SCIENTIFIC AMERICAN

[Entered at the Post Office of New York, N. Y., as Second Class Matter.]

A WEEKLY JOURNAL OF PRACTICAL INFORMATION, ART, SCIENCE, MECHANICS, CHEMISTRY, AND MANUFACTURES.

Vol. LIII.--No. 25. [NEW SERIES.] | NEW YORK, DECEMBER 19, 1885. | $3.20 per Annum. [POSTAGE PREPAID.]

THE ST. MARY'S FALLS CANAL.

St. Mary's Falls Canal is situated at the village of Sault Ste. Marie, Michigan, and affords a navigable channel by means of which the principal rapids of St. Mary's River are passed. The river is the outlet of Lake Superior, and it empties into Lake Huron. The canal is 15 miles from Point Iroquois, the foot of Lake Superior, and by the present route of navigation is 60 miles from Point Detour, Lake Huron. The rapids known as Sault de Ste. Marie are a little more than half a mile in length, and have a fall of from 16½ to 18½ feet, depending upon the stages of water in Lakes Superior and Huron, the mean fall being 18 feet. From Lake Superior to "the Sault," the fall is only one-tenth of a foot; thence to Lake Huron it is about 2 feet, distributed through a distance of about 20 miles.

Hence "the Sault" is the only obstruction to such navigation as the depth will admit of between the two lakes.

Prior to 1845, the fur trade constituted almost the entire commerce of Lake Superior. At that time the development of copper and iron mines was commenced, and "the Sault" was found to be a serious obstacle in the way of the successful prosecution of these enterprises. The products of the mines, the appliances for working them, and the supplies for the laborers had all to be unloaded from vessels at the foot of "the Sault," carried overland to the head, and there reshipped to their destination. At first the portage was made with horses and wagons. Subsequently a tramway was built and operated with horses, in this way greatly increasing the facilities and ameliorating the conditions.

As time passed on, steamers and sail vessels were transported upon ways from below to the head of the rapids, relaunched, and used for carrying the freights which were rapidly increasing and rendering the detention and difficulties of the portage at "the Sault" quite too great to be borne.

Application was made to Congress for relief, resulting in the act of Aug. 26, 1852, by which 750,000 acres of land were granted to the State of Michigan, "for the construction of a ship canal around the Falls of St. Mary's in said State."

It must not be supposed that earlier efforts had not been made toward the construction of a canal at this point.

(*Continued on page* 386.)

