opened, and eight minutes subsequently the wholly inflated balloon appeared on the surface of the water, bearing underneath the anchor block. The lifting has therefore been entirely successful.

"The Superintendent of Equipment of the Imperial Wharf at Kiel. (Signed) "KROKISUS.

"The Superintendent of Harbor Buildings for the Imperial Marine. (Signed) "G. FRANZUS."

The purpose of this demonstration was to prove how easily the Grosser Kurfürst, sunk in the Channel, could be raised at comparatively small cost. None of the witnesses doubted the feasibility of this method, but the German Government would not bear the expense of the trial; it would, however, gladly enter into favorable arrangements with a company formed for that purpose. The treasures lying at the bottom of the sea are immense, and a company formed for the purpose of raising them by a safe method would gain great riches.

The methods hitherto employed for that purpose are very imperfect. The best mode is to fasten airbags to the object to be raised.

The capacity of bearing of a hollow space under water is very great; it is well known that it is equal to the weight of the water displaced. The bearing capacity of a hollow space of 1 cubic meter amounts to 1,000 kilogrammes.

Accordingly a balloon, in form of a globe, of 3 meters radius would possess a bearing capacity of more than 113,000 kilogrammes; while one of 4 meters radius would be able to lift upwards of 268,000 kilogrammes.

The novelty of the new method consists in this: that the airbags are filled with great convenience, the work of pumping being done on shore, and the airbags filled with compressed gas in reserve, which can be used suddenly at a given moment to fill the balloon; unlike the old method, by which airbags are gradually filled on the surface of the water by long tubes with compression pumps.

The leading idea in this new procedure is the following. The gases (especially carbonic acid gas) become liquid by compression and then occupy a very small space, while as soon as the pressure ceases the liquids resume the gaseous form and fill the previous large space. Carbonic acid gas (which moreover is the cheapest gas) assumes the liquid form at the freezing point under a pressure of 36 atmospheres, and in this state occupies $\frac{1}{300}$ of its previous space. A small reservoir may therefore contain an immense amount of gas.

Under common atmospheric pressure, two liters of liquid carbonic acid gas fill in their gaseous state a space of 1,000 liters, or 1 cubic meter.

If a heavy burden lying under water is to be lifted, a sufficient number of airbags must be fastened to the object; each balloon is to be connected with a reservoir containing an adequate quantity of liquid carbonic acid gas, by means of which the airbag can be quickly and safely filled at a given moment.

The table below shows the capacity of bearing of globular balloons, and the amount of fluid carbonic acid gas necessary to inflate them in cases where the balloons are submerged ten meters under water.

Radius of balloon.	Capacity of bearing in distilled water (4° Celsius).	Weight of liquid carbonic acid gas necessary for inflation at 10 m. depth.
1 meter.	4,189 kilos.	13.4 kilos.
1.5 "	14,138 "	45.2 "
2 "	33,510 "	107.2 "
2.5 "	65,450 "	209.4 "
3 "	113,097 "	361.9 "
3.5 "	179,594 "	574.7 "
4 "	268,083 "	857.9 "

Suppose a sunken ship is to be raised, or one aground to be set afloat, a steamer carrying the needed material must go to the spot.

Situation, weight, cargo of the ship, have first to be ascertained; then divers have to find the most available places to fasten the airbags. They are then to be connected with their reservoirs, and filled so far with carbonic acid gas or atmospheric air that they are able to carry their own and the weight of their reservoirs, and to remain in upright position under water. Then they are lowered, and fastened in the most suitable manner on to the ship. Mr. Raydt has devised several ingenious methods by which the balloons may be thus fastened, even on iron ships. Frequently it will be possible to place balloons in the hollow spaces of ships, and to fill them from a reservoir placed on deck of the wreck, by means of gutta percha tubes. The experiments made by the inventor have proved that the liquid gas will pass through such tubes.

When all preparations are made, the most favorable time for lifting the vessel and setting it afloat is chosen. When this has arrived, all the valves of the reservoirs are opened simultaneously by divers or by means of ropes from above, the balloons are filled rapidly, and the lifting of the vessel takes place at once.

A few balloons are already sufficient to lift common vessels, even if they are of iron and freighted; but even monsters as the modern men-of-war may be lifted in the same manner. The Grosser Kurfürst, for instance, which under water has a weight of 5,000,000 kilogrammes, might be raised by 19 balloons of 4 meters radius, the length of the vessel (94 meters) being sufficient for fastening the same.

While it is necessary, according to other methods for lifting ships, to keep up a continuous connection with the surface of the water for weeks, even months, in the method just described this is not necessary. On favorable days the needed work on the sunken ship may be done; it may be interrupted and resumed when desirable; and finally the apparatus for lifting may be left fastened until it is deemed advisable to use it. The experience in lifting vessels according to the old methods show many cases where storms have destroyed the preparations and work of many weeks. By the application of the new method, however, the disturbed condition of a stormy sea has relatively little influence on the success of the enterprise, as the means for lifting, once fastened, may be used at any convenient time, and will then do their duty promptly and safely. If the steamer furnished with the necessary material which is to assist in the lifting of a vessel is soon on hand, it can be set afloat in a very short time; under favorable circumstances a few days will suffice. Especially will this be the case when a vessel has been wrecked. Only a few—say four—airbags, suitably fastened, will suffice to lift the vessel sufficiently for setting it afloat.

What has hitherto been said in favor of the new method is no mere theory; its practicability has been tested, and all difficulties have been practically overcome.

The liquid carbonic acid gas had only been heretofore obtained in small quantities by means of a compression pump worked by hand; it was therefore necessary to show that the fluid gas could be obtained in large quantities in an

easy, cheap, and safe manner. This was done by a steam compression pump made in the machine factory of Mr. Egestorff, in Linden, near Hanover. The difficulties which arise in the manufacture of small quantities of carbonic acid gas do not show themselves in the production of larger quantities. The inventor obtained in one day, with his small pump containing a cylindrical space of one liter, without any difficulty, more than 40 liters of fluid carbonic acid gas, a quantity which probably had never been obtained in all Germany. The same factory has agreed to furnish a compression pump of 40 times greater power than the one above mentioned, so that in one day more than 1,600 liters of fluid carbonic acid gas could be manufactured.

The expense of the gas depends largely upon the quantity which is produced; it will probably not exceed 5 or 10 cents per liter of the liquid gas, and will be still less when manufactured on a large scale.

