Critical Angle Safety Factors

Presented by:

Bruce Smith

Safety Factors

By Bruce W. Smith
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NFPA clearly states that prior to "Life-Loading" a System Safety Check should be conducted. This usually occurs in specific steps.

1. A physical and visual check must be made to ensure proper engineering and rigging.
2. A load test should be performed prior to life-loading the system.
3. Verbal confirmation of these actions must be announced and acknowledged before life-loading the rope rescue system.

Numbers 2 and 3 are pretty self explanatory, but number 1 has many intricacies that may take years to learn and master. One part of this inspection should be to ensure that you have engineered your desired safety factor throughout the engineered system. Inspections should take place to include each component and to be sure that a weak link hasn't been mistakenly engineered into the system.

The strength and safety factors of most system elements are intuitive. The strength of many components are stamped on the piece of gear. However, rope and webbing angles are not so intuitive. Determining the safety factor of a critical angle is not commonly discussed. To quantify critical angles in terms of useable safety factors requires looking at the problem from the "perceived load" on the system to then move through the math and determine the actual safety factor.

About the Presenter

Bruce Smith: Bruce has been passionate about rope work for well over 45 years and doing it professionally for the last 14. He was the curriculum developer for the NCRC for a number of years and a corporate educator in his professional life in the years from 1975-1995. He has been a Board Member of the vertical Section since 1971, Chairman, Treasurer, and was the newsletter editor for the Vertical Section for 14 years. He currently owns On Rope 1 and trains NFPA level students to a high degree of competency as rope technicians. On Rope 1 is an ISO 9001 manufacturing and retail facility with a reputation for the highest quality and reliability in the world of rope user products. Recently, in August 2008, he introduced the Vertical Section's Intermediate Training Course for the intermediate rope user at the National Convention. He has strong passions for caving, wild water, and travel, but especially rope work. He first presented at ITRS in 1988.

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Safety Factors and performing System Safety Checks Prior to Life Loading is a concern and important consideration and requirement everytime we rig to save a life.

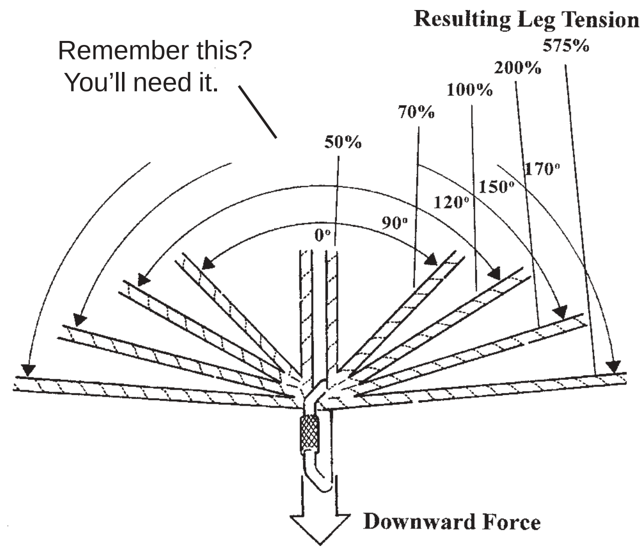
- NFPA asks that we complete a physical and visual check, and verbally confirm that all safety checks have occurred.
- We need to ensure that each element that is to be life loaded, be checked to ensure it is locked, or of the proper size and has a Safety Factor that complements the goals of the situation.

  e.g. An NFPA G rated pulley hs a 36 kN rating. If 1 kN is to be suspended from this pulley, the Safety Factor would be 36 : 1 -- Right?

- Critical angles are not so intuitive. Here is a new way to look at solving this part of **"What's happening when we rig?"**

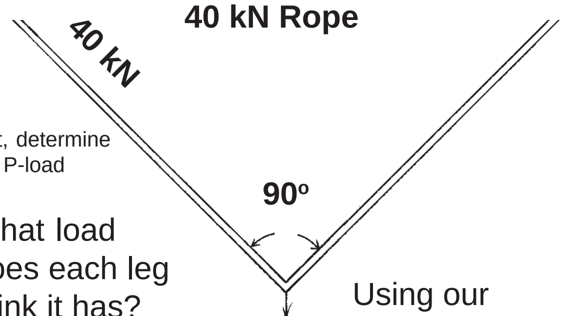
Safety Factor = **All you've got (support strength)** / **Perceived Load (P-Load)**

{P-Load is the load your rig thinks you have}



1. **40 kN Rope**

First, determine the P-load



What load does each leg think it has? (P-Load)