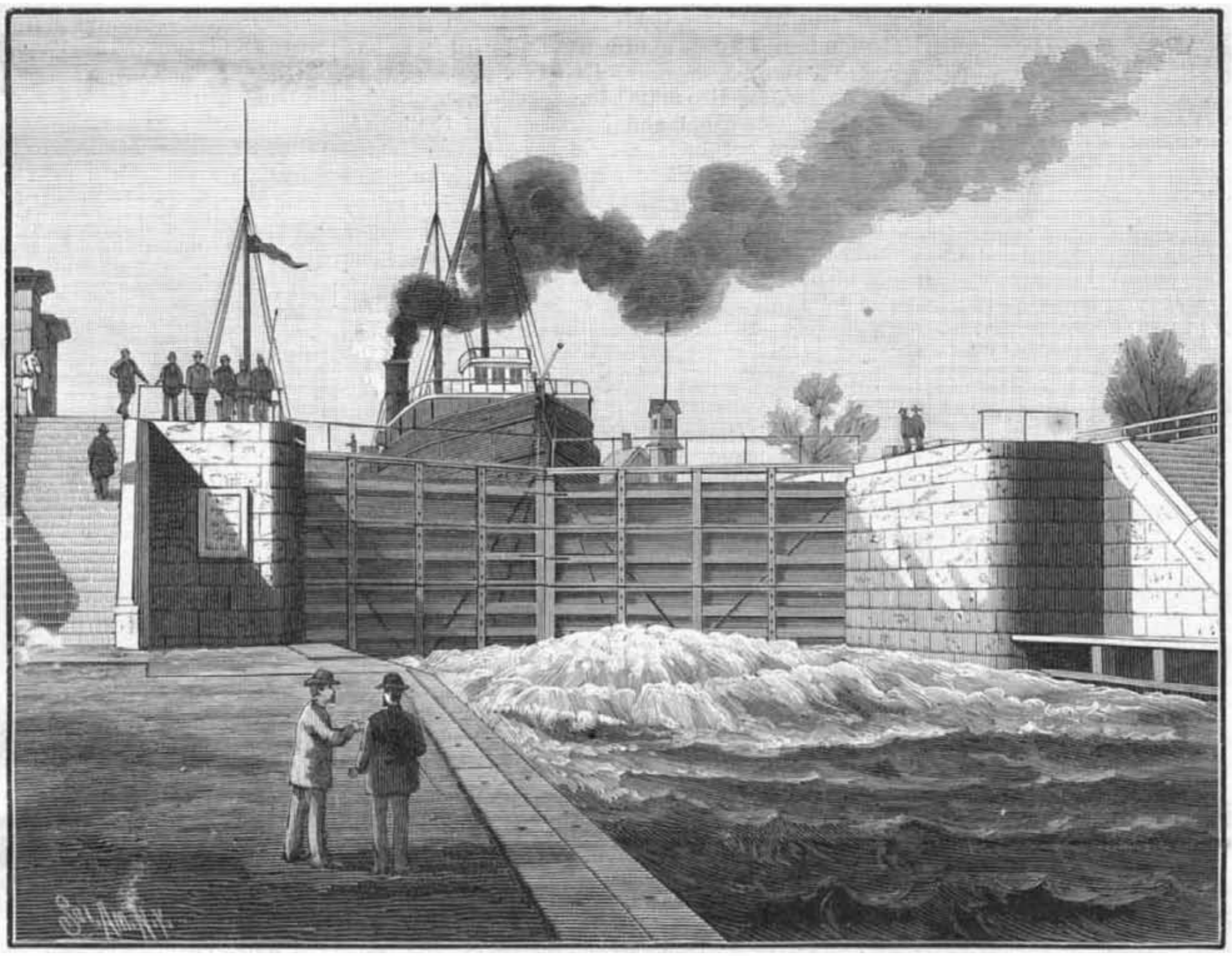

Fig. 1.—ST. MARY'S FALLS CANAL.—END VIEW OF LOCK WITH GATES CLOSED.