The trials have also shown that the gas streams out of the reservoirs and fills the balloons very rapidly and without danger.

The balloon of 3 meters diameter and 14,138 liters capacity that had been used in the trials under water as well as in the air, was inflated in five to eight minutes.

It was feared that the filling of the balloon would be interrupted by the cold that would be induced by the outstreaming of the gas, but the trials have shown that this has not been the case. The explanation of this phenomenon is in the first place that a small fraction of the outstreaming carbonic acid gas, at most 3 per cent., was transformed so as to resemble snowflakes, and thus gave out sufficient heat to change the remainder of the fluid into gas. In the second place the particles of water next to the balloon, which became colder by the instreaming of the gas, grew heavier, and therefore sank, thereby making room for warmer particles of water, which in turn, when cooled, sank again, until by this circulation of the water the temperature of the balloon was made equal to that of its surroundings. In fact the balloon used at the trial in the Bay of Kiel, when withdrawn immediately after its inflation, did not show the least particle of an ice like formation.

As it is known that carbonic acid gas becomes fluid at the freezing point under a pressure of 36 atmospheres, it is evident that the reservoirs must be sufficiently strong. Every danger, however, that might arise may be prevented by previous trials of the powers of resistance of the reservoirs. The chances of explosion are not as great as in boilers of steam engines, for these wear out from the rust produced by the water, and by the steam and air with which they are filled. Besides they are exposed to fire, by which they suffer; and a sudden development of large quantities of steam under high pressure makes them liable to explode. All these dangers are avoided in the case of the reservoirs filled with fluid gas; the metals of which they are constructed are not affected by contact with the gas, nor can a higher pressure suddenly be developed, so that with the necessary caution no danger is incurred. Should it be desirable to diminish the pressure, it may be done by adding another gas to the carbonic acid—say sulphurous acid, which at the freezing point under pressure of $1\frac{1}{2}$ atmospheres becomes fluid. The balloons may be constructed out of canvas coated with India-rubber, or made otherwise impervious; they must be covered by a netting of strong cords, which join underneath; and may be fastened by chains to the hooks destined for the lifting process. The pressure from the inside of the balloon is about equal to that from the outside, as the pressure of the gas is equal to that of the water from without. Still when the balloon rises in the water, and the pressure of the water diminishes, it is necessary, in order to avoid all danger of an explosion, to let the superfluous gas out. For this purpose the bottom piece of the balloon is furnished with self acting safety valves, which open as soon as the outward pressure diminishes, and let the superfluous gas out. In proportion to the advantage the expense of this new method is very small, considering that the larger outlay for the airbags, net of cords, and reservoirs, is only once necessary, and only the filling with the very cheap carbonic acid gas has to be renewed.

To give a proximate estimate, it may be mentioned that the Hamburg steamer Pomerania (sunk in the Channel), which was insured, without cargo, for the sum of \$400,000, would be sold at present, although her position is a very favorable one, for a few thousand dollars, while the expense for the whole of the material necessary for lifting her would be about \$15,000. For lifting the Grosser Kurfürst the German Government has agreed to pay \$250,000, while the cost according to our method would be, on an average, \$50,000. The lifting of the Vanguard would be even more profitable, for the English Government had once offered to a contractor the sum of \$750,000 for it.

PRELIMINARY REPORT UPON THE IMPROVEMENT OF THE NAVIGATION OF THE MISSOURI RIVER.

By MAJOR CHAS. R. SUTER, United States Engineer.

THE importance of the subject can hardly be overestimated, as this river is the longest of any in the United States, and is, with the exception of the Ohio, the largest tributary of the Mississippi. Its channel length from its source in the Rocky Mountains to its junction with the Mississippi near St. Louis, is probably something over 3,000 miles, and it brings forward the drainage of an area of 572,672 square miles. It is navigable for nearly its whole length, for the portion above the Great Falls, near Fort Benton, is already provided with several small steamers. Its tributaries, though often of great length, are not of great size, and are rarely navigable in their present condition.

The country through which the Missouri flows is mostly one of small rainfall, so that its really large discharge is due to the great area of its drainage basin and the mountain snows and ice near its head waters. Its most salient and striking features are the remarkable impetuosity of its current, and its slope, which is considerable for so large a stream. The rapidity of the current and the general instability of the banks and bed give rise to the excessive turbidity of its waters, which have earned for it the title of the "Big Muddy." It is, in fact, the greatest silt-carrier in the country, and the enormous mass of sediment which it brings forward forms the great bulk of that received by the Mississippi from its tributaries. Its influence upon the main river is most marked; indeed it is its prototype in its main physical features, and from the navigation point of view, at least, it may be said to have a marked controlling effect upon the main trunk stream. The subject of its improvement, therefore, is not only of local interest, but is of the greatest general importance, now that the improvement of the Mississippi is receiving serious consideration.

The portion of the river to which this report is confined

is 781 miles in length, and extends from Sioux City to the mouth. The general direction of the valley from Sioux City to Kansas City, 406 miles, is slightly east of south; for the remaining 375 miles it is nearly east and west.

For the period covered by possible navigation—that is, the period when the river is unobstructed by ice—the range of water surface varies from sixteen to twenty feet at different localities and in different years. During the winter the river may fall three or four feet lower, and unusual floods may increase the height by an equal amount or even more, as in the great flood of 1844. This latter flood, however, was entirely abnormal, and due to causes of which we have at present no definite knowledge.

The amount of water discharged is, however, subject to a much greater variation than this range of surface elevation would imply. Our gauging observations at Saint Charles, near the mouth of the river, showed a variation in 1879 from 26,446 to 298,537 cubic feet per second for a range of seventeen and one-third feet on the gauge, or a low-water volume about one-eleventh that of high water. From these observations it was further inferred that the ordinary range of the gauge would give volumes of about 15,000 and 430,000 cubic feet per second for high and low water respectively. This would make the low-water volume about one twenty-eighth that of the high. At Sioux City, 781 miles above, the variation in discharge was about the same, while the total discharge in passing over this distance was increased about 100,000 cubic feet per second in flood, and 8,000 cubic feet at low water.

