tyco
Electronics

The Rochester Corporation

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RE: Cable Handling, Spooling (for use on non-traction systems), Maintenance, and Operation

Electro-Optical-Mechanical Steel Armored Cable

Product as Delivered

The Rochester Corporation takes extreme care in the manufacture of Electro-Optical-Mechanical (EOM) cable to assure the most reliable product for prolonged service life. Most of the products are used in dynamic operating conditions whereby the cables are exposed to multiple deployments, flexure and loading combinations. Typically, these cables are constructed with contra-helical layers of high tensile, zinc-coated steel wires that have been flooded with a corrosion-inhibited lubricant. The application of the outer strength package usually restricts free-end rotation by design to minimize torque and overall elongation. Many of the products that are created for static operations, such as bottom-laid cables, also contain strength packages for deployment, but these packages are generally coated with light oil and covered with a plastic jacket to provide further protection against corrosion. These cables also employ strength packages that minimize the potential for torque or twist.

Cables with an outer armor layer are flooded with a corrosion-inhibited lubricant. The material is gravity fed unto the wires as they are formed prior to entering the closing die. This allows the lubricant to fully wet the cable core and wires. As the cable exits the closing die, a rubber wipe is typically applied to the cable to remove any excess lubricant from the outer-most surface; the result leaves a fine film coating on the wires. The standard material is a petrolatum based compound that exhibits a light brown appearance. The main purpose of this lubricant is to protect the wire surface during initial shipping and short-term storage. Although it is sufficient to protect the strength package during initial deployment, additional line maintenance including a lubrication program is required to promote continued protection.

Working cables are typically designed with torque restricting armor packages to restrict cable rotation and elongation. The manufactured product is generally improved after initial deployments to the designed working load of the cable. Initial working of a cable to the designed working load will remove constructional stretch and help to seat the various components of the cable providing for a more stable product. Manufactured cables also have another element that is considered separate from the designed torque-restricting package known as cast (manufactured residual torque). It is common for the product to display a twist, which can cause the product to form a loop while laid-out under little or no tension. Most often, the weight of the cable by itself is sufficient to prevent the formation of loops due to the torque balance design of the cable package. Cable cast is created during the application of the armor package, controlled by adjusting brake tension on each individual wire, by controlling the distance between the plates on the preform head, by controlling the distance from the head to the die, and the offset of the preform setting used to obtain the proper wire helix. The combination of these settings during the armor application will generate cast (twist) in the manufactured product. This characteristic should not be confused with the term "torque balance", which is derived and "fixed" by the design and construction of the cable. It is desired that the amount of cast be negligible or such that the direction of rotation causes the outer-most wire layer to get tight (whereby improving the smoothness of the package by keeping wires in close contact with their underlying layers). For a left-hand laid wire layer, the direction would be towards 11:00 O'clock when standing behind the reel and opposite to the side of cable entry. Cast is the residual torque that resides in the wire from normal machine back-twist, but is easily managed if accounted for during initial cable deployment. Typically, placement of a dead weight (dummy load similar to expected tool weight) on the end of a cable and allowing the product to rotate on the initial deployment will remove residual cast in the product.

Cable Installation

The importance of proper installation unto a winch cannot be overlooked and is essential in assuring prolonged cable life and performance. Typically, the “as manufactured” product is shipped on light-weight reels under low tensions. Cable wraps are generally applied using a single crossover, parallel, thread-lay practice, but adherence to this practice is loosely followed. The necessity to assure a fully thread-laid product from the factory is not required since the cable will be removed from the shipping reel onto the winch used for operations. It is important to note that shipping reels are not constructed to handle high cable tensions, therefore should remain on the low tension side of the traction winch during installation.

