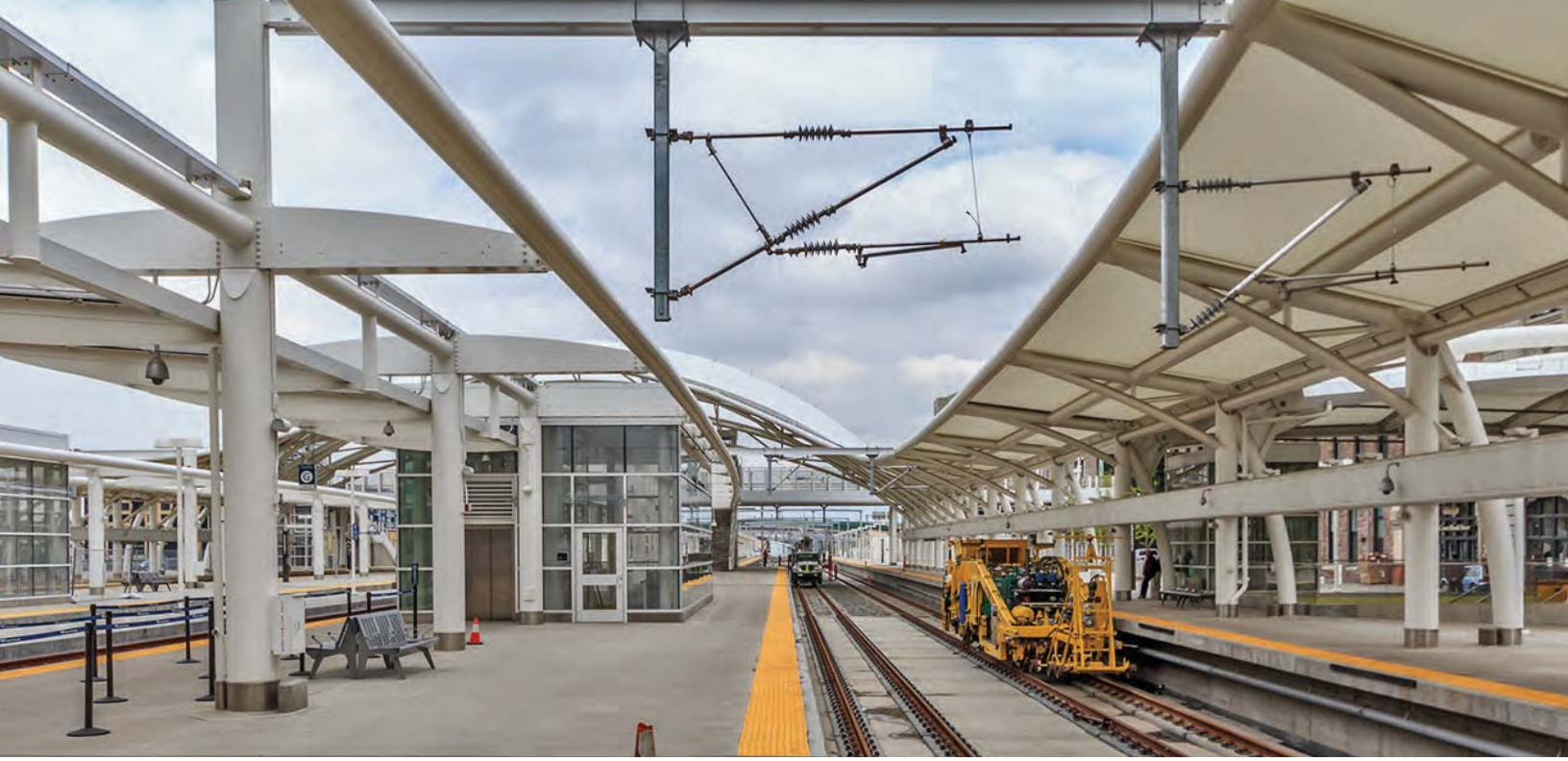

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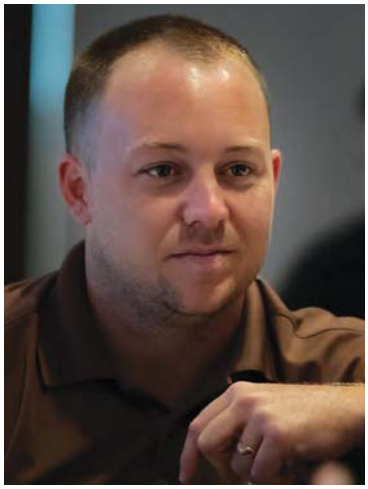

HTETCO Catenary Wire Used in Overhead Catenary Systems for Light Rail Construction

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HTETCO Catenary Wire Used in Overhead Catenary Systems for Light Rail Construction

SECTION 1: INTRODUCTION

The intent of this technical paper is to explain the basic processes involved to properly estimate the installation of catenary wire used in overhead catenary system or OCS as it is often referred to in the industry.

CONSTRUCTION SPECIFICATIONS INSTITUTE

MAIN CSI (Masterformat 1995):
Division 16 – Electrical

RELATED CSI (Masterformat 1995):
Sub-Division 16350
Overhead Contact System Basic Electrical Materials and Methods
Sub-Division 16371
Overhead Contact System

BRIEF DESCRIPTION

The overhead catenary system (OCS) consists of all of the components from ground up on a light rail transportation application. The main components are the messenger wire, contact wire, cantilever/head-span/bridge/backbone anchor/pull-off/counter-weight assemblies, poles, hangers, jumpers, disconnects, down-guys, and insulators along the line section. This paper will detail the steps necessary to develop a lump sum bid for the messenger and contact wire only. A wire run is the length of wire installed between two termination points. The messenger wire specifications can vary depending on project or local governing authority requirements, but generally 500 MCM 37 strand bare copper wire is used. The contact wire is subject to the same aforementioned requirements and is typically 350 MCM grooved bare solid copper wire. The reason light rail systems sometimes utilize a messenger wire is to ensure the contact wire is level and stays in contact at all times with the train. For this reason, the messenger wire has sag and the contact wire is supported by hangers spaced approximately every 80' connecting the messenger and contact wires together. For the purpose of this paper, it is assumed the electrical design has been approved at 95% complete and a complete set of "issued for construction" plans and specs has been issued. As such, all of the required costs will be accounted for and demonstrated including unit costs for material, labor, and equipment as well as indirect costs such as general conditions, insurance, permits, and overhead/profit.