The regular floods are two in number, and usually occur in April and in June. The first is extremely violent and of short duration, rarely lasting over a week or ten days; it seems to come largely from the upper river. The June rise, although generally higher, is of longer duration, being influenced by local rains and the general saturation of the soil. It is followed by a steady fall, which continues with considerable regularity till the freezing weather closes the small affluents as well as the upper river; then a sudden fall of three or four feet takes place, and the river reaches its winter level. There are occasional small rises of short duration besides those mentioned; one, especially, usually occurs late in the fall, but the two first mentioned are from all points of view the most important. The rate of travel of the crest of these floods is, on an average, about six miles per hour. The April rise is generally the most destructive, for it shows, for a time at least, a tendency to follow the channels developed during the low water season preceding, and, as a consequence, the banks are attacked with extreme violence. When the June rise comes, the bed is in a measure shaped for its reception by the preceding flood, and the water passes off with somewhat less destructive results. Both, however, have sufficient power to produce tremendous effects and bring about the most astonishing changes.

The main valley of the river consists of a great rock trough, from one and a half to seventeen miles in width, cut down from the general level of the country to a depth considerably below the present level of the valley. The rocky banks form bluffs along the stream, and the bed is also of rock. This great trough seems to have been filled at one time with the glacial drift deposits, which also cover the adjacent country, and subsequently in part cleared out by the great river that probably occupied it in early postglacial times. The drift deposits seem everywhere pretty well sorted out, boulders are generally found next the rock, and deposits of varying degrees of coarseness above. The main feature is the great preponderance of extremely fine sand, which, with the addition of a very small amount of alumina, forms an extremely tenacious clay, locally known as "gumbo," and which is met with everywhere, and is formed in the bed of the stream wherever the current is unusually slackened. Large beds or pockets of very coarse gravel or pebbles are also met with in borings at different depths below the surface. They are usually water worn fragments of quartz, mostly red and yellow jasper. The general absence of the large, high, and well-defined terraces, which are usually found in valleys of this description, and the general prevalence in the surface soil of the very fine sand before alluded to, leads to the inference that the river, within comparatively recent times, has scoured over the greater part of the area embraced between the limiting bluffs, at least in the narrower portions of the valley. The valley below Saint Joseph averages about two and a half miles in width; above that point it is wider, reaching seventeen miles in the neighborhood of Sioux City.

The general depth of the rock bed below the surface of the valley varies from seventy to over one hundred feet wherever borings have been made. The piers of the numerous bridges erected are founded on rock in most cases, and the borings which have been made at these and other proposed bridge-sites, together with work done under my own direction, enable me to assert with considerable confidence that no rock in place will be met with at a higher level. At the few places where it is found in the bed of the present stream spurs or ledges projecting from the main bluffs are the cause, while the general depth of the rock valley beyond these ledges is unchanged. Moreover, if at any place rock did occur at a higher elevation within the bed of the stream, it would be indicated by a local increase of slope, but such is nowhere the case, except at the points alluded to. As I am of the opinion that at these few points the obstructions can readily be flanked, I think it perfectly safe to count on any amount of depth of channel deemed necessary within the limits stated. At some points on the river layers of boulders of considerable size form the bed of the stream in flood, and have been mistaken for rock in place. At Saint Charles the piers of the bridge pass through a layer of this description, but the bed rock was found below the boulders, and at the usual level.

As may readily be inferred from a comparison of the volume of discharge with the variation in level of the water surface, the velocity of the current is very great. At low water the average is from two to three miles per hour, while in floods it amounts to ten miles per hour or more. Owing to this cause, and also to the large amount of very light material in the bed and banks, the amount of bank erosion and scour and fill of the bed is very great and very rapid. Bank erosion to the extent of two thousand feet per annum, over long distances, has been noted, and to a greater or less extent it is constantly going on, even during low stages. The enormous amount of material thus precipitated into the river, together with that scoured from the bed, causes the formation of innumerable bars, which, even at high water, obstruct navigation. These bars are constantly in motion, their position and shape changing from day to day. The channels through them are also changing both in depth and location, rendering navigation correspondingly uncertain. Owing to the incessant bank erosion the river is steadily increasing the width between high banks, as the bars which are formed opposite caving shores take time to build up to

the general level, and are meanwhile liable to be themselves attacked and swept away. The erosion, which usually occurs on the upper sides of points, causes these points to move bodily down stream. Where the erosion is more rapid than the bar-growth below the point disappears, and the river's course is detrimentally straightened. Where a point or projecting neck is attacked on both sides, a cut-off is soon formed, which also acts detrimentally by increasing the local slopes and inaugurating other destructive changes. The caving of the banks precipitates into the river countless trees, which form the snags that constitute, in the strong current, most serious dangers to navigation, and also assist in impeding the free flow of the stream. The slopes vary from point to point, being, as usual, greatest on the crossings of the bars, and less in the pools above them. The general slope of the river, however, as determined by simultaneous gauge readings, is remarkably uniform. It averages 0'88" to the mile both at high and low water.

Owing to the great movement of sand, when the current is strong, the bars are rapidly built up as the river rises, and although elsewhere the river follows the general law of scouring its bed at high water and filling it at low, yet at these places of local engorgement the depth over the bars, as also in the channels leading through them, is much less than the low water depth plus the rise of the water surface. The actual navigable depth of the river varies from about three feet at low water to nine feet at high water, though, of course, at the latter stage the channels are wider and the number of very shoal bars is reduced.

The amount of sediment carried by the river is very great, and it is only when ice begins to form that the water becomes comparatively clear; at all other stages the water is muddy, the amount of sediment carried increasing with the volume of discharge. From observations carefully made at Saint Charles the sediment carried in suspension past that station for the year 1879 is shown to have amounted to 5,508,229,008 cubic feet, the water discharge for the same period being 2,335,143,946,400 cubic feet; the proportion by volume is 1 to 424, and by weight 1 to 265. For the single day, July 4, 1879, the amount of sediment thus transported would have covered a square mile to a depth of 4'04" feet, and during the entire year an amount of sediment passed Saint Charles sufficient to have covered a square mile to a depth of 197'58" feet. The samples of water that were analyzed were taken at the surface, the mid-depth, and at one foot from the bottom, and the arithmetical mean was taken for the mean result. The true amount would, therefore, of course be greater. Moreover the last foot of depth was not considered, but the increase in amount of sediment from surface to bottom was such as to lead to the inference that the amount moving in this lowest stratum might be fully equal to the amount actually collected. The observations also took no note of the material in motion on the bottom, known to be great in amount but never yet successfully measured. For these reasons it seems probable that the amounts above given would have to be at least doubled to get a just idea of the amount of solid matter brought into the Mississippi by the Missouri. On this supposition the total amount per annum would be 11,000,000,000 cubic feet, enough to cover a square mile to a depth of 400 feet.

