granite offered was at such a price as to exclude it, and no other suitable stone except the Marblehead limestone being offered, he was again driven to use it.

We may add that it was expected that the entire work would be completed last season; but we have not yet heard whether this was successfully accomplished.—*Engineering.*

BOILER BURSTING EXPERIMENTS.

In our last we stated that the American Government had undertaken a series of experiments on steam boilers and we promised to give the results of these experiments to our readers. The following succinct account is from the *Nautical Magazine* :—

Mr. Francis B. Stevens, of Hoboken, New Jersey, before September, 1871, had made several experiments on the strength and proper management of boilers belonging to the United Railroad Companies of New Jersey. So valuable did the results appear, that the executive committee of the United Companies, on the 11th September, 1871, voted $10,000 for the continuation of the experiments.

On the 22nd of November, the bursting experiments commenced; Mr. Stevens invited the principal steam engineers of the United States to attend. The United States Government sent three of their navy engineers to report, and the inspector-general of boilers and other boiler inspectors, professors of engineering, mechanical engineers, &c., were also among the skilled observers.

The first experiment was on a boiler that had been in use for thirteen years, and been removed as worn out. The shell was 28 ft. long; the body 6 ft. 6 in. in diameter, and the front portion, containing the furnaces, was rectangular below, and semi circular above, and this was 7 ft. 8 in. in length; so that the length of the cylindrical part was 20 ft. 4 in. The steam chest was 4 ft. in diameter, and 10 ft. 5 in high. The shell was of No. 3 gauge—that is, .26 in. thick, and single rivetted. At 112 lb. per square inch hydraulic pressure, some of the stays in the flat part gave way; but the circular part of the shell and the semi-circular top of the front stood that pressure. When subjected to steam pressure it was found that at 98 lb. pressure, the steam escaped from the seam joining the steam chest to the shell, as fast as it was made, and a bursting pressure could not be obtained.

The leak produced, pointed to the weak place in the boiler — the opening in the shell at the steam drum; and boiler inspectors should be careful to attend to that in fixing pressures.

The failure of some of the stays, in this and in all similar experiments, indicates the danger produced by constructing a boiler so that the failure of any one stay would be fatal to the whole structure. Stays are seldom fixed to take the strain equally. We have found in boilers in use stays so badly fitted, that some of them would have $\frac{3}{4}$ in. end play when the adjacent stays were taking the strain. It is to this unequal tension of adjacent stays that we must attribute the failure of stays at a pressure much below that due to their united section, if the strain had been equally divided over all the stays. It is also on this account that the Board of Trade surveyors allow a higher strain per square inch of metal in the section of a boiler shell than per square inch of stay section.

By the hydraulic test, the shell was subjected to a strain of 16,600 lb per square inch gross section of shell. Taking the effective section of the shell at 67 per cent. of the solid plate, according to Fairbairn, for single rivetted crossed seams, the strain per square inch of the iron was then 25,000 lb. We have here an illustration of the effect of high hydraulic testing; a boiler, after being thirteen years in use, is subjected to a strain of 25,000 lb. per square inch of iron in the shell, apparently without injuring it.

That boiler, if in a passenger steamer in this country, would, when new, be allowed a pressure not exceeding 30 lb. per square inch. After thirteen years' service, it stands nearly four times that pressure, hydraulic, and they fail to burst it at over three times the pressure by steam The public ought, therefore, to have perfect confidence in our Board of Trade boiler supervision.

The next experiment was upon a box, representing a flat water space, or leg of a boiler that had recently exploded in the steamer "Westfield," at New York. The box was 6 ft. 4 in. long by 4 ft. wide over all. The plates were $\frac{5}{16}$ in. thick, and they were stayed together by screwed stays, $1\frac{1}{8}$ in. in diameter, and the ends of the stays were very slightly rivetted over, only to make them tight, not to act as heads. The stays were apart $8\frac{3}{4}$ in. by $9\frac{1}{8}$ in. This box was burst by steam pressure at 165 lb. per square inch. Not a stay was broken and the threads were not stripped on either the plates or the stays. The slight rivetting was broken off every stay, and the stays were drawn through the holes, the plate, by stretching, having enlarged the holes. Had the stays been provided with nuts, the box would have borne a much greater pressure. Comparing this result with Fairbairn's experiments on a similar box, we find that the bursting pressures are equal to a little more than eight times the following :

Working pressure per square inch :

$$= \frac{40{,}000 \times \text{diam. of stay} \times \text{thickness of plate.}}{\text{Cube of distance between stays.}}$$

These dimensions are to be taken in inches; the diameter of stay is taken over the threads.

There is considerable doubt as to the proper form of the rule in this case, and the above is given subject to correction by further experiments. It is meant for flat surfaces, and for screwed stays without rivetted heads. This is the resistance to drawing through the screwed hole; and, quite irrespective of this rule, the strain upon any stay should never be more than that due to its least section.

On the 23rd of November, the day following that on which the above experiments were made, a boiler, that had been twenty-five years in use in the steamer "Bordentown," was subjected to bursting pressure. The boiler was rectangular, 15 ft. 5 in. length, 12 ft. 2 in. width, 8 ft. 6 in. height, exclusive of steam dome The stays were unequally distributed; the section of each stay was 1 square inch, and the space to be supported by each stay was in some places 228 square inches, and in other 336 square inches. Just before the boiler had been removed from the steamer, the inspector's certificate allowed a pressure of 30 lb. per square inch, or equal to 10,000 lb per square inch upon some of the stays. That is just double the strain that is allowed by our Board of Trade surveyors. The boiler burst at 53½ lb. pressure per square inch. From the pressure of 30 lb., at which in had been in use, the steam pressure increased in 11 minutes to 50 lb., at which pressure a loud report was heard, attributed to the breaking of some of the stays. Two minutes afterwards the boiler exploded with terrific violence. The steam drum, with a portion of the shell attaching to it, forming a mass of about 3 tons in weight, were hurled to a great height in the air, and fell at about 450 ft. from the original position of the boiler. Almost the whole boielr was literally torn into shreds, which were scattered far and wide. The report of the experiments, from which we have gathered these particulars, describes minutely the great destruction produced. The stays in the upper part of the boiler had broken in the welds; those screwed into the water space plates had drawn through the holes in the plates, as in the preceding experiment. There was no flashing of the water into steam, for for ground and grass and shrubs all round were found drenched with the water. The water gauge was examined only seven minutes before the explosion, and showed 15 in. of water above to top of the tubes.

We have said our surveyors would have given just half the pressure that was allowed, and some of our readers may consider that to be an unnecessary strictness. But the result justifies their practice; 15 lb. is more than one-fourth of the pressure at which the boilers exploded. Only thirteen minutes between practice and explosion is far too narrow a margin, where boilers have only one safety valve, and that may not have been opened for weeks in succession, and may be struck in its seat. The age of the shell of the boiler did not affect the result; the explosion was due to the failure of the stays, and these had been put in order just before the experiments.

The importance of these proceedings was so impressed upon the minds of those who were present, that they brought the subject before Congress, and there has been voted the sum of $100,000 to carry out similar experiments on a larger scale. The Commission appointed to conduct the experiments has just made a beginning. It is not unfairly to anticipate the report