Section 2: Types and Methods of Measurements

There are many factors that contribute to the installation of the messenger and contact wire such as direct current feeder lines coming from the DC switch-gear (typically located inside a substation) and any associated conduits or foundations. However, this paper will only focus on the actual installation of the messenger and contact wire in the OCS construction. For this, we will see how to account for all materials, labor, and equipment associated with a 4,740' wire run of line segment track. In order to accomplish this, the estimator will perform a take-off of the wire using the plans and past work data to generate project specific unit costs for materials, labor, and equipment involved. A few things the estimator will need to know to properly estimate these components are as follows:

- Review of manufacturer shop drawings of the messenger and contact wire. Typically, these are provided by a specialty subcontractor/vendor and usually are either a disadvantaged business enterprise (DBE), minority owned business enterprise (MBE), or a woman owned business enterprise (WBE). It is imperative that the design is checked for construction feasibility in regards to the other components in the OCS **before** material ordering is placed. Typically, a large wire purchase order is placed for most of or the entire project with specific wire cut lengths for each line segment of track. It is common practice for a project of this size and type to be designed in phases by percent complete (i.e. 30%, 60%, 95%, 100%). After each phase is completed, the estimator can review and update his estimates and quotes accordingly. Any deviation from the final design usually results in incorrect wire lengths with consequences being long lead times and increased costs due to minimum quantity charges from wire suppliers.
- Review of the drawing plan set for wire run to confirm exact length, accounting for overages in sag and counterweight setup. The sag can be calculated using the following where

  S - Maximum sag distance, in ft.