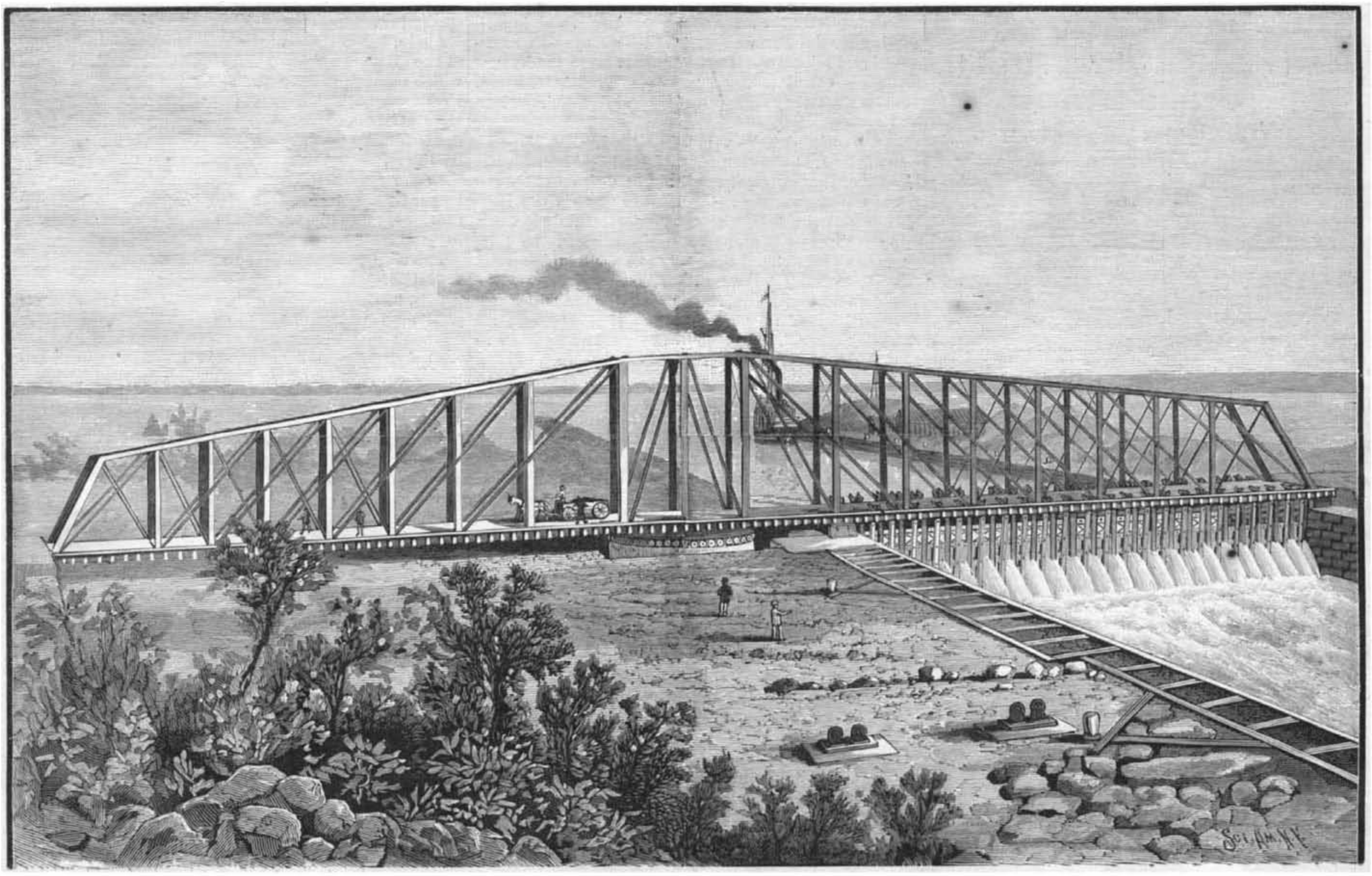

Fig. 2.—ST. MARY'S FALLS CANAL.—VIEW OF THE MOVABLE DAM, CLOSED.

THE ST. MARY'S FALLS CANAL.

(*Continued from first page*).

They were actually begun in 1837, but the history of these is too long to be here given.

In 1853 the State of Michigan accepted the land grant, and soon afterward made a contract with a private company which undertook to build the canal, and to take the granted lands in payment therefor. The surveys for and the plans of the canal and locks were made under the direction of the late Captain Augustus Canfield, Corps of Topographical Engineers, U. S. A., and the company promptly began operations.

On the 18th of June, 1855, the completed canal was opened to navigation, the company having expended in its construction nearly $1,000,000. In view of the large amount of capital required, no return being possible until after the sale of the lands, the isolation of the locality, inaccessible during the five months of winter, and the severity of the winter climate, which greatly retarded operations, the rapid construction of the canal was a remarkable feat. This was the first ship canal made in the United States. The locks and gates were the largest built in the country up to that time. The depth of water was greater than had been called for in any American canal.

The engineering features were thus without precedent in American practice, but they were well worked out, and the canal proved a remarkably successful one. It was 5,400 feet long, had a width of 100 feet at the water line, with slopes of 1½ to 1, paved where the cutting was not through rock, and a depth of 12 feet at mean stage of water. The locks, located near the foot of the canal, were two in number (now known as the "old locks"), combined, each 350 feet long, 70 feet wide, with a lift of 9 feet, with 12 feet of water in the miter sills. At the time the canal was made, it was deemed of ample capacity to meet the needs of commerce through all future time. The depth was sufficient to pass any vessel on the Lakes, fully laden. The locks were large enough to contain at one time a tug and three vessels, of the average size then in use, which generally constituted a "tow."

By the year 1870, owing to the general improvement of channels and harbors on the Lakes, these dimensions no longer sufficed.

The size of vessels had increased, and they were no longer able to carry full loads on a draught of 12 feet; only one of the largest vessels could be passed at one lockage, and the number of vessels engaged in the Lake Superior trade had increased so greatly that they were frequently delayed at the locks several hours. It became necessary to provide for more rapid lockage, and for the passage of larger vessels. The slope walls of 1½ to 1 had been found objectionable, as vessels frequently came in contact with them below the water line, and sustained damage.

In July, 1870, Congress made an appropriation for beginning improvements, and the charge assigned to General O. M. Poe, of the Corps of Engineers, who in August following submitted a project therefor. The project promptly received the approval of the Chief of Engineers. After some modifications it embraced the following points, viz.:

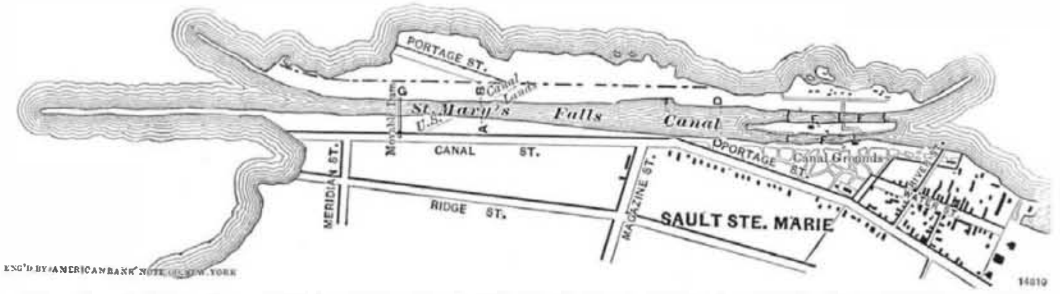

Fig. 4.—MAP SHOWING OLD (E) AND NEW (F) LOCKS AND MOVABLE DAM.

