratio - Pull Force

- Derating reduced cable quantity from 12 to 10

Table 5.5
Typical electrical metallic tubing conduit fill rate for varying cable diameters

Trade size (nominal diameter)	4.5 mm (0.18 in)	5 mm (0.2 in)	6 mm (0.24 in)	7 mm (0.28 in)	8 mm (0.31 in)	9 mm (0.35 in)
3/4	9	6	5	3	3	2
1	14	10	9	6	5	3
1-1/4	25	17	16	11	9	6
1-1/2	34	23	21	15	12	8
2	56	39	36	24	20	14
2-1/2	80	56	51	35	29	20
3	124	86	79	54	45	30
3-1/2	166	115	106	72	60	41
4	214	149	136	93	78	52

in = Inch
mm = Millimeter

Fill Ratio - Pull Force

- Example with 2 bends
- Fill derating = conduit area x (1 – b x 0.15) x 0.4 ÷ c

= 1 sq. in x (1 – 2 x 0.15) x 0.4 ÷ .06834944 sq. In

= 1 sq. in x (0.7) x 0.4 ÷ .06834944 sq. In

= .28 ÷ .06834944 sq. In

= 4.09659538 cables

Fill Ratio - Pull Force

- Derating for two bends reduced cable quantity from 20 to 4!

Table 5.5
Typical electrical metallic tubing conduit fill rate for varying cable diameters

Trade size (nominal diameter)	4.5 mm (0.18 in)	5 mm (0.2 in)	6 mm (0.24 in)	7 mm (0.28 in)	8 mm (0.31 in)	9 mm (0.35 in)
3/4	9	6	5	3	3	2
1	14	10	9	6	5	3
1-1/4	25	17	16	11	9	[illegible]
1-1/2	34	23	21	15	12	8
2	56	39	36	24	20	14
2-1/2	80	56	51	35	29	20
3	124	86	79	54	45	30
3-1/2	166	115	106	72	60	41
4	214	149	136	93	78	52

in = Inch
mm = Millimeter

Fill Ratio - Pull Force

The spec says two 90 degree bends per 100 feet so I'll just use this table in the TDMM.

Three truths in pulling cable?

Coefficient of friction

- Running wire through small diameter conduit increases the contact points between the conduit and wire.
- This increases the resistance, requiring employees to exert more force while pulling.

Tension for curved conduit

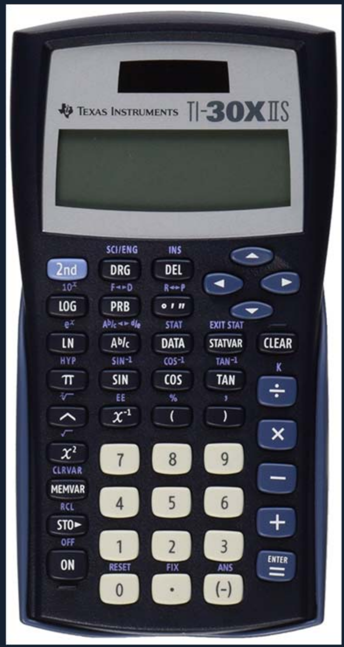
- Pulling wire through bends in conduit creates restriction points, which increases the force required to perform the task.

Hold back tension

- Due to increased weight and stiffness, pulling larger gauge cables requires greater effort than pulling smaller gauge.
- Unwinding wire from spools may be strenuous when wire spools are large and heavy

All three are true?

- Friction makes cable harder to pull
- Bends make cable harder to pull
- Larger cables are harder to pull



Conduit Pulling Tensions

Conduit Pulling Tensions

- The quantity of tension that can be used to pull cables into a length of duct is limited by:
  - Winch line strength
  - Cable strength
    - Maximum Recommended Installation Load (MRIL)
    - Obtain from manufacturer

Conduit Pulling Tensions

- Maximum pulling tension, specified by cable manufacturer, shall never be exceed!

