sia, where they are made into coats. They are worth here \$10 to \$15 each.

Wild cat are used for robes and linings here and in Europe.

Fisher skins are gathered in Canada, the Lake Superior region, and Pacific coast. They are largely sold to go to Russia, where they are made into coats and collars. A dark-cased fisher skin sells for \$9 to \$12, and will bring at auction in Europe \$10 to \$14.

Fox skins are being used this season by the American trade, but at least three-quarters of them go to Russia and Turkey, the latter place taking the poor grades. Red fox are worth \$1.50 to \$2, and this is the skin which sells in Turkey; gray fox \$1, but the silver fox sells at \$25 to \$50 each skin.

Lynx skins sell for the European markets, where many of them are dyed and then reimported. They are worth here \$2 to \$3 each.

Marten is a fine fur. The dark skins are used for trimmings and the pale skins for cloak linings. Marten skins sell at from \$2.50 to \$5 each.

Mink skins are held at far less value than formerly, but they sell in Europe for linings for coats. The best are worth here \$1 to \$2.25 each.

Muskrat sell here at 10c. to 20c. each. They are about the only skins we dye in this country, and many are used here for cloaks and trimmings. Over 700,000 are used yearly in that manner. They are also sold to Russia and Germany, and used for linings, cuffs, and collars.

Otter have increased very materially in value lately, as they are dyed and plucked, and sold as an imitation of sealskin. Three-quarters of the skins gathered sell in this country. Good skins are worth \$5 to \$10 each.

Sea otter is a very valuable fur, worth say \$100 each. They are used for trimmings by the nobility of the Continent of Europe.

The seal skin has been for the past ten years one of the most fashionable of furs. They are the pelt of the fur seal, principally found on two islands of Alaska, one of which, St. Paul, is said to be visited annually by more than five millions of fur seals. These islands, as well as the mainland of Alaska, were discovered by the Russians about 1741, and in 1786 were colonized by the Russian-American Fur Company, who carried on operations there up to the time of the transfer of the country to the United States, which occurred in 1867.

In 1870 a lease of the seal islands was granted by the United States to the Alaska commercial company, of San Francisco, for the term of twenty years, under certain restrictions and conditions. They are only allowed to kill 100,000 seals a year, and these must be males. Upon the skins they pay a tax of \$2.50 per pelt, with a bonus of \$50,000, making a revenue of \$300,000 yearly. There are two hundred and seventy inhabitants in these islands, and they are, by the terms of the lease, permitted to reside there to the exclusion of all others, and are alone allowed to participate in the labors and rewards of the seal traffic. They get forty cents a skin, and take off the whole hundred thousand in about thirty days, averaging to make about \$400 for each working man. They can take a hide off neatly in from two to four minutes.

The skins are piled with the flesh side uppermost, and each profusely sprinkled with salt. After lying in this pickle a week they are bundled up and shipped to San Francisco, and from thence to London, where they are dressed.

The coat of the seal, when ready for sale, is fine and soft, but this is really only an undergrowth, as a coat of long, coarse over-hair has first to be plucked off, which is done by heating the skin, and then the long hair is plucked out, leaving the fine elastic under-fur, which is dyed or painted several times with a solution made chiefly of nuts from the Grecian Archipelago, after which they are cleansed from all impurities, stretched to their fullest capacity, and left to dry. Then all the long hairs are carefully clipped off with scissors, and the skin is ready for the furrier. Some of these skins are finished in this country, but not a great many. There is a company in London who do the most of it, and the preparation and application of the dye is a very fine art.

Sealskins sell according to length and fineness. A skin 29 or 30 inches long sells for \$10 raw, and \$25 dyed and dressed. The longest skins, say 51 inches, sell raw for \$15 to \$20, and dressed for \$50 each. For a lady's sack of ordinary dimensions it takes three to three and a half skins, and for a dolman four skins to each garment.

Coon skins go to Europe in large quantities, being used in natural state or dyed in all parts of that continent. Good coon skins are worth 60c. to \$1.10 each.

