

NEW SOUTH WALES

There is no law governing the rate of decompression — The most important safeguard for health preservation in caisson work :—

Labor Award Provides :—		Theoretical gauge pressure.
Length of shift 4 hrs	Under 26lbs.
Interval between shifts 8 hrs	
Length of shift 2 hrs.	60 ft. 26lbs. and over.
Interval between shifts 8 hrs	

The air-lock used is shown by Plate No. 13, which was the design largely followed by bridge builders in this State.

**CAST IRON BRIDGE CYLINDER USED FOR AIR-LOCK
WROUGHT-IRON TOP AND BOTTOM PLATES**

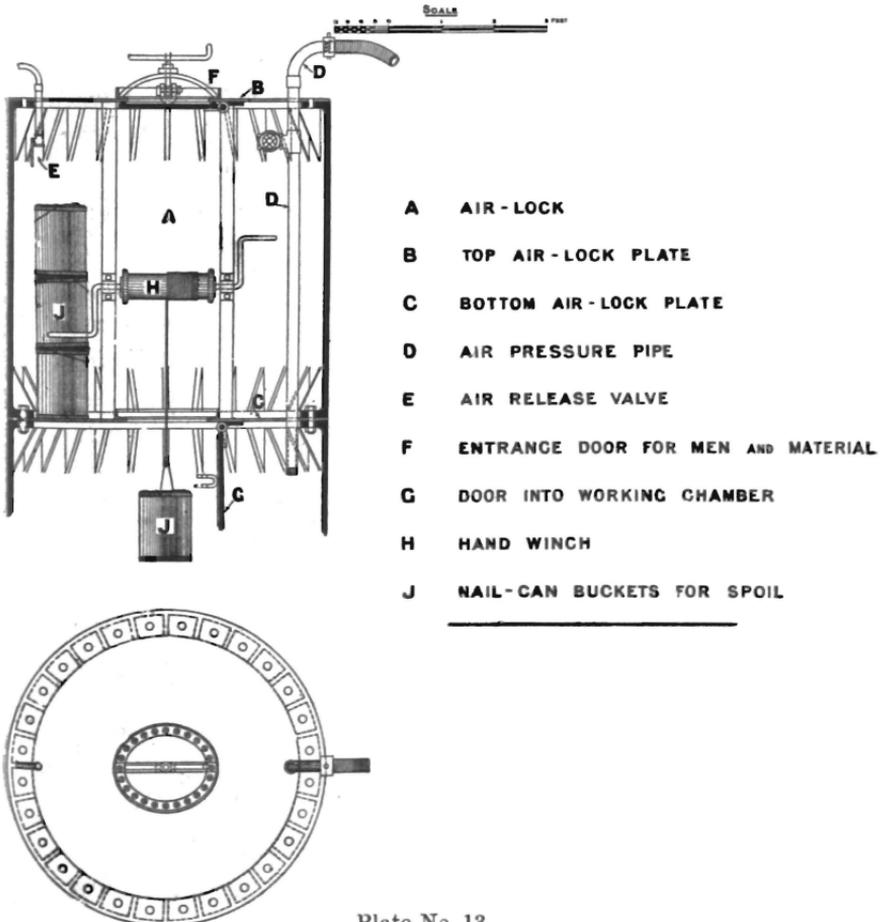


Plate No. 13.

The muck-buckets were fashioned from nail-cans, oil-drums, or any old thing lying around capable of holding gravel. These primitive buckets were filled by the excavators, or "hogs" as they are called in the States, and hoisted up into the air-lock by a hand windlass, and packed around the chamber as closely as possible from the bottom to top plates. At shift-change the excavators would come up also, and wedge themselves into any space left. The engineer was often along—and sometimes got a reserved seat. The writer's reservation was always on top of the windlass-barrel, where he was handy to the blow-off cock, and took command of the decompression arrangements.

On a hot day, with no means of cooling the air-lock chamber, the mass of humanity amid the sludge buckets thoroughly enjoyed themselves—or appeared to.

As mentioned before, everybody is cheerful in the air chamber. Difficulty, however, is generally experienced in making the men put on a coat, or sweater, before leaving. Everybody is perspiring, something more than freely, and the hands who are not acquainted with the "bends" are looking forward to the cool air on expansion. But the engineer is unrelenting, and keeps his hand on the air discharge until all have their jackets on. This important matter of decompression will be touched upon when dealing with methods of sinking.