  - Mechanical pulling device should be equipped with a tension meter or dynamometer

Calculating Pulling Tension

- I failed physics!?!

Pulling Tension Straight Horizontal Conduit

Figure 4.6 Forces acting on cable pulled through straight conduit

$$T = T_0 + Fr \text{ (friction)}$$

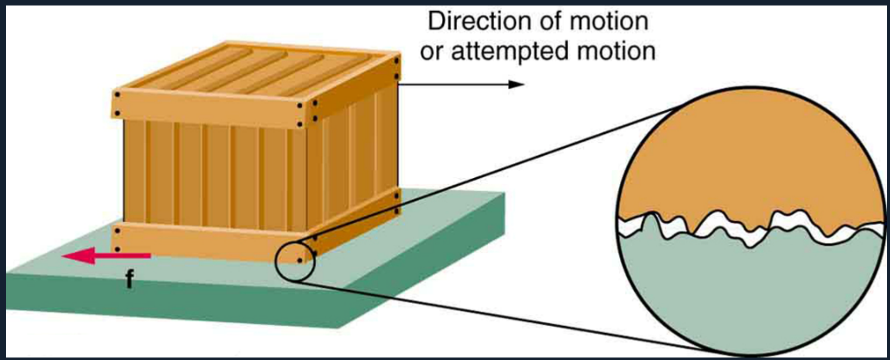
$$Fr = f * w * s$$

Pulling Tension Straight Horizontal Conduit

- $T = T_0 + f * w * s$
  - T = Pulling Tension (measured in pound-force or newton)
  - T_0 = Hold back tension
  - f = Coefficient of friction
  - W = Weight (pounds per foot or newtons per meter)
  - S = Distance (feet or meters)

Coefficient of friction

- Factors that affect the coefficient of friction:
  - Dirt or contamination
  - Type of surface
  - Lubrication of cable
  - Conduit deviations
  - Conduit deformations



Conduit coefficient of friction

- Polyethylene, also referred to as PE, (HDPE & LDPE) is a thermoplastic cable jacket.

Table 4.7 Coefficient of friction

	Sheath Composition			
	High-Density Polyethylene		Low-Density Polyethylene	
Conduit Material	Dry	Lubricant	Dry	Lubricant
Polyvinyl chloride	0.31	0.13	0.36	0.16
Concrete	0.48	0.37	0.57	0.41
Corrugated plastic	0.22	0.13	0.40	0.13

NOTE: Coefficients of friction are unitless and work in both metric and imperial calculations.

Conduit coefficient of friction

- Metal or fiberglass conduit – check manufacturers

Table 3.7.3.5 Typical Coefficients of Dynamic Friction (f) with Adequate Cable Lubrication During Pull

Conductor or Cable Outer Surface	Type of Raceway		
	Metallic	PVC	Fiber
Polyvinyl Chloride (PVC)	0.4	0.4	0.55
Low density Polyethylene (PE)	0.35	0.35	0.5
Chlorinated Polyethylene (CPE)	0.35	0.35	0.5
Chlorosulfonated Polyethylene (CSPE)	0.5	0.5	0.7
Flame-Retardant Ethylene Propylene (FREP)	0.4	0.4	0.5
Cross-linked Polyethylene (XLPE)	0.35	0.35	0.5
Low-Smoke, Zero-Halogen (LSZH)	0.35	0.35	0.35

Metallic = Steel or Aluminum
PVC = Polyvinyl Chloride, Thinwall or Heavy Schedule 40
Fiber = Fiber Conduit

General Cable

- Temperature

Innerduct coefficient of friction

- Pulling lubricated optical fiber cable:
  - Smooth bore innerduct = 0.25
  - Corrugated innerduct = 0.20
  - Fabric mesh innerduct = 0.16

Weight

- Weight in pounds per foot or newtons per meter.

  – Cable weight in pounds is the same as the force of its weight in pounds-force.

