The question whether, in order to strengthen our tracks for the increased loads imposed, the number of ties or the depth of ballast, or both, should be increased, is one upon which opinions vary widely among those concerned. The following is here presented in this connection.

Fig. 3 shows a diagrammatic section of the ordinary standard main line track, in which 7-inch by 8-inch ties are spaced 22 inches apart, or 18 per 33-foot rail, and laid upon 6 inches of ballast. The slopes of the ballast pyramids, transmitting the load from bottom of tie to subgrade, are determined in accordance with Mr. Johnson's premises for the distribution of pressure at the bottom of stone ballast. It will be noted that the width of the base of the ballast pyramid under each tie is 14 inches and the width of the strip of subgrade unloaded and lying between adjacent ties is 8 inches. As shown by Director Schubert's experiments, and in line with the experience of all trackmen, the subgrade line, originally straight, will be disturbed, as AB in Fig. 4, the amount of disturbance being proportional to the weakness of the subgrade and to the ratio of the area of subgrade between the loaded ballast pyramids and that of subgrade beneath the ballast through which the load is transmitted.

By changing the tie-spacing to 20 inches, or 20 per 33-foot rail, as shown dotted in Fig. 3, the ratio of loaded to unloaded width of subgrade at the 6-inch depth of ballast becomes 14/6 instead of 14/8, an increase of 33⅓ per cent. The subgrade is more nearly confined, a condition which, of course, materially increases its carrying capacity. Maintaining the 22-inch tie-spacing and increasing the depth of ballast from 6 inches to 8 inches changes the ratio of loaded to unloaded width of subgrade from 14/8 to 16/6, an increase of approximately 52½ per cent.; while the combination of the decreased tie-spacing and increased ballast depth increases the original ratio from 14/8 to 16/4, or approximately 128.6 per cent.

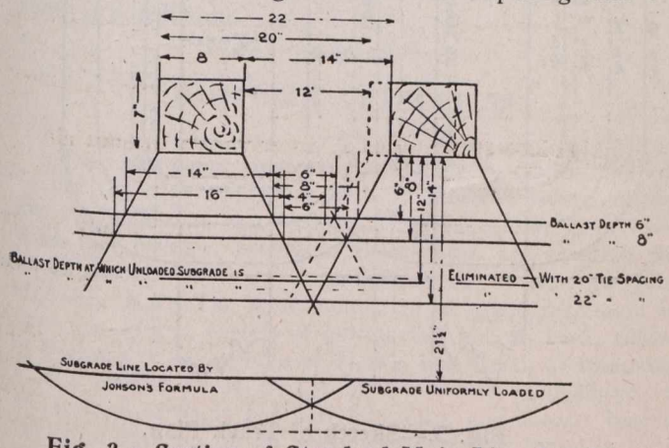

Fig. 3.—Section of Standard Main Line Track.

In the diagrammatic plan of track shown in Fig. 5 it is assumed that the rail load is spread by the tie 18 inches on each side of the rail centres, or, for an 8-inch tie, over an area of 36 times 8 = 288 square inches of the lower face of the tie under each rail, and over somewhat less than the 36 + 6 times 8 + 6, or 588 square inches of the subgrade. The corresponding area of unloaded subgrade is 42 times 8, or 336 square inches, and the ratio of loaded to unloaded subgrade areas is 588/336. Decreasing the tie-spacing to 20 inches will increase this ratio to 558/252, or 33⅓ per cent., while combining with this decrease, an increase of ballast depth of 2 inches, will increase the ratio to 588/168, or 100 per cent.

Fig. 5 also shows that with 18 ties per 33-foot rail the unloaded area of subgrade between adjacent ties becomes zero when the depth of ballast is increased from 6 inches to 14 inches, while with 20 ties per 33-foot rail it becomes zero with a ballast depth of 12 inches.

According to Johnson's formula for stone ballast, uniform distribution of subgrade loading will be obtained with 21⅓ inches of ballast for 18 ties per 33-foot rail and with 18⅔ inches of ballast for 20 ties per 33-foot rail.

Any consideration of the relief to be expected from decreasing the tie-spacing, increasing the depth of ballast or otherwise, should take into account the cost, and in this connection Table II. is presented.

From this table it is seen that a reduction of tie-spacing from 22 inches to 20 inches increases the ratio of width of loaded to unloaded subgrade by 33⅓ per cent. at a cost of $464, $928, and $1,856 per mile for single, double, and four-track lines respectively, while an increase of ballast depth of two inches (from 6 inches to 8 inches) increases this ratio by 52½ per cent. at the respective cost of $256.90, $507.23, and $1,006.51 per inch additional inches of additional ballast. Whether the first or the second or a combination of both is best is therefore somewhat of an open question.

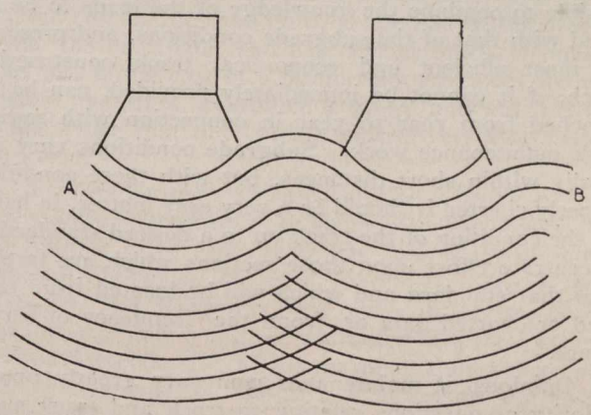

Fig. 4.—Lines of Distortion of Ballast Under Loaded Ties

Some individuals and committees have recently recommended a ballast depth greatly in excess of previously existing standards and still greater than the ballast depths actually obtaining even on our densely travelled lines, without qualification dependent upon either the subgrades or the characteristics of the imposed loads.

Table II.

Statement Showing Comparative Cost of Increasing Number of Ties per Rail Length (33 Feet) from 18 to 20 and Cost per Inch Depth of Putting Additional Ballast Under Standard Track of One of Our Larger Lines.

Ties per mile spaced	Single track.	Double track.	Four-track.
18 per rail length	2,880	5,760	11,520
20 per rail length	3,200	6,400	12,800
Additional ties	320	640	1,280

Cost per tie:

1 tie	$0.90	Volume of 1 tie, 3.3 cu. ft.
2 plates	.28	Cost of ballast, 75cts. per cu. yd.
8 spikes	.11	Cost of laying ballast, 40 cents per cubic yard.
	$1.29	Total cost of ballast in track, $1.15 per cubic yard.