Rabbit skins are used by hatters. These go to Europe from all quarters of the world, and 12,000,000 skins were imported into London in 1880. The skins are worth about 50c. to \$1 a dozen in London. Large quantities come here; they are classed as hatters' furs.

Skunk skins go to Europe, and find sale all over that continent. Good cased skins sell in New York at 75c. to \$1.25, and in London some twenty-five per cent. higher. These skins are graded long stripe, short stripe, and black, the last the most valuable, and they are used in natural color.

Wolf skins are used for robes, but have lost value lately from the fact that China goatskins have taken their place to some extent.

Wolverine skins go to Europe, and are also used here for robes.

Furs in the cold countries of Europe are prized as diamonds are with us.

All furs, but coon, wolf, beaver, and seal, should be taken off "cased," to do this a small slit is cut in the stern and the skin worked off by turning it inside out. The European manufacturers like the cased skins, as they can cut them up at each side, and then have either back or belly to line cloaks with as preferred, the finer cloaks, of coarse, taking the best portions of the skin.

After the skins are sent to market they have to be beamed to get off all the fat. Nearly all kinds are dyed, as fashion dictates that everything in this line must be dark in hue.

Fine furs are dressed by being placed in tubs together with a quantity of rancid butter, and are then trampled upon by the feet of men. The pelt thus becomes softened, as though partially tanned. They are then cleaned by rubbing them with a strip of iron, and the grease removed by tramping again with sawdust mixture, beating them out and combing the fur. This is about all that is necessary to prepare them for the cutter and manufacturer.

Glovers' stocks are distinct from peltries, and used for making gloves. They are antelope, deer, elk, and mountain deer, worth in the Eastern markets 35c. to 45c. a pound. They are nearly all sold to Gloversville and Johnstown manu-

facturers. In the above towns, where more than three hundred firms are engaged in glove dressing and manufacturing, much of the glove stock which comes from both North and South America is made up. The business amounts to from \$6,000,000 to \$7,000,000 a year.

The skins are tanned or tawed for gloves, as follows: If hard stock they are first broken or softened, and placed in limewater to remove the hair. They are then thoroughly worked in pure water to remove the lime and render them flexible. They are now placed in a fulling mill in the shape of a box with two iron hammers working by cranks, which play on the skins and soften them. While going through this process cod oil is poured on, and the skins thus prepared are known as oil-dressed stock. They are now taken out and dried again, after which they are placed in vats containing lime water and soda ash, in order to cut the oil left on the skins by the former process. They are then scoured out and hung up outdoors to bleach, when they come out very white. The skins are then held to an emery rotary wheel and the face finished.

The official statement of exports and imports of furs, as given by the U. S. Treasury Department, we give below. It will enable our readers to form an idea of the extent of the business:

IMPORTS, 1880.	
Fur skins, undressed.....	\$2,543,728
Furs, dressed.....	4,185,392
Total	\$6,729,120
EXPORTS, 1880.	
Furs, undressed	\$5,542,735
IMPORTS, 1879.	
Fur skins, undressed.....	\$2,181,193
Furs, dressed.....	3,054,699
Total.....	\$5,185,895
EXPORTS, 1879.	
Furs, undressed.....	\$6,086,829
IMPORTS, 1878.	
Fur skins, undressed	\$1,454,653
Furs, dressed.....	2,560,684
Total	\$4,015,337
EXPORTS, 1878.	
Furs, undressed.....	\$2,941,602
IMPORTS, 1877.	
Fur skins, undressed	\$1,613,839
Furs, dressed.....	2,157,349
Total	\$3,771,188
EXPORTS, 1877.	
Furs, undressed.....	\$3,709,016
IMPORTS, 1876.	
Fur skins, undressed.....	\$1,442,752
Furs, dressed.....	2,610,950
Total.....	\$4,053,702
EXPORTS, 1876.	
Furs, undressed.....	\$3,750,648

The duty on manufactured furs is 35 per cent., less 10 per cent. For furs dressed on the skin and hatters' furs it is 20 per cent., and raw furs are admitted free of duty. It will be noticed by the above table that the import value of furs is larger than the export. The truth is, that a very large proportion of the article of "furs dressed" is a reimportation of American furs which go to Europe for dyeing and plucking, and are then returned here. We send abroad, for instance, 100,000 sealskins yearly, and nearly every garment made from that material and worn in the United States is from reimported skins which have had to pay duty, freight, and profit on the labor expended on them by European experts.