An examination of the sediment samples collected shows that only the finer materials are carried in suspension within the limits covered by the observations; the coarser particles of sand are either rolled along the bottom or carried intermittently in close proximity to it. As might be anticipated, the water is so heavily charged with sediment that decrease in velocity is immediately followed by a considerable deposit, but the converse of scour following an increase of velocity, although apparent, is not so well marked nor so extensive. This is explained by the fact that the largest portion of the suspended sediment is undoubtedly due to the caving of the banks, in which process a much larger amount of material is thrown into the stream than is due to actual erosion. By this latter action the toe of the bank is undermined, and the upper portion, being unsupported, falls in, when the lighter materials of which it is composed are carried off by the water in a state of suspension, the heavier materials remaining on the bottom. The increase of velocity due to concentration, however brought about, sets up a very heavy scour on the bottom, the bed rapidly deepens, and the excavated material is carried away, the greater portion being probably dropped as soon as the local concentration of volume is at an end.

The regular formation and movement of sand waves is not conspicuous except at low stages; during floods the velocity of the current is so great and the bed so yielding that the materials composing it seem to be moved bodily in mass as if the bed were in a semi-fluid condition.

The difficulties of navigation are mainly due to the small depth on the bars, a description of which is essential to a proper understanding of the subject.

Wherever certain limits of width are exceeded the river very generally shows two narrow pools or channels of deep water, one adjacent to each bank. Between these lies a bar, the depth of water on which is much less than it is in either pool. The pools are narrow and deep, closed at each end, and so located that the head of any one lies opposite a point intermediate between the head and foot of the pool adjacent to the opposite shore. It is generally impossible to pass from one pool to the next succeeding one on the same side of the river, so that in practical navigation boats are obliged to cross the intermediate bar to pass from the pool on one side to the one opposite, then back to the next one, and so on. The bars between the pools are often very extensive. They lie diagonally across the stream, alternating from bank to bank, and are often several miles in length. They are intersected by numerous channels of comparatively small depth. At low water large portions of these bars are laid bare, and under favorable circumstances a growth of willows will start on them, and they then become the nuclei of islands. After the willows get a good foothold the sediment arrested in floods gradually builds up the surface till it is too high for the growth of willows; cottonwoods then succeed, and finally other trees gain a footing, and the island is raised to the general level of the bottoms. In spite of this transformation the connection of the islands with the bar systems remains sufficiently obvious when long reaches of the river are considered.

The general dimensions of the bars depend mainly upon the width of the river. The exterior boundaries follow closely the outlines of the main shores, being separated from them by the water in the pools. In the space between the foot of one pool and the head of the next adjacent one, the bar joins the shore line, and its general direction then changing, it trends toward the opposite shore, which it reaches in the space between two adjacent pools on that side; then the general direction of the river is a curved line, the bars follow the curves closely, the deep pools lying next the concave shores. The general depth on the bars varies also with the width. Where this latter is but little in

excess of that which does not allow a bar to form, the middle bar may be deeply submerged, and only indicated on a cross-section of the stream by a slight rise of the bottom near the middle width. Again, where the width is great, some portions, viz., islands, remain dry even at high stages; while the general position of the bars remains constant, their shape, the depth over them, and the position and depth of the channels through them, are constantly varying. The pools also are, to a considerable extent, influenced by these changes, portions being filled up or excavated from year to year, as the distribution of the flow of water over the bar varies. The side of the bar next the down-stream pool is usually quite steep, the depth on the bar crest is less than at other points, and the slope which connects it with the up-stream pool is very gradual. These bars, extending, as they do, entirely across the stream, act like low or partly submerged dams, and the ponding up of the water due to this cause gives rise to the pools in which the slope is much below the average, while on the crossing from one pool to another it is much above the average. Even at high stages this difference of slope is very conspicuous. In passing from one pool to another the water begins to pour over the bar at the head of the down-stream pool. After reaching the pool the water flows along the lower edge of the bar, receiving as it goes additional supplies from the sheet of water flowing over the bar crest. The volume of water in the lower pool, therefore, increases from its head to a point about opposite the head of the next pool of the series. When this point is reached the second pool begins to discharge into the third, precisely as the first had discharged into the second, and its volume of water diminishes throughout the remainder of its length. Each pool, therefore, shoals toward its head and foot, and its width decreases also, though in a smaller proportion. The result of this double flow along the axis of the pool and across the crest of the bar, is to force the body of water in the pool against the bank, while eddies are generated, often of great size. Under these circumstances there is always a tendency to erode the banks, and in direct proportion to the amount of water coming over the crest of the bar. Where a channel is cut through the crest this action is very powerful, and erosion is generally initiated at such points. After an indentation is once made in the outline of the bank the eddy generated thereby extends the cutting down-stream for long distances, and where the shore line is curved the width of the swath thus cut out increases as it progresses down stream. As the bank recedes the crest of the bar advances correspondingly, its lower face being no longer swept clean by the current in the pool, till the original cross-section of the latter is re-established and the advance of the bar is stopped. In my opinion the caving of banks is almost, if not entirely, due to this action. Where the current flows parallel to the shore without cross currents or eddies there seems to be but little, if any, erosion.

At many points along the river are found reaches of moderate length where the width is too small to allow the formation of a middle bar. At these places, often very narrow, the whole volume of water, even in floods, flows in a concentrated mass, the direction of the current being parallel to the banks. From the date of the earliest land surveys (1817) these places seem to have remained almost unchanged, there having been very little erosion. At these places, as the river rises, the bed regularly deepens, and it fills up again as the river falls, leaving the relative section unchanged from year to year, while the depth, even at low water, is much greater than the average. The slope is usually less than the mean slope of the river. The pools also are of this same general type, but more exaggerated and modified by the peculiar manner of their formation. If the bar crest above them were dry, and all the water entered them through one channel, they would be entirely similar.