  – For metric units cable weight in kilograms must be converted by multiplying it by 9.8 newtons per kilogram.

Example

- Determine maximum pulling tension when a DCMZ 2,100 pair cable is pulled into a 100 ft. (30.5m) straight horizontal section of PVC without lubricant.
  - Assume a tail load of 200 lbf (890 N)

DCMZ 2,100 pair cable

PART NUMBERS AND PHYSICAL CHARACTERISTICS

Part Number	Product Code	Pair Count	AWG (mm)	Nominal Diameter in (mm)	Approx. Weight lbs/kft (kg/km)	Standard Length ft (m)	Approx. Shipping Weight lbs (kg)	Steel Reel Size F x T x D in
19-083-01	DCAZ	900	22 (0.64)	2.49 (63)	4,375 (6,510)	1,600 (488)	7,795 (3,535)	83 x 40 x 42
19-085-01	DCAZ	1,200	22 (0.64)	2.85 (72)	5,770 (8,585)	1,200 (366)	7,720 (3,500)	83 x 40 x 42
19-116-01	DCMZ	600	24 (0.51)	1.70 (43)	1,960 (2,915)	3,900 (1,189)	8,440 (3,830)	83 x 40 x 42
19-118-01	DCMZ	900	24 (0.51)	2.02 (51)	2,860 (4,255)	1,500 (458)	8,275 (3,755)	83 x 40 x 42
19-120-01	DCMZ	1,200	24 (0.51)	2.30 (58)	3,755 (5,590)	2,000 (610)	8,305 (3,765)	83 x 40 x 42
19-121-01	DCMZ	1,500	24 (0.51)	2.57 (65)	4,660 (6,935)	1,600 (488)	8,250 (3,745)	83 x 40 x 42
19-124-01	DCMZ	1,800	24 (0.51)	2.81 (71)	5,545 (8,250)	1,250 (381)	7,725 (3,505)	83 x 40 x 42
19-125-01	DCMZ	2,100	24 (0.51)	3.04 (77)	6,440 (9,585)	1,150 (351)	8,200 (3,720)	83 x 40 x 42
19-126-01	DCMZ	2,400	24 (0.51)	3.22 (82)	7,320 (10,895)	876 (267)	7,205 (3,270)	83 x 40 x 42
19-151-01	DCTZ	600	26 (0.40)	1.38 (35)	1,285 (1,910)	5,700 (1,737)	8,120 (3,685)	83 x 40 x 42

6.44 lbs/ft 9.50 g/m

Example

- $T = T_0 + f * w * s$
- T = 200 + (.36 x 6.44 x 100)
- T = 200 + (231.84)
- T = 431.84 lbf

Example Metric

- $T = T_0 + f * w * s$
- T = 890 + (.36 x (9.8 x 6.44) x 30.5)
- T = 890 + (692.97)
- T = 1582.97 N

Uniformly Curved Segment of Conduit

- $T_b = T_s \times e^{fa}$
  - T_b = pulling tension at end of bend, lbs.
  - T_s = pulling tension at end of straight section entering the bend, lbs.
  - e^{fa} value (see table with for common angles)
    - e = naperian log base (2.718)
    - f = coefficient of friction
    - a = angle of bend (radians)

