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STRAIN MEASUREMENTS OF STEAM BOILERS.

Two 72-inch boilers which had been in active operation for 27 years were contributed for investigative purposes by the late Nicholas Sheldon, treasurer of the Kendall Manufacturing Company, of Providence, R.I. They were made by the Whittier Machine Company, of Boston, Mass., out of "Benzon" steel, were put into service in March, 1881, and had never required repair or renewal in any part. They were made in five courses, two sheets to a course, and had the following general dimensions:

Diameter	72 in.
Length, over dry sheet	16 ft.
Thickness of shell	⅜ in.
Thickness of heads	½ in.
Number of tubes	140
Diameter of tubes	3 in.
Length of tubes	15 ft.
Diameter of dome	2 ft. 6 in.

Longitudinal seams, double-riveted lap joints, ¾-inch rivets, 2-inch pitch, punched holes, rows 2⅛ inches apart, rivets staggered.

Girth seam, ¾-inch rivets, 2⅛-inch pitch.

Heads stayed, each, with 14 braces.

Cast-iron manhole frames and safety-valve nozzle.

Supported by lugs, three on a side.

The feed-water came from the Pawtucket river.

The utmost advantage of this opportunity was secured by placing in charge of the tests James E. Howard, qualified by long years of service as the head of the government test-

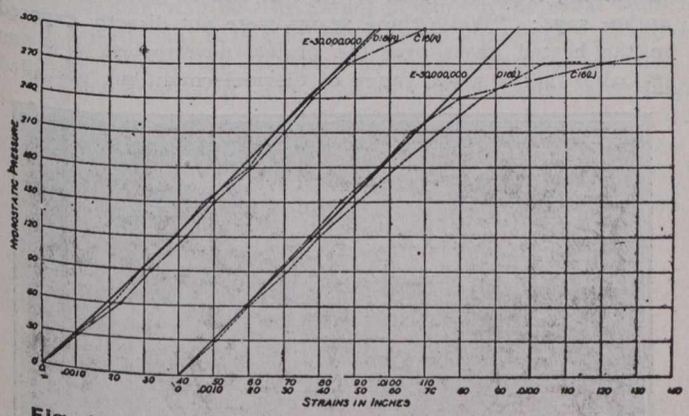

Fig. 1.—Curves of Tangential Extension, Solid Sheets, at Middle of Length of Courses.

ing plant, at the Watertown arsenal and now engineer-physicist of the Bureau of Standards, at Washington. He was advised and assisted by Francis B. Allen, vice-president of the Hartford Steam Boiler Inspection and Insurance Company. The tests were made at the W. H. Hicks Boiler Works, Providence, and form the subject of a paper to be presented at the December meeting of the American Society of Mechanical Engineers, from which the following information is derived:

The tests were made by subjecting the boilers to hydrostatic pressure and measuring the deformation at various points. For this purpose holes about 0.05 inch in diameter and 0.10 inch deep were drilled 10 inches apart in various portions of the shell, and reamed with a reamer having an angle of 65 degrees. A 10-inch strain gauge having conical points with an angle of 55 degrees, adjustable with a micrometer screw, was used to measure the distances between these holes as they varied under stress. The difference in

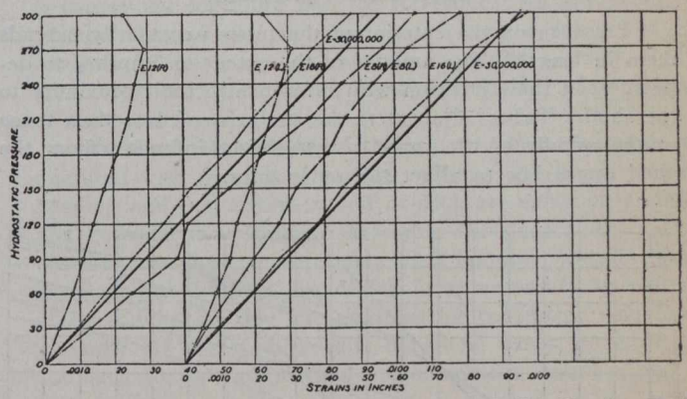

Fig. 2.—Curves of Tangential Extension, Solid Sheets, End Course Near Rear Head, Girth Seam and Middle of Length of Course.

angles made the gauge bear near the surface of the sheet $\frac{1}{10,000}$ and it is believed that the readings are reliable to $\frac{1}{10,000}$ inch. The stress which would produce an elongation of this amount in a distance of 10 inches is 300 pounds per square inch, assuming a modulus of elasticity of 30,000,000 pounds; that is, supposing that the stress per square inch divided by the stretch per inch of length would equal 30,000,000.

The boilers tested were of a very simple type, yet in very few instances were strains developed corresponding to those which would be indicated by the usual calculation for strains in a cylindrical shell subjected to internal pressure.

In Fig. 1 are laid off in a horizontal direction the amounts of stretch which would be produced by various pressures per square inch in a plain cylinder and with a modulus of elasticity of 30,000,000, each at a height corresponding to the pressure required to produce it. A pressure of 60 pounds per square inch in the interior of a cylinder of this diameter and thickness of shell would, for instance, produce a stretch of nearly 0.0020 inch in a length of 10 inches; and a pressure of 300 pounds a stretch of about 0.0095 inch. The points so determined would lie in the heavy straight line of the diagram marked E = 30,000,000. The distortions actually found were set off in the same way and connected by the lighter lines. They show the extensions of the third and fourth sheets of the boiler, counting from the front on the right and left sides of the boiler respectively, taken at the middle of the lengths of the courses. The courses are lettered A, B, C, D, E; C—16 R. on the diagram means gauged length 16 on sheet C, right-hand side. These follow