cause for some gain, but, so far from that, it may be considered uniform in bodies moved by steam, whether ploughs, ships, cars, or manufacturing mechanisms. Whatever may be said to the contrary, we must continue to believe, till controverted by facts, that there can be no saving of steam power by substituting a succession of impulses for continuous pressure, except in cases where the resistance rises and falls with the piston's movements. Whether there are such cases we know not, but it is certain that sudden changes of force and velocity are not the things for steam machinery, no more than are springs and leaps (sensible or insensible) for bodies moved by it.

The popular idea is illusive. It is the impression of many that when the cut-off acts at half-stroke, half is saved; at one-third, two-thirds; and at one-fourth, three-fourths. They forget that pressure indicates quantity. Engines with cut-offs of necessity use steam of greater tension than others, and the less the charge the greater the tension. The only difference is that one class uses small volumes of high pressure, and the other large volumes of lower pressure, the requisite quantity being the same in both. An engine is worked with steam of 100 lbs. on the inch, and cuts off at half-stroke. The mean pressure of the latter half is, therefore, 75 lbs., and that of the whole stroke 87 lbs. on the inch. Observe that twice the force is expended on the first half than suffices for the latter half, and (the resistance being the same) twice the amount required. Where then is the difference in the amount consumed between charging the cylinder with 87 lbs. steam, and with it varying from 100 to 50 lbs. In every case as much of the fluid *must* be admitted as will push the piston to the end of the stroke, whether sooner or later cut off. Another engine has a cylinder of the capacity of twelve cubic feet; and requires steam of not less than 12 lbs. per inch pressure. This does the work without a cut-off. Suppose it be determined to apply one and cut off at half-stroke, would not the tension have to be raised to 24 lbs. on the inch, if cut off at one-third to 36 lbs., and if at one-fourth to 48 lbs? In fine, does it not follow that *theoretically* there is no more to be gained by cutting off at a quarter than at half-stroke, and no more by that (unless in special cases alluded to) than with no cut-off at all. To determine how far practice conforms to theory there is a conclusive experiment—apply the same *quantity* of steam used with a cut-off to the same cylinder without one.

E.

On the Erith Explosion, and the Repair of the Thames Embankment.
By LEWIS MOORE.

Read before the Society of Engineers, Nov. 7th, 1864.

From the London Mechanics' Magazine, November, 1864.

On the south side of the river Thames, between Woolwich and Erith, are several magazines used for the storage of gunpowder, belonging, some to Government, and some to private firms engaged in the manufacture of gunpowder. These are situated within a few yards of the

bank of the river, for the convenience of loading and unloading by water, that being the most convenient and economical, as well as the safest method of transit. These magazines occur at intervals of half a mile or thereabouts. In the river, moored close to the north shore, were, until recently, three or four large hulks, used also for the government storage of powder. Now, however, there exists but one, that being moored between North Woolwich and Barking Creek; the others, which formed part of the Government store at Purfleet, have been removed. On the north bank of the river there appears to be only one magazine in this neighborhood beside the royal magazine at Purfleet. Full details of the arrangements of these magazines have so recently appeared in the public journals that it is unnecessary here further to notice them, save as to their relative positions with regard to the subject of this paper; and this will be clearly seen on reference to the map of the general locality (No. 1).

The scene of the recent explosion was on the south side of the river, in the Erith and Plumstead Marshes, and the magazines which were destroyed were the property of Messrs. John Hall and Sons, of the Faversham Mills, and of the Elterwater and Lowood Gunpowder Companies. The relative positions of these magazines to each other, and to the bank of the river and the adjoining cottages, &c., will be clearly seen on reference to diagram No. 2, which is from actual survey. The magazine of Messrs. Hall and Co. was a substantial brick building, 50 feet square and two stories high, and was situated at the back of the river wall or embankment, on the marsh, at a level of 7 feet or 8 feet below Trinity high-water mark. From this magazine a jetty projected into the river to low-water level. This jetty was used for the shipment of gunpowder, and crossed the river wall on the level of the footpath. In this magazine, and in two barges, which at the time of the explosion were moored, one at the end and one at the side of the jetty, there were about forty-two tons of gunpowder. The magazine of the Elterwater Company was situated 64 yards to the eastward of Messrs. Hall's stores. This building was a similar construction, and measured 50 feet by 28 feet, and contained about $4\frac{1}{2}$ tons of powder. The next nearest magazines were those of Messrs. Curtis and Harvey, which are about 700 yards distant to the westward. The buildings adjacent were the manager's house and two or three cottages, inhabited by men employed at the magazine.