It does not speak well for the efficiency or genius of the American workmen that these raw goods have to go to Europe and be finished there ready for wearing. Then, again, the duty is a severe tax on so fashionable and necessary an article as fur. The subject of dressing and finishing peltries is beginning to engage the attention of manufacturers, and, doubtless, this branch will soon be added to the list of our home industries.—*Shoe and Leather Reporter*.

MICHEL CHASLES.

By the death of M. Chasles, to which we referred in a previous number, modern geometry has lost one of its most ardent and successful cultivators. For more than half a century numerous students, and even distinguished professors of his own and of other countries, eagerly gathered round his chair to listen to his exposition of methods which he himself had invented or considerably developed. Sixty-eight years separate his first mathematical paper from his last communication to the Academy of Sciences, and that long period was one of singular devotion to his favorite pursuits.

The influence of his teaching was great and far reaching. Many of his beautiful theorems have found their way into text-books used in higher collegiate classes, while his more elaborate researches are carefully read in our universities. He was emphatically an original investigator, and may, without detracting from the merit of his predecessors, be styled the Father of Modern Geometry.

M. Chasles was born at Eperon, near Chartres, in November, 1793, and from his early youth showed unusual mathematical talent. His fondness for geometry recalled the passionate devotedness of the brilliant Pascal. At the Lycée Impérial his usual pastime was to explain the difficulties of his class-mates, and work out the more knotty riders given in other schools. Many of his solutions, we are told by those who knew the young mathematician, were remarkably beautiful, and even the great Poncelet more than once publicly commended their ingenuity. Chasles used to call these exercises his "élémentaires," and he was never more cheerful than when he had a good supply by him. It is significant that he discarded analytical proofs, always preferring purely geometrical methods. Before he left the Ecole Polytechnique, that is before completing his twenty-first year, he had devised a demonstration of the double generation of the hyperboloid of one sheet of which the celebrated Monge had previously given an elegant analytical proof. This alone proved him to be endowed with no ordinary mathematical power. In 1814 he ex-

changed his books for the sword, and took part in the defense of the capital; on the conclusion of peace he returned to his studies, obtaining the second place at the final examination which shortly afterward followed. The first candidate on the list was Giorgini, a brilliant student, who had the frankness to admit that he owed his unlooked-for success, in great measure, to the assistance of his class-fellow and competitor.

The military career had but few attractions for Chasles, and he soon made up his mind to relinquish altogether the uncongenial profession of arms. He withdrew to Chartres, where he devoted himself with renewed ardor to his mathematical studies to such an extent as to draw from his friends exclamations of regret at the sad waste of so much talent. But time belied their vaticinations, and few years elapsed before Chasles was looked upon, in the scientific world, as among the most promising of the younger generation of mathematicians.

In 1829 the Brussels Academy offered a prize for the best philosophical discussion of the methods recently introduced into geometry and especially the method of reciprocal polars. This was an opportunity for Chasles, and he replied in a masterly way by his "Aperçu Historique sur l'Origine et les Développements des Méthodes en Géométrie." Such is the modest title he gave to a work which a competent judge calls the most learned and original contribution ever made to the history of science.

From time to time M. Chasles wrote interesting historical essays on various branches of the exact sciences. He studied with great care the works of the Arabians and Hindoos, and in 1843 published his "Histoire de l'Arithmétique," in which he maintained, contrary to the received opinion, that we owe our system of notation to the schools of Magna Græcia and not to the Arabians.