During flood stages the general movement of sand is, in a measure, arrested on the shoals, and, as a consequence, the low water channels leading through them are silted up, while new ones are developed which accommodate the high water flow. As the river falls these latter channels are silted up, and the water ponds up behind the bar until sufficient head is attained to form a breach through the crest at one or several points. These breaches are the low water channels, and through them boats have to pass on their way from one pool to another. The depth in these channels depends mainly on the number; where there are many, and there is also a considerable flow over the crest of the bar, the depth is smallest and navigation the most impeded; where the flow is more concentrated, the depth is proportionately increased.

During the course of the low water season the main channel keeps shifting from one subsidiary channel to another; these changes of location are often very great, and the uncertainty thereon attendant forms one of the greatest drawbacks to navigation. The high water channels, before alluded to, are, in the Missouri, of the same general character as those of low water, but they rarely coincide with them. They are less tortuous as a rule, but not of much greater depth, and they are liable to the same rapid changes of location.

The main points, to which attention should be directed, are the constantly varying slopes, cross sectional areas, and velocities. At the narrow reaches and in the pools we have a small slope and small cross-sectional area, especially characterized by great depth, small width, and high velocity; while on the shoals we have an excessive slope, a very large area of cross-section, with excessive width, very small depth, and low velocity. The amount of water passing is the same in both cases, but the ratio of frictional surface to area of water-way is small in one case and large in the other. The increase slope observable in the last case is its direct and necessary consequence, as the additional head thus created alone enables the water, when flowing through the larger cross-section, to overcome the added resistance due to the increase of frictional surface. It is evident from this fact that the contracted section is more favorable for the discharge of a given volume of water than the other, as the mean velocity is greater, while the slope is much less.

Now, it must certainly be admitted that, at any point and at any time, a river adjusts itself to the various conditions imposed upon it by the bed through which it flows. As the volume of discharge increases, the surface of the water rises, the river spreads out laterally, and thus obtains greater area of cross-section, while the velocity of the current increases. But on rivers flowing through alluvial deposits a further change takes place, for, the bed being of a yielding character, the increased velocity of the current is sufficient to set up scour, which is greater or less according to the increase of velocity and the relative stability of the bed. At the concentrated sections, where a great increase of velocity takes place, this scour is large; whereas at the wide, shallow sections, where the increase of velocity is small, the bed not only does not scour, but actually fills up, as the materials scoured out of the deep pools are arrested there by the decreased velocity of the current. When the river falls, the velocity of the current over the shoals is locally increased,

while that in the deep pools is slackened. Local scour then sets up on the bars, and the materials thus removed are dropped in the pools, where the current is no longer strong enough to move them, and as a consequence the bed of the pool rises. It is the same with the materials precipitated into the river by the caving of banks; the lighter materials are swept off in suspension, while the heavier sand is carried through the pools by the strong current there prevailing, and dropped on the shoals below, where the velocity of the current is less.

Such, in very general terms, are the nature of the changes that take place, and it being obvious that the difficulties of navigation arise from lack of sufficient scouring power at special localities, all systems of channel improvement seek to remedy this difficulty by concentrating the flow of the water at such localities. The method usually followed seeks to concentrate the whole low water discharge and a portion of that pertaining to higher stages into one channel of such dimensions as will best subserve the special object aimed at. This system generally commends itself on grounds of economy, the extent of the works required being, as a rule, small. It is, however, open to many objections. In the first place, its scope is limited, only a moderate improvement being possible. In the second place, it is uncertain, as the amount of the deposit of floods varies from year to year, and may at times be in excess of the capacity of the works of improvement to remove rapidly after they begin to act. In the third place, it is not necessarily permanent, as the high river over which it has no control may, by abrasion of banks and other means, effect such changes as to render the works useless, or even cause them to become actual obstructions. All these difficulties are enhanced when the river is large and its regimen very unstable, and, on the Missouri, this cause alone would, in my opinion, render such a system entirely impracticable. The only system which promises results of permanent value here is one which will control the river at high as well as at low stages. The points which such a system should seek to obtain, at least approximately, are, at any stage, equality of cross-section both in width and depth, uniformity of slope and in consequence uniformity of velocity, while the channel at all stages shall be permanent in location. The width should be such that at high stages the bed will be scoured to the greatest attainable depth, while at low water the greatest depth compatible with navigable width will be retained. The slope should be as small as it is possible to obtain within the limits of the present banks. The volume of discharge, the attainable slope, and the depth to unyielding strata, in this case bed-rock, will alone limit the scope of such an improvement. It would not, of course, be possible to bring the whole river to the dimensions of the pools, as the small slopes which exist there could not be obtained, but a mean result corresponding nearly to the average slope of the river is possible. After a careful study of all the data collected, I am of the opinion that for the portion of the Missouri River under consideration, about eight hundred miles in length, and extending from the mouth to Sioux City, Iowa, a uniform navigable depth of twelve feet at lowest stages can be guaranteed. This depth would allow boats to load to eight or nine feet, and run with perfect freedom, while at higher stages the depth would, of course, be much greater. To effect this improvement the high water width of the river must be decreased and be brought within certain limits which increase with the increased volume as we proceed down stream, while the general direction given the rectified channel must be such as will insure the smallest slope attainable consistent with other conditions. Approximately these high-water widths are as follows:

	Feet.
From Sioux City to mouth of Platte.....	820
From mouth of Platte to mouth of Kaw.....	960
From mouth of Kaw to mouth of Gasconade.....	1,160
From mouth of Gasconade to the Mississippi.....	1,240

At low water these widths become, respectively, 650 feet, 820 feet, 1,020 feet, and 1,100 feet, the low water and high water lines being connected by slopes flat enough to be permanent. The increase of width at high water is nearly such as, with the scour on the bottom, will insure the requisite area for the flood discharge. The dimensions of the high water section are, therefore, regulated by those of the low water section, which is designed to insure a definite depth of twelve feet at lowest stages. The scour which it is expected to induce by this contraction is under, rather than above, what commonly occurs at all the deep sections along the river, and is thought to be readily attainable. When a channel of the dimensions indicated has once been cut through the shoals, any impediment to navigation due to these latter will, of course, disappear, and they cannot reform because, the velocity being uniform, there can be no tendency to deposit at any one place more than at another. As the river falls from high to low water the bed will be uniformly silted up from one end of the river to the other, but not to such an extent as to diminish the expected low water depth.

The range of elevation of water surface from high to low stages will, of course, be somewhat increased, but the actual elevation of floods will probably be lower, as there will be no local engorgements of sand as at the present shoals to raise the surface of the water and diminish the freedom of flow. The whole of the river bottom will, therefore, be benefited in this way, in addition to the security conferred by the works against destructive bank erosion.

