The Editor,  
"International Ropeway Review,"  
Sir,  

I sometimes have cause to speculate whether the Ropeway engineering industry is as fully awake as it should be in these days to the commercial implications of the factors of safety which it adopts.

Our brother engineers who use wings instead of ropes to keep the loads off the ground, know full well that some of the most formidable non-paying passengers in an aircraft are its factors of safety, and they therefore see to it that they are kept to the practicable minimum. Surely, we have no less an interest than they have in avoiding the transportation of unnecessary weight?

The factors of safety which ropeway engineers still tend to use in moments of abstraction are a legacy from the early days of heavy engineering, when a really analytical approach to the calculation of stresses was frequently unknown (or unpopular), and the factors of safety were put in to cater for a fundamental ignorance of what was really happening in a machine part or a structural member.

Moreover, in those days, materials and labour were relatively cheap and much virtue was thought to reside in sheer weight. The words "massive construction" or "rigidly braced" figured largely in specifications; and the resounding sonority of these terms was only equaled by their complete freedom from any exact meaning.

However, the words seemed to comfort both the estimating departments and the prospective customers; and the machinery certainly lasted well. In fact, so far as this country is concerned, the principle founded the long-held, and once completely justified, opinion that British machinery was the most reliable in the world. The truth was that the lavish factors of safety had resulted in high life-factors as well.

Characteristically, it was an American engineer, in one of Kipling's stories of that time, who was made to explain "The British all think weight is strength!" and of course, it is true that our contemporaries in the United States have long been exponents of light construction; on the principle that machinery should be treated as an expendable item, and therefore not designed with a high life factor. The success of the method could not be disputed; but, since the days when Kipling wrote, it is true that there has been a general levelling-up of design, and apart from national characteristics of style, the products of one country are now very similar to those of another.

It is not that weight has no virtue in modern engineering and, in fact, in some cases it is essential to the purpose of the machinery. Machine tools and contractors' plant are two typical examples, but note that they are expensive ones. Weight costs money nowadays.

Theoretically, to align with modern possibilities in design, we ought to look on the safety factors of every detail with as much suspicion as we do the works' cost of its manufacture, and the safety factor ultimately chosen should be no higher than its commercial implications can carry.

I am aware that, in so choosing, it would be necessary to know with accuracy all the stresses we are imposing on the detail in question, and if it costs more to compute those stresses than it does to have the detail made obviously over-rigid, then naturally the latter method must be retained. But, the number of details so limited are not many, and I believe that there still remains a large field of possibilities open for accurate re-computation of stress in the light of modern knowledge, followed by confident design down to low safety factors of commercially justifiable proportions.

W. K. V. Phillips,  
B.Sc.(Lond.), A.M.I.Mech.E.

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Strains in locked coil ropes

The following correspondence took place between Mr. H. F. Shields and Professor Italo Bertolini of Milan Polytechnic. The subject matter is of considerable interest to ropeway engineers. Accordingly, we have obtained Professor Bertolini's permission to publish his views in the hope that other authorities may be tempted to express an opinion.

Dear Professor Bertolini,

On your recent visit to London I told you that I would write to you with regard to a problem concerning the breaking strain of locked coil ropes as made by the manufacturer, and you will notice the construction which has been adopted. I am also sending to you the breaking strain of the wire used in each layer.

You know that I am on the Working Committee of Organizzazione Internazionale Trasporti a Donna (O.I.T.A.F.), and one of our first matters for consideration will be the factor of safety to be used for these large locked coil ropes for passenger ropeways. The International Ropeway Association (I.R.A.) and Fédération Européenne de la Manutention (F.E.M.) have considered that the factor of safety should be based upon the aggregate breakingstrain...
of all the wires because it has been found almost impossible to arrive at an actual breaking strain.

The factor of safety would be a straightforward matter if the wires were all of the same breaking strain per square inch, but when so many wires of different breaking strains are combined into a rope, I hold the opinion that the wires with the lowest breaking strain work at a much lower factor of safety than the wires with the higher breaking strain. These wires with the low breaking strain are shown to be on the outside of the rope because they are of the shaped type. They have the greatest amount of work and yet if the load is distributed over the whole rope evenly, they would be the weakest although they are the most important.

This matter will have to be considered by the O.I.T.A.F. Committee, and I am wondering whether you have ever dealt with this problem in any other case.

Signed
H. F. Shields

Dear Mr. Shields,

I have briefly examined the composition of the rope as described in the papers attached to the letter.

In order to express a definite opinion I indeed need to know the precise operating data of the rope, namely maximum and minimum tension in the rope, number of carriages travelling on the rope, number of wheels in a carriage, load on each wheel of the carriage, foreseen operation rate (that is number of daily travels of carriages, total number of required working days in the life of rope or total required tonnage handled in the life of rope).

As I don’t know the above data, I can only say that in consideration of the diameter of the rope, I suppose it is the track cable of a cableway with high loads per wheel.

If this is right, it seems to me that the wires in the external layers (that is in the layers over the layer composed of 15 rail wires 0.16" and 15 round wires 0.156") are somewhat scarce. This holds particularly for the 43 round wires 0.134" and 38 round wires 0.134" layers, which are not far from the external surface of the rope and so can undergo high pressure by wheels. A small increase in the height of the full locked wires of the external layer too could probably be profitable.

The latter wires are of breaking strain perhaps somewhat too low.

