SOME NOTES ON SINKING VLAKFONTEIN No. 1 SHAFT.

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Vlakfontein No. 1 Shaft is a vertical timbered six-compartment shaft. The compartments are all of the same size, and the inside dimensions of each are 11 ft. by 6 ft. The dimensions of the shaft outside of timbers are 41 ft. 3 in. by 12 ft. 6 in., and the excavation size 43 ft. by 14 ft. 6 in. (equal to about 600 sq. ft.).

It is considered expedient to arrange two stages of sinking to the depth at which it is expected to intersect the Main Reef in this area and a considerable amount of development will have to be done before the connexion can be made with another shaft. The unusually large dimensions of this shaft were therefore adopted in order to provide a large cross-sectional area for ventilation purposes, rapid sinking facilities and adequate hoisting capacity.

Particulars of shaft timbering and sinking equipment are as follows. Sett centres are 6 ft. 9 in.

Pitch Pine ...	Wall Plates ...	9 in. × 9 in. × 41 ft. 3 in.
	End Plates ...	9 in. × 9 in. × 12 ft. 6 in.
	Dividers ...	9 in. × 9 in. × 11 ft. 2 in.
	Corner Studdles	8 in. × 8 in. × 6 ft. 1 in.
	Inner Studdles	10 in. × 4 in. × 6 ft. 1 in.
Karri Guides ...	... ...	8 in. × 4 in. × 27 ft.

Guides are attached to guide brackets by two bolts at joint brackets, and a single bolt at intermediate brackets. Bolts are $\frac{3}{4}$ in. dardelet.

Hanging bolts are $1\frac{1}{8}$ in. by 4 ft., six to each wall plate. Steel plate washers, 5 in. by 5 in. by $\frac{3}{8}$ in. are used.

Rolled steel joists, 12 in. by 6 in., supplied in 18 ft. lengths, jointed, are used as bearers. They are placed at the intervals indicated in Fig. 9.

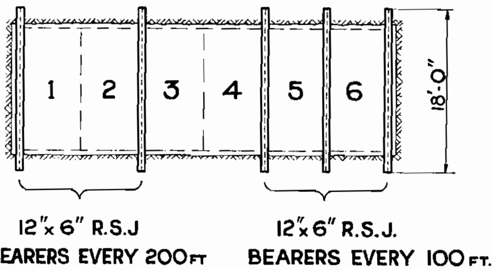


Fig. 9.

Compartments 5 and 6 will carry permanent columns and cables. Compartment 3 carries a 30 in. galvanized ventilation pipe, with Brown's joints. Compartment 4 carries a 6 in. flanged compressed air column on one side and a 2 in. water pipe on the opposite side. Compartment 6 carries the lighting and blasting cables.

For signalling purposes a $\frac{3}{8}$ in. flexible wire rope is suspended in each compartment, running over a pulley in the headgear to a crab winch on the bank. To this rope at the bank is attached, by Crosby clamps, a length of rope to the electric bell and counter-weight crank lever. The crab winches permit of the bell wires being pulled off the shaft bottom at blasting time, and of the extension of the wire as the shaft is sunk.

The ventilation fan is a 46 in. diameter double-inlet high-pressure Sirocco type fan, capable of delivering 14,200 cu. ft. of air per minute against a water gauge of 29½ in. when running at a speed of 1,500 r.p.m. Up to the present this fan has been belt-driven by a 50 h.p. motor at a speed of 725 r.p.m. The delivery has been controlled by a diaphragm. About 10,000 cu. ft. of air per minute are delivered through 3,500 ft. of 30 in. pipe. The water gauge is 10 in., and the motor is running to full capacity. A 150 h.p. direct-coupled motor is in place for future requirements.

The shaft bottom is lit by two clusters of electric lights, each containing four 100 watt lamps, plugged into Stringalite. The Stringalite extends up to the bottom cable junction chamber (chambers are 950 ft. apart). The lighting cable from the junction chamber to the surface is 7-core 7/20 Superite, and will ultimately become a permanent bell cable.