During spooling unto a winch, it is important to maintain a consistent thread lay where gaps between the cable wraps have been removed (minimized). Cable wraps should be tight to restrict movement during subsequent wraps. Critical is the initial layer, referred to as the bed layer or wrap. This bed layer should fill the entire surface of the drum making contact with both inside edges of the reel flange. Most often, filler materials are required to assure proper spacing at the interfaces of the flange to assure an even and smooth bed layer. Although flat drums can be used to support the initial bed wrap, attention should be directed toward the operational loads expected of the cable. Higher service loads typically require improved support of the bed layer. Again, it is the bed layer that determines the overall effectiveness of the entire cable installation process; therefore support of this layer is critical. For higher loads, it is common to utilize reels comprising grooved drums. These drums are grooved to a radius that closely match that of the cable thereby improving the support provided to the bed layer. Once the bed layer is established and is smooth and even, additional layers can be wrapped until the entire length of cable has been installed.

It is always best to begin the spooling process against the flange that will best control cable movement. On cables where the outer layer of armor displays a left-hand lay, it is recommend to fasten and begin the cable on the right flange (as seen standing behind, and opposite to the side of cable entry). For armor packages that display a right-hand lay, the opposite is recommended. In each case, the cable is being spooled to the top side of the drum.

There are basically two fundemental approaches used to thread lay a cable product for EOM cables. The easiest method, and one most frequently used, makes a single break (one crossover per revolution) whereby the cable is wound parallel to the flange and moves over one diameter per revolution. The second approach is more difficult, but provides an improved package. This is referred to as the counter-balance (double break) method whereby the cable is wound parallel to the flange and moves over one-half its diameter at 180° intervals. At the crossover points, the cable is subjected to severe abrasion and crushing as it is pushed over the underlying cables. Minimizing the travel using the counterbalance approach reduces the damage caused by these crossovers.

During the installation process, it is important for the operator to know the expected cable loads to be encountered. Since the winch will act as the main load support for the product, it is necessary to assure that the cable wraps are at a sufficient tension to support the operational loads. On systems employing traction winches, this is not relevent as the reel is used solely as a place for storage; high loads are not encountered. Improper loading of a cable during the installation procedure can cause cable damage resulting in premature line failure. This is particularly true if spooling tensions are significantly lower than the operational loads. The end result of such a condition generally results in cable crushing or flattening, its pulling down into the underlying wraps (referred too as knifing in), and in some cases places compressive loads on the cable structure itself. This effect can cause high attenuation rates of constructions utilizing optical fibers that are packaged in a tight-buffer configuration. To avoid premature cable failure due to improper installation tensions, it is recommended that the cable be loaded, as a minimum, 45% to 60% of its expected working load. It is not uncommon to encounter recommendations that exceed this value, particularly for operations that exceed approximately 2,000 meters of depth. At these depths, increasing tensions up to 80% of the expected work load will help offset the deleterious effects of insufficient spooling tension. It is necessary to understand that once a cable product is deployed for the first time, the actual load profile experienced by the cable will be transferred to the winch. It is the underlying layers that were not exposed to the working load that requires adequate pre-tensioning to support the newly acquired load profile. It is further recognized that excessive installation loads can place unnecessary stress on the cable. Higher installation loads require the use of reinforced reels and drums to support the cable, which are more expensive and costly to operate.

The application of a corrosive inhibited lubricating grease and/or oil is also recommended during the installation process. The application will promote prolonged cable service, as it will provide the adequate lubrication to minimize self-inflicted abrasion (scrubbing), and the required inhibitors to protect against corrosion. To optimize the effectiveness of the combined lubricant/inhibitor, it is important to fill all the open voids within the wire layers. Typically, heavy grease type materials and/or gel containing the required properties are sufficient for this purpose.

Bending Considerations

Recommended bending diameters are provided to assure customer expectations for cable life. "The larger the better" approach applies to bend diameters when it comes to prolonging cable service. Naturally, limitations on space restrict the operation of some cables to bend diameters smaller than recommended. Attached is a graph that depicts the effect bend diameters play on cable serviceability. It is recognized that the data was obtained from wire rope structures, however it is assumed that a correlation exists between the umbilical type cable and wire rope.

