lowed to secure the same result: either a high steam-pressure for a few hours or a low steam-pressure for a comparatively longer period. In either case the brick will attain the same degree of hardness. Most manufacturers are, however, agreed that 8 hours at a pressure of 120 pounds per square inch (2 hours being required to bring the cylinder up to this pressure) is the best and most economical practice. The steam must not be turned in too fast, as the surfaces of the brick will become highly heated while the interiors remain cold; the unequal expansion thus produced causes the brick to check.

Through the overzealous efforts of machinery jobbers, who think only of disposing of their machinery, an erroneous impression has been spread abroad that sand-lime brick can be manufactured at an extremely low cost. The cost of manufacturing sand-lime brick depends upon the same variable quantities as does the manufacture of clay brick or any other product. Labor and fuel are the main items in the manufacture of brick and to produce brick cheaply a dollar's worth of labor must be got for every dollar paid for labor, and for every pound of fuel the greatest possible number of heat units must be utilized. It is the stopping of the little leaks that make the profits in manufacturing.

THE BOYD AUTOMATIC TIDE SIGNALING APPARATUS.*

An ingenious signaling apparatus has been installed at the entrance to the harbor of the port of Irvine in Scotland, the only one of its type in operation. For some years past the authorities of this harbor have been severely handicapped by the difficulty of informing the captains of incoming vessels of the state of the tide, since at low water entrance cannot be effected, and vessels must wait outside the bar for the next tide. The only means available of warning the incoming vessels was a tugboat, and naturally such precautionary measures proved expensive. These shortcomings were so detrimental to the progressive development of the harbor's prosperity, since vessels preferred to put in at some of the adjacent ports to discharge their cargo, that the authorities requested the harbor master, Mr. Martin Boyd, to devise some certain means whereby captains of incoming vessels could learn the depth of water within the navigable channel, and whether the tide was flowing or ebbing, at any time of the night and day from several miles out, and arrange their plans accordingly.

The present apparatus is the outcome of Mr. Boyd's efforts, and is the result of two years' experimentation. This apparatus possesses several ingenious features, and moreover is entirely automatic. In the design of this apparatus the inventor has caused the rising and falling tide to indicate the depth of water within the navigable channel.

At a prominent point near the harbor entrance, a tower has been erected, as shown in the accompanying illustration. Within this tower at the base has been installed gearing connected with a float which is moored in the navigable channel leading to the harbor, and which has a perfectly free rising and falling motion with the tide. Carried on the top of the tower is a staff, upon each side of which are signal balls, twelve in number, working on cables and staggered. Each ball represents a foot rise or fall in the tide. The device by which these balls are raised and lowered from sight is connected with the gearing below. The float in the river is set at a zero point which corresponds with 7 feet of water, at which depth only one ball is visible above the top of the tower. Immediately the depth has increased by one foot two balls become visible, one on each side of the staff, three balls with the second foot rise, and so on until the twelve balls can be seen, at which time there is a depth of 18 feet of water in the fairway. The turn of the tide causes a reversal of the operations, one

greater depth of water than is actually shown by the reading of the signal balls, more especially on the ebb, neither can any allowance be made for any sea, and furthermore there is generally less water at either side. In addition a block signal is shown consisting of two black balls in a vertical line exhibited from a flagstaff immediately adjacent to the signaling tower. The readings, however, cannot be confused, as the balls on the signal station are staggered, while the block signals are vertically one above the other. Mari-

THE BOYD AUTOMATIC TIDE SIGNALING APPARATUS AT IRVINE HARBOR, SCOTLAND.

To inform incoming ships of the depth of water in the channel. In this picture ten balls are visible, indicating a depth of 16 feet in the navigable channel.

ners are thus warned when it is impossible for some means or other, such as a wreck in the fairway, to enter the harbor, and similarly the same signal serves to warn mariners on outgoing ships within the harbor of the impossibility of leaving their anchorage.