The general principles of the air-lock will be clear from the diagram. After the column of cylinders has been lowered to the river bed, and the lock fixed in position on top, operations are commenced by closing the bottom door, which is secured by a man-hole bar similar to that shown on the top door. Air is admitted below the bottom door by direct pumping from the compressor, or from an air-receiver. At Kempsey the refinement of an air-receiver was not in evidence, and the discomfort of direct pumping had to be endured.

Pumping is continued until the gauge on the air-lock indicates that the pressure is about balancing the head of water from the cutting-edge of the column to the river surface. The working shift of three or four men then enter through the top man-hole, with their tools and buckets, and take their places around the sides of the lock chamber.

A signal is then given to the outside lock attendant, who screws down the top man-hole cover.

The inside lock man then turns the air-valve, admitting the compressed-air to the lock-chamber, and releases the fastenings of the bottom door, which falls open automatically when the pressure in the lock is equal to that in the working chamber below.

Candles have been lit in the meantime, and stuck around the walls of the lock by means of lumps of clay, the latter being the usual candlestick for carrying into the workings.

A stone dropped through the bottom door will usually splash into water, and the leading hand signals for more air, and descends through the man-hole, fishing for the rope ladder with his feet.

After a few minutes a candle at the bottom of the column reveals the man standing on a flange of the cylinder connections. Then comes the "gurgle and swish" of the "blow-out," and the workings are hidden in a cloud of vapour which brings a cool draft upwards into the air-lock. The new chums "perk-up," tools and buckets are lowered, and all hands except the windlass man start operations below.

Before describing the methods of sinking, the system adopted for setting out the piers will be briefly outlined. The system will be generally followed by reference to Plate No. 14. False-work under the trusses is not erected until the piers are completed, and the location of the cylinders for large river bridges is usually determined by triangula-

tion. With care, the greatest accuracy can be obtained, and there should be no excuse for any serious error between centres of bearing for the bridge trusses.

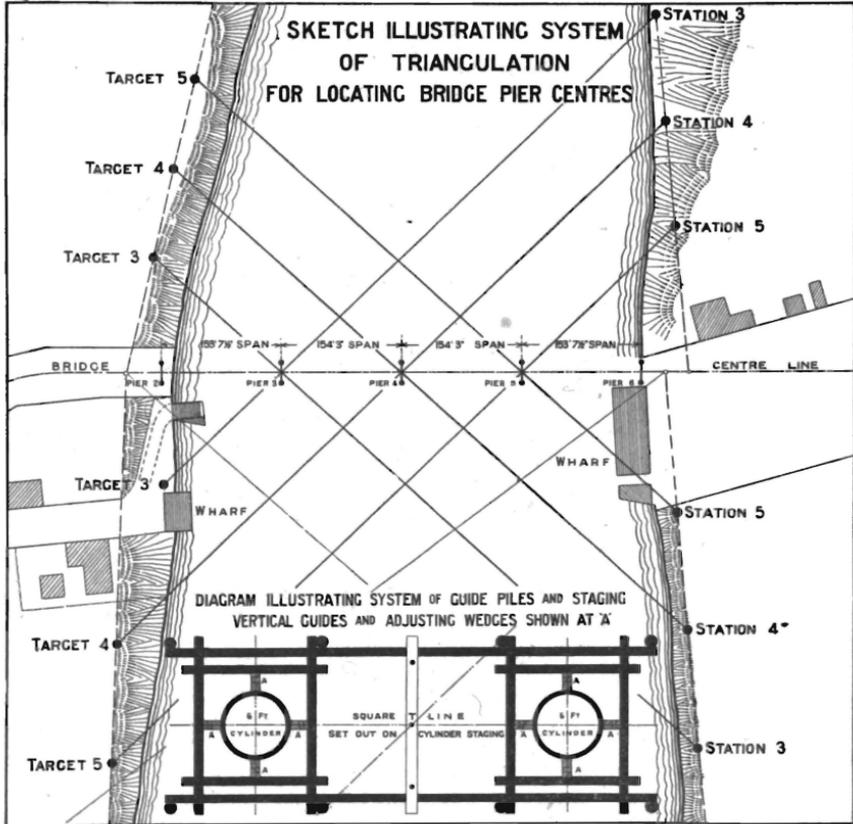


Plate No. 14.