  H - Horizontal tension at each end, in lbs.

  w - Weight per unit length, in lbs./ft.

  l - Span length, in ft.
- Though changes do occur between design phases, the estimator relies heavily on past experience and knowledge base to account for items left out or missed during the initial design phase bid of 30%.

Section 3: Specific Factors to Consider in Takeoff and Pricing

ACCESS/EXISTING CONDITIONS

The OCS is just one part of a multilayer project that involves much more, including earth excavation/stabilization, light rail track work, concrete foundations, etc. In order to install the messenger and contact wires, all of this work has to be completed, including poles and wire support assemblies, such as cantilevers, have to be installed. As such, the estimator must factor in the possible access and any existing conditions into his determination of material, labor, and equipment rates. For access, this includes where it's feasible for the wire pulling truck to get on/off the track. Normally, this is at the nearest crossing or station platform. For existing conditions, this includes any field deviations on pole locations, track-to-pole offsets, and overall wire run termination point locations.

Due to lengthy material lead times, the catenary wire may have already been delivered to the contractor's storage yard. The main material quantity problem occurs when a wire run is either shorter or longer than what was originally designed. Before the order was placed, the estimator would account for waste and overage at the counterweight at a total of 10%. It can be possible to switch wire reels originally cut to length for one wire run and use it for another. If this problem occurs, typically an additional wire order will need to be placed immediately for two or more wire runs. This order most likely comes with a expedite charge, or in some cases the wire supplier may have a wire reel available with more than the needed amount, which results in more waste.

Another consideration is the labor productivity factor. When the estimator originally estimates the catenary wire installation, some overtime and holiday time must be accounted for. This is due to the heavy project schedule constraints to have certain wire segments fully operationally for revenue service by milestone dates. During these lower productivity dates, crews are typically overstaffed to ensure project deadlines are met.

Lastly, the equipment used in catenary wire installation is extremely specialized and can be costly to maintain and/or repair. Typically this includes two bucket trucks, a boom lift truck, wire reel cart, wire puller/tensioner, and pulleys/blocks.

SCHEDULE COORDINATION

Since there are specific milestone deadlines to meet, coordination between contractors is key in maintaining those owner-expected and project-driven dates. The estimator should examine the overall project schedule to see how other trades' progress will affect the installation of the catenary wire. Lack of float in preceding work can lead to extra coordination meetings with other contractors and vendors, decreased productivity rates and increased pay rates in order to accelerate to meet deadlines.

WEATHER EFFECTS

Due to the length of a typical project like this, weather can also play an important role in meeting deadlines and keeping crews productive. Of course, most government projects have a specific amount of weather days allotted in the schedule depending on the season. However, the estimator should consider the allotted weather days vs. historical data (if available) to account for loss in productivity, which will increase overall labor costs

This lump sum amount includes material, labor, and equipment to perform the scope of work stated.

QUALITY ASSURANCE

Due to long lead times, high material costs, and tight project deadlines, typically the owner will have a quality assurance team that verifies the installation of all work performed. Since the contact wire is specially designed and ordered, it is extremely important that the installation is done without damage to wire. Therefore, the estimator may be required to add labor cost for areas of low overhead clearances and limited access.

Section 4: Overview of Labor, Material, Equipment, Indirect Costs and Markups

In a lump sum bid, the estimator will present a package to the owner or general contractor that includes his scope of work, inclusions, exclusions, and a total dollar amount. This lump sum amount includes material, labor, and equipment to perform the scope of work stated. These three costs make up the total hard cost for the project. Indirect costs are added on top of this hard cost, as well as overhead and profit markups resulting in a final lump sum bid amount.

