completed, it will serve the twofold purpose of providing a passage by which pit-timber, rails and heavy stores of all kinds can run from the quay direct into either of the two cages in the shaft, and so sent below, and of assisting the ventilation of the mine.

When sinking was suspended at a depth of 149 t. the walling of the shaft was begun, a bed for a "walling curb" having been prepared at a depth of 120ft., and when it had been carried up to the level of the floor of the tunnel, the sides and roof of the latter were also walled, the brickwork being bonded into the shaft walling. The finished dimensions of the tunnel, where it opens into the shaft, are 14ft. wide by 12ft. high to the crown of the arch, but these will be reduced to 8ft. by 10ft. in the next length of 12ft. of lining. The natural surface of the rock at the mouth of this shaft sloped rather steeply towards the harbour, there being a difference of no less than 7ft. between the levels of the front and back "lips" of the shaft. The brick walling was, therefore, carried up beyond the natural surface, and finished at a height of 80ft. above low water mark. In connection with the plan, which had been decided upon for the ventilation of the shafts during sinking, an archway was formed in the shaft-walling on the southern side of the shaft, immediately behind the "buntons" built into the shaft-walling. The bottom of this opening is 7ft. 6in. below the finished level of the shaft top, and its dimensions are 5ft. wide by 6ft. 6in. high to crown of arch, thus giving a clear area of about 30 square feet. The archway was built of sufficient length to pass right through the large concrete foundations which were afterwards put down for the permanent headgear, all round the outside of the shaft-walling from the solid rock upwards to the finished level of the shaft top. It may be mentioned that the sinking and walling of this shaft to the depths mentioned was completed on 15th September, 1897. The methods adopted in carrying out the work will be more fully described in another part of this paper.

In the case of the Jubilee Shaft, sinking was begun on the 5th August, 1897. The steam crane used at this shaft had sufficient room on its barrel for rope to allow of a depth of 225ft. being reached in the sinking. A bed for a walling curb was prepared at a depth of 170ft.,

from which, when sinking was suspended, the brickwork was carried up to a point 23ft. 6in. below the finished level of the mouth of the shaft. Walling was then suspended, and the excavation begun of the chamber for the permanent ventilating fan as well as of the main air drift from the shaft to the fan-chamber.

The excavation for the drift consisted of an open-cut, 16ft. 9in. wide by 23ft. 6in. deep by 35ft. long, made in the rcok on the southern side of the shaft, at right angles to the line of the "buntons." The excavation for the fan-chamber was opened at right angles to the main air drift, and had a width of 25ft. (sufficient for the fan-chamber and both side drifts), a length of 44ft. 6in. from the side of the main air drift, and a depth sloping from 23ft. 6in. to 6ft. While this work was being carried out, the shaft was, of course, covered over at the level of the floor of the air drift, and when the excavation was completed the shaft walling was carried up to the surface, the sides of the main and side air drifts lined, and the main air drift arched over, between the shaft and the fan-chamber, and finished at the permanent level of the pit-top.

The sinkin gand walling of this shaft to the depths mentioned, was completed on 13th November, 1897.

Meanwhile the Birthday Shaft was also being connected with the permanent fan-chamber, by means of an air drift connected with the opening already described as having been left in the walling near the top of that shaft. This drift was formed by making an open cut in the rock and throwing a brick arch over it, so as to finish at pit-bank level. The arch was sprung from steps cut in the sides of the open-cut. The dimensions of this drift are 3ft. 6in. wide, by 4ft. 9in. high to crown of arch, thus giving a clear area of about 15 square feet.

Two pairs of winding engines were bought in the colony for the sinking of the shafts. They had been imported from England, some years previously, by two different companies which contemplated opening collieries near Newcastle, but which went into liquidation. The engines were of dimensions suitable for raising the loaded buckets from the deep sinkings contemplated; they were made by good English firms and were quite

new—never having been erected. A general description of these engines, with their leading diemnsions, is as follows:—

A pair of horizontal, coupled, direct acting high pressure winding engines, having cylinders 28in. diameter by 5ft. stroke, with Cornish equilibrium valve-gear and link motion reversing gear; diameter of steel valves 8in., diameter of exhaust valves 9in. Cornish equilibrium throttle-valve. Winding-drum 14ft. diameter by 5ft. 6in. wide with two brake-flanges, one on either side of the drum. These flanges were originally rough and fitted with wooden blocks, on which a wrought iron brake strap, operated by the engineman's foot, worked half way round the circumference. This arrangement was altered some time ago, the flanges being turned in their present position, and fitted with brake blocks (Burn's type), whilst the leverage was also more than doubled, and is now 64 to 1. An auxiliary drum has also been fitted on the crank-shaft, inside the main drum, on which that part the sinking rope, no tactually in use for the time being, is coiled. When the increasing depth of the sinking requires it, any length of rope desired can be paid off the small internal drum, on to the main drum, by simply drawing the keys of the former and turning it, by hand, it being bored large enough to allow this to be done easily.