In commencing operations on the first river pier, eight heavy guide piles were driven as indicated on the sketch. A slight error in the location of these guide piles is of no consequence, as ample room has to be left for cross-bracing, and the vertical guide timbers which direct the exact location of the cylinders. As illustrated, these guide-timbers are backed with folding wedges for the purpose of giving—or assisting in giving—lateral movement to the column.

The contour of the Macleay River banks enables base-lines to be run at right angles to the longitudinal axis of the bridge, on which station-points were located, with centres corresponding to the distances between piers. Permanent sighting targets were put down on the opposite banks as illustrated, so that when sinking was about to commence in the deep water channel, all location lines could be given without delay, and the cylinder positions checked by direct sight with the theodolite from the various station points.

Cylinder Sinking.

Plate No. 15 illustrates the Kempsey Bridge piers in course of sinking. The first land pier has been sunk to rock, and the wrought-iron bracing fixed in position. The sinking of Pier No. 2, in the deep water channel, is in progress, and the sandbags, for use as dunnage, are seen piled up on the top platform of the staging ready for use.

The plate gives a good general idea of the river staging around the cylinders. The position of the cylinders is watched closely every day, and the exact position of the cutting-edge, as well as the top cylinder, checked up at every shift. If found out of plumb or position, the excavators are directed to undercut on the side of the cylinder most distant from the true centre, as determined by a plumb-bob dropped from the lock-chamber which has been previously centred. This undercutting, together with manipulation of the folding wedges backing the guide timbers, will tilt the entire column, and give a lead to the cutting-edge towards the true centre. Sinking is resumed for a calculated distance and the column again set plumb.

An ancient log is occasionally met with, and if that happens with an untrained crew there is likely to be trouble if the timber is under the cutting edge. The excavators will possibly go on sending up gravel from the side away from the log, a procedure which generally causes bad tilting.