Uniformly curved segment of conduit

- e^{fa} value for common angles

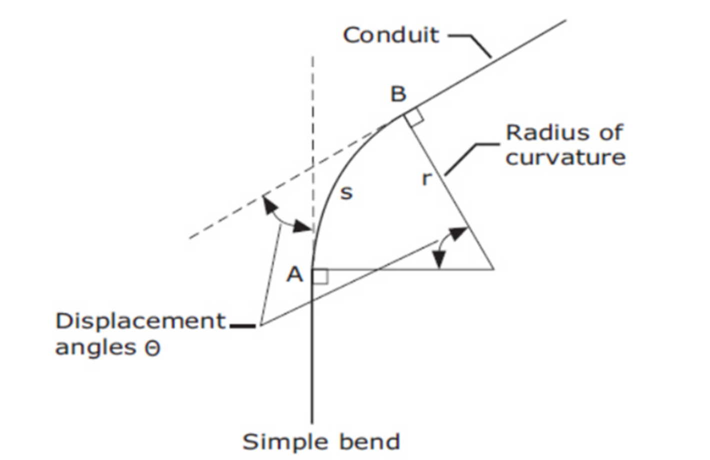
VALUES OF e^{fa} FOR COMMON ANGLES

Bend Angle (°)	e^{fa}					
	f = 0.7	f = 0.6	f = 0.5	f = 0.4	f = 0.3	f = 0.15
15	1.20	1.17	1.14	1.11	1.08	1.04
30	1.44	1.37	1.30	1.23	1.17	1.08
45	1.73	1.60	1.48	1.37	1.27	1.13
60	2.08	1.87	1.68	1.52	1.37	1.17
75	2.5	2.19	1.92	1.69	1.48	1.22
90	3.00	2.57	2.19	1.87	1.60	1.27

Curved segment of conduit

- e^{fa} value for other angles
  - capstan equation

Figure 4.8 Simple bend



Example

- Determine the maximum pulling tension when the DCMZ 2,100 pair cable is then pulled into a 90 degree bend of PVC conduit.

Example

- $T_b = T_s \times e^{fa}$
  - T_s = 431.84 lbf.
  - e^{fa} value (see table with for common angles)

Example

	Sheath Composition			
	High-Density Polyethylene		Low-Density Polyethylene	
Conduit Material	Dry	Lubricant	Dry	Lubricant
Polyvinyl chloride	0.31	0.13	0.36	0.16
Concrete	0.48	0.37	0.57	0.41
Corrugated plastic	0.22	0.13	0.40	0.13

Example

- Coefficient of friction .36

VALUES OF e^{fa} FOR COMMON ANGLES

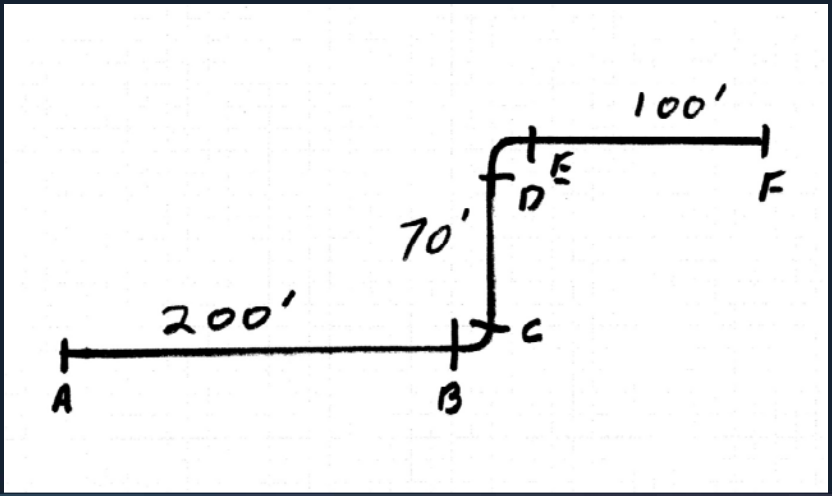
Bend Angle (°)	e^{fa}					
	f = 0.7	f = 0.6	f = 0.5	f = 0.4	f = 0.3	f = 0.15
15	1.20	1.17	1.14	1.11	1.08	1.04
30	1.44	1.37	1.30	1.23	1.17	1.08
45	1.73	[illegible]	1.48	1.37	1.27	1.13
60	2.08	1.87	1.68	1.52	1.37	1.17
75	2.5	2.19	[illegible]	1.69	1.48	1.22
90	3.00	2.57	2.19	1.87	1.60	1.27