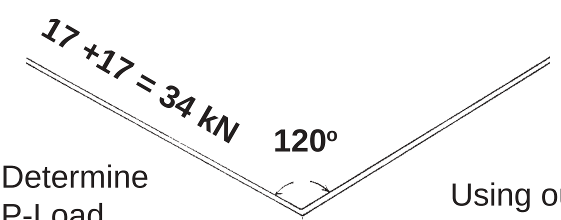
2 kN

Using our formula

2 kN x 70% = 1.4kN

$$\frac{40}{1.4} = 28.5 : 1$$

2. **W3P2 w/1" tubular webbing**



Determine P-Load

3 kN

Using our formula

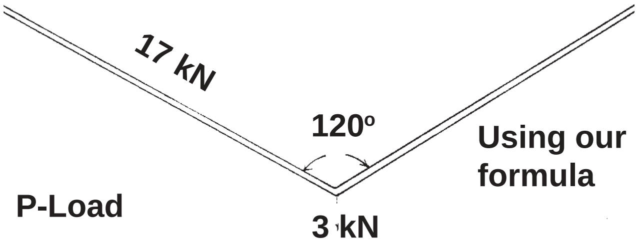
3 kN X 100% = 3kN

$$\frac{34}{3} = 11.33 : 1$$

More Safety Factors on the Critical Angle

3.

W2P1 w/1" tubular webbing



Using our formula

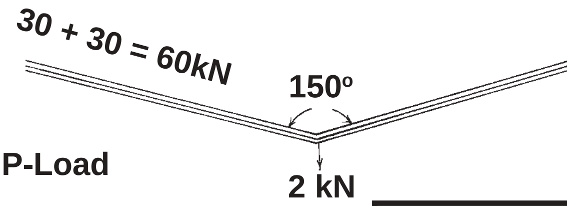
P-Load

3 kN x 100% = 3 kN

$\frac{17}{3}$ = 5.67 : 1

4.

Double Rope High Line w/ 30 kN rope



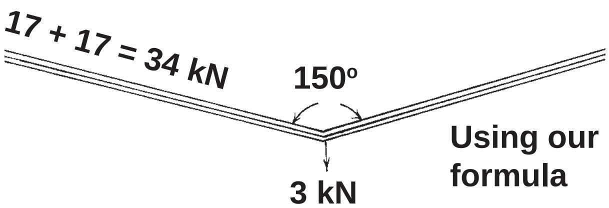
P-Load

2 kN x 200% = 4 kN

$\frac{60}{4}$ = 15 : 1

5.

W3P2 w/ 1" tubular webbing



Using our formula

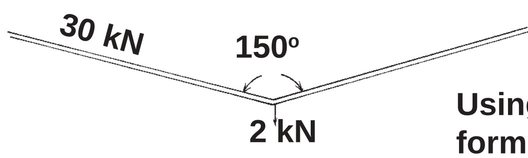
P-Load

3 kN x 200% = 6 kN

$\frac{34}{6}$ = 5.7 : 1

6.

Single rope High Line w/30 kN rope

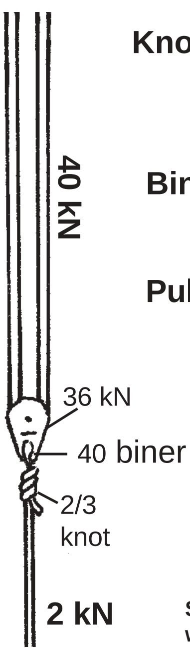


Using our formula

P-Load
2 kN X 200% = 4kN

$\frac{30}{4}$ = 7.5 : 1

7. **40 kN Rope**



Knot 2/3 X 40 kN = 26.7 kN

$\frac{26.7}{2}$ = 13.3 : 1

Biner **$\frac{40}{2}$ = 20 : 1**

Pulley **$\frac{36}{2}$ = 18 :1**

Critical Angle

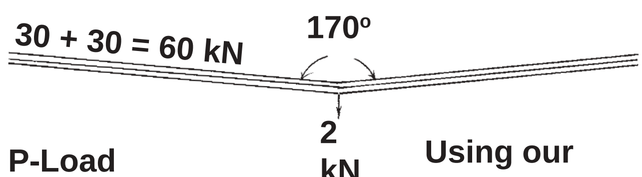
P-Load **0º = 50%**

2 kN x 50% = 1 kN

$\frac{40}{1}$ = 40 : 1

Safety factor identifies with the weakest link--- In this case, The Knot!