The penthouse required under Regulation 22 (1) consists of 9 in. by 3 in. planks, resting on the dividers, leaving only sufficient room for the skips to pass through. This penthouse constitutes the manifold platform, and exemption from Regulation 22 (1) has been obtained from the Inspector of Mines to the extent that the penthouse may be situated not more than 75 ft. from the shaft bottom instead of 50 ft.

Two chain ladders are carried from the lowest set of timbers to the bottom of the shaft, and for 100 ft. up the shaft. Application to the Inspector of Mines for exemption from the requirements of the chain ladders to the bottom of the shaft was made, in view of the fact that each of the six sinking skips is equipped with a ladder attached to the long bridle, permitting access to the shaft timbers from the shaft bottom, and that blasting is carried out electrically from the surface, but this was refused owing to the suggested danger of sudden flooding or caving ground.

Shaft sinking started in January, 1935, with two hand jib cranes and two winches, hoisting 20 cu. ft. side-tipping truck pans. By April, 1935, solid rock at a depth of 114 ft. had been reached, the collar sett and concreting to this depth completed, a temporary wooden headgear 42 ft. high erected, and three winches installed to operate 20 cu. ft. kibbles.

The winches served four compartments. No hoisting took place in Nos. 1 and 6 compartments. No. 2 compartment was served by a 35 h.p. Pikrose air-driven single-drum winch. Nos. 3 and 4 compartments were served by a double-drum 50 h.p. electrically-driven Fulton winch. No. 5 compartment was served by a 50 h.p. electrically-driven Fulton winch. The drums of all the winches were 2 ft. diameter by 25 in. wide, with flanges 8 in. deep. $\frac{3}{4}$ in. ropes were used, and the kibbles were fitted with brackets for side tipping in 20 cu. ft. side-tipping truck chassis, and guided by steel cross heads.

With this hoisting equipment the shaft was sunk 710 ft. in five months, an average of 142 ft. per month. Blasting took place on two shifts only, and timbering on the third shift. During this period the ground encountered was amygdaloidal diabase, and the drilling was slow.

In October, 1935, two temporary steam hoists were brought into commission to serve compartments 1, 2, 3 and 4, and the double-drum Fulton electric winch was shifted to serve compartments 5 and 6. The temporary steam hoists were 400 h.p. geared Robeys, one a slide valve and the other a drop valve, with 8 ft. diameter drums. Their gear ratio was 2·26 to 1, and their maximum winding speed for rock 1,200 ft. per minute. $\frac{7}{8}$ in. ropes were used.

Sinking proceeded with 20 cu. ft. kibbles in all six compartments, and three-shift blasting. 719 ft. were sunk in three months, an average of 240 ft. per month. A depth of 1,600 ft. was reached with this equipment. The 20 cu. ft. kibbles suspended from $\frac{7}{8}$ in. rope developed excessive spin when hanging below the bottom setts, free of the cross-heads above the shaft bottom. On two occasions natives were flung out of spinning kibbles with serious results, due to the kibbles being inadvertently delayed between the shaft bottom and the cross-head stops.

In January, 1936, one year after sinking commenced, the permanent 145 ft. steel headgear and one permanent winder were brought into commission. Shaft sinking was stopped for 15 days to change over to the steel headgear and sinking skips. The temporary wooden headgear was dismantled, and the temporary sinking bins of 350 tons capacity, with tipping paths, etc., for sinking skips, completed.

Sinking was resumed on the 17th January with the following equipment :—

Compartments 1 *and* 2 were served by the slide valve Robey, operating duralumin 2-ton skips and long bridles, the duralumin construction being adopted to permit of the operation of this hoist to a depth of 3,800 ft., by which time the permanent winder was expected to be ready.

Compartments 3 *and* 4 were served by the drop valve Robey operating 3-ton steel skips with long bridles. The capacity of the 3-ton skips was reduced to $2\frac{1}{2}$ tons by welding shaped plates on the inside of the skips. This reduction in load was necessary to keep the rope safety factor over six at the ultimate depth of 2,900 ft., for which this hoist was licensed.

Compartments 5 *and* 6 were served by a Ward-Leonard 14 ft. drum electric winder of 2,900 h.p., with a Stubbs-Perry steam turbine generating set, and a 22-ton flywheel, operating 3-ton skips in long bridles.

