CABLE PULL TENSION CALCULATIONS

PLANNING, CONCERNS, & CONSIDERATIONS

"This correspondence is neither intended, nor should it be relied upon to provide professional consultation or service. It is only my technical opinion and for general information purposes."

Mohammad Sadrzadeh | Manager, Southwire Solutions

You have probably seen or heard of cable manufacturer's research indicating that about 95% of premature cable failure is due to damage during cable handling on job site, cable pulling or both. I will not argue this figure, but I do agree that majority of cable damage happens during on job sites. During last several years, I have been in hundreds of different job sites and witnessed many successful cable pulls. Unfortunately, I have seen damaged cables, conduits, tools, and equipment during these times as well, which mostly occurred during cable pulls.

Moreover, manufacturing and shipping/handling damages are limited in percentages and are visible. Thus, they can be caught, fixed, or replaced before starting the cable pull. Cable pulling damages on the other hand, usually are also not visible at all. Such damages will not come to light until the pull is completed and cables are either under final test or operational.

We can all agree that spending a little time to explore our options and advance planning can save a lot of time and eliminate risks of confusion and frustration later. However, despite of all benefits, performing this simple but important step seems to be discounted within the industry. When it comes to designing or installing any conduit/raceway system, performing Cable Pull Tension Calculation should become a habit.

A little attention to installation parameters, proper design, and installation of a raceway/conduit systems can not only eliminate the risk of damages (Cables, Conduits, Equipment, etc.) but also prevent human injuries. It is a good practice, since it can help in reducing the number of people, equipment and tools involved and their associated costs, while speeding the cable pulling process.

CABLE PULLING CALCULATORS AND PLANNING

There are many different Cable Pull Calculators available to those who prefer to use a software or an app for such planning. However, they all require certain information to perform this calculation. To name a few:

WHAT?
(SHOULD WE KNOW TO PERFORM CABLE PULL CALCULATION)

Bend Radius, the higher the better.

- Phase Wires (Number, Size, Type, Metal, Jacket Type...)
- Neutral and Ground Wires, when applicable (Number, Sizes, Type, Metal, Jacket Type...)
- Wire/Cable's OD, Weight/Length and Coefficient of Friction (C.O.F.)
- Wire/Cables' Min. Bend Radius, Max. Allowable Pull Tension and Max. Allowable Side Wall Pressure
- Conduit Type and Inner Diameter
- Total number of bends, their angles, bend radius directions and exact locations.
- Length of the Conduit/s and Cables
- Job site limitations / restrictions, preferred payoff direction (if any)
- Other factors (e.g., Ambient Temperature, Incoming Tension, ….)

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WHY?
(WOULD WE NEED THESE DETAILS)

1. LIMITING FACTORS

While excessive pulling tension can have a negative impact on the integrity of a cable, the Side Wall Pressure (SWP) is a more important factor in cable pulling damages. SWP is the amount of the normal force pushing a cable against the conduit wall when going through the bend. This radial force, which is inflicted at the bends, is the most common limiting factor in pulling a cable because usually, the amount of SWP exceeds the manufacturer's maximum allowable value, long before a pulling tension reaches to its maximum. The examples below demonstrate that normally the amount of SWP exceeds its allowable value long before the pulling tension reaches to its maximum. As well as the impact of COF and Pull Direction on both pull tension and SWP.

2. MAX. ALLOWABLE PULLING TENSIONS

Maximum allowable Pull tension is based on the pulling strength of the conductors, since conductors normally bear the pulling forces of the cable. However, this is not the case when using column baskets or other pulling grips as these rely on the outer jacket.

Consequently, this will limit the maximum allowable pulling tension.

3. PULLING GRIPS

It is a better practice to use pulling grips that grip by conductor instead of the jacket or insulation. If this is not possible, then we should check the pulling grip manufacturer's specs and recommendations to discover the maximum allowable tension and use that value in our calculations.

4. OTHER LIMITATION FACTORS

Maximum allowable value can be restricted by other factors as well. (e.g., Cable Puller, Pulling Rope, Pulleys & Sheaves, the strength of the support if cable puller is going to be bolted/ secured by those structures, etc.)

6. INCOMING TENSION

Usually incoming tension of the cable coming off the reel does not have a major impact, however sometimes this value is large enough to cause the actual pulling tension and SWP amounts to exceed the maximum allowable values. Weight of the cables on a reel, quality of the reel, jack stands, the axel, arbor hole, and any tension adjuster or breaking mechanism can impact the value of the incoming tension.