Owing to the prominent position occupied by the signal station, the code can be read for many miles distant at sea, and by comparison with the signal code issued by the harbor authorities the captain is able to ascertain at a glance the depth of water in the channel, and by watching whether the balls increase or decrease in number, accurately learn whether the tide is ebbing or flowing.

For night signaling an ingenious arrangement has been provided, acting in concert with the signal balls. As may be seen in the illustration, the front wall of the building is pierced in a central vertical line at regular intervals by four orifices. These openings are fitted with powerful lenses. Through these openings signal lights are thrown, corresponding with the reading by the balls, varying in color either green, white, or red, according to the printed code. Thus for instance when there is 7 feet of water in the channel, one green light is visible. When the tide rises a foot an eclipser comes into action, and converts the green light into a red. The next foot rise similarly eclipses the red for a white light. By combination of these three colors any state of the tide between the zero at 7 feet and the maximum of 18 feet is shown, the reading for the latter comprising four white lights in a vertical line. As the tide falls the arrangement is reversed until the zero is once more regained. For the block signal at night two red lights one above the

THE CODE OF SIGNALS, NIGHT AND DAY.

Shown by the Boyd Automatic Tide Signaling Apparatus, indicating the depth of the navigable channel.

ball disappearing from sight with every one foot of fall in the water until a depth of 7 feet is again attained, when the cycle of operations is repeated, rising and falling alternately and continued without cessation. The depth of water indicated is that which prevails in the center of the channel with smooth water. Owing to the positive working and indication of the apparatus, mariners cannot calculate upon a

other are displayed. An ingenious feature of the night arrangement is that the apparatus automatically shuts off and turns on the lights as required according to the signal code, thereby effecting an economy in the consumption of the gas, which is the illuminant employed.

It will be seen that the movement of the float in the channel governs the whole of the movements of the signaling apparatus, thereby rendering it entirely automatic in its action, so that it can be left without

the slightest attention for days without any apprehensions as to its safe operation. Moreover, it is infallible; and owing to the small number of moving parts involved in the gearing, the possibility of breakdown is extremely remote. The night signals, as in the case of the signal balls, can be readily observed several miles distant, owing to the utilization of the lenses.

WHAT ARE EARTHQUAKES?*

By HUDSON MAXIM.

THERE are few subjects less understood than earthquakes. Among the many theories that have been advanced to explain them, there are none, to my mind, not open to serious objections. The theory here presented I believe to be in the main new.

The three recent terrific seismic disturbances at San Francisco, Valparaiso, and Kingston, following the eruptions of Mont Pelée and Vesuvius, forcibly remind us that there is a tremendous terranean power of some sort underlying the deep foundations whereon we build our cities and our hopes.

The most common explanation offered is that the earth's shrinkage from loss of heat sets up stress in the earth's crust, which becomes greater and greater until the crust yields along old faults or lines of weakness.

Few people have any idea how enormous are deep earth pressures, or know that these pressures must be taken into serious account in the study of seismic phenomena.

It matters not whether the earth be considered as a solid all the way through, or as consisting of a great molten interior with a relatively thin crust upon it, for solid rock and molten lava behave the same at depths of a few miles. *Granite flows like wax at a depth of fifty miles, and the earth is eight thousand miles in diameter.* If the molten interior of the earth were to be removed and the space filled with air under a pressure sufficient to sustain the crust, this air, were it not to liquefy, would immediately under the crust have a density greater than gold.

If two tempered solid steel balls the size of the earth, hard as the harveyized face of armorplate, were to be taken in two Jovian hands and placed gently together in space and released, what would happen? They would behave exactly as though they were liquid, and would fall together and coalesce with each other like two drops of water, while the highest prominence or mountain on the new globe thus formed could not have a height of fifty miles, because it would flatten out under its own weight.

If we had a tank, say five hundred miles in height, made of material refractory enough and strong enough, provided with a faucet at the bottom, and should fill it to the brim with cannon balls, hard files, and steel rails, we could, without the application of any heat, draw the molten steel from this enormous tank, because, under its own weight, the steel would be forced to flow in a stream through the faucet.

