double the live load plus impact, would obviously have a factor of safety greater than two, throughout; would be uniformly safe; and would be considered a prudent design. The two clauses in question are intended to accomplish this end in every bridge design.

Each bridge possesses some members in which the unit stress resulting from overload, increases at a greater rate than the rate of increase in the load applied. All members, in which the dead load stress is of opposite sign to that of the maximum live load stress, belong to this class; likewise all members, the maximum live load stresses of which are produced by a partial loading of the span.

The total stresses in the chord members and end posts are directly proportional to the total loads covering the entire span length, hence to double the live load will increase the unit stresses in these members by a constant percentage, always less than 100 per cent., so long as the dead load stress is not zero. This same overload will generally increase the unit stresses in the web members in a much greater ratio than for the chords, hence the following two clauses in the specifications:—

"Members subjected to dead and live load stresses of the same character and in which the maximum live load stress is produced by the maximum live load covering the whole span, shall be proportioned for the sum of the dead load, live load and impact stresses on the basis of the allowable unit stresses f given for tension or compression, as the case requires. This applies generally to chords and end posts. Then, with the section so obtained for the middle chord member, and a total stress $S' = D.L. + 2 \times L.L. (1+I)$, find the unit stress f' resulting from 100 per cent. overload in the live load; and also, find the factor $k = f'/f$ (always less than 2) which represents the ratio of increase in the unit stress f due to 100 per cent. overload. This factor k will necessarily be a constant for all members of this class, and is to be used as directed in the following paragraph.

"Members subjected to dead and live load stresses of the same or opposite character and in which the live load stress is produced by a partial loading of the span, as for web members generally, shall be proportioned for the algebraic sum of the dead load stress and twice the live load stress plus impact, using a unit stress kf, where f is the allowable unit stress in tension or compression, as the case requires. Where a reversal in live load stress is possible, the sectional area should be computed separately for each combination with the dead load stress and the larger area will govern the design."

A structure so designed will have a uniform factor of safety well within the elastic limit for an overload of 100 per cent. in the live load; and will have a minimum factor of safety of two on the elastic limit, for the assumed live load. The unit stresses for the overloaded condition will thus approach the elastic limit for short spans wherein the dead load stresses are small compared with the live load stresses, while for long spans with excessive dead loads the effect of the overload is less severe.

The following example will illustrate the method of finding the required sectional areas of members after the dead and live load stresses are known:—

Example.—Given the *d.l.* and *l.l.* stresses in a single-track steam railway bridge of 452-ft. span, with [illegible] panels (intermediate span of Memphis Bridge). The negative sign indicates compression. Required to section the members. The impact formula is $I = \dfrac{165}{L+150}$, where L is the loaded length producing the *l.l.* stress.

Top Chord, central section U_6U_8 (by clause 1).

Dead load stress	= — 1,200,800 lbs.
Live load stress	= — 889,500 lbs.
Impact stress for I = 0.275	= — 244,500 lbs.
Total stress S	= — 2,334,800 lbs.

Allowable unit stress $f = 17{,}000 - 60\dfrac{l}{r} = 15{,}650$ lbs.

Hence, area required $= \dfrac{2{,}334{,}800}{15{,}650} = 149.3$ sq. ins. gross.

This is as per clause 1, for a top chord member.

Now find $S' = D.L. + 2 \times L.L. (1 + I) = 1{,}200{,}800 + 2 \times 889{,}500 \times 1.275 = 3{,}468{,}800$ lbs.; which represents 100 per cent. overload, and $f' = -\dfrac{-3{,}468{,}800}{149.3} = -23{,}260$ lbs., whence $k = f'/f = \dfrac{23{,}260}{15{,}650} = 1.485$.

Centre diagonal U_8M_7 (by clause 2).

Dead load stress	= — 20,100 lbs.
Live load stress	= — 111,900 lbs.
Impact stress for I = 0.408	= — 45,700 lbs.
Total stress S	= — 177,700 lbs.

Allowable unit stress $f = 16{,}000 - 80\dfrac{l}{r} = 10{,}675$ lbs.

$kf = 1.485 \times 10{,}675 = 15{,}850$ lbs.

Total stress S' with 100 per cent. overload = — 335,300 lbs.

Hence, area required $= \dfrac{335{,}300}{15{,}850} = 21.15$ sq. ins. gross.

The area required without the consideration of overload would have been $\dfrac{177{,}700}{10{,}675} = 16.64$ sq. ins. gross, for which the 100 per cent. overload would have produced a unit stress of $\dfrac{335{,}300}{16.64} = 20{,}150$ lbs. per sq. in., whence $f'/f = \dfrac{20{,}150}{10{,}675} = 1.89$.

This shows that, for double the live load stress, the unit stress in the top chord was increased 1.485 times, and for the post U_8M_7, the same overload would have increased the unit stress 1.89 times on the basis of 16.64 square inches of area, while the actual area required for this post by clause 2 is 21.15 square inches. This same post also receives a counter stress in tension equal to the compression, but, as the dead load stress is compressive, the counter stress did not give the maximum gross area required.

This illustrates how the above specification clauses operate to produce a structure of uniform strength throughout up to the practical limit of safety for the structure as a whole, which is at the elastic limit of the material. This method, therefore, accomplishes in a systematic manner everything necessary to safeguard the design of any member without resorting to crude and illogical devices which are usually wasteful and do not always accomplish the desired result.

The actual labor involved by this method is not excessive as might seem from the above figures, all of which are not required, but are given to show the nature of the results.

As to the allowable unit working stresses given in section D, Part 1, these are believed to represent the best modern conservative practice, and are all based on static load equivalents, assuming that all dynamic effects have been commuted into static effects by impact additions. This applies also to the working stresses given for bridge timber, concrete, masonry and foundations.