Example

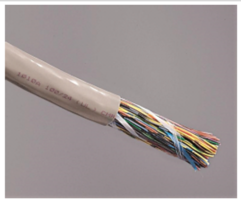
- $T_b = T_s \times e^{fa}$
- T_b = 431.84 lbf x 1.87
- T_b = 807.54

Example

- Determine maximum pulling tension to pull a 100 pair Cat3 cable through corrugated plastic conduit with lubricant



Example



1010A Category 3 U/UTP Cable, non-plenum, gray jacket, 100 pair count, 5000 ft (1524 m) length, reel

Product Classification

Portfolio	CommScope®
Product Type	Twisted pair cable
Regional Availability	Asia | Australia/New Zealand | EMEA | Latin America | North America

Construction Materials

Jacket Material	PVC
Conductor Material	Bare copper
Insulation Material	PVC
Ripcord Material	Nylon

Dimensions

Cable Length	1524 m | 5000 ft
Cable Length Tolerance	±5%
Cable Weight	172.00 lb/kft
Diameter Over Jacket, nominal	18.923 mm | 0.745 in
Jacket Thickness	0.813 mm | 0.032 in

Electrical Specifications

ANSI/TIA Category	3
Characteristic Impedance	100 ohm

Example

General Specifications

Cable Type	U/UTP (unshielded)
Packaging Type	Reel
Pairs, quantity	100
Cable Component Type	Backbone
Jacket Color	Gray
Product Number	1010A
Conductor Gauge, singles	24 AWG
Conductor Type, singles	Solid
Conductors, quantity	200

Mechanical Specifications

Pulling Tension, maximum	68 kg | 150 lb

Example

- $T = T_0 + f * w * s$
  - T = Pulling Tension (measured in pound-force or newton)
  - $T_0 = 0$
  - f = Coefficient of friction
  - W = Weight (pounds per foot or newtons per meter)
  - S = Distance (feet or meters)

Conduit coefficient of friction

	Sheath Composition			
	High-Density Polyethylene		Low-Density Polyethylene	
Conduit Material	Dry	Lubricant	Dry	Lubricant
Polyvinyl chloride	0.31	0.13	0.36	0.16
Concrete	0.48	0.37	0.57	0.41
Corrugated plastic	0.22	0.13	0.40	0.13

First Segment

- $T = T_0 + f * w * s$
- T= .13 x 1.72 lb/f x 200
- T = 44.72

Conduit coefficient of friction

VALUES OF e^{fa} FOR COMMON ANGLES

Bend Angle (°)	e^{fa}					
	f = 0.7	f = 0.6	f = 0.5	f = 0.4	f = 0.3	f = 0.15
15	1.20	1.17	1.14	1.11	1.08	1.04
30	1.44	1.37	1.30	1.23	1.17	1.08
45	1.73	1.60	[illegible]	1.37	1.27	1.13
60	2.08	1.87	1.68	[illegible]	1.37	1.17
75	2.5	2.19	1.92	1.69	[illegible]	1.22
90	3.00	2.57	2.19	1.87	1.60	1.27

Pull from A

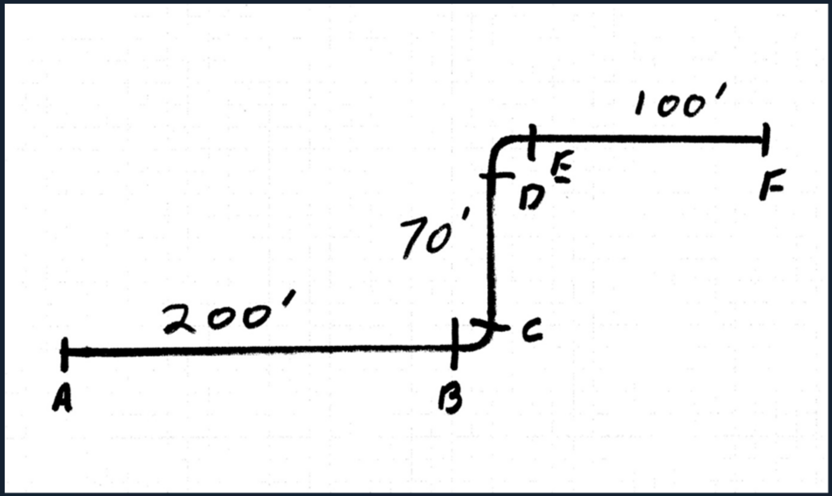
- Tension B = .13 x 1.72 x 200 = 44.72
- Tension C = 44.72 x 1.27 = 56.79
- Tension D = 56.79 + [.13 x 1.72 x 70] = 72.44
- Tension E = 72.44 x 1.87 = 92
- Tension F = 92 + [.13 x 1.72 x 100] = 114.36 lbf