These engines (which, except so far as the shaft sinking is concerned, are really only temporary) are erected close enough to the shaft to leave room behind them for the erection of the permanent winding engines. The distance from the centre of the pit to the centre of winding drum is 60ft. Being temporary, the engines are seated on beds built of brickwork, set in lime mortar, and the engine-house is of timber and corrugated iron, so that the whole can be easily worked when the permanent winding engines are ready for work.

These engines are of exactly the same type as those at the Birthday Shaft. The cylinders are, however, rather larger, being 30 inches diameter, but the stroke, diameter of valves, etc., are the same.

The winding-drum is 13ft. diameter by 5ft. 1in. wide. These engines will be part of the permanent plant (at

any rate until the output required to be drawn from the mine reaches figures which will necessitate coal-winding at both shafts, and larger engines at this one), and, when the mine is at work, will be used for raising and lowering men, etc., when required. They are set on the solid rock, into which all holding down bolts are secured. The "race" for the drum, pit for steam and exhaust pipes, etc., are excavated in the rock. The engine-house is built of brickwork, set in cement mortar, the walls being panelled inside and outside; it is 47ft. long by 33ft. wide inside, and the height from the concrete floor to the top of side walls is 22ft. It has a queen-post principal roof, the tie beams being of sufficient size to be used for lifting from, in case of necessity. The distance from the centre of the pit to the centre of the winding-drum is 105ft., thus giving a long lead from the drum to the head-gear pulleys, and reducing side friction on the rope.

A temporary timber pulley-frame was erected at the Birthday Shaft for carrying on the sinking until the permanent steel head-gear could be made and erected. It was built of oregon, the main and back legs being 12in. x 12in., and the front legs 10in. x 10in., the whole being strongly braced. The height from the mouth of the pit to the centre of the 15ft. diameter pulley-wheel was 37ft. 6in.; and as a safeguard against overwinding, the necessary detaching gear for an Ormerod's safety hook was fixed at a height of 30ft. 6in. from the pit mouth. This head-gear carried the sinking down to 1420ft.

The permanent steel head-gear was erected outside of, and over, the temporary frame, without stoppage of sinking for more than a few days. To enable this to be done with safety, a large platform was erected at the detaching gear level of the temporary frame, from which it was chiefly supported. The platform was made large enough to cover the pit top, and to shelter the banksmen, in case of workmen on the head-gear dropping tools or rivets. The permanent head-gear contains 80 tons of steel lattice work and plating. The main and back legs are 2ft. by 2ft., the corner angles being 5 by 5 by $\frac{5}{8}$ inches, and the straps and diagonals $2\frac{1}{2}$in. x $\frac{5}{8}$in. The front legs are 2ft. x 2ft., the corner angles being 4 by 4 by $\frac{5}{8}$ inches. The foot of each leg rests in a strong cast

iron shoe, set on and bolted down to massive concrete pillars resting on the solid rock. The height to the centre of pulley wheels is 70ft. 3in. above the pit mouth, and, when coal is being drawn, there will be the same head room from the landing level of the cages. The head-gear is arranged to carry two main pulley wheels, each 18ft. diameter, and set 7ft. 3in. apart, centre to centre of "treads." These pulleys will not, however, be put in position until the permanent winding engines are ready for work. The 15ft. diameter pulley wheel, used on the temporary head-gear, has been set in position, so as to run the sinking rope exactly in the centre of the shaft, and will be used to complete the sinking. Had one of the permanent pulleys been used, the sinking rope (which is, of course, much smaller than the coal winding ropes will be) would have worn a "false" groove in the pulleys, which would be detrimental to, at least, the first larger rope run over that pulley. Provision is, of course, made in the permanent head-gear for prevention of accident in case of overwinding, the detaching girders being made to suit the load which they would have to bear if a treble decked cage, carrying 6 tubs holding 6 tons of coal, were suddenly suspended by the safety detaching hook. The height of the detaching girders is 56ft. 3in. above the pit mouth. At the same height, girders are also fixed to carry two 6ft. diameter pulley wheels for the capstan ropes. These pulleys are arranged at right angles to the sinking rope pulley above them, and also so as to bring the three ropes, i.e., the two capstan ropes, with the sinking rope between them, into one common "fore and aft" centre line. This allows of the two capstan ropes being used as guide ropes for the sinking bucket.