Build a new lock opposite the old locks, parallel to them, at a clear distance of 100 feet. Take down the guard gates with their masonry, and rebuild them 700 feet nearer the head of the canal, and at a lower level. Form entrances at the new lock—at the foot, by excavating out to deep water, and revetting the channel with pier work: above, by widening the canal from the new lock to the new position for the guard gates. Remove the slope walls, and use a timber revetment with a nearly vertical face. Where the cutting was through rock, the revetment to be placed on the first sound rock reached. Below the base of the revetment, the rock to be cut to a slope of one horizontal to four vertical; where no rock was found, the revetment to be built from the new grade of canal bottom. The improved canal to be made 16 feet deep at ordinary stages. At the time the canal was originally made, it was feared that in the spring of the year ice might be driven into it at the head to such an extent as to delay its opening for navigation. To guard against this, a curve was made near the upper end, so that the direction of the canal above the curve was nearly normal to the direction of the current in the river, which is quite rapid here. This rendered the entrance difficult to a single vessel and impracticable to a tow of three or more. Experience showed that there was really no danger to be apprehended from the ice. The direction of the upper entrance was therefore changed so as to make the canal straight. At the completion of the new lock, replace the guard gates by a movable dam.

Fig. 3.—MAP SHOWING LOCATION OF ST. MARY'S FALLS.

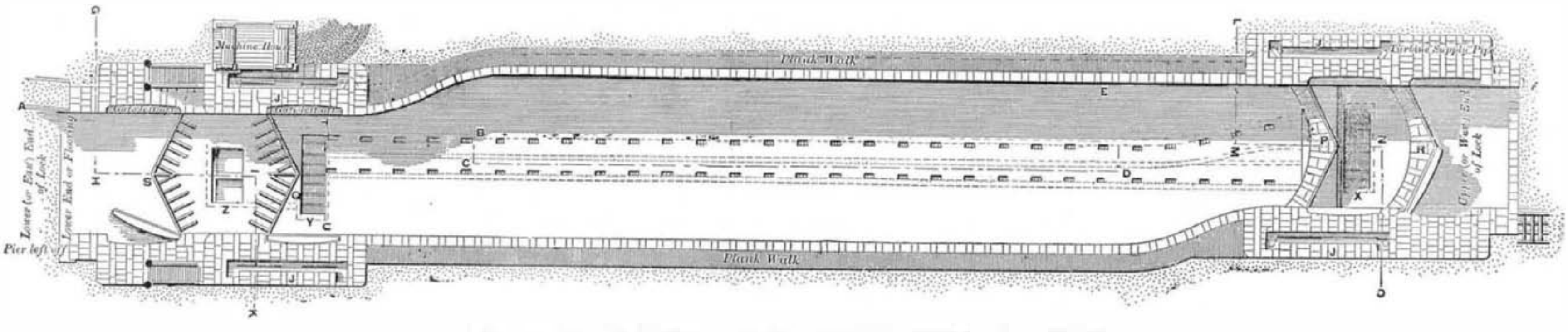

Fig. 5.—ST. MARY'S FALLS CANAL.—PLAN OF LOCK.

From its beginning to May 1, 1873, the work was in charge of General O. M. Poe, Corps of Engineers, U. S. Army, and from that date to completion in charge of the late General G. Weitzel, of the same corps.

From October, 1870, to completion, the local engineer was Mr. Alfred Noble, to whom the greatest credit is due for the accomplishment of this magnificent work.

The effect of the canal improvement is shown by the fact that the commerce has increased from 1,567,741 tons of freight in 1881 to 3,300,000 in 1885. That is, it has more than doubled in four years.

It is now proposed to further improve the canal by making it 20 feet in depth, and replacing the "old locks" of 1855 by a single one having horizontal dimensions equivalent to the *two*, and a depth on the miter sills of 21 feet.

