HOW TO CHOOSE WINCH WIRE

By Max and Marjorie Breitenbach

The selection of wire is a frequently recurring problem for organizations which depend on power winches to keep their ships in the air. The appendix to this article demonstrates that the most suitable wire for a specific winch can be easily determined by substituting specific values in a given formula. (Nos. 3 and 4). No effort is made here to design a winch, nor is it suggested that takeoff loads do not at times exceed the values "P" determind. It is simply a matter of the most efficient use of standard materials and present equipment.

Tables are appended for the non-mathematical, which list recommended wire specifications and show the relationship between drum size and wire diameter, using high tensile strength steel wire.

With any winch the optimum wire size is a function of drum diameter, wire diameter, tensile strength of the wire, and Young's modulus of elasticity. (That ratio, within the elastic limit of a material, of **stress** (pounds per square inch) and **strain** (inches distortion per inch of length).

Any other size wire than that given in Table I will give a smaller maximum permissable tension load at release hook. For example, for a 12-inch drum radius:

Wire	Diameter	Tension Load
No. 9, Brown & Sharp	.1144 inches	380 lbs.
Optimum Wire	.096 inches	434 lbs.
No. 12 Brown & Sharp	.0808 inches	403 lbs.

TABLE I

Radius of Drum (R)	Optimum Wire Diameter (D)	Maximum Permissable Tension Load (P)
12 inches	.096 inches	434 lbs.
14 inches	.112 inches	590 lbs.
16 inches	.128 inches	770 lbs.
18 inches	.114 inches	978 lbs.
20 inches	.160 inches	1205 lbs.

These figures are based on 180,000 p.s.i yield stress. Wires most suitable for winch operation have the following specifications:

	Ultimate Load	Yield Point
Spring Steel, QQ-W-465	200,000 psi	160,000 (est)
Music Wire, AN-W-17	260,000 psi	195,002 (est)
Corrosion-Resistant Steel	200,000 psi	180,000-190,000

Wire gauges most nearly approaching these optimum diameters will have to be substituted for the size actually determined.

It will be observed that Table I is based on the yield strength of the wire, and thus the wire is good for a higher load than indicated before it actually fails. Every time, however, that the values of Table I are exceeded the wire accrues further work hardening and is subject to earlier fatigue failure. This eventual failure is inescapable with many present-day winches. In spite of this the wire recommended remains the best for a given drum diameter.

NACA report TN 844 by Wolfgang Klemperer gives the results of experiments measuring the actual loads at the wire release hook. The figures suggest that most contemporary winches are designed with drum diameters too small for launching two-place ships.

Winch wire is subject to two stresses (a) the pull at the release hook and (b) the bending of the wire around the drum. This derivation sums up the two stresses and determines wire and drum dimensions which give the highest ratio of release load stress to total wire stress.

f—Yield stress of material (PSI)
P—Maximum tension load at release hook
E—Young's modulus of elasticity
R—Winch drum radius
D—Wire diameter
*M—Bending moment (in lbs.) $= \frac{EI}{R}$

where I=moment of inertia of wire (which cancels out)

The stress (a) due to load at the release hook is:

$f(a) = \frac{P}{A} = \frac{4P}{\pi D^2}$ where $\frac{\pi D^2}{4}$. cross section area of the wire.

The stress (b) due to bending the wire about the winch drum is

$$f(b) = \frac{{}^{*}MD}{2I} = \frac{D}{2I} \times \frac{EI}{R} = \frac{ED}{2R}$$

thus:

1. $f = f(a) + f(b) = \frac{4P}{\pi D^2} + \frac{ED}{2R}$

solve for P when

$$f - \frac{ED}{2R} = \frac{4P}{\pi D^2}$$

or

2. $P = \frac{\pi}{4}\left(fD^2 - \frac{ED^3}{2R}\right)$

Differentiating P with respect to D shows that

$$\frac{dP}{dD} = \frac{\pi}{4}\left(2fD - \frac{3ED^2}{2R}\right)$$

or, (solving for D) P is maximum when

3. $D = \frac{4fR}{3E}$

Substituting Eqn 3 into Eqn 2

$$P = \frac{\pi D^2}{4}\left(f - \frac{ED}{2R}\right) = \frac{\pi D^2}{4}\left(f - \frac{E}{2R}\,\frac{4fR}{3E}\right) = \frac{\pi D^2}{4}\left(f - \frac{2}{3}f\right)$$

or

4. $P = \frac{\pi D^2 f}{12}$

• *Mid-South Contest*

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Illinois were challenged. Although none showed up the group did show a serious interest in competing next year.

On May 29 and 30 the group moved to the Starkville Airport where the various pilots exchanged analysis on various sailplanes. The Weihe was performance tested by Dick Johnson and later a comparison test was made between the Schweizer 1-23, flown by Coverdale, and the Flat Top A-1 flown by Dick Johnson. As performance tests had shown previously the 1-23 outperformed the Flat Top at all speeds except at the minimum sinking speed of the Flat Top. Prior to this test the Engineering Research Station staff had removed the pitot in the Schweizer 1-23 and installed a nose pitot and also covered the ventilator opening.

These changes were expected to reduce the drag coefficient a small though worthwhile percentage. Computations on these tests are now being completed and will be published later.

Point Results of Mid-South Contest

Shelly Charles	368	Bill Coverdale	159
Dick Johnson	313	August Raspet	82
Ray Parker	186	Bill Cunnyngham	21