To accomplish these results it is proposed to employ the methods already successfully applied for some years past at various points along the river, and which have been described at length in my annual reports. By the use of suitable devices the velocity of the current is checked where desired, so as to induce a deposit of the sediment which it carries. By taking advantage of the season of floods, when the amount of material moving is large, deposits of very great extent can be readily induced.

The object is to so locate these deposits that they shall occupy those portions of the river bed that it is designed to abandon, leaving unobstructed those portions to which it is desirable that the channel shall be directed. The river is thus expected to build up the new banks and excavate the new channel. By following up this action it is anticipated that after one or two seasons the rectification will be completed and the new banks will be raised sufficiently high to support a growth of vegetation. They, and all other banks exposed to erosion, will then be protected by light mattress revetments. The work so far done under this permeable system of improvement, although largely experimental, has given very encouraging results, and the cost of the silt-catching devices, revetments, etc., has been brought to very low figures, so that in the case of a river which, like the Missouri, is very heavily charged with sediment, works may safely be projected to accomplish results of a scope and magnitude utterly unattainable by any other methods.

Work already done furnishes me the means of approximately estimating the cost of this improvement, which, if carried out on a large scale, and with liberal appropriations, will probably not exceed \$10,000 per mile. This would put the cost for the whole eight hundred miles under consideration at \$8,000,000, and from Kansas City to the mouth of the river at \$3,750,000. If this work is undertaken it will, in my opinion, be absolutely necessary to confine the work at any time to such a length of river as will allow of the rectification being entirely completed with the sum appropriated. In other words, the money should be allotted to the improvement of a certain reach of the river, and the engineer in charge should be left entirely untrammelled to decide how and where within that reach the money should be expended. In order to economize in the outlay for plant, these reaches should be in lengths of not less than fifty nor more than one hundred miles, and the work should be continuous—that is to say, as soon as one reach is finished the next in order should be taken up. For many reasons it would be advisable to begin at the mouth of the river and work up stream, making the improvement continuous and complete as it progresses. It must be distinctly understood that the estimates submitted are based upon the supposition that work will be carried on in the manner indicated; if the money is to be frittered away at isolated points, and the improvement carried on in a disjointed and arbitrary manner, no estimate of the ultimate cost is possible, but it would probably be three or four times greater than the figures given here. In work of this kind it is essential, both for the sake of economy and to insure ultimate success, that the money shall be available when work can be done to best advantage, and in such amounts that each separate piece of work may be pushed at once to completion. Anything left unfinished is pretty certain to be destroyed, and the ultimate cost will thus be enhanced, not to mention the trouble and expense attendant on the frequent revision of plans thus rendered necessary.

The benefits attendant on such an improvement can hardly be over-estimated. With a guarantee that at lowest navigable stages a safe and permanent channel, having nowhere a less depth than twelve feet, will be available, boats and barges as large as any now used on the Lower Mississippi could be built and safely navigated. They could also be provided with heavy power and staunch hulls such as would be needed to cope with the strong current of the Missouri River. Snags, which now are great and ever present obstructions, would be to a great extent swept away by the deep scour of floods, and the supply of new ones would be materially reduced by the general prevention of bank erosion. The amount of sediment carried into the Mississippi would be proportionately reduced by the same work, and very substantial benefit be thus indirectly received by that river. The whole valley of the Missouri is extremely fertile, and if reclaimed, as it would be by this improvement, would soon all be under cultivation, and the amount of grain which would seek the river transportation would be enormous. The estimate for the whole work thus sketched out is \$8,000,000, which could, with due regard to economy, be expended at the rate of \$1,000,000 per annum. At this rate the whole improvement would require eight years for completion, or from Kansas City to the mouth four years, with proportionate increase of time if the annual appropriations should be smaller than here indicated.

THE INSTITUTION OF NAVAL ARCHITECTS.

THE annual meeting of the Institution of Naval Architects for 1881 began on the 6th of April. The President, the Earl of Ravensworth, filled the chair. He said that at no time before did so many questions of importance present themselves for consideration in connection with the institution, and he now proceeded to dwell at some length on the present commercial position of Great Britain in general, and of her shipping interests in particular. He found the Clyde held her honored position at the head of the list, having built last year one-half more tonnage than she did in 1879, and 1879 was a very fairly active shipbuilding year all over the kingdom. The Wear built one-third more than in 1879. The Tees more than 50 per cent. increase over 1879; the Tyne only built one-tenth more, and she actually built twenty-one vessels fewer, but she built upwards of 10,000 tons more shipping than in 1879. Now, that was important, because it showed that the efforts of our shipbuilders were directed to larger and more powerful, and consequently swifter vessels. The figures were as follows: The Clyde built, in 1879, 191 vessels, with 168,460 tons; in 1880 she built 209 vessels and 236,579 tons. The Tyne built, in 1879, 130 vessels and 139,843 tons; in 1880 she built 109 vessels only, but with 149,082 tons. The Wear built sixty-five vessels in 1879, and 92,176 tons; and in 1880 seventy-seven vessels, with 116,227 tons. The Tees built twenty-five vessels, with a tonnage of 31,756; and in 1880, thirty-eight vessels, with 48,506 tons; and the value of the vessels in the north-eastern ports, built last year, amounted to seven millions of money. In February last there were building in the various ship-building establishments in this country no less than 650,000 tons of shipping under Lloyd's rules, and in addition to that there were 150,000 tons more not under Lloyd's qualification, making a total of not less than 800,000 tons of shipping in course of construction in February last. Our steam fleet had increased since 1850 from 1,350 vessels to 6,690 vessels, representing 2,731,000 tons of shipping, or one million more tons than of all other steamships of the world put together. He was therefore justified in saying that we held a very fair position in the carrying trade. He knew that some high authorities thought that steel was the material for the future, both for our merchant and for our war vessels; but, at the same time, they must remember that price has a great deal to do with material, and the present price of steel would probably for some time to come be a serious impediment to its employment for the ordinary ship and rougher description of merchant vessels. But there were eminent authorities, and he was rather disposed to be with them, who considered that the days of iron for ship-building purposes were numbered. He wished to quote a fact from the chairman of the Cunard Company to show the advance in Cunard ocean steamers. He said that when the Britannia made her first voyage, forty years ago, she measured 1,139 tons, cargo capacity 225 tons, and she steamed 8¼ knots. Referring to the French bounty system he said that the French bounty upon the first cost of a vessel had been variously estimated to be very nearly one-fifth of the cost. Supposing a vessel to cost £50,000, the bounty would amount to something very near £12,000. But there was another branch of it. There was a bounty upon the navigation of the vessel amounting to 1½¢ per registered ton per 100 miles run on any direct line. Now that had been calculated to amount in one year to 17½ per cent. upon the first cost of the vessel, and he would put the navigation bounty at 12½ per cent. more upon the navigation,

which amounted to no less a sum than 30 per cent. of the capital invested in that ship in one year. The effect of that appeared to him to be to put absolutely at least half that amount into the pocket of the shipowner in the shape of profit. We must look to greater care in the conduct of experiments upon designs in our shipbuilding establishments in order to bring ingenuity and theory to the test of practice.