MATERIAL COSTS

It is one of the estimator's responsibilities to monitor daily copper prices as catenary wire prices can fluctuate daily based on its high copper content. It is also the estimator's responsibility to verify any project requirements to meet DBE, MBE, WBE percentage goals. It is very common for government projects to have these requirements such as, "at least 30% of all materials used in an assembly must be supplied by a DBE, MBE, or WBE." This may or may not drive material costs up depending on factors such as local supplier competition, geographic location of the project, and lead-time schedules. It is wise for the estimator to put the daily copper price used in his bid assumption notes since copper prices could be significantly higher by the time the bid has been awarded. Another consideration to a government project is sales tax. Typically, sales tax is exempt for materials used on a government project provided the contractor fills out the proper documents and submits their tax information to the material supplier to keep on record.

LABOR COSTS

A crew rate is made up of different individual rates of varying level personnel.

The cost of labor for a self-performing contractor is a very high priority. Since material costs will be comparable from contractor-to-contractor bidding on the same project, the labor cost can be that extra edge to win the bid, as this a cost the contractor can directly control based on how well the project is managed. Of course, other factors play a part, as previously discussed, such as scheduling and quality assurance. However, properly staffing and controlling the labor force on a project can mean big savings in the overall big picture. A crew rate is made up of different individual rates of varying level personnel. For example, a wire pulling crew may consist of three lineman apprentices, one journey lineman, and one foreman. To obtain the crew rate, the estimator must first develop each employee's rate by taking their base pay and adding insurance, payroll taxes, benefits, and union fees (if applicable). An example breakdown of this is shown below:

STRAIGHT TIME ST	AP APPRENTICE	JY JOURNEYMAN	FM FOREMAN
Percentage of Journeyman's Pay –		85%	11.3%
	$ 22.37	$26.32	$29.29
Composite Insurance & Taxes	$ 2.28	$2.68	$2.98
Fixed Value Benefits			
Health & Welfare	$ 7.19	$ 7.19	$ 7.19
Local Pension	$ 10.02	$ 10.02	$ 10.02
Training	$ .56	$ .51	$ .51
LMCC	$ .25	$ .25	$ .25
Percentage Based Benefits			
NEBF 3.0%	.67	.79	.88
NEIF 1.0%	.22	.26	.29
Benefits Sub-Total	$ 18.91	$ 19.02	$ 19.14
Full Loaded Rate - Total	$ 46.56	$ 48.02	$ 51.42

Next, the sum of the weighted individual employee rates divided by the total number in the crew will equal the crew rate. In this example, the total crew rate is $46.03 per hour.

EQUIPMENT COSTS

Since all of the equipment used during the installation of catenary wire is specialized, the contractor will most likely own it. Therefore, the estimator will use an hourly or daily rate to charge the project for the use of that piece of equipment. This rate is determined by overall purchase price, annual maintenance costs, and depreciation. If any additional equipment is needed and can be rented, a quote should be obtained, including the cost of the rental, delivery fees, fuel surcharges, etc.

INDIRECT COSTS

Unlike the material, labor, and equipment costs, indirect costs are based more on the overall project costs rather than individual activities within the overall scope. Indirect costs vary by project but typically include indirect supervision such as project managers, field engineers, safety supervisors, quality managers, and office administrative staff. Some other typical costs include small tools and supplies, staff vehicles, fuel, personal protective equipment, site trailer/storage, temporary fencing, temporary facilities, field supplies, office supplies, permit fees, and insurance costs. Insurance costs can be further broken into builder's risk, liability and surety bonds. Since these costs are calculated on the overall project, the estimator can proportion out percents of these values based on the hard cost for the installation of catenary wire compared to the overall project hard cost.

MARKUPS

Overhead for a company is the cost of being in business. This isn't always a recoupable cost. For example, if the company did not make money on a project or did not have any work for a month, this cost would still exist and be incurred. It includes items such as office leasing, office equipment, supplies, non-project related staff, company-wide incentives, etc. Profit, on the other hand, is directly related to how well a project does financially. Each project has its own profit margin set before the bid is sent out. There are two types of overhead and profit markups-- line item inclusive and 'below the line' items. The first typically refers to subcontractor bids used in an estimate. These bids typically include all labor, material, equipment, and indirect costs including markups. Another key point to being a competitive bidder is that the more work you can self-perform, the more potential cost savings exists due to decreased overall markups on a project. For this reason, the decision to add the correct profit percent on the bid is critical to obtaining a winning bid. Some projects are bid with low or even no profit simply to get work in hopes more work will be available at a later date. Typically, profit margins can range from three to eight percent on a project of this size.