The river wall at this point consisted of an ordinary puddled clay embankment (the top of which was about 4 feet 6 inches above Trinity high water), battered about two to one, and faced on the river side with stones, to protect it from the wash of the sea; along the top was a foot-way about 4 feet or 5 feet wide. At the foot of the wall, on the land side, was the marsh that it reclaimed, and on the river side a shelving mud bank, falling at about the rate of one in six or seven to low water. The section will be clearly seen in diagram No. 3.

Trinity high water is 12 feet 6 inches above ordnance datum, but the spring tides have been known to rise to a level of 16 feet—14 feet being the height to which they frequently rise. At the time of the

explosion which took place at twenty minutes before seven o'clock on the morning of Saturday, the first of October last, the tide was ebbing, and was within an hour and a half of low-water—a most fortunate circumstance; for, had the accident occurred one hour later, it would have been impossible to reinstate the wall, and the marshes, as well as some of the surrounding country, must inevitably have been inundated, as it was impracticable (as afterwards proved) to have contended with the flowing tide in the limited time available. Of the immediate cause of the accident it will be here unnecessary to speak, as that will probably never be known; but with regard to the results there is more tangible matter to deal with. From the evidence afforded by the displacement of earth at various points, there is every reason to believe that there were three distinct explosions, occurring probably in the following order: 1. The barge lying alongside the jetty and near the bank; 2. Messrs. Hall's magazine; and 3. The Lowood Company's magazines. The barge at the end of the jetty is presumed to have been empty, as no disturbance appears in the soil beneath where she lay, whereas in the other cases the earth was blown out to a considerable depth, presenting the appearance of a smouldering crater, with fissures in all directions. The reasons which lead to the supposition that the explosions occurred in the order above stated are that portions of the river wall were found in the hole or pit caused by the barge exploding, and this could only have been the case by the magazine exploding after the barge, and forcing the wall back towards the river, thrusting portions of it into the pit already formed by the barge. Had the magazine exploded first and thus ignited the barge, the ground beneath her would have been clear of fragments, as the wall would probably have been blown inland by the last explosion. The magazine last referred to would communicate with that of the Lowood Company, which, in its turn, was demolished. The concussion caused was felt from 60 to 100 miles off; this was the result of the explosion of $46\frac{1}{2}$ tons of gunpowder or 1040 barrels, each containing 100 lbs. The effects to property, both immediate and remote, are universally known; as regards the river wall, a breach was made of 130 feet in length, the earth being cleared away 8 feet or 10 feet below the level of the marsh, exposing the whole of the country to the rising tide for about five hours every high water, or twice in twenty-five hours. The extent of land positively imperilled would be about 4000 acres; and should it have passed Woolwich and Greenwich by the large sewer it might have done immense damage, the whole of the southern and eastern side of London being more or less below the level of high water. The full estimate of the impending calamity can only be realized by those acquainted with the levels of the localities referred to, and the character of the banks of the Thames. Diagram No. 4 shows a section of the river wall after the explosion, the dotted line shows a contour of the temporary dam. In an able article in the *Builder*, upon the subject of the catastrophe, the fortuitous conjunction of circumstances is thus described: "Every circumstance of time and tide, availability of competent direction, presence of men at the works of the main drainage,

vicinity of a great and disciplined military force with tools and appliances, and even the soil at the spot, happened to be favorable; and a more serious disaster than has occurred within recollection, by a breach in an embankment of the Thames, was, by the greatest exertions, stayed off and at length averted. The instance may be instructively compared with the experience of previous accidents, as related in various books, where the loss to landowners, and the injury to the navigation of the Thames, through the year's duration of breaches, and by the repeated failures of attempts to close them, is graphically related."