The Rochester Corporation specifies on its DATALINE a bend diameter that is intended to yield good performance and service. If a sheave is used that is smaller than that specified, degradation to cable components will accelerate. On the other hand, larger sheaves will provide the opposite action resulting in prolonged life and service. Our recommendations are based on factors that have been proven to provide adequate cable life, life that is acceptable to most cable users.

It is not our intent to restrict cables from running over smaller than recommended sheaves, but to inform the user that his action may deviate from our standard and accepted practice. Selection of smaller sheaves will accelerate the degradation process. Again, the customer must decide if the loss in service merits the reduction in sheave diameter.

It is preferable to have a cable take a single deflection than several along its path. Regardless of the length of contact, once a cable takes the shape of its support member and conforms to the circumference, it has experienced the effects associated from it. Only if the load is such that the cable does not take the shape of each individual member (a point contact) is this method an improvement. Many times reeving will contain small idler rollers and guides to control the path of a cable. Even though the main sheaves may be of adequate size, if these smaller guides cause the cable to take their shape, damage occurs and the goal of using larger sheaves is compromised. To limit space required to deflect a cable, roller bridges are sometimes constructed. Again, if the cable conforms to the radius of the small rollers (used to create a larger arc), damage from flex induced fatigue will result.

Often space available for the winch and handling system is limited causing compromises in the cable path. Reducing, preferably eliminating, any reverse bending along the cable path will further enhance the life of the product. Fleet angles between rollers and sheaves should also be kept to a minimum recognizing that angles of 1.5E or less are desirable. Angles greater than 1.5E have been used with success, but can accelerate cable degradation resulting in reduced life cycles. To enhance cable performance due to space limitations and increased fleet angles, sheaves should be mounted such that they self-center to the cable axis. Poorly aligned sheaves will cause accelerated wear and often induces unwanted twist in the product.

Operations and Maintenance

There are numerous factors to consider depending upon the application of the product. Each application may require its own specific set of parameters causing changes in the methods of handling. General points to consider include, but are not limited to, location of operation, depth, equipment to be deployed, and operating conditions (sea state, temperature, etc.). During deployment, a cable is required to handle its own weight in water as well as the weight of equipment attached. Torque-restricting armor packages are used to prevent excessive line rotation when an end is free to rotate, and torque if both ends are restrained. As load is increased, so is the stress exerted in each armor layer. Since armor packages are designed to limit this torque element, a job can proceed without incidence. A cable that has been deployed under tension should not be allowed to touch the seabed or go slack. A release of tension in this extended-tensioned state will cause a loop to form, as residual torque will try to equalize along the length. Pulling on a cable after it has formed a loop will result in a hockle (or knot) causing permanent line failure. As with all cable products, controlling line tension is important to prevent cable buckling or conductor "Z" kinking. Brief, severe changes in line tension, typical with high sea states, can cause internal cable components to yield resulting in buckling. The severity of this change, coupled with other energy disturbances can have a prominent effect on cable life.

For prolonged service, it is necessary to establish a preventive maintenance program to assure continual protection of the product. This would include the periodic rinsing of the cable with fresh water and application of corrosive inhibited lubricating oil. Lubrication is perhaps often misunderstood as it is intended to not only lubricate, but also to provide corrosion protection. A working cable contains many individual moving parts, all which require lubrication, exposed armor layers provide numerous voids for entrapping water and debris. This entrapment of corrosive material will result in accelerated deterioration of the galvanized steel wire layers. Removal of debris entraped by the wire itself is best completed by frequent repetitive fresh water rising and/or pressure flushing. If a cable is permitted to operate for extended periods prior to flushing, debris will eventually fill and pack all void space in the armor layers making it impossible to remove. For cables in this condition (where frequent cleaning is lacking), using a pressure lubrication system to flush and flood the armor with new lubricating grease or gel can be ineffective, leaving the internal voids dry with corrosive debris. For this reason, particularly if there is a poor frequency of rinsing, our recommendation is to use a light corrosive inhibiting oil. This material should preferably be a penetrating type oil to allow penetration into the material for improved saturation, and coating of individual wires.

