CABLE MANUFACTURING & ASSEMBLY CO. INC.

DESIGN GUIDE

General Applications

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Table of Contents

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Construction

All wire rope and mechanical cables are fabricated from individual wires that are helically twisted into a strand. Most small commercial cables are made using a core as their central member, with a given number of strands helically wrapped around the core. All cable is made using two or more strands as a basis of its construction. The number of wires is in a strand and the number of strands in a cable is controlled by the construction that is specified.

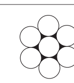
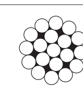
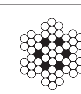
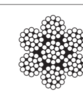
Cable is specified by the number of strands in the cable by (x) the number of wires in each strand. Commercial quality "aircraft grade" type cables are most typically 1 x 7, 1 x 19, 7 x 7 and 7 x 19. The most popular strand is 1 x 7, which consists of 1 center core wire, which is straight, and 6 wires helically stranded around the core. This basic strand is used to make 1 x 19, 3 x 7, 7 x 7 and 7 x 19 cable. Flexibility of the same diameter cable is a function of the number of wires in the cross section with 1 x 7 being the stiffest and 7 x 19 being the most flexible standard construction. Each cable use must be analyzed to determine the most suitable construction for the application.

All cables consist of individual wires, a center core and outer strands as shown. Most "aircraft grade" type cables are made with performed wires (except for the center wire of a strand) and performed strand. Performing allows the cable to lay straight and reduces the tendency of the wires to pop or fly apart when the cable is cut mechanically.

Cable can be stranded with either a right or left hand lay, which is the direction that the outer strands are "laid" around the core. All commercial quality "aircraft grade" cable is made and stocked in right regular lay configuration. Wires in the strand are laid to the left and each strand is laid to the right. The length of lay is the dimension in inches for one strand, or one wire to make one helical revolution around the center core. The length of lay is determined by the specification for the particular strand or cable, or by the application.

Standard Cable Constructions

Commercial Quality "Aircraft Grade" Galvanized and Stainless Steel

SIZE RANGE	DESCRIPTION	TYPICAL USES/APPLICATIONS	CONSTRUCTION
3/64" thru 1/4" Diameter	Basic strand for all concentric cable, relatively stiff in larger diameters, offers the least stretch.	Basic strand, straight pull-pull assemblies, tension members.	 1 x 7
1/32" thru 3/8" Diameter	Smooth outside diameter, fairly flexible resists compressive forces, strongest construction in sizes above 3/32" diameter.	Tension members, guy lines, push-pull controls, pull-pull controls.	 1 x 19
1/32" thru 3/8" Diameter	Durable higher flexibility and abrasion resistance. Good general-purpose construction for strength and flexibility.	In small diameters can be used over pulleys, pull-pull cable controls.	 7 x 7
1/16" thru 3/8" Diameter	The strongest and most flexible of cables, with greatest stretch.	Over pulleys, drive cables, reciprocating applications, and lanyards.	 7 x 19

Cable Assembly Design Factors

The information contained in this section is intended to assist you in the design and specification of a cost-effective cable assembly appropriate to your application. Some cable assemblies perform simple functions, while others are required to perform multiple tasks, making every application different.

Many design factors and specifications are unique to cable and cable assemblies. These should be carefully considered in the design phase, so that a successful application will result. The data in this section is based on industry standards and state-of-the-art assembly and production techniques. For critical applications, we highly recommend the fabrication of samples for testing in the actual or simulated use.

Cable Stretch

All cable stretches under an applied load. There are two types of stretch – constructional and elastic. In the majority of cases, where a cable of the correct diameter and construction has been specified, stretch is not a factor in the function of the assembly.

Constructional Stretch

All cable contains small clearances between the individual wires and strands. With the application of the initial load, this clearance is minimized, allowing the cable to "stretch" in length. The amount of the load, type of cable construction, and the length of the assembly all affect the amount of constructional stretch. Cable with more wires in its cross section, as compared to that of less, will stretch more during the application of the same load.

Most cable assemblies are specified with a safety factor greater than the working load. This in many cases may minimize constructional stretch as a design factor.

In applications where stretch is a factor, constructional stretch of a cable assembly can be practically eliminated by "proof loading" it to 60% of the cable's minimum breaking strength. Proof loading can be specified at additional cost. This cost can sometimes be eliminated by proof loading the cable at the time of assembly or duration installation in the product or system.
It should be noted that cable stretch will occur, and should be planned for in the cable design and installation procedure.