The author of the paper, residing in the locality, was enabled to be on the spot within half an hour of the explosion, and seeing that the sufferers were properly cared for, he proceeded to the immediate repair of the wall, although, at the time, the reinstatement of the wall before the return of the tide appeared hopeless, such was the magnitude of the gap. The first step was to set to work the men who were fortunately present, in number about forty—these were set to puddle the rents and deep fissures in the hole caused by the exploded barge, and which were below low-water level, but were temporarily protected by the fragments upheaved around the edge of the hole; had not this been done before the water came into the hole, it could never have been got at again, and the whole superstructure, however solid, must have been undermined and washed away. It may be readily inferred that the bases of operations were of the worst possible description, being lumps of earth and clay separated by large fissures several feet in length, and extending under the intended dam. The next thing was to send for assistance from the nearest point; fortunately this was obtainable at the Crossness works, about a mile off, and at the garrison at Woolwich, about four miles distant from the spot. At about ten minutes before nine o'clock, the call was promptly responded to by the arrival from the Crossness works of about 350 navvies, with their picks, barrows, &c., who came none too soon to complete the puddling of this treacherous foundation before it was covered by the tide. Between ten and eleven o'clock 1500 military arrived, fully equipped with some appropriate implements, and they devoted themselves entirely to the backing up with immense quantities of earth, the work which the navvies were puddling in front, thus making it sufficiently substantial—consistent with speed and means at hand to contend with the now rapidly rising tide. In this, as is well known, by a manful struggle, they only just succeeded—racing, as it were, inch by inch with the rising waters.

Having given a general outline of the subject of the paper, it is now necessary to consider in detail the means employed and the measures taken to prevent the ingress of the water.

The first and greatest difficulty that presented itself was the portion blown out by the barge in front of the river bank, and below low water, inasmuch as the soil was very much broken up and disintegrated over a large area, and the time during which puddling could be done was exceedingly limited.

It may be here mentioned that an erroneous impression prevailed among some persons present that it would be necessary to dig out this portion to a good bottom, in the usual manner of commencing the construction of a river wall, and the author had much difficulty in persuading them that immediate puddling of the fissures and broken ground below low-water mark was the only hope of succeeding, inasmuch as the cutting a grip would have occupied all the precious time employed in filling up. This puddling was most important in order to prevent percolation, the danger most necessary to be averted. When the navvies arrived from Crossness, they were immediately set to continue this important part of the work, and also the filling of the actual gap. It required some little time to arrange the number of men to advantage, but, being accompanied by able superintendents, they were soon allotted to their separate works of digging clay—wheeling it to the spot, and carrying water for the punning, where the clay was well worked with iron punners.

While the puddling, &c., was being vigorously carried on by this large force of men, the military arrived, commanded by General Warde and Colonel Hawkins, R.E. The difficulty of immediately rendering available, without confusion, the labor of all these men in so small a compass and on the spur of the moment may readily be imagined. With the greatest promptness, Colonel Hawkins adopted the suggestions offered him by the author, as to the method of proceeding. Several barrow roads were laid leading to the gap, numbers were employed in digging and loosening earth, filling and wheeling. The number of implements available for the use of the soldiers was, of course, limited; but, nothing daunted, they were formed into lines between the barrow roads, and passed from hand to hand towards the gap the lumps of earth and clay dug up by those at the back, the whole of the clay and earth for that purpose having to be brought from a distance of 60 or 70 yards by the barrow roads, and by hand, the soldiers passing lumps from one to another for this distance, which, when deposited in place, were immediately punned down perfectly solid. Having to deal with some 20 feet head of water, it was necessary to extend the width of the dam at the base, which absorbed an incredible amount of earth, the width of the breach being 130 feet. When the tide had reached and filled the front hole, it was found that the level of the water was within 2 feet or 3 feet of the top of the progressing work. The tide rising very rapidly, fears were entertained that sufficient soil could not be obtained to enable the work to keep ahead of the tide. At this juncture, the military produced a quantity of bags used for making sand-bag batteries, and a number of men were set to fill them with the soil at the back of the work. These bags were at first being thrown in indiscriminately, when the author directed that they should be laid at the back of the puddled face in the form of an arch on plan, to receive the horizontal pressure of the water. These bags were laid in courses, as shown in diagram No. 5, and punned so as to come in perfect contact. By this means the bank could be raised of sufficient strength with about one-half the material, and the disposition of the