It is not proposed to disturb the new lock (of 1881), but the increased depth of the canal prism will make available the full depth of 17 feet on its miter sill.

The new lock (of 1881) seems to be nearly perfect. After five years of use, there is no improvement to be suggested. Its operation is rapid, quiet, and in every way satisfactory. It has attracted more attention abroad than at home, especially among the Germans and Russians. Only a couple of weeks ago General Barminsky, of the Imperial Russian Engineers, visited it and fully investigated its operation, devoting a couple of days to the inspection, and upon the conclusion remarking that it is the most effective work of its kind in the world.

The relative positions of the new and old locks are shown at F and E E respectively on the map, Fig. 4. The chamber of the new lock is 515 feet long between the hollow quoins and 80 feet wide, narrowed to 60 feet at the gates; the depth is 39½ feet. Its capacity is 1,500,000 cubic feet. The lift of the lock is 18 feet, and the depth of water on the miter-sills 17 feet. The sills are placed 1 foot below the canal bottom, so as to be protected from injury by vessels. A guard gate is placed at each end of the chamber, making the length of the walls 717 feet. The walls for 14 feet from each end are 13 feet wide from top to bottom; then for 121½ feet at the west end and 133½ feet at the east end they are 25 feet wide from top to bottom. Between the wide walls the width is 18 feet for 10 feet up from the foundation, then it narrows in 2 feet for four offsets, 5 feet apart vertically, until the wall is 10 feet wide, at which width it is carried up to within 6 inches of the top of the coping, which is 5 feet wide, as shown in the plan view of the lock, Fig. 5. The masonry is all laid in cement mixed with sand in the proportion of 1 to 1. About 35,000 barrels of cement were used in the construction of the 34,207 cubic yards of masonry.

In the miter walls for the upper lock and guard gates there are nine courses of cut stone, each 2 feet thick. The walls are 14 feet wide at the miter angle, are arched to resist the pressure on the gates, as shown at the right in Fig. 5, and are bonded into the lock walls. The top course of stone is set back 1 foot, so as to leave an offset, on which the oak miter sills rest; these sills project 2 inches above the masonry.

The foundation is on rock throughout. In excavating the lock pit, rock was reached at from 1 to 15 feet above the grade of the lock floor. A floor of timber and concrete extends across the bottom of the lock and 5 feet under each wall; the rest of the wall foundation is concrete, one-half to 2 feet thick on the rock. All the foundation timbers are of pine, 1 foot thick. The miter sills are of oak, 12 x 18 inches, and are held in place by bolts, 10 feet long, fox-wedged and concreted in the rock, and also by timber braces bolted to the rock.

The positions of the four gates, designated as upper and lower lock gates and upper and lower guard gates, are shown at P Q R S, respectively, in Fig. 5. The guard gates are only for use when repairs are being made to the lock; they are opened and closed by means of temporary block and tackle operated by a power capstan. Both leaves of the upper guard gates are provided with valves through which to fill the lock after it has been pumped out. The framework of the gates, shown closed in Fig. 1, is of white oak, and the sheathing is of Norway pine. The weight of one leaf of the upper lock gate is 40 tons, and of one leaf of the lower lock gate 76 tons. Each leaf is thoroughly braced by transverse and diagonal rods, and around each end post are straps bolted to the cross pieces.

Water is let into the lock from culverts under the floor extending from the well, X (Fig. 5), above the upper lock gate to the well, Y, above the lower lock gate. The two culverts are separated by a longitudinal bulkhead, and each is 8 feet square. The floor of the lock forms the roof of the culverts. The water passes into the lock chamber through 58 apertures in the floor, shown in Fig. 5. The total area of these apertures is 174 square feet; this outlet area is increased to 190 square feet by manholes left in the bulkhead at the lower end of the culverts. The combined area of the cross sections of the two culverts is 128 square feet. Having the inlet area considerably less than that of the outlet tends to diminish the velocity of the water when projected upward into the lock chamber. The water in passing out of the lock goes down through the well, Y, which, as well as the well, X, is covered with a grating, thence through short culverts and up through the well, Z.