The permanent head-gear at the Jubilee Shaft, the erection of which is almost completed, is of iron-bark timber, the main and back legs tapering from 16 inches square at the bottom to 14 inches square at the top, and the front legs from 14 inches to 12 inches square. The height from the pit mouth to centre of pulley wheels is 54ft. As in the case of the Birthday Shaft head-gear, a single 15ft. diameter pulley will be used in sinking the shaft, and there is similar provision for safety detachng

gear and capstan pulleys. The legs rest in cast-iron shoes, bolted down through concrete pillars to the solid rock .When shaft sinking is completed, this head-gear will carry two 15ft. diameter pulleyw heels, set 7ft. 6½in. apart, centre of centre of "treads."

Two pairs of capstan engines are erected between the Birthday and Jubilee Shafts. They are set "back to back" in the same engine-house, and on the centre line of both pits, one pair for each shaft. The engines are coupled, direct acting, horizontal, with cylinders 14⅛ inches diameter by 2ft. 6in. stroke, fitted with slide valves with link motion reversing gear. The crank shaft is geared down to the third motion or drum shaft in the ratio of 9 to 1. On the third motion shaft two drums are keyed, each being 6ft. 4½in. diameter by 5ft. 6in. wide. They are set 8ft. apart, centre to centre, to correspond with the centres of capstan pulleys on both headgears, and thus replace the lead of the ropes when coiling at either side of the drums. The distance from the centre of each pit to the centre of its capstan drums is 59ft. 6in. These engmes are permanently erected on concrete and solid rock foundations, and the house which contains them measures 63ft. 6in. long by 24ft. 3in. wide inside, the height of side walls being 18ft. 6in. It is built of brickwork set in cement mortar. The walls are panelled outside. The roof has kingpost principals. When the colliery is at work, these engines will drive the screening and coal-conveying plant from their present position, and they will also be available as capstans, for practically immediate use in raising or lowering any gear in either shaft, in case of emregency.

Five boilers have been placed in position, of which two are now under steam. They are of the Lancashire type, and are 30ft. long by 8ft. diameter, constructed for a working pressure of 120lb. per square inch, and fitted with the latest improvements. They are seated in brickwork, in the way usual to this type of boiler, and the top of the side flues, between each boiler, as well as of the main flue, is covered with stone flagging 4in. thick. Provision is made for increasing the number of boilers to fifteen, and a chamber has been built for a Green's economiser of 832 pipes. The boilers are fed

from a reservoir (constructed to contain 80,000 gallons) by Evans' compound feed-pumps (in duplicate), having cylinders 8½in. and 12in. diameter, and rams 8in. diameter, the stroke of all being 9in. A temporary wrought iron chimney, 60ft. high by 3ft. diameter, is now in use, but the permanent brick stack is now being built, and when completed will be 192ft. high by 8ft. 2in. inside diameter at the top. It has a square base 42ft. high, above which it is circular. The gable walls and one side wall of the boiler-house are of brickwork, the other side wall being temporarily of timber and corrugated iron, to allow of extension. The roof is in "bays," one of which covers the economiser chamber, whilst each of the others covers two boilers. The girders, which support the kingpost principals between the gables, rest on cast iron columns seated on the top of the division walls between the flues.

The boiler-house, at present, measures 90ft. 6in. by 54ft. 6in., the height from firing floor to underside of principals is 20ft. 3in., whilst from the top of the boiler-eating it is 13ft. 9in. The feed pumps are placed in a brick house, of which one wall of the boiler-house forms part, measuring 40ft. 6in. by 14ft.

It was necessary for the writer to digress from the account of the shaft-sinking—as completed when the first section was carried out by means of the cranes—but it may now be resumed.

Unfortunately, the boom in the engineering trade in England delayed the delivery of the boilers, and several months' time was lost from this cause.

However, the sinking of the Birthday Shaft was resumed at a depth of 149ft. on 27th June, 1898, since which it has progressed very favourably, the depth now being 2084ft., of which 2066ft. has been permanently walled with brickwork. The actual time occupied in carrying out this work has been 109 weeks.