men was so arranged as not to interfere with the other parts of the work. In this way about 3000 bags were used, and it was satisfactory to find they answered the purpose admirably; but even with this assistance, the tide was following the work very closely.

An alarm was now raised that the water was coming in, and it became apparent that there was considerable percolation under the dam—probably through the broken ground upon which so much labor had been bestowed in puddling—and making its appearance many yards at the back of the work, it was difficult to arrive at the treacherous point. This was most disheartening by the knowledge that a small stream would soon increase in newly made earthwork and undermine the whole. The exertions were redoubled, but it is feared that these would have proved of no avail, but for the timely settlement of the structure and consequent compression of the substrata. By this providential circumstance the leak was staunch, so that the settlement, apparently a source of great apprehension, proved really a matter for congratulation. Sole attention was now turned to raising the bank and protecting the face from the wash caused by passing steamers. Timber breakwaters were hastily constructed and floated in front of the work, and this in a great measure protected it from being undermined. By half-past one the tide was at its highest, and the bank was but a few inches above it; the structure successfully withstood the pressure of the water, but it was evident to all that the backing up must be continued before the danger was past, and the men, therefore, worked on until the tide had far receded. A large staff of men continued the operations throughout the night of Saturday.

On Sunday morning the bank was found to have settled some four feet, and, in consequence of high wind from the east and a heavy sea running, threatening to undermine the works, the author telegraphed to General Warde, Commandant at Woolwich, for 500 sappers and miners, who arrived in time to reinstate the dam. The whole of the past month has been occupied in restoring the wall to its original condition, and it is now as secure as any other portion of the embankment.

Breaches of the river wall reclaiming the marshes from the river Thames have been very frequent in times gone by. These have not arisen from causes similar to the one under consideration, but from high tides, defective sluices, and even rat-holes. In 1527 the river made an irruption at Plumstead and Erith, and so much land was submerged that it was not all regained until 1590, a matter of sixty-three years. This breach occurred within half a mile of the present one, and there are now existing traces of the inland embankments by which it was reclaimed piecemeal. In the time of Henry the Eighth, the marshes of Plumstead and Lesnes, now the Woolwich practicing ground, were submerged by the water coming in from the Erith breach. But the most recent, as well as the most important, was the Dagenham breach, which occurred in 1707, at a point exactly opposite the southern or fall works of the London sewerage. Continued attempts to stop this breach were made for eight years, but without suc-

cess, when Captain Perry undertook to reclaim it. At this time the breach is stated to have been on one occasion 50 feet below low water, or seventy feet below high water, caused by the ingress and egress of the flood and ebb tides. Captain Perry, it is stated, employed three hundred men for five years before he succeeded in stopping this breach, making thirteen years in all, during which time an immense quantity of the marshes were washed into the river, greatly obstructing the navigation of that important highway. The means he adopted were, first, forming sluices in the river wall to reduce the scour by allowing freer access to the water, and after so doing he drove dove-tailed or grooved piles from either side of the breach, protecting them as he went on with clay. The increased scour caused by this impediment threatened to deepen the channel so as to be beyond the reach of piles, and if the depth above stated was correct, it would have been impossible to have succeeded by this method; so the inference is that he chose a shallower portion of the breach; certain it is that he did succeed, although at a ruinous cost.