Actual examples of Excessive Pulling SWP on Cables

TRIAL CABLE PULL SCENARIO

The purpose of this experiment, however, is to show the effect of a few factors on Cable pulling tensions.

252' OF 4/C 500 KCMIL + 1/C 1/0 (RWU90 CU) IN A 4" PVC CONDUIT

Enter wire info in purple areas that will go into the raceway					
	# of wires	Wire Type	Wire Size	Wire OD	Wire Wt/ ft.
Phase Wires	3	CU RWU90	500	0.983	1.67
Neutral Wire	1	CU RWU90	500	0.983	1.67
Ground Wire	1	CU RWU90	1/0	0.523	0.38
Total Cables	5	Sets	Reel Size (D X W)	Feet	Gross Wt.
		1	N25F (40" X 27")	252	1,856

Equipment GW sizing of OCD per CEC Table 16	800 amps	CU 1/0 CU
		AL 3/0 AL

Enter raceway info in purple areas			
Raceway Type	PVC Sch 40		
Raceway Size	3 1/2	Min Conduit	3.5 in. Per NEC
Conduit ID 3.521		Maxis Size Grip	Min size conduit using 4 grips & jacket
% Conduit Fill 33.4%		D	3 1/2

Graphs are courtesy of one of Southwire Calculators
and you can find more on **www.southwire.com/calculators**

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EXAMPLE 1: COF Values and Pulling Tensions (COF 0.3 vs. 0.2)

Total wt./ ft	7.077
Configuration	COMPLEX
Wt.correction factor	1.40
COF	0.30
Incoming tension	25

Maximum Pulling Force (lb.)	10,000
Max Sidewall Pres. (lb.)	1,000
Jam Probability	Very Small

Reverse Pull

	Straight Section			Bend Section				COF 0.3 CU RWU90	
Wire pull / Segment	Angle (Slope)	Wire is being pulled …	Segment Length ft.	Bend Type	Up, Down, N/A	Degree of elbow	Radius (in.)	continuous tension (lbs.)	sidewall pressure (lbs.)
A	90	Down	20	VCUP	Down	90	Std	2	1
2		HZTL	100	HZTL	N/A	45	Std	416	233
3	45	UP	14	VCDN	Down	45	Std	717	402
4		HZTL	80	VCUP	Down	90	Std	1,847	1,034
5		HZTL	30	VCUP	UP	90	Std	3,745	2,097
B	90	UP	8					3,801	2,097
6			0					0	0
8			0					0	0
9			0					0	0
10			0					0	0
11			0					0	0
12			0					0	0
13			0					0	0
14			0					0	0
15			0					0	0
16			0					0	0
17			0					0	0
18			0	Call Southwire if you neeed additional segments				0	0
		Total Length	252'						

COF 0.3

Total wt./ ft	7.077
Configuration	COMPLEX
Wt.correction factor	1.40
COF	0.20
Incoming tension	25

Maximum Pulling Force (lb.)	10,000
Max Sidewall Pres. (lb.)	1,000
Jam Probability	Very Small

Reverse Pull

	Straight Section			Bend Section				COF 0.2 CU RWU90	
Wire pull / Segment	Angle (Slope)	Wire is being pulled …	Segment Length ft.	Bend Type	Up, Down, N/A	Degree of elbow	Radius (in.)	continuous tension (lbs.)	sidewall pressure (lbs.)
A	90	Down	20	VCUP	Down	90	Std	2	1
2		HZTL	100	HZTL	N/A	45	Std	249	131
3	45	UP	14	VCDN	Down	45	Std	422	222
4		HZTL	80	VCUP	Down	90	Std	901	474
5		HZTL	30	VCUP	UP	90	Std	1,491	785
B	90	UP	8					1,547	785
6			0					0	0
8			0					0	0
9			0					0	0
10			0					0	0
11			0					0	0
12			0					0	0
13			0					0	0
14			0					0	0
15			0					0	0
16			0					0	0
17			0					0	0
18			0	Call Southwire if you neeed additional segments				0	0
		Total Length	252'						

COF 0.2

Graphs are courtesy of one of Southwire Calculators and you can find more on **www.southwire.com/calculators**

EXAMPLE 2: Pull Direction and Pulling Tension (Pulling from A to B vs. B to A)

Total wt./ ft	7.077
Configuration	COMPLEX
Wt.correction factor	1.40
COF	0.20
Incoming tension	25

Maximum Pulling Force (lb.)	10,000
Max Sidewall Pres. (lb.)	1,000
Jam Probability	Very Small

