boiler under pressure has been computed, and it has been found that a cubic foot of water, at a temperature due to a pressure of 60 or 70 pounds of steam to the square inch, has about the same explosive energy or force as 1 pound of gunpowder.

In exploding, gunpowder produces sufficient force to raise its own weight to a height of nearly 50 miles, while water, under the conditions existing in a steam boiler under pressure, has energy stored in it sufficient to raise its own weight nearly one mile in height.

Taking an ordinary horizontal cylindrical tubular boiler, such as is rated at about 60 h. p., and having dimensions about as follows: Diam. 60 in., length, 15 ft., containing 66 tubes, 3 in. diam., which will have about 900 square feet of actual heating surface, and would likely carry an average of 75 pounds per square inch, and would contain 8,225 pounds (or nearly its own weight) of water and 20·84 pounds of steam; and according to a table prepared by R. H. Thurston, the stored energy contained in the water would be 50,008,790 foot pounds, while that stored up in the steam in the same boiler would be equal to but 1,022,731 foot pounds, or only $\frac{1}{50}$ the quantity stored up in the water. When we reflect that the total explosive force or energy stored up in this boiler, according to Mr. Thurston's calculations, is 51,000,000 foot pounds, or sufficient force to raise its own weight one mile high, with an initial velocity of 600 feet per second, and of this enormous energy but 1,022,731 foot pounds, or about 4 per cent. of the total, are contained in the steam, it is, I think, very plain to us all that the bulk of destructive force in the event of an explosion emanates from the heat stored up in the water, which will at all times be of a temperature corresponding to the pressure of steam carried, and will, in the event of an explosion, expand itself down to atmospheric pressure so suddenly and with such terrific force as to cause great wreck of property, and in some instances a lamentable loss of life.

It follows then, and must be equally plain to us all, that that class of boiler containing the greatest quantity of water must in the event of explosion cause the greatest amount of damage, just the same as a large cannon, if charged proportionately with powder, would carry its projectile to a greater distance and with greater force than would a smaller cannon having been loaded with a less quantity of powder (explosive force). This fact accounts for the terrible destruction which follows the explosion of a large, plain cylindrical, or an English Lancashire or Galloway boiler, all of which contain large quantities of water in one chamber. The same holds good for proof of the claims made by builders of the many types of sectional or water-tube boilers as to the safety from explosions of such boilers, whose water spaces are divided up into many small compartments or sections, and which, in the event of a rupture, the water and steam escapes very much as it would through a blow-off cock, and generally without causing much damage.

The causes to which the explosion of steam boilers have been attributed are legion, and may, perhaps, be classed under the heading of, 1st, the known, 2nd, the possible, and 3rd, the improbable and nonsensical. Among the 1st causes may be classed bad workmanship, defects in design and insufficient staying of flat surfaces, general weakening and wasting of the structure from old age, constant use, external and internal corrosion, which are often much aggravated by mismanagement, careless handling and failure to inspect and detect the many small and constantly increasing imperfections by which every boiler is attacked from the day it is first put into operation until it is taken back to the rolling-mill for scrap; or, as happens at times, when without any warning the boiler itself, tired, so to speak, of being abused and neglected, starts off on a journey of its own accord and creates destruction of property and life as it goes out through walls and roofs. Under this same head may be classed, also, badly arranged and inadequate fittings, especially safety valves, for it is no uncommon thing to find a safety valve on a boiler of so small a capacity that the pressure will accumulate 20 or 30 lbs. above the pressure for which the valve is set, even with the engine running, so that it is not too much to assume that with an old boiler, fitted with too small a valve, and a good fire burning and engine shut down unexpectedly, such an accumulation of pressure might result as to cause the boiler to explode, and in fact I have no doubt that many explosions have occurred from such causes.

I have often seen one safety valve arranged in such a manner as to relieve two or more boilers with stop valves placed between the safety valve and each boiler, in order that a boiler could be shut off at any time, and only one steam gauge for the two or three boilers, as the case may be, and in a case of this kind it would require no great stretch of imagination to suppose that in a case of three boilers fitted up as I have described, and one boiler having been let down for cleaning, is filled up again and fired up, the steam gauge and safety valve being both shut off, and the fact overlooked until the pressure within had reached the point at which the boiler gave way, and this pressure may in many cases be far below the calculated bursting pressure found by the usual formula, owing to bad workmanship, general deterioration, etc. Under this head comes also the overloading and wedging down of safety valves by ignorant attendants, who do not know the danger of such a foolish act, or if they do, are wilful enough to carry it on.

The overloading or wedging of safety valves is in my estimation an offence for which every engineer or fireman caught practising it, should be discharged forthwith from his position.

Only a few days ago, in making a "steam on" inspection of a boiler which was allowed a working pressure of 80 lbs. per square inch, I found a lever safety valve overloaded so that I am doubtful if it would have raised at 150 lbs., and on trying to demonstrate the folly and danger of such a practice to the man in charge (who, by the way, ought to have known better), I was told that the safety valve was leaking a little and he took this means of making it tight, and as *he* himself said, there was *no danger*, as *he* never allowed the pressure to exceed 75 lbs., as *he* was there all the time *himself*. I suggested several possibilities, one of which was that he might go home that night and be taken ill and die, and some man in the mill be deputed to fire up in the morning who knew nothing about the valve, etc., and then he admitted he had done wrong, as he had never looked at it in that light.

(2.) Among the 2nd possible causes of explosion may be mentioned low water and consequent overheating of the boiler, with the introduction of cold feed water on the red hot plates, but as I intend to treat some on this question, and submit some experiments which have been made in England by pumping cold