The water enters the lock through filling valves, A A (Fig. 6.), located in the well just above the upper lock gate. Each valve, when shut, closes the entrance toone of the culverts. Each valve is 10 feet wide by 8 feet deep, so that when open it gives a clear aperture greater than the cross section of the culvert. Bolted to the woodwork at the culvert is a heavy iron frame in which the axle of the valve has bearings. The valve consists of a cast iron frame covered with boiler iron and made of such size as to leave a space of ¼ inch at the edges between it and the rectangular frame. Lugs projecting from one face of the valve carry the end of a pitman joining the end of a piston rod operated by water entering the cylinders, L, Fig. 6. Water from the accumulator, described below, can be admitted to either end of the cylinder, which is 15 inches in diameter. The two emptying valves are similar in construction to the filling valves, and are located in the well just above the lower lock gate. Each culvert is complete in itself, so that if an accident should occur to one, or to its valves or engines, the other could still be used.

The power is obtained from two 30 inch turbines, geared to a main shaft, and fed through a supply pipe, B C, Fig. 6, from the canal above the lock. A belt from the shaft runs two force pumps, each having three plungers, which pump into an accumulator loaded so as to give a pressure of about 120 pounds to the square inch. Water is taken from the accumulator to the engines operating the gates and valve.

The interior diameter of the accumulator cylinder is 21 inches, its length 124 inches, and its capacity is 1,859 gallons. The plunger carries a heavy crosshead moving up and down on guides fastened to the iron girders of the machine house. The weight case is suspended from the crosshead by rods. The weights are cast iron plates made to fit the weight case. As the area of the cross section of the cylinder is 346 square inches, it requires 69,200 pounds of weights to produce a pressure of 200 pounds to the square inch. The water enters and leaves the accumulator at diametrically opposite points at the base. When the accumulator is full, the belts which run the pumps are automatically thrown on loose pulleys.

The position of the four gate engines is shown at J J J J, Fig. 5. The interior diameter of the cylinder is 15 inches, and the length 132 inches. The piston rod projects from both ends of the cylinder, as shown in Fig. 6. Water is taken from the accumulator, and is admitted through pipes to either end of the cylinder, and controlled by hand valves. Each crosshead is constructed with two sheaves. One end of a wire rope is adjustably fastened at I, Fig. 6, and, passing around one of the engine sheaves, is led by suitably located sheaves down through the well in the lock wall, around the drum, Q, and to a leaf to which it is secured. The four ropes necessary for the opening and closing of each gate are clearly shown in Fig. 6. When the engine makes a stroke, the end of the rope attached to the gate moves four times as far. With a pressure of 200 pounds per square inch, the total pull on the leaf of the gate is 8,835 pounds, less friction and rigidity of rope. It will be noticed from the drawing, Fig. 6, that each closing rope is attached to the leaf at the opposite side of the lock. Hand power capstans can be used in case the gate engines are disabled.

The centrifugal pump for emptying the lock is run by a belt connected with the main shaft. A power capstan, located on the lock wall near the machine house, Fig. 5, is run by belts from the main shaft, and is used for warping vessels into and out of the lock.

The location of the movable dam, shown in perspective in Fig. 2, is indicated on the map, Fig. 4. It is about 3,000 feet above the locks, and is designed to check the flow of water so that the upper guard gates could be closed if the lock gates were accidentally carried away. It consists of an ordinary swing bridge, one end of which can be swung across the canal. A series of wickets, Fig. 7, are suspended side by side from a horizontal truss hung beneath the bridge and abutting at either end (when the bridge is closed) against heavy buffers securely anchored to the masonry. One end of each wicket can be let down until it rests against a sill, O, in the bottom of the canal. When the wickets are all down, they form a vertical bulkhead or dam, as shown in Fig. 2.

Each of the twenty-three wickets is supported in an iron frame, and turns on an axle, H, and is let down and drawn up by chains attached to each end as shown. Each wicket frame is hinged upon a shaft passing through its upper end. The operating ropes are wound upon windlasses, K, provided with pawls and friction brakes. A wicket fully drawn up is shown at L, another in the act of dropping into position is shown at G, and another after it has been dropped at G, Fig. 7. In dropping a wicket, the down stream end is first let go until it strikes the water, the up stream end is then let go by the run, and the frame swings down until this end strikes the sill, the wicket then lying horizontally in the water and presenting only its end surface to the current. The wicket is then drawn into a vertical position by the chain at its down stream end. When the wickets are in position, there is a space of one inch between the frames. The axle, H, is so placed as to leave the pressure of water on the upper and lower parts of the wicket nearly equal. The dead weight on the truss due to the wickets and frames is 1,600 pounds per running foot, which is counterpoised by brickwork at the other end of the truss.