Periodic examination of all surface areas coming in contact with the cable product should also be apart of a preventive maintenance program. The importance of proper sheave alignment to the cable path is required to minimize cable abrasion and induced torque (twist). Sheaves in contact with the product should be adequately sized to properly support the high stresses placed on the cable. Typical groove sizes would be machined 2% to 4% larger than the cable product and support 140E to 150E of the cable circumference. Worn or damaged sheave and guide rollers will accelerate cable failure and should be replaced immediately.

Electrically, most cables have the ability to function fully loaded while dissipating 1.5 to 1.75 watts/foot (~20°C ambient outside temperature). Environmental conditions such as temperature and depth must be considered when applying full power to a cable. Typically, cables that are deployed to full depth are less likely to overheat than cables used in shallow waters. Operation in shallow water during times of elevated outside temperature may create the need for external cooling of the reel since excess cable wraps are present. Maximum heating generally occurs within the center wrap sections, away from the drum and flanges.

Wear and Detection

All wires are coated with zinc for added protection. The appearance of white rust (zinc oxide, a by-product of corrosion) is an indicator that the zinc is being sacrificed and that the cable needs to be cleaned and new lubrication applied. The appearance of red rust (iron oxide) is an indicator that the zinc has been compromised and the base steel is being attacked. This attack comes in the form of surface pitting resulting in eventual failure of the steel wire. Periodic line flushing with fresh water and the reapplication of corrosive inhibited lubrication is essential in prolonging the life of the product. Wires should be periodically tested when signs of deterioration are exhibited. Two simple tests that can be completed during the termination process to assure cable integrity include the “e” kink test and measurement of wire wear. The “e” kink test involves the removal of each wire (~18” to 24” in length) from the cable. While holding each end of the wire, form it into a loop. Pull the loop taught forming the shape of a small letter “e”. A wire break indicates that the material may be brittle and not fit for service. A failure rate of 30% or more is reason for taking the cable out of service. To measure wear and abrasion, measure the diameter of the wire in two orthogonal planes being sure that one plane is perpendicular to the natural wire helix (cable axis). This will provide two measurements, one revealing the wire “thickness”, the other its width. If a wire is worn (its crown flattened), the measurement will be smaller than the wire width (which in this case is assumed to be close to the original wire diameter). A 20% loss in wire diameter of any single wire indicates abrasive wear and replacement is indicated. A visual examination is another easy step that can be taken to distinguish the need to increase the test frequency. The lack of zinc from the wire surface generally indicates wear and/or corrosive attack. Individual wires where surface pitting (depth of pitting) is determined to be greater than 6% of the wire diameter is another reason for replacement.

Other factors that can cause accelerated cable wear, besides poor lubrication and cleansing, involve poorly aligned sheaves, incorrect sheave grooves, small bending radii, rubbing on fixed structures, and improper installation tensions resulting in cable deformation (crushing). As noted earlier, minimize fleet angles, periodically measure sheave grooves for proper cable fit and support, ensure that the proper bending diameters are being maintained, and prevent contact with fixed structures.

Periodically reversing a cable (end for end) will promote service life. This will change the cable’s position in the reeving and place the whip end (equipment end) of the cable on the drum thereby reducing the effects of flex-induced fatigue. More often, cable failures from excessive flexure occur within 150 meters of the whip end when attached to free-flying vehicles. For this reason, if reversing a cable is not practical for the operator, periodic removal of the cable end and re-termination will prevent catastrophic failure.

Cable Loading

Rochester typically specifies two load values on the Dataline. The first value is referenced as the "Breaking Strength" and the second our recommended "Working Load". Occasionally, our customer's are concerned that working loads are too low and inadequate for operational dynamics. When this occurs, we are requested to place a third value on our Dataline. We refer to this value as "Peak Working Load".

