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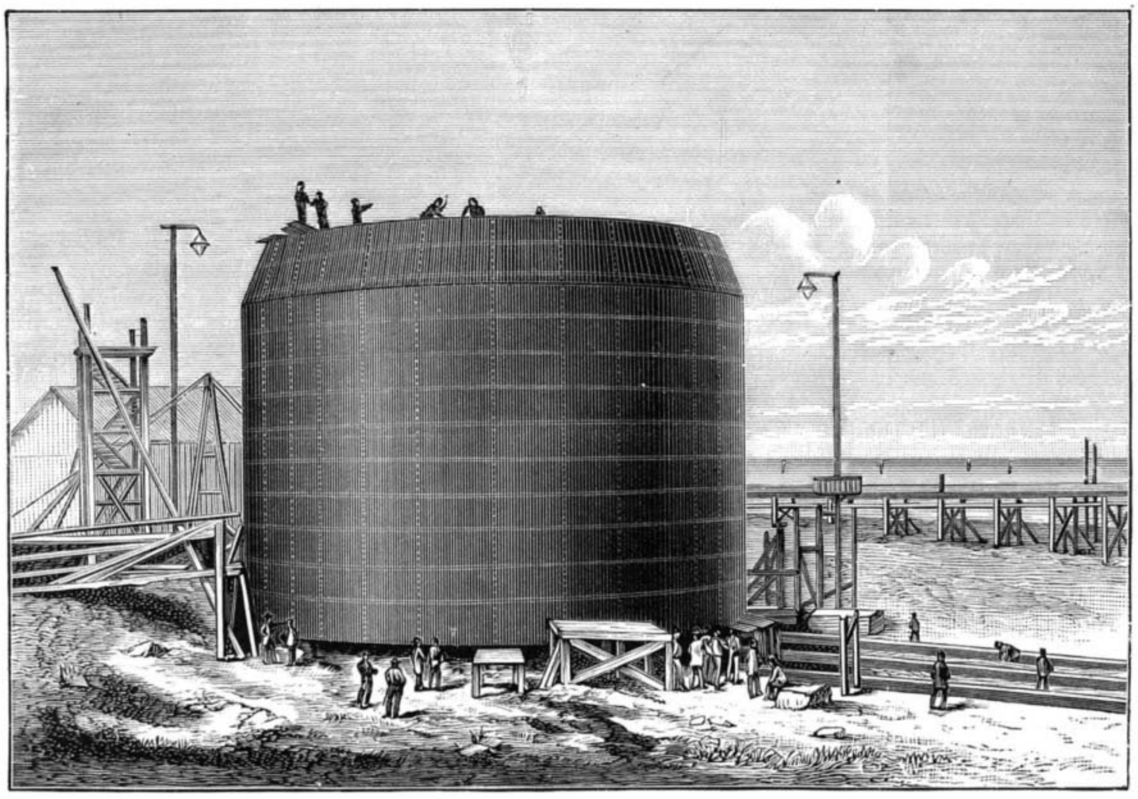
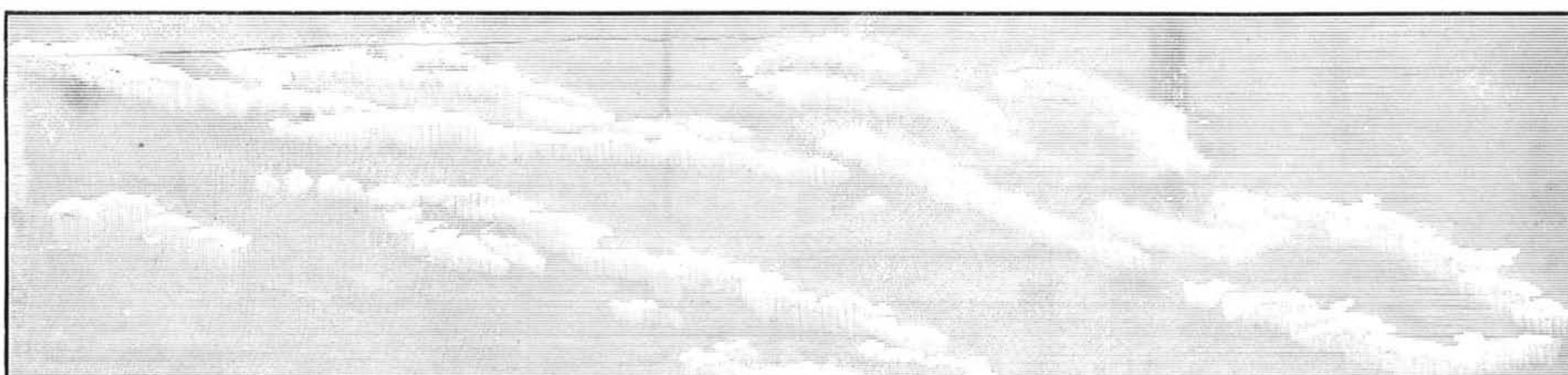
THE FORTH BRIDGE.