The winding ropes on the steam hoists were $1\frac{1}{8}$ in., and on the electric hoist, $1\frac{1}{2}$ in. All bridles were 48 ft. long, made in three sections, and fitted with iron rung ladders from the top of the skip to the top of the bridle.

With this hoisting equipment the shaft was sunk 368 ft. in 29 days in February, and 422 ft. in 31 days in March. During this period the shift routine was as follows :—

The shift interval was from blast to blast, usually eight hours, sometimes extended to nine, and sometimes as short as seven.

When the shaft bottom was clear of fumes, the shaft sinker and the helper, each with nine boys, descended to one sett above the manifold platform. The manifold platform was inspected, and, if damaged, repaired. The timber and shaft walls were inspected and dressed down to the bottom of the shaft. The remainder of the native shift was then lowered with all hoists, taking about ten minutes, and lashing commenced. The native strength at the shaft bottom was about 80 (20 machine boys, 20 spanner boys, 3 jumper boys and 37 lashing boys).

During the lashing period the boys were distributed as follows :— The machine boys did the picking, breaking up and lifting of big rocks. They also operated the Quimby pumps when necessary. The spanner boys and jumper boys assisted in the lashing, with the exception of three boys who operated the bell wires, under the direct supervision of the helper. About 60 boys were therefore continually lashing, 20 to a skip, when three skips were at the bottom at the same time. The maximum number that could lash into any skip at one time, except skips 1 and 6, was about 40.

The lashing boys' equipment was North British rubber suits, at least two aluminium hats each, iron lashing shoes and lasher shovels B4 (renewed once a week). The lift from the top of the broken rock to the lip of the skip was 50 in. back and 40 in. front.

The time required to clean a $4\frac{1}{2}$ ft. round (90 skips, 225 tons), was usually four hours. In a shaft bottom of this area, if 3-ton skips could have been used in all compartments, this lashing period could possibly have been reduced by 20 per cent., or a 5 ft. round cleaned in four hours.

Blowing over the shaft bottom was not started until all broken rock had been removed. The preliminary blowing over, to complete the cleaning, was done with 1 in. blow pipes, flattened at the ends. The lashing boys were sent to the surface after this preliminary blowing over, and the sinker and helper blew over the shaft bottom again with approved copper blow pipes, plugged all sockets and blew out misfires. The sketch of the shaft bottom was made by the helper and countersigned by the sinker as the responsible official under Regulation 100 (13) (*b*).

On completion of the examination of the shaft bottom, the machines and drills were lowered and drilling commenced. The round consisted of 100 6 ft. holes (cut holes 7 ft.), and was drilled as shown in Fig. 10. 18 to 20 machines, 3 in. and 3½ in. hand-held drifters were used. Machine 1 in. air hoses were 25 ft. long, connected to four 6-tap 2 in. manifolds, suspended from four 2 in. hoses, behind the wall plates, from 6 in. manifold with five 2 in. connexions at the end of the 6 in. pipe.