Breaking strength is defined as the ultimate tensile strength of the product; it is expected to part at that load, or slightly above. Most often, we would expect this to be a minimum figure, although we do state it as a nominal value. Due to the various conditions that can be applied to a cable, its ultimate tensile strength can vary. As with most products there is a slow degradation process occurring as they are being worked. Interestingly, a slightly used product typically breaks higher than a newly manufactured product until the effects of wear, abrasion, and fatigue become a factor. This is due to the fact that on initial runs, manufactured (permanent) stretch is removed from the product, and stress is more evenly distributed among the individual cable components. Breaking strength is often taken from calculated values and is assumed that the cable is properly terminated and pulled straight in a fixed position and perpendicular to the cross head (load cell, etc.). Cables pulled at an angle or bent around sheaves will experience lower than specified values.

Recommended working load shown on our Dataline should be considered for quasi-static operations. These values are based on cable strain and are below the yield limits of internal components. More often than not, the copper components comprising a cable are the limiting elements, not the optical fibers. Often, it so happens that the working load is one-fourth of the cable breaking strength, therefore a good rule of thumb when breaking strength is known. It should be recognized that we rate working load on cable strain data, not the 4:1 factor. For this reason, there can be exceptions to the 4:1 rule. Quasi-static is a term used to indicate that a cable is in constant motion while deployed, but load transients are controlled and limited. For this reason, we recognize that the working load value should contain a factor of safety. Since we rate working loads on cable strain, we specify values that are well within the yield limit of cable components. This permits operation at loads that exceed our recommended working load. We do not advertise working at higher than recommended values since normal operational conditions will typically experience short "controlled" spike loads that are too short to be displayed by equipment, and that consume the built-in safety factor of our working load value.

When requested, we will display a "Peak Working Load" value on the Dataline. This value represents a load whereby cable strain is at, or near the yield limit of internal components. The safety factor used for recommended working load is not present and operation at this level must include the expected transient (spike) loads experienced in most operations. Since most gauges do not have the sensitivity to react to these transients, operations at the peak-working load may cause accelerated cable degradation. Transient loads that exceed the peak cable load need to be gradual and controlled.

When taking readings of cable tension, it is important to recognize the delay and sensitivity of the measurement equipment, the operating conditions (sea state), length of cable deployed, etc. Most detrimental to cable operations are the synergistic effect of cable loading and transient wave forms (energy disturbances) existent within the cable. These can comprise:

- *Compression waves - Compression waveforms are those that compress and expand adjacent matter.*
- *Longitudinal waves - Longitudinal waveforms are those that displace backward and forward in the direction in which the waves are traveling.*
- *Transverse waves - Transverse waveforms are those that travel in paths, which are at right angles to the direction of the waveform.*
- *Standing waves - Standing waveforms are those that travel in two directions simultaneously.*

As tension increases, so does the velocity of disturbance in the cable from transient waveforms. This energy disturbance can result in conductor buckling and premature cable failure. Typically, deep deployment schemes are friendlier on cables due to the dampening effect of the ocean environment, conversely, initial deployment, and retrieval in shallow depths, and at the surface are severe, and therefore caution is needed to minimize these detrimental effects.

Cable Storage & Handling

Depending on cable weight and size, The Rochester Corporation typically uses steel shipping reels for storage and transporation. These reels are constructed to handle maximum spooling loads of approximately 3,000 lbf and are intended to get the product to the destination point where they are off loaded. These reels are not intended to be used multiple times as their construction does not permit excessive handling. Upon request, reels can be supplied to handle higher spooling tensions and multiple uses. These reels are generally heavier and reinforced for this purpose.

Reels should always remain upright resting on both flanges. Movement with fork lifts or overhead cranes is encouraged, but some rolling is acceptable providing proper safety precautions are in place to prevent uncontrolled movement. Rolling of a reel on its flange should be restricted and only used to aid in lining it with other lift equipment. A good rule of thumb is to restrict rolling to one revolution or less. Placement of a reel on its side is not recommended and may cause cable to unwrap and tangle. Cable reels are constructed to support the product while upright.