There are two causes which work together to produce earthquakes: first, the escape of pent-up steam and molten matter, followed by the settling of the crust to fill the voids; second, the tension in the earth's crust set up by contraction from loss of heat. The shrinkage of the earth from loss of heat is so slow, however, that this factor is not so important; besides, the weight of the earth's crust is so great that the bed-rock flows and adjusts itself to the stresses produced by mere shrinkage without producing earthquakes or volcanoes. This shrinkage, however, holds the ledges under tension, and the tension aids in the earth movements produced by the disturbing element of water. Water heated to incandescence in a space where it can not expand exerts a pressure equal to that which would be produced by the most powerful dynamite exploded in the same space. The effect is the same as though many portions of the earth's crust were actually resting upon gases of exploded dynamite trying to escape.

The theory is frequently advanced that planets, and even suns, sometimes explode, and that the earth may some day blow up like a bombshell. No celestial body the size of the earth could possibly explode. If the entire molten interior of our globe could be replaced with nitroglycerin and detonated, the explosion would not lift the earth's crust. In other words, if we assume that the crust of the earth is from fifty to one hundred miles in thickness, it would require something much more powerful than even nitroglycerin to burst this shell. It is necessary only to do a little figuring to see that the pressure of the earth's crust at a depth of from fifty to a hundred miles far exceeds the pressure exerted by the most powerful high explosive.

If we assume that the thickness of the earth's crust is fifty miles, and that its average density is about five times that of water, then we may also assume that the pressure at a depth of fifty miles is somewhat in excess of half a million pounds to the square inch. It is a safe conclusion that within a large portion of the earth's crust there exist pent-up gases, particularly steam, under a pressure equal to that exerted by the most powerful high explosives. High explosives probably exert pressures ranging from 200,000 to 350,000 pounds to the square inch. When a high explosive is detonated, the amount of pressure depends upon the volume of gases liberated and the temperature of the gases. Nitroglycerin exploded in a space where it could not expand would exert a pressure of probably from 300,000 to 350,000 pounds to the square inch. The pressure would certainly be less than half a million pounds to the square inch, although the temperature of the gases would equal the boiling point of steel. As

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

* Success.

the density of water is not quite so great as that of nitroglycerin, the pressure which incandescent water exerts is not so great as would be exerted by pure nitroglycerin, volume for volume. But weight for weight, the energy exerted would be virtually equal. In deep subterranean chambers there are necessarily large quantities of water heated to a temperature representing a pressure equal to that of exploded dynamite.

Through all geologic time, water, always water, has been both builder and destroyer. Water has piled the mountains up and ground them down again with storm and glacier, pulverizing the *débris*, sifting and separating sand from pebble, and stone from boulder; cutting deep cañons in the rock, laying out the plain, throwing islands into the sea, and giving continents new coast lines.

Water, too, was the original architect of the earth's crust. There was a time when the globe was too hot to allow water to remain on the surface in a liquid state. Then the ocean hung in the sky in the shape of steam, mixed with a vast amount of carbonic acid gas, for then the great beds of peat and coal had not yet been formed. From this great vaporous envelope the heat was quickly radiated into the cold of outer space, producing rapid condensation. Through long ages Niagaras of rain plunged from sky to earth in a continual downpour over the entire terrestrial surface. The pressure of the superincumbent atmosphere was then many thousands of pounds to the square inch, instead of but fifteen pounds to the square inch as now. Under such enormous pressures the boiling point of water was not, as we know it, 212 deg. F., but was red heat. The first rivers that flowed upon the earth's surface were red-hot. Granite dissolved in those floods like sugar in a cup of tea. The granite bedrock was formed by the precipitation of mica, quartz, and feldspar from aqueous solution. Deep down under the earth's crust to-day, where water has entered through faults, to be entrapped and highly heated, with no room for

when, in 1883, its top blew off with a shock felt clear through the earth, and with a blast that sent a wave of air around the earth three times, while the fine volcanic dust did not entirely settle out of the atmosphere for more than two years, as was indicated by the unusually brilliant display of red sunsets. It is estimated that more mud was ejected from the mountain on that occasion than the Mississippi River discharges in two hundred and fifty years. This was the greatest volcanic eruption in historic times. The distance is not too great nor the time too remote for the eruption of Mont Pelée to have caused the earthquakes of San Francisco, Valparaiso, and Kingston, while possibly Vesuvius may have played a material part.