The Dagenham breach began with the failure of a sluice which had been allowed to get out of repair, and quickly extended from a gap of fourteen feet, and ultimately led to the obliteration of a thousand acres of land. But that was not all; about one hundred and twenty acres were actually washed away into the bed of the river by the flow of sillage, and the soil so washed formed a bank about a mile in length, reaching half-way across the river.

Perry in his work on Dagenham breach proceeds to explain how this sillage, driven into the river, was deposited at the mouth of the breach, and above as well as below it, in the reaches of the Thames. He remarks that the deposit had been particularly detrimental to Erith Reach; and that even in Woolwich Reach, as he had been informed, the depth of water was lessened. All breaches, he observes, must be attended with a considerable flow of sillage into the river. After mentioning breaches that had occurred before his time, including one in the levels of Dagenham Beam, not three years and a half since, and several near Dagenham since he had been concerned there, he says, he attributes all such breaches, not to any damage from the tides washing down or running over the tops of the banks or wells, but to the bad workmanship, decay, or defect of the sluices or trunks which are made for the drain of the levels, &c., and he alludes to sluices made of wood as a prevailing custom in England, and as generally insecure and unskillfully placed. He recommends, therefore, a law to oblige all sluices on the banks of the Thames to be made with stone, cemented with tarras. The reasons why they have not been made so, he thinks, are, first, that men in England are not very willing to depart from the way of their fathers; and, secondly, the matter of foundations. He argues, however, that if the foundations were constructed after the manner of buildings in Holland, the sluices might be formed of stone, or a sort of brick, as in Holland and Flanders, and might endure thousands of years.

The greater portion of the land bordering on the Thames, including

the south of London, indeed from Richmond to the Nore, is below the level of high water, and reclaimed by walls varying but little in their construction, the general character of which is an embankment, the face of which is puddled with clay to a slope of $2\frac{1}{2}$ to 1, and protected from the wash of the sea by a stone face. In some cases where the steepness of the bank necessitates a greater slope, the face is stepped, and at each step a row of stakes driven to keep the stone facing in place. In constructing these walls, a grip about 6 feet deep and 6 feet wide is cut into the marsh to be reclaimed on the site of the wall, and puddled before the bank is made to prevent percolation. These walls and the necessary sluices for drainage require careful watching, for any portion failing would cause a catastrophe equal to the Dagenham or middle level inundation. The extent of these walls or embankments is very considerable, being about 300 miles in length.

It is a very remarkable circumstance that the marshes on the river side of the walls, still unreclaimed and termed "salt marshes," are invariably at a level of high water, whereas the land reclaimed is generally 5 feet or 6 feet below that level. Whether the constant action of the tide raises the land subjected to it, or whether the absence of that influence allows the level of the marshes to subside, or whether it is due to both these circumstances, is a fit subject for discussion, but, be it as it may, there is no question of the fact that they do so exist.

Another material point for discussion is furnished by the supposition that failure had attended the attempt to stop the recent breach, and that the waters had regained possession of their old territory, some seven feet deep at high water over an area of from 3000 to 4000 acres. Assuming this to be the case, the breach would be rapidly widened and deepened, and, were the old system adopted, the reclamation would occupy many years. It would be a work of from three to four times the magnitude of the Dagenham reclamation; and on the authority of Lambard, the land inundated by the breach which occurred in 1527 near the recent breach, as before noticed, was not all reclaimed in sixty-three years.

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Limes, Cements, Mortars, and Concretes. Collected from the observations and experiments of Generals Gilmore and Totten, U. S. A., and MM. Vicat, Chatoney, Rivot, and Dupont. By CHAS. H. HASWELL, Civil and Marine Engineer, N. Y.

(Continued from vol. xlix, p. 367.)

No. 2.

Calcareous Mortar.—Being composed of one or more of the varieties of lime or cement, natural or artificial, mixed with sand, will vary in its properties with the quality of the lime or cement used, the nature and quality of sand, and the method of manipulation.

Mortar.—Lime, 1; clean sharp sand, 2.5. An excess of water in slaking the lime, swells the mortar, which remains light and porous, or