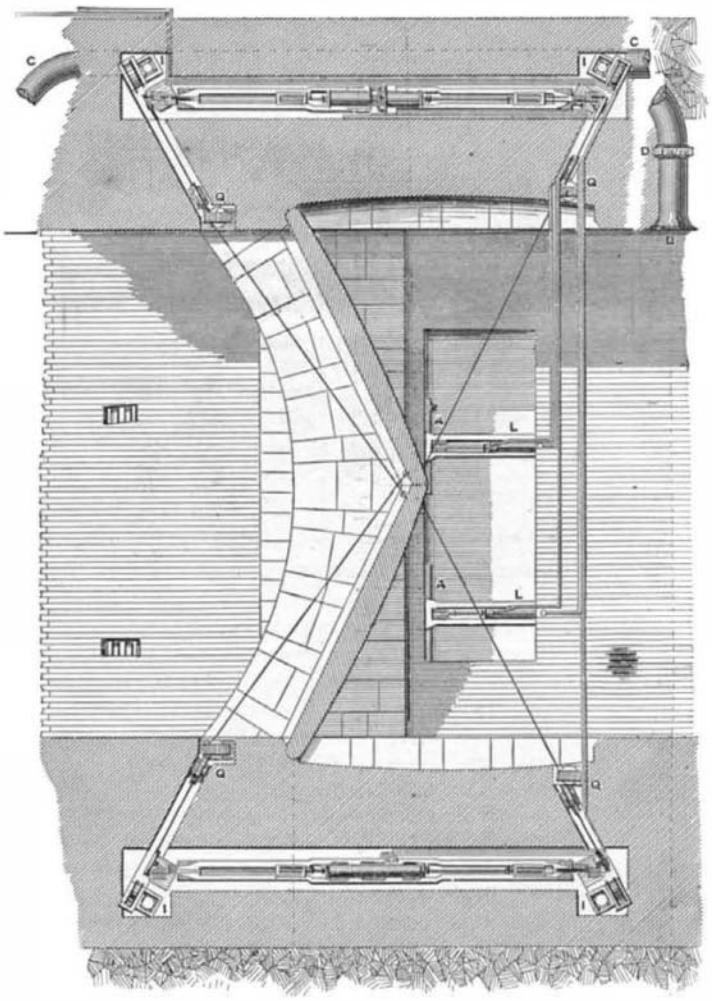

Fig. 6.—PLAN OF UPPER LOCK GATE SHOWING OPERATING MACHINERY.

The total amount expended upon this improvement, up to June, 1885, is $2,400,000.

We wish to acknowledge our indebtedness to Gen. O. M. Poe, by whom these improvements were planned and under whose direction the work has been most successfully carried to completion, for notes and drawings.