Section 5: Special Risk Considerations

Due to the nature of dealing with electricity, there are special risk concerns that must be addressed by the estimator to accurately determine a bid.

CREW SAFETY

First, some projects require working around live line segments, which can be dangerous if lockout/tag-out procedures are not followed. Typically, these projects are done at night during non-operating times for the light rail transit authority so visibility is another concern. As the installation of catenary wire relies heavily on other trades' workmanship, coordination between contractors is key to ensure the project timeline and budget is met.

PUBLIC SAFETY

Since light rail transit lines typically run through urban areas, the safety of the public is also a major area of concern. Traffic control devices must be in place while working over a roadway crossing. Netting should be in place on all bridges over street traffic. Temporary fencing should be installed for work performed at an existing train station, such as tying into an existing line segment.

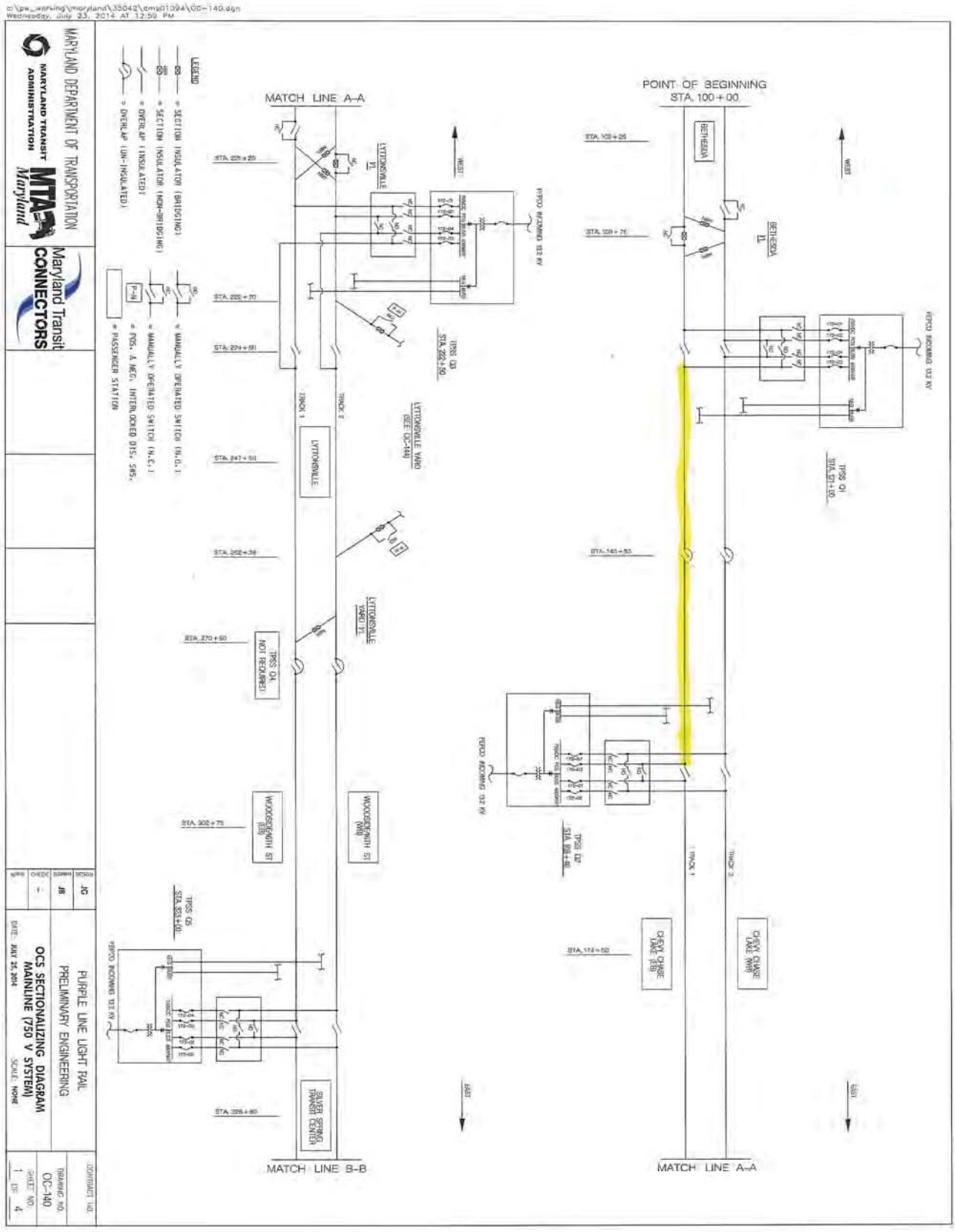
Section 6: Ratios and Analysis

An estimator is only as good as the work he/she produces. Therefore, testing the bid against historical data is crucial to verifying the accuracy and completeness of any estimate. There will always be fluctuations in material and labor costs due to factors such as availability, geographic location, and inflation. Comparing individual unit costs will not prove accurate since projects will have variations in design and installation techniques. Instead, the estimator can calculate the project costs on a linear foot basis to properly compare to the historical linear foot costs for installed catenary wire.

Section 7: Miscellaneous Pertinent Information