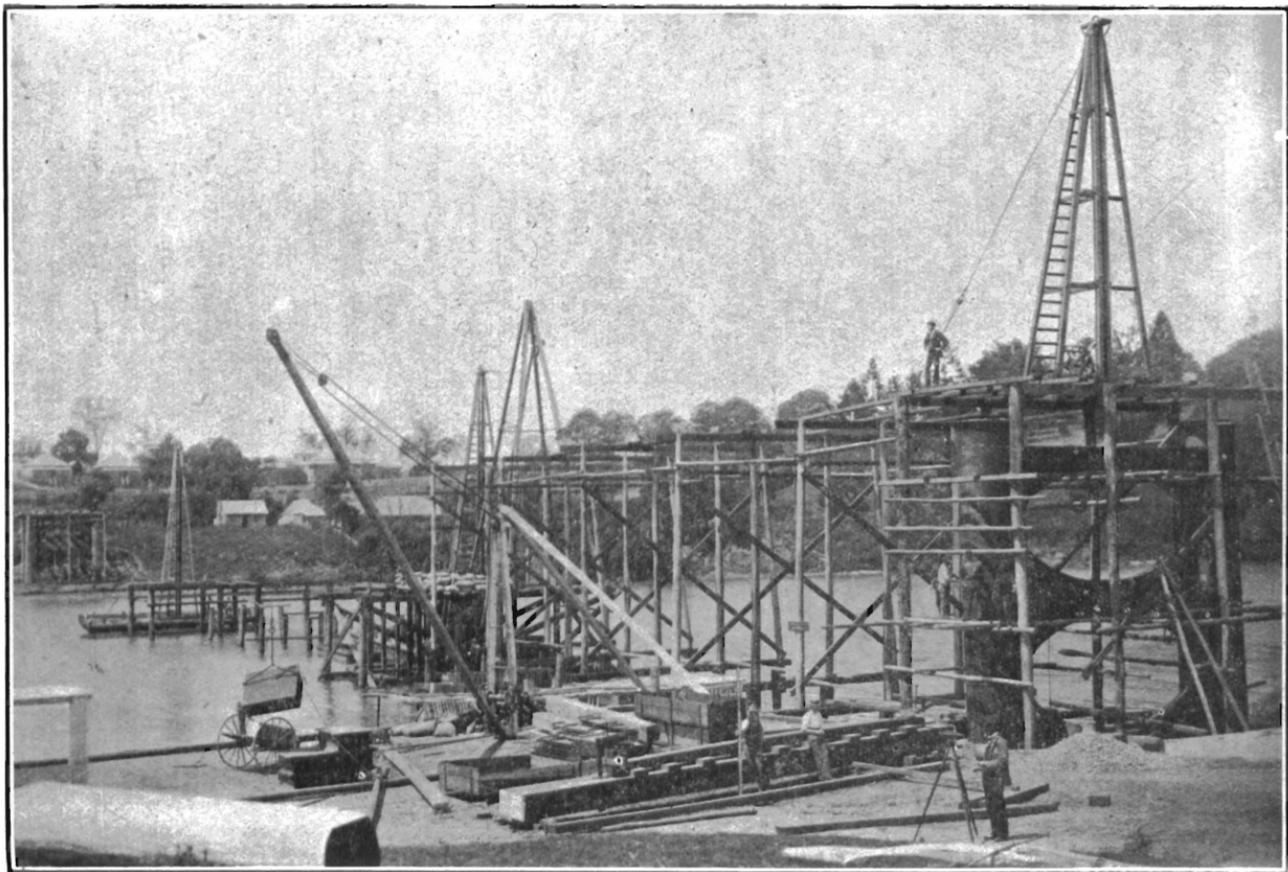


Plate No. 15.

As the excavation continues, the sinking progresses with more or less rapidity, endless difficulties appear to arise, especially as the depth passes the 80 feet mark, or theoretical gauge pressure of 35 lbs., and generally the engineer requires a lot of tact to get the men to "stick it." Some of the "new chums" get scared with bleeding from the nose and ears, and something of a mild panic arises at times.

Most text-book writers insist that a medical lock should be employed on all compressed-air work when the pressure exceeds 30 lbs., so that patients can be removed into it from the working chamber and relieved by slow decompression.

At Kempsey Bridge, with the pressure sometimes nearer 40 lbs. than 30 lbs., there was no medical lock, and at one critical period, with the caisson within a few feet of the rock, all hands struck work and refused to go into the lock for any wage offered.

However, a few little "nuggety" men were got together, and work was continued until the cutting-edge was safely founded into the hard rock bottom.

The big men appeared to suffer most from the pressure—in fact, a fat man should not be permitted into the workings, above, say 20 lbs. pressure.

The old theory as to the cause of caisson disease—commonly called "bends"—was that the nitrogen from the air was dissolved in the blood. Later investigations appear to show that it is due to a mechanical action of the dissolved air in the blood and tissues, which, liberated in the form of bubbles, expand and tear the tissues, injure the spinal cord, froth up the blood, and cause a slowing up of the circulation, and, in severe cases, stopping the action of the heart. The most satisfactory cure has been found in scientific decompression. In other words, it may be said that filling a man with air under 30 or more pounds pressure is, in effect, something like aerating a bottle of soda water.

When charged with the gas, and the cork in, the bottle looks harmless enough—so does the man. To safely open the bottle of soda water, however, the cork should be withdrawn slowly, until the violent bubbling has subsided. After that the bubbling will continue for some time after the cork is out, but the contents will not fly out of the bottle. A pneumatic caisson may be likened to a physiological soda-water factory, and the engineer with his hand on the blow-off cock performs a similar function to that required for opening the soda-water bottle. He releases the high pressure air very slowly, and never gives a full bore until the gauge gets well down. The bubbling continues for some time in the man, but if the decompression has been carefully done, the bubbles will not affect him seriously.

With a hospital-lock, this decompression can be carried out in something like comfort, but with a working lock, full of men anxious to get home after a heavy grind below with pick and shovel, it is difficult at times to carry on without doing them an injury.

As previously shown on Plate No. 9, the State of New York has instituted laws governing air-pressure work, and although objected to by many bridge engineers as being somewhat unpractical, have nevertheless served a useful purpose in drawing attention to the necessity for adequately safeguarding the lives of the men by regulating the process of decompression.

Plate No. 16 shows further progress in the construction of the Kempsey piers, with the wrought-iron bracing fixed, also the caps and bed plates.

The erection of the superstructure is shown, following up the completion of the river piers.

During the construction of this bridge, several floods were experienced. When this view was taken, the water

had subsided, leaving a large raft of timber and debris, which had been washed down and collected on the staging piles.

At this time the piers were securely braced, and, although considerable trouble was experienced in breaking up the interlocked tree-branches, which in places formed a solid dam from the bed of the river to the surface, no damage was done to the bridge.