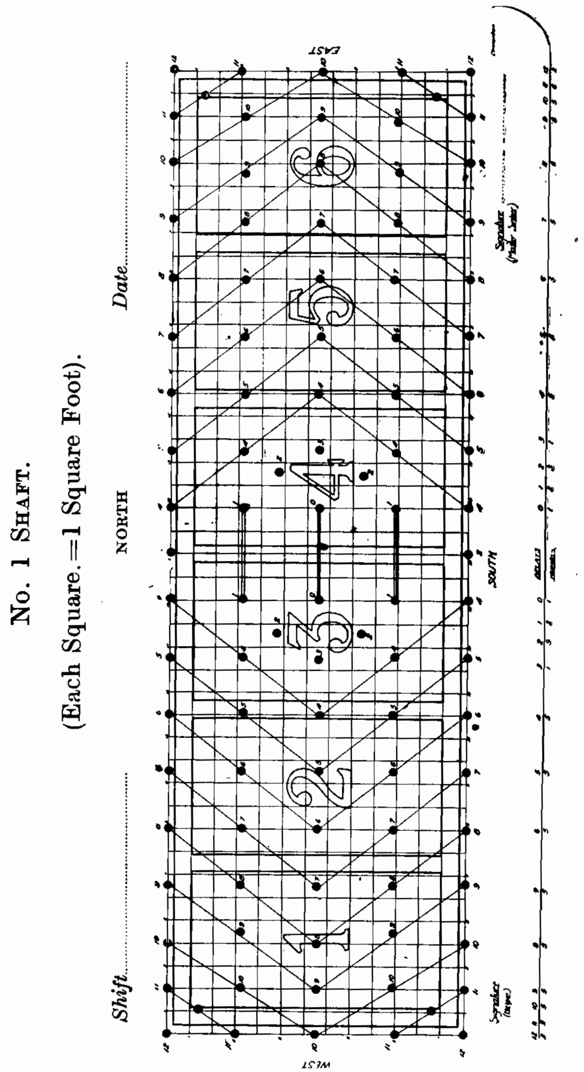


FIG. 10.

Drill steel (1 in. hexagon) used, was as follows :—

Size.	*Maximum Length.*	*Gauge of Bit.*
1	3 ft. 0 in.	2 in.
2	5 ft. 0 in.	$1\frac{7}{8}$ in.
3	6 ft. 6 in.	$1\frac{3}{4}$ in.
4	7 ft. 6 in.	$1\frac{5}{8}$ in.
5	8 ft. 6 in.	$1\frac{1}{2}$ in.

The machines were fitted with anvil blocks, but early in March the chucks were altered to take $1\frac{1}{2}$ in. by $\frac{7}{8}$ in. round hexagon shanks. Before changing over, the drilling speed in the hard quartzite encountered during that period was about 4 in. per minute. After altering the shanks an increase in drilling speed of about 20 per cent. was immediately apparent.

The drilling speed of the $3\frac{1}{2}$ in. machines was greater than the 3 in. machines, but owing to the greater weight of the $3\frac{1}{2}$ in. machines and the difficulty in handling, a machine boy could usually drill five or six holes in the same overall time with a 3 in. machine as with the heavier machine, and with less effort.

The drilling of the round therefore took about two hours. During the drilling period there were 46 boys on the shaft bottom. On the completion of drilling, the machines, steel and 30 boys were sent up. Charging up was then completed in 30 to 40 minutes, as described below under " Blasting."

In a shaft of similar dimensions, equipped with six 3-ton skips, at a depth not exceeding 3,000 ft., in rock which permits of a drilling speed of 8 in. or more per minute, it seems possible that 465 ft. might be sunk in 31 days.

Timbering.—When sinking at a rate of between 13 ft. and 14 ft. per day, it is necessary to swing two complete setts of timber (6 ft. 9 in. centres) every 24 hours. This daily operation can be completed in an hour to an hour and a quarter by two timbermen and sixteen boys, and is usually done during the drilling period of the afternoon shift. The procedure, in some detail, is as follows :—

The timber is laid out on the bank as it has to go down, *i.e.*, four wall plates opposite No. 5 compartment, end plates opposite Nos. 1 and 6 compartments, studdles, dividers and sinking guides opposite the compartments, as required.

The slings are put on shortly before the setts are to be lowered. Wall plates are slung by 15 ft. slings attached to eyebolts through the hanging bolt holes 10 ft. from the end. Dividers and end plates are slung by 12 ft. slings attached to timber shackles through the guide bolt holes in the guide shoes. Sinking guides are slung from an eyebolt through a special hole. Corner posts and studdles are secured by a hemp rope through a hole drilled about 18 in. from the top end. They are lowered inside the skips.