Thus far, we have discussed the various factors the estimator will consider while creating an estimate for a lump sum bid. Some other important information to consider for light rail transit projects includes special general requirements. These requirements can be certified inspectors or OSHA trained employees. While contractors are obtaining certifications more often just as a part of doing business, it is important to note the added costs if special certifications are required. Some government funded projects will also have an "American made" clause specifying how much of a typical assembly of materials has to be either manufactured and/or assembled in the United States of America.

Section 8: Sample Sketch



Section 9: Sample Takeoff and Pricing Sheet

Messenger & Contact Wire- Take Off- 4,740' Wire Run

Description (FT)	QTY (FT)	Weight (LB/FT)	Tension (LBS)	Sag (FT) (FT)	Waste (5%)	Counterweight Setup (5%)	Calculated Length
500 MCM-37 strand	4,740.00	1.54	8,000.00	551.55	264.58	264.58	5,820.70
350 MCM-solid grooved	4,740.00	N/A	N/A	N/A	237.00	237.00	5,214.00

Equipment- Per Linear Foot Messenger Wire

Description	QTY	HRS	Price/HR ($)	Subtotal
Bucket Truck	2.00	0.05	$ 150.00	$ 15.00
Boom Truck	1.00	0.05	$ 225.00	$ 11.25
Wire Reel Trailer	1.00	0.05	$ 200.00	$ 10.00
Total Equipment Rate				**$36.25**

Equipment- Per Linear Foot Contact Wire

Description	QTY	HRS	Price/HR ($)	Subtotal
Bucket Truck	2.00	0.03	$ 150.00	$ 9.00
Boom Truck	1.00	0.03	$ 225.00	$ 6.75
Wire Reel Trailer	1.00	0.05	$ 200.00	$ 6.00
Total Equipment Rate				**$21.75**

Labor-Unit Cost

	APPRENTICE	JOURNEYMAN	FOREMAN	Sum Crew	Crew $/HR
Wages	$ 22.37	$ 26.32	$ 29.29		
Add Ons	$ 21.19	$ 21.70	$ 22.12		
Total	$ 43.56	$ 48.02	$ 51.42		
Crew	3	1	1	5	
Hrs/Wk	40	40	40	200	
Wages	$ 2,684.64	$ 1,052.80	$ 1,171.77	$ 4,909.21	$ 24.55
Add Ons	$ 2,543.08	$ 868.09	$ 884.96	$ 4,296.13	$ 21.48
TOTAL	**$ 5,227.72**	**$ 1,920.89**	**$ 2,056.72**	**$ 9,205.33**	**$ 46.03**