Unfortunately the conditions prevailing during a flood when the pneumatic sinking was in progress, gave little time for photography, otherwise some more interesting views could have been obtained showing the race between the river and the bridge-builder's reinforcements.

Another view of "After the Flood" is shown on Plate No. 18. The raft between the piers looks peaceful enough, but to walk upon it would give ample assurance that it was very much alive. The log-breakers tie their overalls to their boot tops with spun-yard, which is effective against the larger brands of vermin washed down by the flood—the smaller brands, however, are annoying no matter what the precaution adopted.

These little episodes certainly relieve the monotony of life within the air-lock.

Owing to the difficulties experienced in sinking by the pneumatic process to the great depths required, it was decided to experiment with divers, utilising one of the cylinder columns as an open caisson.

At first divers and their assistants were brought up from the metropolis. The selection made may have been unfortunate, or suitable bridge foundation divers may have been scarce, but their introduction to the workings was not a success.

At first a tally-board was introduced to keep tab on the buckets of gravel sent up per diver per shift. This proved useless, as a man can fill his bucket from the centre of the cylinder, where it is nice and loose, and soon beat the tally of a good man who has been digging under the cutting-edge, thereby allowing the cylinder to sink. The latter did all the useful work and the former got the credit—temporarily.

During this period the advisability of returning to the pneumatic lock was considered, as progress was very slow, and the work costly. However, a couple of diver's dresses were made available on the works, and some young and enterprising recruits from neighbouring farms put into them on Saturday evenings—and possibly next day—for a "try-out." One of the pupils was a young Australian nugget with the degree of a Salvation Army Captain. He proved a wonder during the "try-out." The procedure was for the pupil and coach to go overboard from the punt, and reach bottom by means of a rope ladder. A code of signals was arranged similar to a Morse code, which could be tapped out on the pupil's face-glass. If that failed to impress the required meaning, it was made instantly clear by spreading the open hand over the glass, which indicated, in the manner of a famous poster, that the pupil "mustn't argue," but simply follow the leader, or go up.

It was not long before the lusty pupils were far ahead of their coach—especially when it came to filling the buckets with river gravel. A good plan is to sink on the knees, with the bucket pinched between, using a very short-handled shovel held at arms' length across the bucket, then a downward stroke into the gravel and an upward jerk into the bucket. As with a novice at golf, a lovely strike is made, with but disappointing results as regards the object aimed at. In the case of the diving novice, he

discovers, after the strike, that nothing is left on the shovel or gone into the bucket. The movement through the water has washed it off.

However, it was not long before a good team of young Australians were getting the cylinders down quicker than was done with the pneumatic, and, as proved by the cost-sheets for the first pier, at more than five shillings per cubic yard cheaper.

This must not be accepted as a guide for all classes of soil excavated. The even nature of the gravel passed through in sinking some of the Kempsey piers was especially suitable for removal by divers.

Table A, Plate 19, gives various depths of water with equivalent or balancing pressure. It will be seen that to reach rock at 70, 80 and at times nearly 90 feet, the young divers were doing fairly deep work—at 90 feet the usual limit for effective work is just about reached.

When an engineer has witnessed the initiative and versatility of the young Australian in difficult situations he can fully understand how such men, trained as they are in France, have made names for themselves that will live long in history.

The concrete filling in the bottom 6 feet length of cylinder was placed by diver when working as open caisson. The rock bottom was first of all levelled off under the cutting-edge all round, leaving the centre high. On completion of this work ready for inspection, the wire rope from a crane head was furnished with a lead weight which gave a convenient platform for the inspecting engineer's feet. Standing up with the helmet in place, and grasping the wire, the signal is given to let go. With the usual parting "pat" on the helmet the drop is made, usually at a steady pace at first, slowing off as deep water is reached.

PNEUMATIC FOUNDATIONS

AIR PRESSURE TABLES.

ROUGH RULE: Used by Drivers and Workmen :— $\frac{1}{4}$ lb. Air per Vertical Foot.

TABLE A.

Air pressure per sq. inch—to nearest pound.

	Depth Vert. Ft.	Pressure lbs. per sq. inch.	Depth Vert. Ft.	Pressure lbs. per sq. inch.
Ordinary work ..	20	9	90	39
	30	13	100	43
	34	15	110	48
	40	17	120	52
	50	22	130	56
Fairly heavy work }	60	26	140	61
	70	30	150	65
	80	35		

Deep work.