8. **Double High Line w/30 kN rope**



Using our formula

P-Load
2 kN x 575% = 11.5%

$\frac{60}{11.5}$ = 5.2 : 1

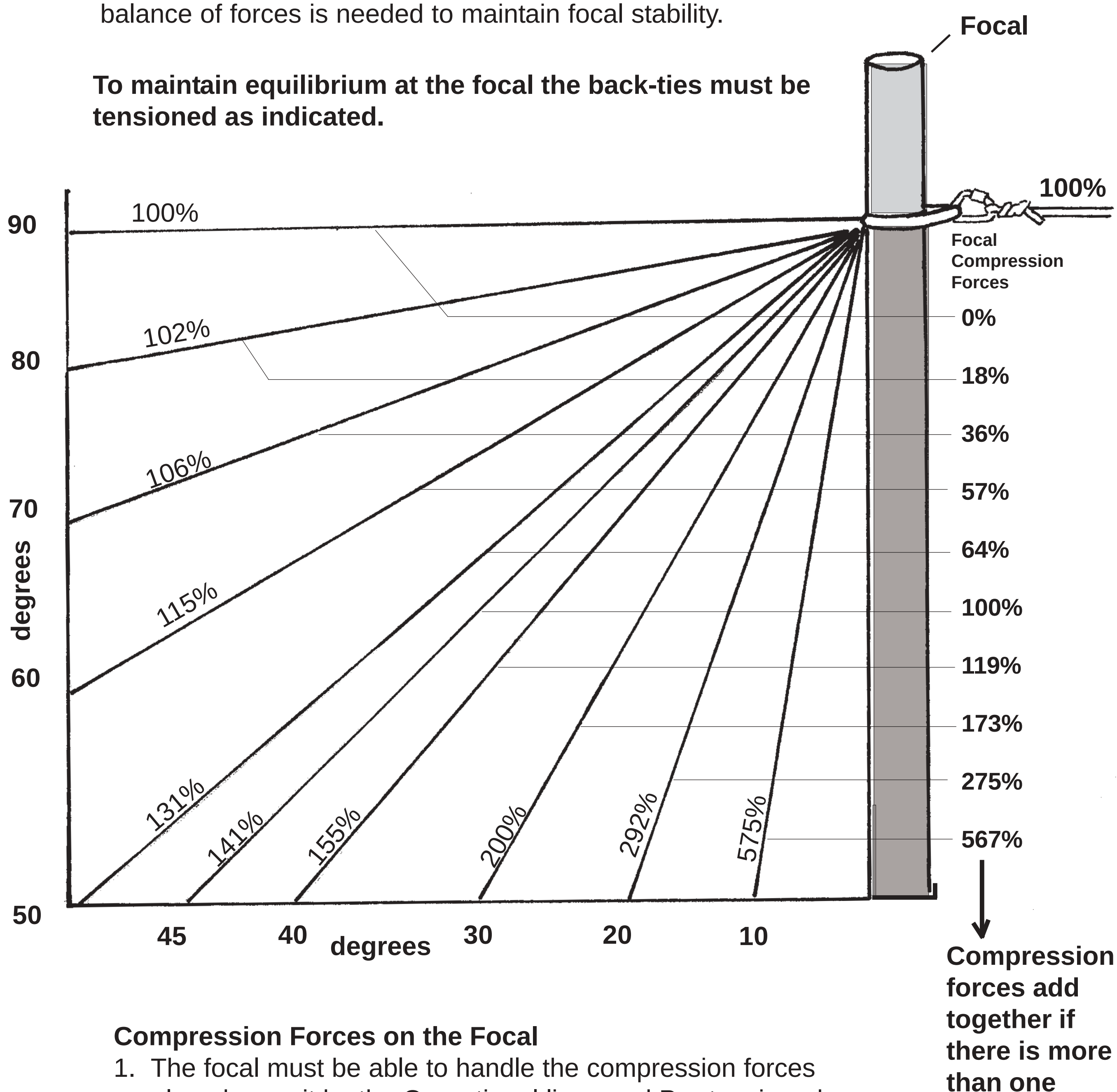
Note: The ultimate safety factor will be lowest of all the individual components--the weakest link so-to-speak. But here is a way to determine a not so intuitive elusive link that is not always obvious. If you're not sure of the angle, get a **goniometer.**

Bonus Page

Pre-tensioned Back-tie Forces and Compression Forces

The steepness of the pre-tensioned back-tie determines its necessary force. Low angle = low forces, steep angle = high forces. This balance of forces is needed to maintain focal stability.

To maintain equilibrium at the focal the back-ties must be tensioned as indicated.



Compression Forces on the Focal

1. The focal must be able to handle the compression forces placed upon it by the Operational lines and Pre-tensioned back-ties.
2. **"Focals in space"** have no compression forces to worry about. Orbs provide the opportunity for clean Focals in space.