COF 0.2

Reverse Pull

	Straight Section			Bend Section				CU RWU90	
Wire pull / Segment	Angle (Slope)	Wire is being pulled ...	Segment Length ft.	Bend Type	Up, Down, N/A	Degree of elbow	Radius (in.)	continuous tension (lbs.)	sidewall pressure (lbs.)
A	90	Down	20	VCUP	Down	90	Std	2	1
2		HZTL	100	HZTL	N/A	45	Std	249	131
3	45	UP	14	VCDN	Down	45	Std	422	222
4		HZTL	80	VCUP	Down	90	Std	901	474
5		HZTL	30	VCUP	UP	90	Std	1,491	785
B	90	UP	8					1,547	785
6			0					0	0
8			0					0	0
9			0					0	0
10			0					0	0
11			0					0	0
12			0					0	0
13			0					0	0
14			0					0	0
15			0					0	0
16			0					0	0
17			0					0	0
18			0	Call Southwire if you neeed additional segments				0	0
		Total Length	252'						

Pulling from A to B

Total wt./ ft	7.077
Configuration	COMPLEX
Wt.correction factor	1.40
COF	0.20
Incoming tension	25

Maximum Pulling Force (lb.)	10,000
Max Sidewall Pres. (lb.)	1,000
Jam Probability	Very Small

COF 0.2

Reverse Pull

	Straight Section			Bend Section				CU RWU90	
Wire pull / Segment	Angle (Slope)	Wire is being pulled ...	Segment Length ft.	Bend Type	Up, Down, N/A	Degree of elbow	Radius (in.)	continuous tension (lbs.)	sidewall pressure (lbs.)
B	90	Down	8	VCUP	Down	90	Std	2	1
5		HZTL	30	VCUP	UP	90	Std	95	50
4		HZTL	80	VCDN	UP	45	Std	316	166
3	45	Down	14	HZTL	N/A	45	Std	330	174
2		HZTL	100	VCUP	UP	90	Std	820	432
A	90	UP	20					962	432
6			0					0	0
8			0					0	0
9			0					0	0
10			0					0	0
11			0					0	0
12			0					0	0
13			0					0	0
14			0					0	0
15			0					0	0
16			0					0	0
17			0					0	0
18			0	Call Southwire if you neeed additional segments				0	0
		Total Length	252'						

Pulling from B to A

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HOW
(TO OPTIMIZE OUR CABLE/ CONDUIT INSTALLATION)

- Communication between designer, field person and cable manufacturer could be the best option.
- Lowering the number of elbows as much as possible. Sometimes one more bend can result in excessive SWP.
- Utilizing wide elbows, larger conduits, pulleys, and sheaves can make an impossible pull, possible.
- Setting up the reel/s close to conduits and pulling through bends first, whenever possible.
- Using Cables with very Low Coefficient of Friction (e.g., Southwire's SIMpull Cables, ….)
- Not using a pull box to change cable/conduit direction, otherwise making enough space for using larger pulleys.
- Making manhole entrances (or pull boxes) larger than the cable's bend radius, when possible.
- Ensuring conduits are in good shape and clean.
- Gravity can be a good friend in cable pulling, try not to pull against it if possible.
- Using pulling ropes with lowest coefficient of friction, smallest possible pulling grips, swivel clevises, etc.
- Exploring the pulling tension and SWP values if pull direction is reversed. (If that is an option)

CONCLUSION



With proper planning, Pulling Cables can be a pleasant experience, quick, with less people, and equipment.

Following above-mentioned I would like to reiterate that Raceway Design and Cable Pull can be way more sophisticated than some might normally expect. It is a good practice to perform this calculation prior to conduit installation to minimize any risk of damaging your material and equipment as well as job site injuries during the cable pull. Finally, this practice is a great step in finishing the job way faster with less people, least number of tools and heavy equipment which translates to productivity and profitability.

Hope you will find this letter of interest and feel free to reach out with any questions, comments, and suggestions.

ABOUT MOHAMMAD SADRZADEH, B.SC. ENG.

Mohammad Sadrzadeh is the Manager, Southwire Solutions. He has over 25 years' experience in variety of different technical fields including 7 years of wire & cable experiences gained through many institutional and commercial projects across Canada.

Mohammad has done many jobsite surveys, technical calculations, conduit optimization, and cable pull planning set ups, etc. He is very passionate about sharing his expertise on better and safer Underground Duct Bank Configuration, Conduit Optimization, and Cable Installations.

Mohammad can be reached by phone at **647-468-1384** or via email at: **Mohammad.Sadrzadeh@Southwire.com**.