1ft. Head at 62°F = 433lbs. per square inch

The usual limits for deep work by Divers in bridge caissons is about 90 feet or 100 feet.

The usual maximum limit for deep work by expert Divers is 150 feet, at which depth they will seldom stay down longer than 20 minutes.

TABLE B.

Head in feet of water—corresponding to pressure in lbs. per sq. inch.

Gauge pressure lbs. per sq. in.	Head of Water in feet.	Absolute Pressure.
10	23	25lbs
15	34 = 1 Atmosphere	2 Atmospheres
20	46	35lbs.
30	69 = 2 Atmospheres	3 Atmospheres
40	92	55lbs.
45	104 = 3 Atmospheres	4 Atmospheres
50	115	65lbs.
60	138 = 4 Atmospheres	5 Atmospheres
65	150	5 $\frac{1}{4}$.. (approx)

Actual Atmospheric Pressure at Sea Level = 14.7lbs. per square inch

The writer's practice was to provide himself with a few deck spikes, and, on reaching bottom, to sit down on the high rock in the centre and slide down backwards until brought up by the cylinder. The diver's spade was then stuck up against the cylinder to mark the starting point. Proceeding then with hands on the rock for leverage, the journey round the cylinder would be commenced—still sit-

ting—with the feet pointing towards the centre. No lights were used, but it is very easy to discover by feel if the cutting edge is properly bearing.

If on completing the journey round to the starting shovel the work was found unsatisfactory, the diver was sent down again to adjust the defects. It sometimes happens that the cylinder edge will be found bearing on regular spots of rock all round, with gaps between the bearing points. If these gaps are not serious, a deck spike is shoved into the gap, as a mark for the diver, who is sent down later to drive in specially prepared wedges between the rock and the cutting-edge. If properly carried out, as shown by subsequent inspection, the rock surface is cleaned, and the first lot of concrete placed.

In the deep piers, onion bags were loosely filled with concrete, and stamped in around the cutting edge by means of the diver's boots. A bucket, with double doors opening downwards, was then filled with concrete, protected with a bag cover, and lowered through the water. The diver would release the bottom doors just over the onion bags, without disturbing the concrete mass more than necessary to secure a fairly good layer. More bags of concrete would follow, then the concrete skip, and so on, until a height of about six feet had been deposited.

After setting, the water in the cylinder was removed by valve buckets. In all cases the concrete was found to be set rock hard, the only fault being a surface coating of slimy matter, which was easily removed, and the concrete bed washed out. The remainder of the concrete filling, up to within a few feet of cast iron level, was then deposited in the open.

The wrought-iron cylinders and bracing were then erected and rivetted, when the concrete would be brought up to the level required to receive the truss bed plates or holding-down bolts.

Plate No. 20 gives an illustration of the steel truss bridge over the Hunter River at Luskintyre, one of the largest steel truss highway bridges erected in the State.

The most interesting work in connection with this bridge was the truss erection, a description of which must be deferred until a future occasion.

The bridge consists of two main steel truss spans of 200 feet centres. The centre pier rises about 60 feet above the river level, and the trusses were 25 feet between centres of chords. In addition to the truss spans, there are fifteen timber approach spans, giving a total bridge length of 920 feet.

In sinking the piers for this bridge considerable resistance was encountered by skin-friction. As the Hunter River was at that time constantly flooding, there was some difficulty in loading the cylinders with the usual sand-bag dunnage. Rises were sometimes very sudden, and to remove the bags, unship the lock, and make all snug for the coming flood would at times have required some rapid hustling to prevent loss of valuable plant.

A scheme was therefore devised for internal loading, as indicated on the diagram (Plate No. 21). At first a timber platform was constructed across the cylinder, giving head room in the working chamber of about two cylinder lengths. From this platform a timber shaft was carried up in sections. The buckets of excavated material were hauled up by the windlass until clear of the shaft section, and were then emptied into the space between the shaft and the cylinders. This proved very effective as far as loading was concerned, but as the shaft could not always be kept watertight, there was considerable discomfort in the working chamber, and this system was subsequently abandoned.