From time to time we have published accounts of the progress of the Forth Bridge, and in the present issue we give illustrations of the caissons for the Queensferry Pier. It will be remembered that there are three main piers known respectively as the Fife Pier, the Inch Garvie Pier, and the Queensferry Pier, and upon each of these there is built a huge cantilever stretching both ways. The Fife Pier stands between high and low water mark, and is separated by a span of 1,700 feet from the Inch Garvie Pier, which is partly founded upon a rocky island in mid-stream. Another span of 1,700 feet carries the bridge to the Queensferry Pier, which is at the edge of the deep channel. The total length of the viaduct is about 1½ miles, and includes two spans of 1,700 feet, two of 675 feet, the shoreward halves of the outer cantilevers, fifteen of 168 feet, and five of 25 feet. Including piers, there is thus almost exactly one mile covered by four main spans, and half a mile of viaduct approach. The clear headway under the center of the bridge is 150 feet above high water, and the highest point of the bridge is 360 feet above the same datum. The contract was let to Messrs. Tancred, Arrol & Co., on December 21, 1882, for 1,600,000*l*., and work was commenced in the following month.

Each of the main piers comprises four columns carried down to the rock on the bowlder clay. Three of the Fife columns are completed, and the remaining one is in progress; at Inch Garvie one pier is complete, one is in progress; while at Queensferry the work on the caissons is advanced. All the pneumatic caissons will be filled with concrete up to low water mark, of a mixture having



THE FORTH BRIDGE.—THE CAISSON READY FOR LAUNCHING.



THE FORTH BRIDGE.—LAUNCH OF A CAISSON 70 FEET IN DIAMETER.

a crushing strength of 50 tons per square foot. Above low water the cylindrical piers, which are 49 feet in diameter at the top, 55 feet at the bottom, and 36 feet high, consist of the strongest masonry, the hearting being flat bedded Arbroath stone, and the facing, Aberdeen granite. In each cylindrical pier there are 48 steel bolts, 1½ inches in diameter and 24 feet long, to hold down the bed plate and superstructure of the main spans. One of the Fife piers was built by aid of a timber and clay cofferdam, and one by means of a half tide dam. At Inch Garvie much of the work of the shallow piers had to be done at low tide under great difficulties.

The Queensferry Pier consists of a group of four cylindrical caissons 70 feet in diameter at the bottom edge. Owing to the special conditions of the site, the work differs in some respects from ordinary pneumatic caissons. The bed of the Forth at the Queensferry Pier is of very soft mud for a depth of from 20 feet to 35 feet, when the bowlder clay is reached, the surface of both the mud and the clay falling sharply toward the 200 feet deep channel between Queensferry and Inch Garvie. The caissons had to be floated out and sunk about one-third of a mile from shore in an exposed seaway. To facilitate operations, the caissons have double skins, 7 feet 6 inches apart, and vertical bulkheads between the skins. By filling the space between the skins with concrete to varying heights, the irregularity in the level of the bottom, and the hardness of the mud, could be to some extent compensated for, as the weight brought upon the cutting edge of the caisson could be regulated as desired. Iron being cheap, a liberal use was made of it in conjunction with concrete where masonry or brickwork might have been employed. Strong lattice girders and cross girders stiffen to the required extent the roof of the working chamber. These girders are subject to a heavy bending stress upward and downward, owing to the tide, the range of which is about 20 feet. Thus if sufficient concrete were filled over the roof to balance the air pressure at mean tide level, then at high water the excess of air pressure, unbalanced by the weight of concrete, would obviously be that due to the half tide difference of height, and at low water, similarly, the excess weight of concrete would be of the same amount. There would thus be a force of more than 1,100 tons tending to bend the girders downward at low water and upward at high water.

Two shafts 3 feet 6 inches in diameter, with air locks for passing out the excavation, and one shaft with double air lock for the men, are provided, together with ejector pipes for the mud, water pipes, supply pipes for the concrete, and other conveniences.

For the above particulars and our engraving we are indebted to *Engineering*. Further descriptions of the great Forth Bridge and additional engravings will be found in SCIENTIFIC AMERICAN SUPPLEMENTS 354, 457, and 478.

Toughened Filter Paper.

Mr. E. E. H. Francis recently read a paper at the Chemical Society in which he showed that filter paper, ordinarily so weak, can be rendered tough and at the same time pervious to liquids by immersing it in nitric acid of relative density 1·42, then washing it in water. The product is different from parchment paper made with sulphuric acid, and it can be washed and rubbed like a piece of linen. It contracts in size under the treatment, and undergoes a slight decrease in weight, the nitrogen being removed and the ash diminished; whereas a loop formed of a strip 25 millimeters wide of ordinary Swedish filter paper gave way when weighted with 100 to 150 grammes, a similar loop of toughened paper bore a weight of 1·5 kilogrammes. The toughened paper can be used with a vacuum pump in ordinary funnels without extra support, and fits sufficiently close to prevent undue access of air, which is not the case with parchment paper. A good way to prepare filters for use with the pump is to dip only the apex of the paper into nitric acid, then wash it with water. The weak part is thus effectually toughened. Toughened filter paper will be exceedingly useful, not only to chemists, but to other scientists, both practical and theoretical.