On the question of the aggregate breaking strain and of the actual breaking strain of a rope, I point out that on tension tests to destruction of a rope, many times the outer wires of smaller breaking strain do not break before the others, because they generally possess a higher plasticity and so they can suffer a great elongation before rupture: so before the breaking of the rope, came out a somewhat more favourable distribution of stresses among the wires.

Moreover theoretical calculations and some experiments I carried out with strain gauges seem to indicate that in the elastic range the external wires undergo lower stresses than the internal ones. So the difference between the actual factor of safety of the internal high resistance wires and of the external ones is probably lower than one could infer barely considering their breaking strain.

On the other side the new Italian Regulations on Ropes, at present in course of preparation, will state a minimum value of the ratio between the breaking strain of the low strength wires (shaped wires) and that of the high strength wires (round wires): a minimum value of 0.75 is anticipated.

The Swiss Regulations on Ropes prescribe, since the year 1946, that the breaking strain of round wires should not exceed by 30 per cent the breaking strain of shaped ones.
Moreover the question of the safety factor against breaking caused by tension strain in a track cable is worthwhile only in view of an exceptional increase of the tension strain in the rope or of an internal not detectable deterioration caused by corrosion or by fatigue or by fatigue-corrosion.

Conversely, the breakages of wires actually occurring in operating track cables are almost always due to fatigue effects coming from the repeated stresses produced by the wheels. Such stresses may be very high if the wheels are not lined with rubber, but unfortunately it is not easy to calculate them and so to estimate their consequences.

As a result, the safety factor of wires against breaking by tension, if we evaluate as commonly the stress in the wire from the tension strain acting on the whole rope, does not agree with the actual safety factor of wires against breaking occurring in operation.

So in my opinion it would be as well to consider the aggregate breaking strain and to prescribe in addition a minimum value of the ratio between the strength of shaped wires and that of round wires.

Further it would be even better to consider a minimum value for the ratio between actual breaking strain and aggregate breaking strain of the rope, in order to have a check on the manufacture. I trust I have made clear to you some of my ideas on your subjects, and I will be pleased to answer to any other question of yours.

(Signed)  
Italo Bertolini

Dear Professor Bertolini,

I am glad to see that you have given some consideration to the problem of ropes which are made up of wires having several different breaking strains, and it is very interesting to note that the wires having the lower breaking strain do not break before the other, and I would agree with your suggestion that this is because they possess higher plasticity and can take a greater elongation before rupture.

Your penultimate paragraph seems to me to be the key to the situation, namely, that the aggregate breaking strain of all the various wires is the one to consider, but that there should be a ratio between the strength of the shaped wires and that of the round wires.

The question which we will have to decide when we discuss this matter at O.I.T.A.F. is whether a factor of safety of 3 on this aggregate is too low for passenger ropeways, and whether it would be better to increase the factor for these special circumstances.

I am sure that the benefit of your advice and experience will be appreciated by all the Members of O.I.T.A.F., when this is considered.

You are correct when you refer to the rope, of which I have sent you a section. It is a Cableway rope and the particulars are as follows:

- Maximum Tension: 140,000 kg.
- Minimum Tension: 80,000 kg.
- Number of Wheels in the carriage: 8
- Load on each wheel: 2,250 kg.
- Speed: 370 metres per minute
- Centres of wheels: 800 m/m
- Diameter of wheels: 600 m/m.

Please accept my grateful thanks for the trouble that you have taken in this matter.

(Signed)  
H. F. Shields

We are happy also to publish a letter on the same subject from another correspondent.

Dear Mr. Shields,

Modulus Value—Lock Coil Wires

You will recollect as we parted after the last A.R.A. meeting you made a statement re the above. Ever since I have had at the back of my mind the necessity for checking but have just been unable to get down to it until now.

I think the following may be of interest to you:

Wires in lock coil and half lock ropes

<table>
<thead>
<tr>
<th>Shape of wire</th>
<th>Modulus of Rounds</th>
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<tbody>
<tr>
<td>HALF LOCK</td>
<td>23.7 x 10⁶ / 24 x 10⁶</td>
</tr>
<tr>
<td>FULL LOCK</td>
<td>24 x 10⁶ / 25 x 10⁶</td>
</tr>
<tr>
<td>ROUNDS in half lock ring</td>
<td>25 x 10⁶ / 26 x 10⁶</td>
</tr>
</tbody>
</table>

Steel wire, av. 53.5 ton tensile: 30 x 10⁶ lb./in²
Annealed steel wire, av. 35 ton tensile: 29 x 10⁶ lb./in²
0.41 Carbon steel: 29.6 x 10⁶ lb./in²
1/7% Carbon steel: 30.2 x 10⁶ lb./in²
Nickel steel: 28.5 x 10⁶ lb./in²

If one roughs out the extension between the round and, say half lock wires on the outer covering of a half lock coil rope with rounds forming the core, ignoring rope construction, i.e., treating the wire alone, with a uniform load on the wire in proportion to that corresponding with areas, and loading to one third of the ultimate, then the difference of extension over 1,000 feet is, say 1.34 in. Thus, if the wires of the outer layer are securely held the loading in each wire obviously cannot be the same—equivalent areas, of course, and so on—actually about 8 per cent. difference.

If you have any test figures for 'E' on the different shaped wires and carbon content, I should very much appreciate details.

(Signed)  
C. S. Lowe