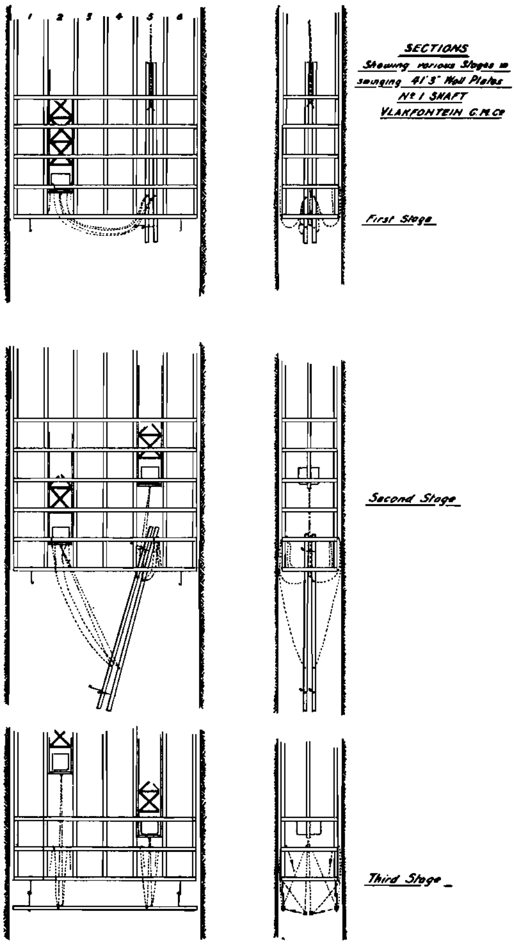


FIG. 11.

As soon as the skips are available, two timbermen and their boys go down to the bottom sett in compartments 2 and 4, and place the top portion of the hanging bolts in the bottom sett. They also bring slings across from No. 2 compartment to No. 5 compartment, underneath the dividers, and put hemp ropes and eyebolts below the dividers and behind the wall plates of the bottom sett, and take a turn round the wall plates of the second bottom sett.

The wall plates are then lowered, slung below the skip, in No. 5 compartment, until the second lowest hanging bolt holes are opposite the bottom sett. In this position the eyebolts, with slings, are inserted in the hanging bolt holes corresponding to No. 2 compartment on the wall plates, and attached to skip in No. 2 compartment, and hanging bolts inserted in the end, or No. 1 compartment holes. No. 5 skip is then lowered and No. 2 raised, simultaneously, until the bottom of the sling reaches the bottom sett. Hanging bolts are then inserted in the end, or No. 6 compartment, holes. The eyebolts, with hemp ropes attached, are inserted in No. 5 hanging bolt holes. The wall plates, hanging together in the centre of the shaft, are then again lowered by No. 5 skip and raised by No. 2 skip until they are in the approximately correct horizontal position. The wall plates are kept slung together while raising to the horizontal position to avoid contact with the walls of the shaft. The hemp ropes are then pulled taut and the slings slackened off, thus allowing the wall plates to part company and swing out to their respective sides.

The boys of Nos. 1 and 6 compartments then climb down on to the swinging sett and connect the bottom and top hanging bolts. The wall plates are now swinging on the hanging bolts of Nos. 1 and 6 compartments. The boys in the other compartments then climb down and connect all hanging bolts.

The slings are then taken off and the skips rung clear. The remaining two wall plates are then lowered from the surface, and swung in exactly the same manner. When both pairs of wall plates are swinging on their hanging bolts, and the skips rung clear again, the banksman hangs two end plates, two dividers and two sinking guides each under Nos. 1 and 6 skips, and places corner posts and studdles for the first sett inside the skips, fastened with slings as mentioned above, and tied at the top with a hemp rope, and these are lowered to position above the swinging setts. As they reach this position, the skips in compartments 2 and 5 arrive at the bank, and the slings of two dividers and two sinking guides (lying on the bank) are attached to the bottom of each skip, and the corner posts and studdles for the second sett put inside the skip. These skips are then rung up, the dividers and guides swing clear in the shaft, and the banksman rings clear.

When the timbermen see skips 1 and 6 move down, they ring them down to position and proceed to put the dividers in. The two timbermen, with one boy each, stand on the bottom sett and loosen the ropes which secure the tops of the dividers to the slings. The dividers, slung at the centre, swing into a horizontal position. The boys on the swinging sett hook them over the wall plates. The sharp taper of the joint (8 in. top, 4 in. bottom), allows the divider to fall right into position without hammering. The divider hooks prevent the wall plates from opening out.

The skip in No. 3 compartment is waiting with the dividers and sinking guides for the centre compartments, and these are put in place. The sinking guides are bolted at the top only, as the setts are not yet tightened up.