Loaded-Unit Costs

Description	Qty	Unit	Material ($/LF)	Labor ($/HR)	Labor ($/LF)	Equipment ($/LF)	Subtotal
500 MCM-37 Strand	5,820.70	LF	$ 10.00	$ 46.03	$ 2.30	$ 36.25	$ 537,114.96
350 MCM-Solid Grooved	5,214.00	LF	$ 7.00	$ 46.03	$ 1.38	$ 21.75	$ 389,885.50

Indirect Labor Cost - Per Linear Foot Wire

Description	QTY	HRS	Price/HR ($)	Subtotal
Project Manager	1.00	0.01	$ 75.00	$ .75
General Foreman	1.00	0.01	$ 50.00	$ .50
Superintendent	1.00	0.01	$150.00	$ 1.50
Total Indirect Cost				**$ 2.75**

Final Bid

Description	Subtotal
Messenger Wire	$ 537,114.96
Contact Wire	$ 389,885.50
Indirect - General Conditions (5% of hard cost)	$ 30,345.43
Conditions (5% of hard cost)	$ 46,350.02
Bonds/Insurance/Permits (2% of hard cost)	$ 18,540.01
Overhead (8%)	$ 81,778.87
Profit (5%)	$ 51,111.80
Total Lump Sum Bid	**$ 1,155,126.59**

As shown in the takeoffs on page 27, the estimator would calculate the true wire length of the messenger wire using the provided sketch and sag formula along with the wire weight, waste, overage, and tension factors listed above. The contact wire is virtually sag free due to being supported by the messenger wire. Therefore, only waste and overage will need to be factored into the calculated length. Next, the equipment rate can be calculated using the hourly rates above. Using the hourly labor rates calculated earlier in this paper, the estimator would multiply that by the hourly rate for equipment usage to obtain the labor price per linear foot of wire. For example, for the messenger wire it would be: $46.03 X .05 = $2.30. Next, the estimator would add the linear foot cost of material, labor, and equipment. Then, multiply by the quantity of wire to obtain the total installed wire cost for each wire. The indirect labor cost is calculated in the same fashion as the equipment and multiplied by the total footage of wire. The indirect general conditions cost is calculated at 5% of the total of the messenger and contact wire line items. Bonds/insurance/permits are calculated the same as the general conditions. Overhead and profit are calculated with the sum of all of the previously mentioned items multiplied by the specified percent (i.e. 8% or 5%). Finally, adding the overhead and profit to the total equates to a final lump sum bid.

Section 10 : Glossary

Overhead Catenary System: Refers to all components related to the electrification of light rail construction, including but not limited to the catenary wire..

Messenger Wire: The power supply and support wire for the contact wire. This wire is feed from a power substation to a specified termination point. Typically, this wire is larger than the contact wire..

Contact Wire: The wire that feeds the panograph of the light rail train. This wire is supported by the messenger wire and has virtually no sag due to rigid metal hangers connecting the messenger and contact wires together.

Cantilever: A single insulated wire support assembly connected directly to a pole. These assemblies come in various configurations depending on the project design requirements.

Head-span: An insulated multiple wire support assembly connected directly to two poles. These assemblies come in various configurations depending on the project design requirements.

Pull-off: An insulated assembly designed to pull the messenger and contact wire to a specific stagger from center of track. This stagger is specified by the design team. This is assembly is connected to one pole.

Backbone anchor: An insulated assembly designed to pull multiple messenger and contact wires to a specific stagger from center of track. This assembly spans between at least two poles.

Disconnects: A manually or remotely operated switch to energize/de-energize a specific line segment of track.

Counter-weight: An insulated assembly designed to hold a specific tension on the catenary wire at all times using a series of weights and pulleys.

DC switch-gear: Manufactured equipment that coverts alternating current to direct current.