CEMENT PIERS.

AFTER a ten years' test of the cement cylinder piers at San Francisco by the State Harbor Commission, it is accepted that that form of dock construction has come to stay, and that in all probability no stone docks will ever be built on the Pacific ports.

The first of these cement cylinders were put in on the San Francisco water front in 1894, and have undergone the test of time at the dock, which is used by the army transport service. The cylindrical cement piers under this dock, which has been in constant use by the transport service, show no signs of deterioration.

No port on the Pacific had previously felt able to provide for the cost of construction of stone docks, such as have been built at immense outlay in the harbors of the Old World. Freight sheds of simplest design supported on wooden piling adorn the water fronts of the harbors of Washington, Oregon, and California.

The life of the wooden piers is only four years. Attacked by the *Limnoria terebrans* between the high and low-water marks, and eaten by the *Teredo navalis*

The strength of these cylinders is independent of the wooden stave coverings, which may rot away in time, leaving the interior cement with its protected cluster of piles intact. In practical experience it has been found that the ravages of the ship worm on these staves is not nearly as great as in the case of the ordinary piles, which soon become honeycombed.

In building these last three docks, a temporary floor was put down and tracks laid upon it, on which the concrete was conveyed in ore cars to fill the cylinders. The cars were filled from a double-decked mixing contrivance, having two tilting boxes in which the concrete was alternately mixed and dumped into the cars.

Besides the eight completed docks in San Francisco and the three under construction, the government has adopted the cement cylinder in the quarantine wharf now being built at Honolulu, and other government work is contemplated.

Naturally, the entire freedom from frost in San Francisco has been in favor of cement construction, and it may be that that is one reason that the California harbor commissioners have been the first to permanently adopt the cement dock, but the inventor claims that with ordinary protections against ice the cement cylinders will stand in any latitude.

The illustration shows the work of the ship worm (*Teredo navalis*) on the piling of the section of the old dock left standing during the placing of the new cylinders.

Experiments have been carried on by J. Tribot at Paris upon the evolution of carbon, water, and ash in function of age, in plants. In this case he took barley as the subject of experiment. It was sown in flower pots and placed under a shed, so that the plants received only diffused light. At the beginning of the tests, which were made in the suburbs of the city, all the pots were filled with the same earth, as homogeneous and nearly alike as possible. The age of the

CONSTRUCTION OF A CEMENT PIER.

expansion, it dissolves the rock. And as, under the enormous pressures, it forces its way through narrow crevices to new positions, it cuts new channels in the granite floors, just as in glacial time subglacial streams cut passages through the ice. Consequently, when the eruption of a volcano takes place, relieving the pressures in the deep passages under it, there is a rush toward the outlet, of streams of incandescent water made syrupy with stone in solution. As these streams of silica-charged water find vent at the volcano, the expansion of the pent-up stream takes place with explosive violence, forming volcanic dust and pumice stone, which are belched forth in stupendous quantities. Then portions of the earth's crust, which have been resting upon a support of steam under dynamite pressures, naturally sag and shift when those pressures are removed or materially lessened.

It matters not whether under the deep subterranean pressures and temperatures the incandescent water be actually liquid or gaseous; its density is the same. Under such conditions, there can be no finely-drawn line between the liquid and the gas.

The pressure exerted by water under these conditions is sufficient to cause subterranean streams of lava and quartz-charged water to flow to long distances, even thousands of miles, leaving vast voids behind. The bedrock then settles and closes the passages, just as in glaciers the ice yields and closes the courses of subglacial streams.