Pull from F

- Tension E = .13 x 1.72 x 100 = 22.36
- Tension D = 22.36 x 1.27 = 28.4
- Tension C = 28.4 + [.13 x 1.72 x 70] = 44.05
- Tension B = 44.05 x 1.27 = 55.95
- Tension A = 55.95 + [.13 x 1.72 x 200] = 100.64 lbf

Example both directions

- Pull from A Tension F = 114.36 lbf
- Pull from F Tension A = 100.64 lbf



Dry Pull from A

- Tension B = .13 x 1.72 x 200 = 44.72
- Tension C = 44.72 x 1.87 = 83.63
- Tension D = 83.62 + [.13 x 1.72 x 70] = 99.27
- Tension E = 99.27 x 1.87 = 185.63
- Tension F = 185.63 + [.13 x 1.72 x 100] = 208 lbf

Example

General Specifications

Cable Type	U/UTP (unshielded)
Packaging Type	Reel
Pairs, quantity	100
Cable Component Type	Backbone
Jacket Color	Gray
Product Number	1010A
Conductor Gauge, singles	24 AWG
Conductor Type, singles	Solid
Conductors, quantity	200

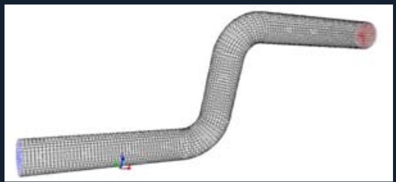
Mechanical Specifications

Pulling Tension, maximum	68 kg | 150 lb

Calculate both directions

- Designer can ensure usefulness regardless of the reel location by calculating the expected pulling tensions for the cable pulled from either direction and use the larger value for design purposes.

Cabling distribution design implementation for installation



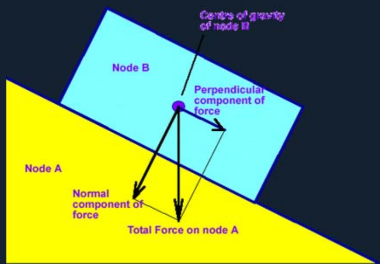
Design considerations

- Conduit bend locations and the geometry of each bend (horizontal and vertical) are important factors to be considered throughout the conduit design

Design considerations

- “To enable optimum use of the conduit structure for subsequent cable placing operations particular care should be given to the MH location and spacing.”
  - Maximum lengths of cable that can be put on a reel should be considered when placing MH

Design considerations



- A conduit system should be designed with a minimum number of horizontal and vertical directional changes.
  - The ideal structure is essentially straight runs between MH with a grade drop for water run off.

Further Deign Considerations

- Manufacturer: Maximum Recommended Installation Load (MRIL), bend radius
  - Training and bending (Jamming potential)
- Conduit or Innerduct Friction
  - Bend, vertical and horizontal, sidewall pressure
- Clearance for pulling

Back To Basics

Agenda

- Pathway fill
- 40% fill ?
- NEC Chapter 8
- Firestop % fill
- Firestop Assemblies
- Examples
- Fill Ratio - ~~NO Math~~
- Examples
- TDMM tables
- Cable Pull Force

The End?

- Thank You! Questions?

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