Reels may be stored indoors or out, but covered from exposure to direct sunlight or UV radiation. Covers (tarps, etc.) should be placed loosely around the product to allow open air circulation. For long term storage, it is recommended to apply an additional lubricating spray to the outer-layer of armor to protect against normal atmospheric corrosion. Storage temperatures of -25°C to 60°C are acceptable, although the lower temperature (~0°C to ~30°C) is preferred. Storage in low humidity areas (<50%) are also recommended, but not always practical. Temperatures exceeding the low and high temperature range may be detrimental to the product.

General

Wire Characteristics

- *Steel Wire*
  - *Young's Modulus of 28 x 10^6 psi*
  - *Least likely to deform (yield) at work load*
  - *Elongates approximately 2.3% to break*
  - *Typical yield is at 0.65% to 0.70% elongation*
- *Copper Wire*
  - *Young's Modulus of 17 x 10^6 psi*
  - *Most likely to deform (yield) at work load*
  - *Elongates approximately 30% to break*
  - *Typical yield is at 0.15% to 0.20% elongation*

Optical Fiber Characteristics

- *Proof Load is typically 150 kpsi to 200 kpsi*
- *Elongation to proof load is 1.5% to 2.0%*
- *Ultimate tensile strength is 800 kpsi (pure silica)*
- *Attenuation rates (typical)*
  - *SMF @ 1310 = 0.4 dB/km*
  - *@ 1550 = 0.25 dB/km*
  - *MMF @ 850 = 3.6 dB/km*
  - *@,1300 = 1.6 dB/km*

Voltage Ratings

Typically, ratings are adjusted to meet desired voltage stress levels. Voltage stress levels at normal atmospheric pressure exceeding 55 v/mil for AC circuits and 77 v/mil for DC circuits will cause the generation of corona (a partial discharge or ionization of air which occurs when a high-voltage difference is impressed between a conductor and ground). Corona is the ionization of gas occupying the voids surrounding the interface area between the dielectric and conductor. This charged gas is detrimental to the dielectric and will result in its eventual break down. It can also interfere with other transmission circuits since the electrical discharge may be impressed upon them causing "electrical noise". Working cables typically operate with voltage stress levels that exceed the inception and extinction level. This is acceptable since other factors reletive to working cables are generally the primary cause for failure (flex induced fatique, corrosion, external damage, etc.). It is recognized that excessively high voltage stress levels can play a factor and will shorted the service life of a cable. Thin wall dielectric extrusions, which result in higher voltage stress levels, are also more susceptible to mechanical wear *in working cables. For these reasons, cables are designed to provide a balance between the desired electrical and mechanical performance properties.*

$$S = \frac{E}{xLog_e(R/r)}$$

Where:

S = electrical stress, volt/mil
x = distance from the center of conductor to the point of stress calculation, mils
r = radius of center conductor, mils
R = radius of core (or inner radius of outer conductor), mils
E = voltage between inner conductor and outer conductor

Conductor Resistance

Conductor resistance is affected by temperature and can cause slight changes in the operating system. To better understand the effect of temperature on copper conductors, refer to the attached temperature correction chart at the end of this discussion.

