the heavy reference line for the ideal condition quite closely upon one side of the boiler, but the leaning to the right of the plotted lines of the other diagram indicates more than a normal stretch.

The strains produced at the various places measured are plotted in this way and the diagrams accompany the paper. E-8 was taken near the girth seam between this and the next sheet and E-16 in the centre of the rear sheet close to, but not spanning, the longitudinal joint. Diagrams of the boiler are given in the paper showing the location of each of the spans measured. Fig. 3 shows the extension across the longitudinal seam on the middle course, curve C-7 being taken at the front edge, C-11 at the rear edge and C-15 in the middle of the sheet. The author points out that in the case of a three-course boiler with one sheet to a course, as found in current construction, it would seem that a double riveted lap joint might occasion (by reason of the greater extension) an excessive stress in the solid sheet abreast the end of the seam, under certain pressures.

Pressure on the exterior of the tubes necessarily extends them in length. The amount of the extension appears to depend upon their position with reference to their proximity to the shell. Tubes adjacent to the shell extend less than those at the middle of the rows, a restraining influence from the shell appearing to affect the outer ones.



Fig. 3.—Curves of Tangential Extension, Across Longtudinal Seams, at Middle of Length of Course and at Edges.

In a plain cylindrical shell, increase in diameter would necessarily be attended by a definite amount of endwise contraction, eliminating the effect of pressure on the heads. The tests showed that there were parts of the boiler which were nearly free from longitudinal strains, while there were other places in which the strains were reversed and longitudinal extension shown instead of contraction. Along the lower quarter of the boiler the longitudinal strains were contractions, while along the upper quarter they were in part contractions and in part extensions. Figs. 4 and 5 show the amount and character of these strains at 270 pounds in the middle of the sheets and across the girth seams respectively.

It will be noticed that the lower part of the shell contracted notwithstanding the fact that the tubes were extended by the exterior pressure to which they were subjected. This behavior calls for bending at the flanges of the heads to compensate for the difference of these movements. The six through braces would relieve the shell of a portion of the longitudinal tension coming from the heads in the upper half of the boiler. Longitudinal gauged lengths on the upper part of the shell showed diminished contractions over those observed on the lower portion or displayed strains of extension. On the very top of the boiler the strains were extensions of a pronounced order. The tests for which the figures and diagrams in the paper are given were made upon only one of the boilers. In the tests of the first boiler greater strains were displayed in the vicinity of the dome and the manhole frame than at other parts of the shell, which resulted in an early failure at these places. Actual rupture of the dome was not accomplished, but leakage along its single-riveted longitudinal seam became so great at 266 pounds that it was necessary to remove the dome and close the opening to it in the shell with a patch in order to reach higher pressures with the pump available.



Fig. 4.—Longitudinal Strains on Solid Sheets at Middle Length of Courses. Minus Signs Indicate Longitudinal Contraction; Plus Signs, Longitudinal Extension.

At 270 pounds the cast-iron manhole frame fractured across the middle of its length. Another patch was then put on the shell covering the manhole and the test resumed, when at 295 pounds the rupture of three braces of the front head occurred. The test was then discontinued and the boiler dismantled. The strain measurements made upon the boiler were of the same order as those reported for the second and the results were similar.

A feature, however, in the test of the first boiler was absent or obscure in that of the second. Measurements of strains across the longitudinal seams increased progressively in passing from the front to the rear end of the boiler. The author says: "While these seams were not directly exposed to the heated gases over the grates, nevertheless it seems probable that a wider range of thermal conditions prevailed



Fig. 5.—Longitudinal Strains Across Cirth Seams, Also Strains on Diagonal Cauged Lengths of Courses.

in the vicinity of seams at the front end over those at the rear end of the boiler. If such was the case it would aid in explaining the greater slip of the forward seams." Leakage at the longitudinal seams began at 120 pounds and became general at 180, but at this time the slip of the joints had become pronounced and necessarily disturbed the calking.

The second boiler was stripped of its dome and manhole frame and the openings covered with patches before it was