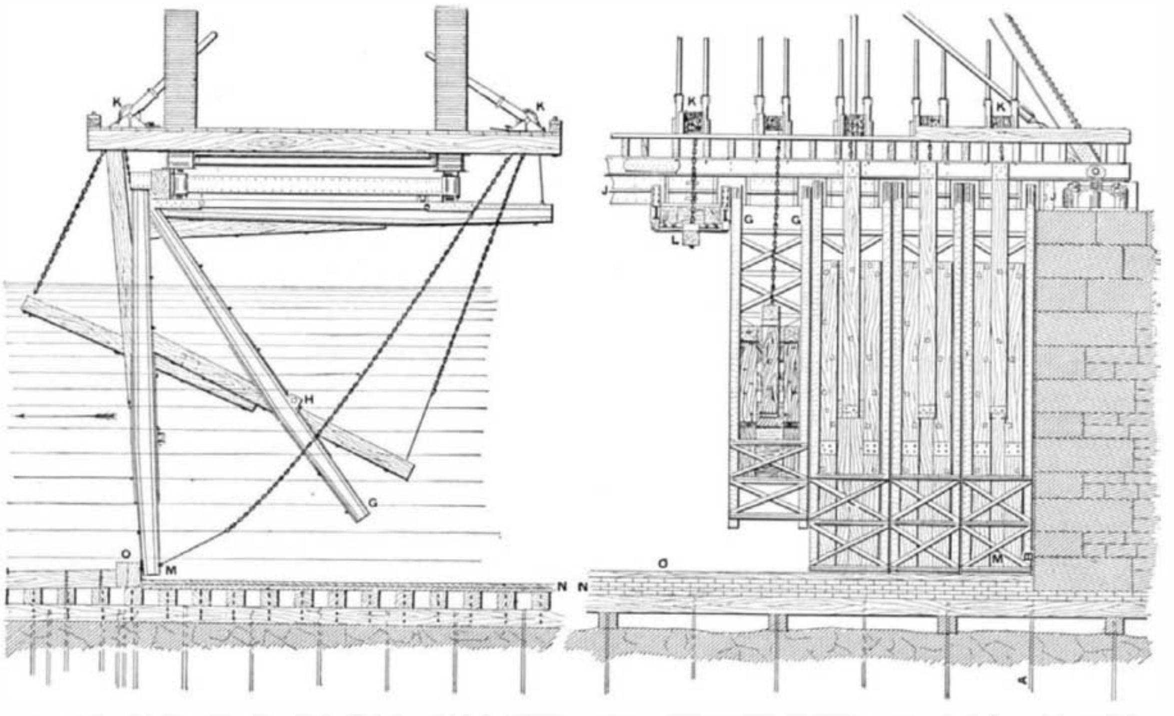

Fig. 7.—THE MOVABLE DAM.—SHOWING THE ARRANGEMENT OF THE WICKETS.

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COCAINE, like fire or alcohol, is again proved to be a good servant but a bad master. A Chicago physician addicted to its use experimented not only upon himself, but upon his wife and children, until he is a raving lunatic and they are incurable wrecks.

Engineering by the Ancients.

At the meeting of the British Association, the president of the section on Mechanical Science, B. Baker, civil engineer, recalled certain engineering feats of the ancients: "I have no doubt that as able and enterprising engineers existed prior to the age of steam and steel as exist now, and their work was as beneficial to mankind, though different in direction. In the important matter of water supply to towns, indeed, I doubt whether, having reference to facility of execution, even greater works were not done 2,000 years ago than now. Herodotus speaks of a tunnel, 8 feet square and nearly a mile long, driven through a mountain in order to supply the city of Samos with water, and his statement, though long doubted, was verified in 1882 through the abbot of a neighboring cloister accidentally unearthing some stone slabs. The German Archæological Society sent out Ernst Fabricius to make a complete survey of the work, and the record reads like that of a modern engineering undertaking. Thus, from a covered reservoir in the hills proceeded an arched conduit about 1,000 yards long, partly driven as a tunnel and partly executed on the 'cut and cover' system adopted on the London underground railway. The tunnel proper, more than 1,100 yards in length, was hewn by hammer and chisel through the solid limestone rock. It was driven from the two ends like the great Alpine tunnels, without intermediate shafts, and the engineers of 2,400 years ago might well be congratulated for getting only some dozen feet out of level and little more out of line. From the lower end of the tunnel branches were constructed to supply the city mains and fountains, and the explorers found ventilating shafts and side entrances, earthenware socket pipes, with cement joints, and other interesting details connected with the water supply of towns."

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Two Forms of Liquefied Air.

In a recent communication to the *Comptes Rendus* on the liquefaction of air, Herr S. Wroblewski states that he has obtained from air two liquids, different in appearance and in composition, which can exist together as separate layers with a perfectly visible meniscus between them. To obtain this result, Herr Wroblewski liquefied at —142° C. a certain quantity of air in the ~~tube of the apparatus which he employs~~ for using permanent gases as cooling mixtures. He then allowed a quantity of gaseous air to enter the tube, so that, the pressure of the gas having become equal to 40 centimeters, and its optical density the same as that of the liquid, the meniscus entirely disappeared. He then slowly lessened the pressure, and at the moment when the gauge indicated a pressure of about 37·6 atmospheres, he saw a new meniscus formed at a point in the tube much higher than the place previously occupied by the vanished meniscus. A few minutes afterward the first meniscus reappeared at the place where it was seen to disappear, and at the same moment two liquids, different in character, were distinctly seen, one on top of the other. The liquids remained separated for several seconds. Afterward a current of very small bubbles formed and ascended, detaching themselves from the meniscus separating the two liquids.

In consequence of this phenomenon, the upper liquid became a little opaque; the meniscus, gradually destroyed by the current, ultimately disappeared altogether; and the last result was a single liquid homogeneous in appearance. In this experiment, air (which is a completely colorless liquid) presents an enigmatical optical phenomenon, which immediately precedes the appearance of the upper meniscus. This part of the tube assumes a feebly orange coloration, which vanishes immediately upon the formation of the meniscus. Nothing like this ever precedes the formation of the lower meniscus. By means of a small metal tube introduced into the apparatus, Herr Wroblewski has succeeded in taking at will a sufficient quantity of either the top or bottom liquid for analysis. While the lower liquid contained 21·28 to 21·50 parts of oxygen, the upper one only contained 17·3 to 18·7 of the same element.