It may be mentioned that the section of strata, passed through in sinking the shaft, corresponds in a very marked way with that proved by the Cremorne bore; for instance, the depth at which the chocolate shales were struck in the bore was 883ft. below low-tide level, whereas in the shaft it was 944ft. 9in., thus showing a dif-

ference of level of only 61ft. 9in. in a distance of 3¼ miles, and proving that the measures have not been disturbed by any dislocation. Further, the "grits" were struck in the Cremorne bore at 1763ft. below low-tide level, whilst in the shaft they were met with at 1828ft., thus showing a difference of level of only 65ft., the difference being in the same direction as that indicated by the chocolate shales. The chocolate shales and grits, it should be mentioned, form distinct and well-defined horizons.

The method adopted in sinking is, briefly, as follows:—Assuming that the walls of the shaft have been dressed down fairly level with the bottom, the drilling of "sumphing" holes is begun, and, as a rule, six of such holes are put down. They are started at points about 2ft. from the sides of the shaft and are given a slight inclination, so that, when at their full depth of from 6ft. to 7ft., the bottom of the holes are considerably nearer the centre of the shaft than the drills were when started. This, of course, is done with the object of giving a lifting power to the shots. When these holes have been charged and fired, the filling and sending of the "muck" to the surface is begun, and before the operation is completed the drilling of the side holes is well under way. The latter, generally eight in number, are put down vertically round the circumference of the shaft, so that, when fired, they shoot off the "canches" or "benches" which the "sumphing" shots have left. These operations are repeated, the number, position, and depth of holes put down, depending, of course, on the nature of the rock. To begin with, the explosive used was rack-a-rock, but when a depth of about 650ft. was reached, gelignite was substituted with advantage. The mode of firing shots is either by electricity or by fuze, connected to denotators. In the case of the former the shots are fired from the surface by means of a rack-bar exploder. About 3½ tons of rack-a-rock and 3¼ tons of gelignite have, so far, been used in the Birthday Shaft.

No difficulty has been experienced with water in the sinking, the quantity made being only about 500 gals. per hour. This all comes from above the 700ft. level, and is collected in "garlands" or "water-rings," formed

of steel plates 8in. wide by ⅛in. thick. These, where put in, are fixed to the walling curbs by coachscrews, the upper edge of the plates being slightly "dished" inwards so as to catch the water running down the sides of the brickwork. Pipes lead the water from these water-rings to the bottom of the shaft, where it is, for the most part, filled away with the muck. A water bucket, having a capacity of about 225 gals., and with a self-acting valve in the bottom, is used for raising the water which collects in the shaft during any stoppage of sinking.

From a depth of about 400ft. the practice has been to temporarily timber the sides of the shaft, pending the permanent brick walling being put in. This has been done to secure the sides of the shaft, which, after being exposed, have a tendency to "flake off." The timbering consists of "curbs" of 6in. by 5in. hardwood, in twelve segments, which, when bolted together, form a complete ring all round the shaft, leaving room behind for "backing deals" of 6in. by 1in. hardwood. These "curbs" are set 6ft. apart, centre to centre, measured vertically, and each one is not only hung from the curb above it by hanging "deals," but is also supported by iron dowels let into the sides of the shaft at regular intervals. Twelve "punch props" of 3in. by 3in. hardwood are also set between the curbs, one prop being set to each segment.

The depth of each section sunk before the permanent brick walling is put in varies according to the nature of the ground, but is generally from 100ft. to 150ft.

The permanent curbs for each section of walling are of ironbark timber 12in. wide by 4½in. thick. These are set either on beds dressed in the sides of the shaft, or, where a satisfactory bed of this kind cannot be got, they are laid on 2in. iron dowels, sixteen in number, let into the sides of the shaft a distance of 2ft. The walling curbs are built up in 12 segments, and, when bolted together, form an annular ring, having an inside and outside diameter, of 18ft. and 20ft. respectively. These are set level and true to the centre of the shaft, and the brick walling is then begun. This is built perfectly solid for a distance of not less than 6ft., after which it is carried up as thick as can be worked, without cutting

bricks, the space between the brickwork and the shaft sides being filled up with concrete, composed of sieved engine ashes, sand, and cement. The brickwork is set in cement mortar.

Buntons, of ironbark timber 14ft. 6in. long by 10in. by 6in., are built into the walling as it proceeds. They are set 6ft. apart, centre to centre, measured vertically, the space between them being 5ft. 2in. Measured across the shaft, the distance between the buntons is 12ft. 9in. These buntons will, eventually, carry the steel rail guides for the cages.