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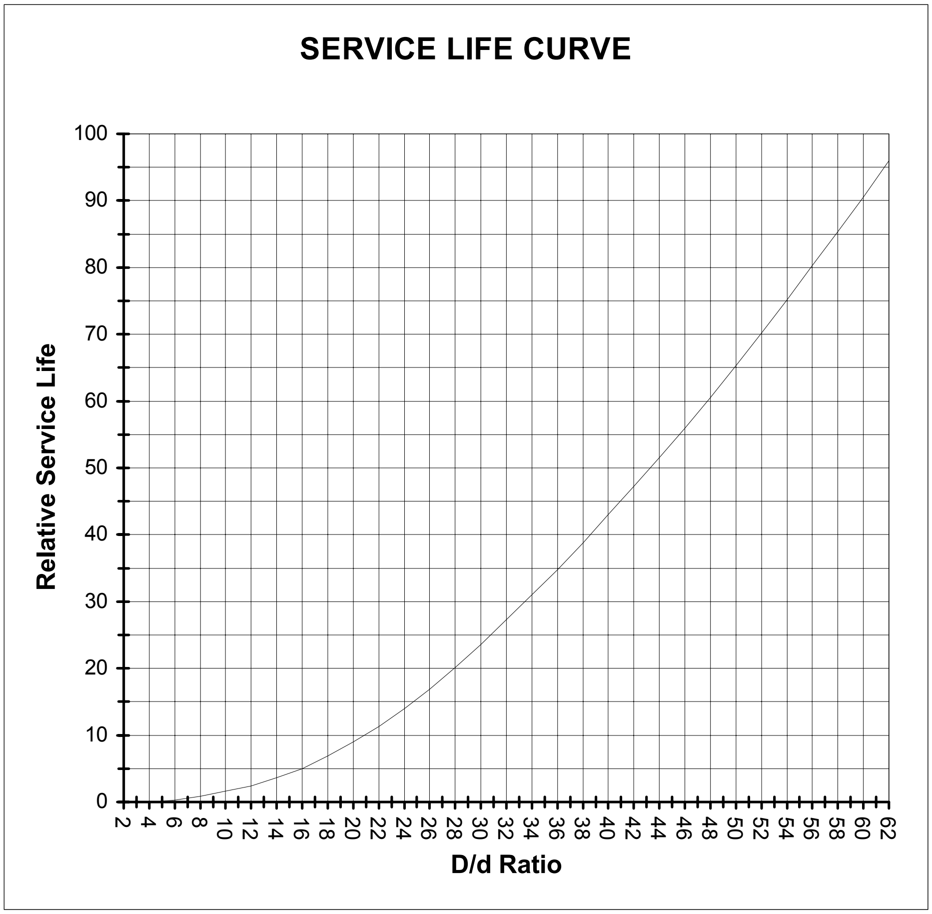
05-Jun-2002

RELATIVE SERVICE CURVE OVER SHEAVES

(Laboratory testing on Wire Rope Constructions)



How used: Graph shows the effect of sheave size on the service received from the product. Assume that a 1” cable is used over a 16” sheave. This would be a D/d of 16:1 = 16. On graph, a D/d of 16 gives a relative service life of 5.0. Now assume that the same 1” cable is to be used with a 24” sheave (D/d = 24:1 = 24). From graph, a D/d of 24 gives a relative service life of 14. This means that changing from a 16” to a 24” sheave will produce an increase in service of 14:5 = 2.8. The larger sheave will provide approximately 2.8 times as much service as the 16” sheave (a 180% increase in life).

Data was taken on various wire rope constructions and laboratory data based on bending stresses that were introduced by a specially designed machine. The curve is a simple parabola having an equation of $X^2=39_y$. Similar curves can be found in various wire rope publications. Only laboratory testing conducted on the specific cable in question will provide more meaningful data. This chart is provided as a reference only. Data was obtained from an unknown source; although we believe it to be accurate information to the best of our knowledge, no warranty is given with respect to such information.

TEMPERATURE CORRECTION CHART

(for bright copper wire; corrected to 20°C)