Elastic Stretch

Elastic stretch is the actual elongation of the individual wires in a strand or cable. It occurs when a cable is subjected to a load that is less than the yield point of the metal. The elongation is approximately proportional to the load applied. When the load is removed from a proof loaded cable it will return to its original length, providing the load has not exceeded the yield point of the metal, causing permanent elongation or failure. The elastic stretch of a cable can be calculated using this formula:

$$ES = \frac{PL}{EA}$$

Where: ES = Elastic Stretch in Inches
P = Pounds Load
L = Length in Inches (of Cable Assembly)
EA = EA Value *(Product of the Metallic Cross Sectional Area and Modulus of Elasticity)*

Note: *1. The formula is based on using cable that has been proof loaded to 60% of its breaking strength to remove constructional stretch.*
2. The EA values listed in the CMA Cable Specifications are conservative and are intended for general information only. The actual EA value of any cable can vary based on the materials used and the manufactured quality of the cable. Testing a proof loaded cable assembly under the working load is the most accurate way to determine elastic stretch.

Cable and Assembly Breaking Strength

The minimum breaking strength of any cable is defined as its minimum ultimate tensile strength in pounds or kilograms. The minimum breaking strength of any cable used in your assembly should be based on the maximum working load, any potential shock load and a reasonable safety factor (Refer to the Commercial Cable Data Sheet).

Recommended Minimum Safety Factors Ratio	Minimum Cable Breaking Strength	:	Maximum Working Load
Normal Applications	5	:	1
Shock or Peak Load Applications	8	:	1
Critical or Safety Related	10	:	1

Assembly Strength

Most standard CMA fittings were designed to hold 80% of the minimum breaking strength of the cable. Maximum holding strength is insured by swaging fittings to bare cable. When coated cable is specified, the jacket must be stripped away for proper application of the fitting. Variations in the holding strength are possible if a fitting is swaged to a smaller cable, swaged over the coating or when commercially acceptable variations occur in cable diameter and the fitting's material hardness. The holding strength of a fitting swaged to a cable should never be specified at or near the minimum breaking strength of the cable! A minimum holding strength based on 80% of the cable breaking strength should be specified for most assemblies, except for ball fittings, which should be specified at 50%. This results in a specification readily obtainable in production on a consistent basis. Requirements higher than 80%, if required, can be obtained based on cable and fitting selection. More expensive rotary swaged fittings and "MS" aircraft terminals can generate holding strengths equal to the minimum breaking strength of the cable. Standard and custom fittings can be tested to determine the maximum allowable holding strength for any given application.

A 50-piece SPC capability study to establish minimum holding strength specifications is recommended in critical applications. Consult CMA's Engineering department for further details.

Holding Strength/Cable Protrusion

Cable protrusion on ball fittings, plug fittings, ball and shank fittings, as well as most eye fittings, contributes to the maximum holding strength of the fitting and cable selected. The protrusion can be ground flush on plug and ball fittings, if required, at an additional cost; however a lower holding strength must be specified.

Cable Selection

Cable constructions listed are suitable for most applications as defined and are based on a comparison of the same diameter cable made from the same wire material.

Characteristic	Greatest →			Least
Flexibility	7 x 19	7 x 7	1 x 19	1 x 7
Tensile Strength	1 x 19	1 x 7	7 x 19	7 x 7
Stretch Resistance	1 x 7	1 x 19	7 x 7	7 x 19
Relative Cost	7 x 19	7 x 7	1 x 19	1 x 7
Corrosion Resistance	Coated Stainless Steel	Bare Stainless Steel	Coated Galvanized Steel	Galvanized Steel

CABLE CONSTRUCTION Type of Application	Recommended	Acceptable
Straight Tensile Load	1 x 19	1 x 7
Tensile Load with Flexing	7 x 19	7 x 7
Over Pulleys	7 x 19 Coated and Lubricated	7 x 7

Cable Lubrication

All commercial quality "Aircraft Grade" cable is available either dry or lubricated. Lubrication applied to the wires and strands during fabrication increases cycle life and is essential for cable applications using pulleys or sheaves. This allows the wires and strands to move easily against one another while flexing back and forth over pulleys. For most static applications, dry cable is acceptable and should be specified.

Pulley Materials/Types

Pulley materials and construction should be selected based on the application and system environment.

Commercially available pulleys are made from aluminum, steel, nylon, acetal, and other thermoplastic resins. Most are available with sintered bronze bushings, open or closed ball, or roller bearings. Dynamic loads, RPM's, expected life cycles, corrosion resistance, and cost all must be considered as factors in pulley and bearing selection.