A New Clock.

A very interesting clock has been fixed opposite the National Provincial Bank in Bishopsgate Street, London. It is on the 24 hour principle, and is remarkable as possessing probably the simplest method which has yet been introduced for indicating time upon the new enumeration. The new clock has only one hand, the long minute hand, and the figures around are placed as heretofore; instead, however, of indicating the hours, they indicate the minutes only, which are marked from 5 to 60. The hours are shown on a sunk dial revolving under the upper dial, a space being left in the upper dial in which the next hour figure comes forward instantaneously upon the minute hand completing its circuit of 60 minutes. In short, the solitary hand marks the minutes, and the sunk space shows the hour.

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(Illustrated articles are marked with an asterisk.)

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No. 488,

For the Week Ending April 4, 1885.

Price 10 cents. For sale by all newsdealers.

CONCERNING TELESCOPES.

A correspondent in Omaha, Nebraska, asks for information on three points: 1. What would be the cost of the largest telescope with unlimited means?

There are two kinds of telescopes, differing radically in construction, each possessing advantages peculiarly its own. One is known as the refracting telescope, because it depends on the refraction of light through glass lenses. The other is called the reflecting telescope, because it acts by reflecting the light from a concave mirror. Refractors are almost exclusively used in the United States, for they are easily managed, convenient, and have proved themselves to be the best working instruments, while the greater part of the astronomical observations of the present century have been made with them. We therefore infer that our correspondent refers to this kind of telescope. We have no means of estimating the cost of the largest telescope that can be constructed with unlimited means, but we can give the cost of some of the great telescopes now in use.

The telescope of the Naval Observatory in Washington, mounted and ready for use in 1873, cost $50,000. It has an aperture of 26 inches, and was, until 1881, the largest refracting telescope in the world. The great Russian telescope at Pulkowa, a refractor of 30 inches aperture, finished in 1882, now enjoys the distinction of being the greatest refractor in the world. Messrs. Alvan Clark & Sons, of Cambridgeport, made the object glass for this huge instrument, at a cost of about $12,000, the mounting being the work of Messrs. Repsold & Sons, Hamburg, Germany.

The Russian telescope will not long enjoy the supremacy. The Messrs. Clark are now in process of making a refractor for the Lick Observatory on Mt. Hamilton, California, with an aperture of 36 inches, which will, when finished, take the first rank in size and probably in cost.

The reflecting telescope of the Earl of Rosse, in Parsonstown, Ireland, takes the lead in size among reflectors. It cost $250,000. The speculum, or mirror, is 6 feet in diameter, weighing 4 tons, and the focal length is about 54 feet.

M. Flammarion, a French astronomer of renown, was firm in the faith that the moon was inhabited. He determined to prove his position by the construction of a monster telescope with such magnifying power as to reveal the men in the moon to terrestrial observers. He planned an immense refractor, far larger than any in existence, which was to cost $200,000. He earnestly solicited contributions from the whole civilized world to help in his project. For some reason, the plan fell through, and we have heard nothing of it since 1879.

The second question (2) is, How much larger could one probably be made than has ever been made, or now being made to your knowledge?

In the case of refractors, it is almost certain that there is no advantage to be gained by increasing the diameter of the object glass or aperture beyond a limit somewhere between 30 and 36 inches. As the aperture and magnifying power increase, the defects in the instrument become more apparent. The first difficulty telescope makers had to contend with was chromatic aberration. This was obviated by the use of two lenses instead of one, a concave lens of flint glass and a convex lens of crown glass, so arranged that their aberrations destroy each other. Telescopes are now made in this way, and are called achromatic telescopes.

A second difficulty now arose, known as the secondary spectrum. It is due to the fact that flint glass as compared with crown disperses the blue end of the spectrum more than the red, and the result is that the refracting telescope is not perfectly achromatic. The defect is scarcely noticeable in a small telescope, but becomes a serious obstacle in a great telescope, increasing with the diameter of the aperture. Since the trouble is inherent in the glass, there seems to be no possible method of overcoming it.

In the case of reflectors, the trouble lies in keeping the great mirrors in perfect figure in every position, the mirror being liable to bend on account of its own weight and elasticity. Such was the case with the reflector at the Paris Observatory. It has a mirror of silvered glass, the diameter being nearly four feet. It was mounted in 1874, but the glass bent under its own weight, and was rendered useless.

The greatest foe to the mammoth telescopes is, however, the atmosphere. The waving and trembling, the moisture, and the currents so pervade the atmosphere at the sea level, that the most powerful telescopes can be used to advantage during but a small portion of the nights of the year. The remedy or amelioration of this trouble is to establish observatories in elevated positions where the air is dry, clear, and steady. These conditions prevail on the mountains and elevated lands of the western and southwestern portions of North America. When, therefore, the largest refractor in the world is mounted and ready for use in the Lick Observatory, under the serene sky that arches above Mount Hamilton, 4,000 feet above the level of the sea, it is reasonable to hope that important tidings from the star depths will be the result.

The third question (3) is, Would the largest and most powerful one that could be constructed create general