C	F	Corr.	C	F	Corr.	C	F	Corr.	C	F	Corr.
-40	-40.0	1.30856	1	33.8	1.08070	42	107.6	0.92042	83	181.4	0.80155
-39	-38.2	1.30186	2	35.6	1.07613	43	109.4	0.91710	84	183.2	0.79903
-38	-36.4	1.29524	3	37.4	1.07159	44	111.2	0.91381	85	185.0	0.79653
-37	-34.6	1.28868	4	39.2	1.06710	45	113.0	0.91054	86	186.8	0.79404
-36	-32.8	1.28218	5	41.0	1.06264	46	114.8	0.90729	87	188.6	0.79157
-35	-31.0	1.27575	6	42.8	1.05822	47	116.6	0.90407	88	190.4	0.78912
-34	-29.2	1.26939	7	44.6	1.05384	48	118.4	0.90087	89	192.2	0.78668
-33	-27.4	1.26309	8	46.4	1.04949	49	120.2	0.89769	90	194.0	0.78425
-32	-25.6	1.25685	9	48.2	1.04518	50	122.0	0.89453	91	195.8	0.78184
-31	-23.8	1.25067	10	50.0	1.04091	51	123.8	0.89140	92	197.6	0.77945
-30	-22.0	1.24456	11	51.8	1.03667	52	125.6	0.88829	93	199.4	0.77707
-29	-20.2	1.23850	12	53.6	1.03246	53	127.4	0.88520	94	201.2	0.77470
-28	-18.4	1.23250	13	55.4	1.02829	54	129.2	0.88213	95	203.0	0.77235
-27	-16.6	1.22656	14	57.2	1.02415	55	131.0	0.87908	96	204.8	0.77001
-26	-14.8	1.22067	15	59.0	1.02004	56	132.8	0.87606	97	206.6	0.76769
-25	-13.0	1.21485	16	60.8	1.01597	57	134.6	0.87305	98	208.4	0.76538
-24	-11.2	1.20907	17	62.6	1.01193	58	136.4	0.87006	99	210.2	0.76309
-23	-9.4	1.20335	18	64.4	1.00792	59	138.2	0.86710	100	212.0	0.76080
-22	-7.6	1.19769	19	66.2	1.00395	60	140.0	0.86415	101	213.8	0.75854
-21	-5.8	1.19208	**20**	**68.0**	**1.00000**	61	141.8	0.86123	102	215.6	0.75628
-20	-4.0	1.18652	21	69.8	0.99609	62	143.6	0.85832	103	217.4	0.75404
-19	-2.2	1.18101	22	71.6	0.99220	63	145.4	0.85544	104	219.2	0.75181
-18	-0.4	1.17556	23	73.4	0.98835	64	147.2	0.85257	105	221.0	0.74960
-17	1.4	1.17015	24	75.2	0.98452	65	149.0	0.84973	106	222.8	0.74740
-16	3.2	1.16480	25	77.0	0.98073	66	150.8	0.84690	107	224.6	0.74521
-15	5.0	1.15949	26	78.8	0.97696	67	152.6	0.84409	108	226.4	0.74303
-14	6.8	1.15423	27	80.6	0.97323	68	154.4	0.84130	109	228.2	0.74087
-13	8.6	1.14902	28	82.4	0.96952	69	156.2	0.83853	110	230.0	0.73872
-12	10.4	1.14385	29	84.2	0.96584	70	158.0	0.83577	111	231.8	0.73658
-11	12.2	1.13873	30	86.0	0.96219	71	159.8	0.83303	112	233.6	0.73445
-10	14.0	1.13366	31	87.8	0.95856	72	161.6	0.83032	113	235.4	0.73234
-9	15.8	1.12863	32	89.6	0.95496	73	163.4	0.82762	114	237.2	0.73024
-8	17.6	1.12365	33	91.4	0.95139	74	165.2	0.82493	115	239.0	0.72815
-7	19.4	1.11871	34	93.2	0.94785	75	167.0	0.82227	116	240.8	0.72607
-6	21.2	1.11381	35	95.0	0.94433	76	168.8	0.81962	117	242.6	0.72400
-5	23.0	1.10895	36	96.8	0.94084	77	170.6	0.81699	118	244.4	0.72195
-4	24.8	1.10414	37	98.6	0.93737	78	172.4	0.81437	119	246.2	0.71991
-3	26.6	1.09937	38	100.4	0.93393	79	174.2	0.81177	120	248.0	0.71788
-2	28.4	1.09464	39	102.2	0.93052	80	176.0	0.80919	121	249.8	0.71586
-1	30.2	1.08995	40	104.0	0.92713	81	177.8	0.80663	122	251.6	0.71385
0	32.0	1.08530	41	105.8	0.92376	82	179.6	0.80408	123	253.4	0.71185

Measured resistance (at temperature) multiplied by the correction factor equals the resistance at 20°C.