These were the objects and purposes of this institution, and it is in the fulfillment of this great purpose that they would gain for themselves that to which he thought they were fairly entitled—the title, namely, of one of the most useful and practical institutions in the country.

The first paper read was by Mr. J. D'A. SAMUDA,

ON THE ALMIRANTE BROWN ARGENTINE, CASED CORVETTE, AND THE EFFECT OF STEEL HULLS AND STEEL-FACED ARMOR ON FUTURE WARSHIPS.

The author said that the Almirante Brown was, he believed, the first vessel afloat which had been constructed entirely of steel and coated with steel-faced armor, and he believed that a reference to her guns carried, the armor-resisting power obtained, and the great capability of steaming without recoiling, would show advantages beyond those possessed by any previous vessel of similar tonnage and power, results mainly due to the material employed in the construction of hull and armor. This is a vessel of moderate size, combining all the latest improvements in construction, armor, and armament. The hull is built entirely of Siemens steel; the armor is "compound" or steel-faced, consisting of an armor belt extending 120 ft. in length, and protecting the engines, boilers, and magazines with cross-armored bulkheads at ends of belt reaching from 4 ft. below the water-line to the main deck. Above the main deck amidships is an armor-plated battery with double embrasures at the fore end, and containing in all six guns. The armor-plates are worked on a teak backing, and are screwed to the skin with bolts and nuts from the inside, so arranged as not to wound the steel face of the armor. Horizontal armor of steel plates is worked from the battery to the ends of the vessel, forming a shell-proof and water-tight deck 4 ft. below the water, protecting the steering apparatus, etc. The bottom is covered with teak planking 3 in. thick, and zinc sheathing from keel to 3 ft. above the water, as a protection against fouling. This vessel is fitted with a double bottom, and divided by transverse bulkheads and steel decks into forty-eight water-tight compartments. The plating of the hull varies from ½ in. to 1½ in. except behind the armor, where it is 1 in. thick. She has two pole masts, and an area of sail of 10,000 square feet. The armament consists of six Armstrong's improved type 8-in. 11 ½-ton long breech-loading guns fitted in battery, and so arranged as to give an all-round fire; one similar gun on upper deck forward and one aft; also six 4½ in. broadside guns on upper deck. Her machinery consists of two sets of inverted compound surface condensing engines of the collective indicated power of 4,500 horses—each set working its own screw, and being fitted in its own separate engine-room. The boilers are eight in number, cylindrical, the boiler room being divided into four separate water-tight compartments. The steel-faced armor used, 9 in. thick, has been found in practice to be equal in shot resistance to iron armor of 12 in. thick, and to resist a shot from a 12-ton muzzle-loading gun at 10 yards; while the guns used in this vessel, though weighing each only 11 ½ tons, are able to penetrate 13-3 in. of ordinary armor at 70 yards, and this is equal to the penetrating power of the surface muzzle-loaders of 18 tons in weight. Five of the guns can be brought to act almost in a direct line ahead, while an all-round fire is obtainable in which nearly every gun can participate. The speed is expected to reach 13¼ knots, and the coal carried is sufficient to enable the vessel to steam at a low rate of speed—say 8 knots—6,000 miles, or at a speed of 10 knots to cover 4,300 miles of distance. The effect of substituting steel for iron in the hull, and steel-faced armor for iron armor, has been to obtain the same strength and resistance to shot that could only be obtained in an iron vessel of similar size and strength with 510 tons additional material, and when increased in dimensions to meet this—as given below—a further 350 tons would be needed for the extra weight to the enlarged hull. An iron-built and armored vessel constructed to carry this additional weight, and of such extra dimensions as would be necessary if the same speed were to be maintained, draught of water preserved, and coal-carrying capacity maintained, would have to be increased in size, displacement, and power as follows. The iron ship would have to be constructed: Length, 260 ft.; breadth, 55 ft.; displacement, 5,200 tons; coal to be carried, 750 tons; power, 5,000 horses; while the steel vessel, with steel-faced armor, as already described, would be: Length, 240 ft.; breadth, 50 ft.; displacement, 4,200 tons; coal to be carried, 650 tons; power, 4,500 horses. It would involve 1,000 tons additional displacement, and 500 additional horse-power to get in the iron ship equal speed and shot-resisting power, and she must carry 70 tons additional coal to enable her to travel an equal mileage without recoiling.

ON THE PECULIARITIES OF STEEL PLATES SUPPLIED FOR THE BOILERS OF THE IMPERIAL RUSSIAN YACHT, LIVADIA.

By MR. W. PARKER, Chief Engineer Surveyor of Lloyd's.

This paper, of which we give an abstract, as was to be expected, attracted great attention, and the hall was crowded. It is to be regretted, however, that no representative of Messrs. Cammell, of Sheffield, the makers of the plates in question, was present. Mr. Parker began by calling attention to the steady increase in the employment of steel for boilers, and then went on to two points open to doubt, namely, the rate of corrosion of steel plates, and, secondly, the chance of meeting with brittle plates. On the latter point he might state, on his own experience and on the authority of all the engineer surveyors of Lloyd's, that not one single instance of a brittle steel plate had come under their notice during the manipulation of 17,000 tons of steel; and it was not until the peculiar behavior of the plates of the Livadia's boilers occurred that they had any fear on the score of brittle plates. During the construction of steel boilers much was heard of mysterious fractures in steel plates which had stood all the tests required, been riveted up into their places, and had then, as it was termed, cracked without being touched. A great number of these cases had been investigated, and in every instance they had been clearly traceable to improper manipulation of the material, and the plates in the vicinity of the fracture were found to be perfectly ductile after the fracture had relieved the strain upon the material. These cases were quite as numerous in steel manufactured by the Siemens process as by the Bessemer process. They were clearly shown to be due to internal stresses set up in the plates by improper manipulation, and under certain conditions a tearing action was set up.