Pulley/Bearing Description	Features	Typical Uses
1. Plain metallic or thermoplastic pulleys	Lowest cost, light loads, low RPM, intermittent operation.	Low frequency drive cable and lift cable applications.
2. Metallic or plastic pulleys with sintered bronze bearings	Self-lubricated bearings, cost-effective, durable, higher load, shock resistant.	Higher RPM, medium load drive, index & lift systems.
3. With open free turning or precision closed & lubricated ball bearings	Minimum friction, precise tracking, medium load, high RPM.	High speed drive, and index cable systems.

For axial and radial load capacities and maximum recommended RPMs, consult individual bearing and pulley manufacturers' literature.

PULLEY DIAMETER TO CABLE DIAMETER RATIO			
Cable Construction	Preferred Minimum (D:d)	Absolute Minimum (D:d)	Absolute Minimum (D:d) for Aircraft Applications
3 x 7	50:1	40:1	Not Recommended
7 x 7	42:1	30:1	40:1
7 x 19	24:1	18:1	35:1

D = Pulley Tread, or Root Diameter
d = Nominal Bare or Coated Cable Diameter

Groove Design

The recommended groove diameter should be calculated as follows:

1.5 x Diameter Tolerance (Plus tolerance of bare cable or coating) + **Maximum Cable Diameter (Bare or coated diameter for either)**

Refer to the Commercial/OEM Cable Specifications Chart

Proper groove diameter is also essential to cable life expectancy. A small groove will pinch the cable, while a large groove will flatten it. The pulley groove should be molded or machined so it is smooth and free of imperfections.

Installation

The environment, alignment, installation procedures, unnecessary overloading and lubrication all affect pulley, bearing and cable life expectancy. Attention to these factors in the design and specification stages of your project will help to insure a functional system.

Pulley, capstan and cable systems should be designed so that their alignment is within acceptable fleet angles. For most drum or capstan installations, it is recommended that the system design accommodate a minimum fleet angle of 1/2 degree and a maximum of 1 1/2 degrees (2 degrees for a grooved capstan) from the outside edge (flange) to the centerline of the drum or capstan. Adherence to these limits should allow proper payoff and re-winding of the cable on a consistent basis. This minimizes the potential for crushing, abrasion, and stacking of the cable.

Assembly and Fitting Tolerances

The specification of realistic tolerances is essential to producing cost-effective cable assemblies. In most cases, standard block tolerances should not be used for cable fittings and assemblies. The swaged areas of most fittings should be specified as reference dimensions, unless that part is critical to the installation and assembly. Where fittings must nest or fit into a mating part, after swage dimensions can be specified within the tolerances indicated on the fitting charts. Extremely close tolerances on fittings and assembly lengths can add unnecessary cost. The chart below indicates acceptable length tolerance conditions for commercial cable assemblies.

Cable Assembly Tolerances

Assembly Length in Feet	Tight Tol.+/- in./mm	Normal Tol.+/- in./mm	Relaxed Tol.+/- in./mm
0-2 ft.	.030/0.76	.060/1.52	.125/3.18
2-5 ft.	.060/1.52	.125/3.18	.188/4.8
5-10 ft.	.188/4.8	.375/9.53	.500/12.7
10-20 ft.	.375/9.53	.500/12.7	.750/19.0
20-40 ft.	.500/12.7	.750/79.0	1.00/25.4
40-50 ft.	.750/19.0	1.00/25.4	2.00/50.8
>50 ft.	DICTATED BY APPLICATION CONTACT CMA		

*NOTE: Tolerances tighter than shown are sometimes attainable at additional cost.
Contact CMA Engineering for additional information.*

A small load is applied to any cable assembly in order to keep it straight and true, permitting accurate measurement. Any special tolerance conditions and/or inspection procedures should be reviewed with CMA Engineering and Quality Control personnel prior to drawing release and quotation request.

Cable Installation and Assembly Procedures

Proper handling and installation of cable and cable assemblies is important to obtain maximum cable life and to avoid premature failure. Cable assemblies should never be twisted, or the fittings rotated, during installation. Twisting and rotation will either unwind or over wind the strands, which can result in cable failure. Care should also be taken to avoid nicking, kinking, or bending of the cable during installation.

Any cable used in high life cycle reciprocating pulley applications should be inspected on a regular basis to confirm its integrity and condition.

Cable Assembly Design Criteria

A systematic approach to recording design criteria can help in reaching an appropriate design and proper specification for most cable assemblies.