A granite glacier fifty miles high would flow exactly like a glacier of ice a mile thick. The bedrock is a vast rock glacier threaded by numerous waterways which erode and cut passages through it, and the water courses are again closed by the yielding walls of granite under the awful pressure just as the glacial waterways were closed by the yielding ice. The earth's surface then assumes new levels, this adjustment resulting in earthquakes.

The vast amount of solid matter ejected at times from volcanoes is difficult of comprehension. The great volcano Krakatoa had been extinct for ages

from the low-water mark down to the mud, the wooden-pile dock was but a makeshift at best, and the harbor commissioners of the American ports have been confronted by a serious question.

Three large docks are now under construction in San Francisco, supported by cement piers. Two of these are for the Pacific Mail Company and the third for coast traffic, and the commission has permanently committed itself to the cement dock. The result is that, instead of issuing \$200,000,000 of bonds as at Liverpool, or \$40,000,000 as at Calcutta and Antwerp, to run for long periods, the San Francisco docks will be paid for in a short term of years out of their own rentals, while the rentals of stone docks only provide for the payment of interest on debenture bonds.

In the construction of the two docks for the Pacific Mail Company little change has been made in the type as it was first designed by Howard C. Holmes, chief engineer of the San Francisco Dry Dock Company, in December, 1900.

These two piers, which are 650 feet long and 140 feet wide, rest on cement cylinders, which are constructed in the following manner:

A cluster of three wooden piles 50 feet in length is driven close together and to slightly different depths. Around these is placed a wooden stave cylinder, of four feet inside diameter, which is driven with the ordinary piledriver used for driving the three piles in the center. The cylinders are of Douglas fir staves four inches thick and bound together by steel bands with tightening lugs. After these have been driven from 10 to 15 feet into the mud, the water and mud are pumped out to a depth of four feet below the outside mud level. A cylinder of expanded metal is then placed around the piles inside the wooden cylinder, which is then filled with a rich concrete of broken rock and hydraulic cement, contained in 25-pound bags for the first five feet.

Structural-steel caps are set on the top of the cylinders, and the wharf floor laid of steel I-beams and fir stringers and planking.

plants which were examined varied regularly from 18 to 96 days, using 23 different pots in the tests. First he measured the average height of the stalk and found it to be 4.2 inches at 18 days, or at the start of the test. There seems to be a maximum for the height about the 74th day, and then it commences to diminish, the highest value being 26 inches. As regards the amount of water in the plant, he finds that starting from the maximum point there is a slow dehydration which is well marked; thus at 18 days we find 89.67 parts water for 100 of the plant, at 71 days 91.22, which is the highest, and at 96 days, or the end of the test, 79.59 per cent. The amount of mineral matter as shown by analysis of the ash, also diminishes after a certain point, and this is in concordance with the results of the author's preceding analyses upon the mineral matter contained in bones. The variation of the percentage of ash in the plants depends not only upon the age, but also upon the composition of the earth, which is necessarily somewhat variable, and to eliminate the influence of the earth, he calculates the ratio between the percentage of ash of the plant and the ash of the earth. This ratio rises very rapidly during the first period of growth of the plant, then more slowly, passing by a maximum between the 40th and 50th days, then lessens gradually toward the end. At the beginning or 18th day it is 0.170, at the 49th day it is 0.226 and at the 96th day it drops to 0.166. Comparing the percentages of the carbon of the plant and the carbon of the earth, it is seen that there is no relation between these two quantities, and the carbon of the earth remains about constant in the experiments while that of the plant varies, having a maximum which nearly coincides with that of the ash. The present researches may be taken as the preliminary work upon a series of researches as to the evolution of the quantity which Solvay designates as Ef/Ec , where Ef represents the energy taken up by the plant and given off in the heat of combustion, while Ec is reduced, according to the conclusions found above, to the calorific and luminous energy.