In completing each section of walling the brickwork is "keyed" perfectly tight, with solid work and "grouting," under the curb at the bottom of the section previously walled.

The walling is carried on from a scaffold suspended by the capstan ropes already mentioned. It is double-decked, the upper deck, on which the men work, being 17ft. 6in. diameter. It is fitted with two hinged "flaps," one on either side, which, when raised, allow the scaffold to pass freely between the buntons.

This scaffold is permanently suspended in the shaft, and when sinking is being carried on, the covering of a hatchway in the upper deck, measuring 6ft. 6in. square, is removed so as to allow the buckets to pass up and down through it. The hatchway in the bottom deck, which is always open, is 8ft. 6in. square, and, between the decks, the tapered opening thus formed is lined with T. and G. boards.

The weight of the scaffold is about 4 tons 15cwt., which is sufficient to keep the capstan ropes suspending it sufficiently rigid to serve as guides for the ascending and descending buckets. The ropes have, together, a breaking strain of 86½ tons. The maximum load on these ropes, if the walling scaffold was suspended at a depth of 3000ft. and loaded with the customary complement of workmen, bricks, and mortar, would be about 14 tons, at the pulleys.

The use of guides in a deep sinking shaft not only reduces the time taken in steadying the buckets before being raised from the shaft bottom, but admits of an increased speed of raising and lowering the buckets.

The following trials of speed, recently made, may be of interest:—

The average speed of winding muck from this shaft, from a depth of 1826 feet, is as follows:—Lowering empty bucket from pit bank to bottom, 1826 feet, 66⅔ sec., or 1643 feet per minute. Raising load from 1826 feet to surface, 60 1-30th secs., or 1825 feet per minute. When men are being raised or lowered the speed is greatly reduced, the average being as follows when the depth was 1952 feet. The time taken in lowering a bucket of men from surface to bottom, a depth of 1952 feet, was 2 mins. 4 secs., or 944 feet per minute; and for raising from pit bottom to surface 1 min. 32 secs., or 1273 feet per minute. The above times and speeds were averaged from a series of trips taken during the ordinary sinking.

The building of the buntons into the brick walling of the shaft, and the construction of air drifts, from the top of both shafts to the chamber of the permanent ventilating fan, have already been described.

In order to form a separate compartment for the "down-cast" and "up-cast" air columns in the shaft, "bratticing" is fixed between the buntons. It consists of T. and G. deal, 6in. wide by 1in. thick, made on the surface, in sections ready for use in the shaft. These sections are fixed between the buntons, being secured by "arris cleats." The object of the sloping sides of these cleats is to prevent any possibility of pieces of stone lodging on the buntons behind the bratticing, where they could not be seen when the shaft is being examined after blasting. Of the two compartments thus formed in the shaft, the larger is the "down-cast," and the smaller, having an area of 12 square feet, is the "up-cast." This is connected with the air drift at the surface.

The ventilating current is at present produced by means of a steam-jet, playing into the drift near the top of the shaft. A temporary brick chimney 30ft. high by 3ft. 3in. square is connected with this drift, thus increasing the height of the "up-cast" column.

The result of this method of ventilation is entirely satisfactory, but it may be mentioned that, if required,

the permanent ventilating fan, already erected, can be used for ventilating both sinking shafts.

It is of the Walker indestructible type, its diameter is 24ft. and width 8ft., and it is guaranteed to produce a ventilating current of 400,000 cubic feet of air per minute with 4½in. water gauge. The engines for driving this fan are of the compound, horizontal type, having cylinders 19in. and 35in. diameter by 4ft. stroke. The fan is rope-driven from the engines, 11 cotton ropes being provided. The driving wheel on the crank shaft of the engines is 18ft. diameter, whilst the driven wheel on the fan shaft is 9ft. diameter.

Ordinary flare lamps were first used in the shaft, followed by acetylene gas lamps, which were very satisfactory. Owing to occasional "blowers" of gas having been met with, recently, when nearing shale beds, safety lamps have been adopted, but will shortly be superseded by electric light, for which a plant has been erected, consisting of a Crompton dynamo having a capacity of 230 volts and 112 amperes at 550 revs. per minute, and belt-driven from a pair of compound horizontal engines, having cylinders 8in. and 12in. diameter by 2ft. stroke.

In this paper, the writer has endeavoured to give a practical description of the development of the Sydney Harbour Colliery to date, aid trusts it may be of interest to members of this Association.

The successful completion of the work in hand should surely be looked forward to by all who have at heart the interests of Sydney in particular, and the colony in general.