DESIGN CRITERIA:

DEFINE APPLICATION: ____________________

ASSEMBLY WILL BE SUBJECT TO:
- TENSION LOAD ____________________
- COMPRESSION LOAD ____________________
- STATIC LOAD ____________________
- DYNAMIC LOAD ____________________

APPLICATION REQUIRES:
- CABLE ASSEMBLY: COMMERCIAL/OEM ____________________
- CYCLE FLEX MINIATURE ____________________

DEFINE:
- WORKING LOAD ____________________
- SHOCK LOAD (IF ANY) ____________________
- SAFETY FACTOR ____________________
- USE/LIFE CYCLE ____________________
- ENVIRONMENT ____________________

SELECT CABLE:
- CONSTRUCTION ____________________
- DIAMETER ____________________
- BARE/COATED ____________________

SELECT FITTINGS/TERMINALS:
- STANDARD ____________________
- CUSTOM ____________________
- TYPE ____________________

DEFINE TOLERANCE CONDITIONS: (See Assembly Tolerances Chart, page 7)
- TIGHT ____________________
- NORMAL ____________________
- RELAXED ____________________

NOTE: The completion of the CMA Application Data Sheet on our web site, or available from the CMA Sales Department, will also assist you in defining your requirements for a cable assembly design.

Detailing and Specifying Cable Assemblies

An engineering drawing, or sketch which is complete in terms of specifications and required control dimensions, provides a clear picture of the proposed assembly. This results in a more accurate quotation and evaluation of the design. CMA's Engineering, Sales Staff and Field Representatives are ready and willing to assist you in the design and specification of your cable assembly.

Note: For length tolerances refer to page 7.

Thermoplastic-Coated Cable

Cable life and/or the appearance of any assembly can be enhanced by specifying CMA PlasticCable. The pressure extruded thermoplastic coatings become an integral part of the cable and are highly recommended for use with lubricated cable in pulley applications. The coating seals out contaminants, retains cable lubrication, cushions the strands, resists abrasion and increases the life cycle capability of cable used in flexing applications. CMA's extensive background in cable coating technology and extrusion capability produces smooth, uniform and concentric coatings of high quality. Our standard "PC" resins, listed below, offer a selection of choices and colors suitable for pressure extrusion on cable. For specific recommendations based on your requirements or information on special and custom coatings, please contact CMA Sales and Engineering departments.

STANDARD PLASTICABLE COATINGS

Material	Part Number	Description	Typical Uses/Advantages
Nylon ((Polyamide)	PC 100	A very flexible and abrasion-resistant resin for use in high life cycle applications. Color- Slightly gray/translucent tint	Thin wall & pulley applications- . standard coating for Cycle-Flex miniature drive cables. Heat stabilized.
	PC 110	General-purpose resin with adequate flexibility and abrasion resistance. Color- Milky white/green tint	Most applications for cable 1/16" & larger, Lanyards, restraint cables.
	PC 113	General-purpose weather- resistant resin similar to PC 110. Color-Black	Most outdoor cable uses for larger dia. cables. Heat & light stabilized.
	PC 114	Very flexible and abrasion- resistant for larger diameter cables in pulley applications. Color- Black	High life cycle pulley applications, physical fitness equipment. Heat & light stabilized.
	PC 115	Relatively stiff, higher heats, chemical and abrasion-resistant resin. Color- Clear	Cable controls, lanyards, etc.
Vinyl (Polyvinylchloride)	PC 300	General purpose PVC resistant to fatigue, high flexibility. Color- Clear	High flexibility, appearance applications. Readily color matched security cables, lanyards.
	PC 301	Color – White/Opaque	Same as PC 300.
	PC 302	Color – Black/Opaque	Good mechanical properties with excellent flame resistance.
	PC 303	Color – Yellow/Opaque	Same as PC 300.
	PC 304	Color – Green/Opaque	Same as PC 300.
	PC 305	Color – Blue/Opaque	Same as PC 300.
	PC 307	Color – Red/Opaque	Same as PC 300.
TPE (ThermoplasticElastomer)	PC 904	Extrusion grade resin with rubber-like properties. Highly resistant to moisture and chemicals, good flexibility. Color-Black	Good for outdoor applications, tailgate cables, parts requiring flexibility and weather resistance.

NOTE: Other coatings are available such as polyethylene, polypropylene, urethane, etc. Custom resins and colors are available to suit your application. Contact CMA Sales and Engineering departments for additional information.

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