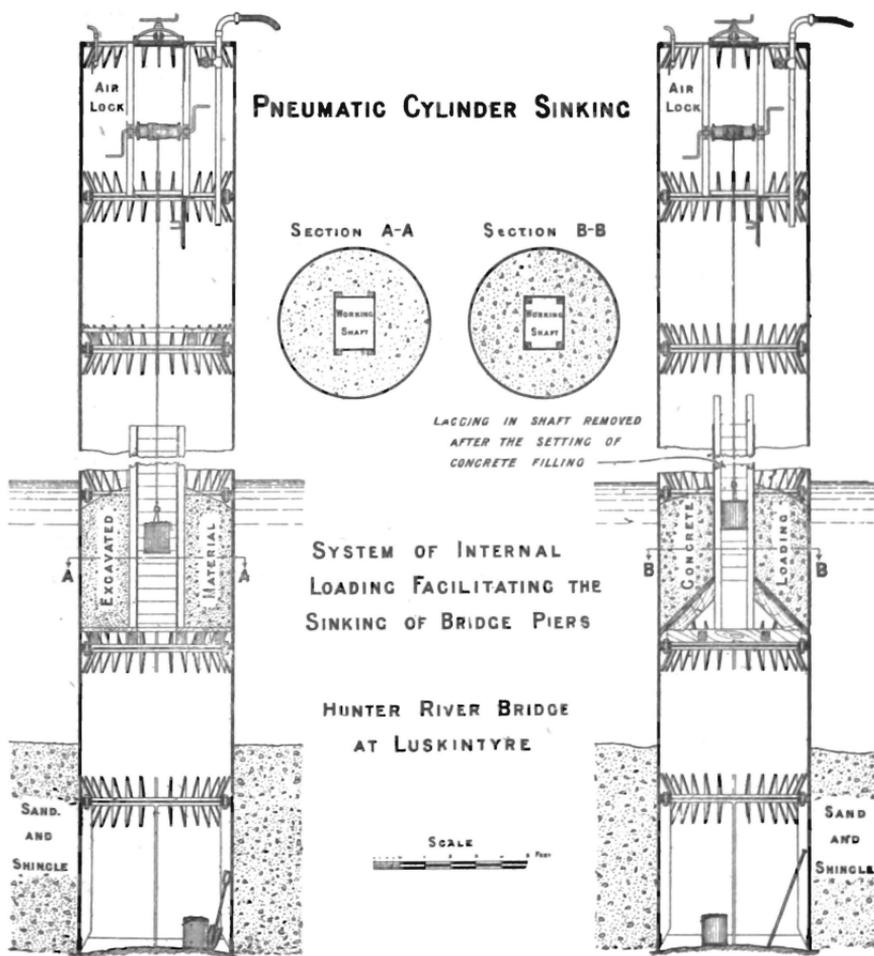


Plate No. 21

After reaching and founding on rock, the bottom concrete was deposited under air-pressure. After setting, the air-lock was removed, and the excavated material lifted by means of a crane and large buckets. The work was then thoroughly cleaned, and the remaining concrete deposited in the open.

The second scheme, which was finally adopted for internal loading, is illustrated on the diagram.

A temporary timber shaft was carried up in a similar manner to the previous scheme. The platform, however, was sloped upwards as shown, from the sides of the cylinder to the shaft, for the purpose of securing a perfect junction between the bottom concrete and the concrete filling around the shaft.

When the concrete filling put in for loading purposes was thoroughly set, the boarding which lined the shaft was removed, giving better clearance for men and materials.

When the column was founded on rock, the bottom concrete was put in under pressure, as in the former case. The shaft was then thoroughly cleaned, and the heart filling placed, as before, in the open. This cylinder had all the good points of the cast-iron skin as regards minimum friction, with the added advantages of a concrete-caisson as regards weight. The sinking was rapid, and no difficulty was experienced in keeping the column perfectly plumb, and in correct position.

In cylinder sinking, it is customary to pile up as many sections as possible, with the object of getting down with as few removals of the air-lock as can be arranged. Taking off the lock means not only letting in the water, and possibly quantities of drift sand, etc., but also giving the cylinder time to "set" and accumulate a strong frictional resistance.

With a fairly high column of cylinders showing above the staging, and many tons of sand-bags piled on top, the outfit is apt to be top heavy and unwieldy, often giving a lot of trouble to keep in position.

A table of Frictional Resistance in pounds per square foot of exposed surface of caissons, compiled by Mr. H. L. Wiley, M. Am. Soc. C.E., is given on Plate No. 22.

The pneumatic caissons quoted were, with three exceptions, of timber construction, a type at one time favored