In 1852, appeared his great work, the "Traité de Géométrie Supérieure." It was specially written for those who followed his lectures at the Sorbonne, and was the first elaborate treatise on modern geometry. We should, however, add that Dr. Mulcahy, of Trinity College, Dublin, published, in the same year, his "Principles of Modern Geometry," a treatise which, though good in its time, has been superseded by the works of the Rev. Prof. Townsend. Quite recently M. Chasles rewrote his original work, and had the satisfaction of seeing the last sheets through the press a few months before his death. In 1865, he completed his second great work, viz., "Les Sections Coniques." All subsequent writers on this subject have largely drawn on this famous treatise. Indeed no book would now be considered complete without embodying the more important of Chasles's discoveries. The reader of Salmon's Conics—which is unquestionably the best English text-book we possess—will remember with what frequency the labors of the French geometer are referred to.

Though far advanced in years, M. Chasles continued still to be an indefatigable worker, as the *Comptes Rendus* bears abundant evidence. He would never miss the weekly meetings of the Academies nor fail to hold the evening receptions, at which he entertained, with equal grace and hospitality, the most distinguished scientific workers and the leaders of thought of the French capital. Simultaneously with the revision of his treatise on Modern Geometry, he proceeded with a "Histoire Générale de l'Ecole Polytechnique," but time was not given him to finish this work of love. It is, however, pleasing to know that this historical sketch of the great French school is well advanced.

M. Chasles had completed his eighty-seventh year when summoned away from the sphere of his extraordinary activity and well-deserved triumphs. A fellow-academician of his, M. Bertrand, has summed up his life-work in these words: "More than once M. Chasles, while adopting purely geometrical methods, has shown with rare success, the narrow and mysterious link that unites the various mathematical truths. We are indebted to him, in one of the highest and most difficult theorems of the integral calculus, for several elegant and much admired deductions; he contributed to mechanics a classical chapter on the displacement of solids; he discovered, in the theory of attraction, beautiful and general properties which have completely renewed the theory of statical electricity, while his papers on the attraction of ellipsoids, admired and praised by Poincaré, have excited a noble emulation among analysts and pure geometers, to the great advantage of science."

M. Chasles was appointed in 1841 to the professorship of geodesy and applied mechanics in the Ecole Polytechnique; in 1846 the chair of higher geometry at the Sorbonne was specially founded for him, and in 1851 he was elected member of the Institute of France. Our Royal Society, fully appreciating his numerous and profound discoveries, and nominally his theory of characteristics, awarded to him in 1863 its most coveted distinction, the Copley Medal.—*Engineering*.

NEW METHOD OF RAISING SUNKEN VESSELS.

By Dr. W. RAYDT, Professor at the Lyceum, Hanover, Germany.

EXPERIENCE shows that the most important inventions are often not carried out practically for years, because the needed capital and enterprise are lacking. Such an invention, the utility and advantage of which are unquestionable, is the method by which heavy bodies under water—for instance, sunken vessels—may be lifted by means of carbonic acid gas made liquid by compression, of which we will give an account, and which has been patented in the countries mentioned below.

The mathematical correctness of the calculations in regard to this invention has been testified to by eminent German physicists and mathematicians. The well known Professor Weber, in Göttingen, more especially, has given testimony to this effect, and has expressed his unlimited confidence to the inventor, who is also in possession of a commendatory letter from Field Marshal Count Von Moltke.

A completely satisfactory demonstration of the practicability of this new method has been made before competent witnesses on August 28, 1879, in the outer reservoir of the Imperial Wharf at Kiel, the more important details of which are given in the following account, signed by responsible persons of high standing:

"KIEL, August 28, 1879.
"Under the above date a trial was made by Dr. Raydt at the Imperial Wharf, in presence of the undersigned, in order to test his new method 'of inflating balloons rapidly under water by means of carbonic acid gas rendered fluid, and thereby to lift objects immersed.'"

"The balloon to which the reservoir containing the gas was attached was fastened to an anchor block of 15,000 kilogrammes weight, and immersed to the depth of 10 meters under water, when the valve of the reservoir was

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 $\frac{1}{36}$ 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 "	286,083 "	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 needful 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