The fractures of the steel used in the boilers of the Livadia

were entirely different from anything they had previously had experience of, and they had still later experience of other steel behaving in the same way, and he thought the time had come when steel makers must sift the matter to the bottom, and not only find out the cause, but find out the remedy. He then went on to say that he had obtained every facility for testing the plates of the boilers of the Livadia and obtaining other information concerning them. It appears that the plates were specified to be Messrs. Cammell's sub-carburized steel, made by the Siemens process, each plate to have a tensile strength of not less than 26 and not more than 30 tons per square inch, with an ultimate elongation of 15 per cent. in a length of 6 in. In all there were 154 plates supplied, and from these 219 pieces were cut for bending tests; the cold bending and temper tests were made—and were nearly all satisfactory when made—from the rough shearings, and in those cases where the rough sheared pieces broke before bending to the required curve, duplicate test pieces were planed and properly prepared, when they all proved to be satisfactory. There were also fourteen tensile tests made at the works, the tensile strength varying between the limits of 26.1 and 28.3 tons per square inch, the elongation in 8 in. varying from 27.3 to 34.3 per cent. The tabulated results of these tests, supplied by Messrs. Elder & Co. and Messrs. Cammell & Co., are set forth in the tables. On the arrival of the plates at Glasgow, Messrs. Elder, for their own satisfaction, had some check tests made, which practically corroborated those previously made at the steel works. The Livadia, it may be mentioned, was intended to be fitted with eight double-ended and two single-ended cylindrical boilers, each 14 ft. 3 in. diameter by 16 ft. long and 8 ft. 6 in. long respectively, constructed to work at a pressure of 70 lb. per square inch, the shells being of steel and the internal portions of iron. The shells were ¾ in. thick, made in three courses of plating—lap-jointed, treble riveted in the longitudinal seams, and double-riveted in the circumferential seams, as shown in Figures 2 and 4, and would be eligible, by the rules of Lloyd's Register, for determining the safe working pressure in marine boilers, to work at a pressure of 75 lb. per square inch. The plates were all punched, the holes being about 1½ in. less diameter than that of the rivets, then slightly heated and bent to their required curvature, and afterwards put together and the rivet-holes rimed out fair to the finished size in place. While under this treatment one of the plates accidentally fell from the slings on to a piece of metal, which indented it considerably, but did not crack or injure it in the vicinity of the indentation, but it was observed that the plate had cracked at a number of the rivet holes. Messrs. Cammell were, in consequence, communicated with, and Mr. Alexander, their representative, who examined this plate, gave it as his opinion that the plates had all been injured by punching, and should be properly annealed to restore the material to its normal condition. Accordingly, the plates were all sent to the maker's works at Sheffield and annealed in a furnace which had been specially altered for this purpose. The plates were afterwards returned to Glasgow, and riveted up in their places, and the boilers completed without any further cause for alarm. On subjecting the first boiler to hydraulic pressure, before the test pressure of 140 lb. per square inch was reached, the boiler shell tore asunder in three places, the cracks appearing to have started among the rivet holes of the longitudinal seams, and to have extended at the back of the rivet holes across the plate. In the second boiler, which it was intended to test, the shell plates were found to be cracked in a similar manner behind the rivet holes, before any water had been put into the boiler. Mr. Bryce, the manager of the engineering department of Messrs. Elder's works, at once gave instructions to cut the whole of the steel shells from these boilers, and they were replaced by others made of steel manufactured by the Steel Company of Scotland. These plates, which were worked in precisely the same manner, gave no special trouble in working, and the boilers proved to be satisfactory under test. On examination of the cracked or torn shell plates they were found to be extremely brittle; large pieces were easily broken off by one blow from an ordinary sledge hammer. In other words, here was a material which had satisfactorily withstood all the mechanical tests recognized by Lloyd's Registry, the Admiralty, and the Board of Trade, as sufficient to determine its suitability for the purpose for which it was being used, and was now shown to have become as brittle as cast iron, or even more so, after having apparently undergone only the working usual in boiler making. Chemical analysis was resorted to as being likely to throw some light on the subject. They do not show any reason why the material should behave in an anomalous manner.

Mr. Kirk, of Messrs. John Elder & Co., was the first speaker. He said he had been asked by Mr. Parker to make some tests, and he had done so. The first thing which came out was that the plates would bear very little manipulation. A strip about a foot long, slightly bent, would not bear straightening cold by gentle pressure. It cracked at once; but when heated and forged into a bar ½ in. square, it was so much improved that the bar could be bent cold on itself, so he thought that the material was good, but the manufacture bad. He then took some Siemens-Martin plates and tried to spoil them; he could injure them, but not make them as bad as the Livadia plates. Annealing might improve or spoil plates, according to how it was done. He showed a sample strip of the original metal bent cold on itself without crack. A second sample, equally good, had been left in a forge furnace for twelve hours, the damper being down, and the air excluded; the plate was uninjured. Two other samples heated in much the same way, but with the doors open and dampers up, so that a current of air passed through the furnace, were spoiled. A good plate could not be improved by annealing.

Mr. Thorneycroft said that if they would look at the drawing of the annealing furnace they would see that the plates had been so stacked on each other that uniform heating was impossible. The more work was put into steel the better. He used large quantities of thin steel—¾ in., and it was usually tougher and better than thicker plates.

Dr. Siemens, who spoke next, succeeded in attracting no small attention by making a most extraordinary statement. It is well known that he is rather given to surprising his hearers, and he must have been satisfied by the expression of blank amazement with which those present heard him assert that annealing steel plates did them no good. He began by saying that the performance of the Livadia plates was so extraordinary, that he had asked for and obtained a sample for analysis. He could break the plates up with a hammer. The chemical composition was extremely irregular; and Mr. Parker had omitted all mention of one element, silicon, which was present to the extent of 0.03 per cent. Phosphorus was twice as great in quantity on one side of the plate as on the other. How did that come about? Was the ingot all