Corner posts and studdles for the first sett, which are inside the skips in compartments 1 and 6, are taken out, put in position and secured by their ropes to the sett above, and a boy steadies each one. Boys then start to tighten up the hanging bolts, and the skips in Nos. 1 and 6 compartments are rung clear. The skips in compartments 2 and 5 arrive with the studdles and corner posts for the second sett, and they are placed in position in the same way. The centre hoist is handed over to the sinker as soon as possible, so that he can commence bailing. After the setts are completed the sizes of the blocks required for the previous two setts are measured.

After the round has been blasted and lashing commenced on the next shift, the same timbermen and boys take down 36 measured blocks for two setts (the third and fourth from the bottom) and four blocks for the bottom sett.

The blocks are secured by ropes and clamps, and these are not removed until the blocks are wedged. The bottom sett is temporarily blocked to prevent any movement of the sett on the long axis of the shaft when a skip is resting on an uneven bottom. Without this blocking there is a danger of the timber being shifted out of plumb by the side thrust of the long bridle of a skip on an incline bottom, with possible jamming of a skip in an adjacent compartment, slack rope and subsequent falling of the jammed skip when the skip on the bottom is rung away.

For permanent blocking, the silk lines are hung from a given and checked plumb mark, 3 in. from the end plates and 3 in. from the wall plates in opposite corners. This plumb mark is given every 12 setts from the steel plumb lines. The four corners are blocked from these lines.

A line is run from end plate to end plate. The intermediate blocks are then driven up with wedges until the wall plate is 4 in. from the line over the whole distance.

Steel 20-gauge piano wires on reels, previously on the banks but brought down to a new base, checked by the surveyor, on the wall plates opposite the bottom cable junction chamber as sinking proceeds, are used for the plumbing. Two lines are hung in diagonally opposite corners of the shaft, and the position of each is 5 in. from the wall plate and 5 in. from the end plate. The lines are lowered from the reels weighted at the ends with a $\frac{5}{8}$ in. nut, and are left hanging in the shaft. When the lines are used for plumbing, a 45 lb. plumb bob is attached in the following manner. Two 12 in. by 2 in. planks are put diagonally across the timbers and secured by ropes (if the plumbing is not done at the manifold platform). An iron bucket, 3 ft. deep by 2 ft. wide, is placed on the planks and also secured by a rope. The 45 lb. plumb bob, secured by a $\frac{1}{2}$ in. hemp rope, with shackle, to the timbers, is then attached to the steel plumb line and lowered into the bucket by the $\frac{1}{2}$ in. rope. When the weight has been taken by the plumb line the $\frac{1}{2}$ in. rope and shackle are removed. The heavy plumb bob steadies very quickly. The bucket and planks are a precaution against the breaking of the wire.

The manifold platform is lowered three setts every day or two by a third timberman during the lashing period of the morning shift. The platform consists of 9 in. by 3 in. pitch pine planks, with straight grain, cut to lengths of 6 ft. 8 in. fitted with cleats to hold them in position against the dividers and end plates. They are held down by sprags and wedges.

The planks are lowered by the timberman's boys with ropes 40 ft. long. The ropes have eyebolts spliced in the ends, the planks in the top position are secured to the eyebolts and the ends of the ropes tied round the setts before the planks are lowered.

Bearer hitches are cut from a special platform 200 ft. to 300 ft. from the shaft bottom. The hitches are cut 12 in. to 18 in. deep with jackhammers, using drills with rose bits, and are not blasted. The drilling of the hitches is done during the lashing shift.

The 6 in. air and 2 in. water pipes are extended when necessary by the manifold timberman at the beginning of the morning shift, while the sinker is dressing down. The 30 in. ventilation pipe is extended by the same man during the drilling period of the night shift. The blasting cable is extended with the manifold platform.

Hoist and rope inspections are made during the drilling period of the morning shift. Permanent guides are put in during the drilling periods of the morning and night shifts.

Blasting.—Up to January, blasting was done with 1¼ in. 60 per cent. gelignite, No. 8d. detonators and Bickford-Smith special smokeless sinking fuse in lengths of from 12 ft. to 16 ft. per hole. The cost per blast for fuse, detonators and igniters was £2 15s.

In January electric blasting was introduced. Rolfes, Limited, detonators were chosen in preference to those offered by African Explosives for the following reasons :—

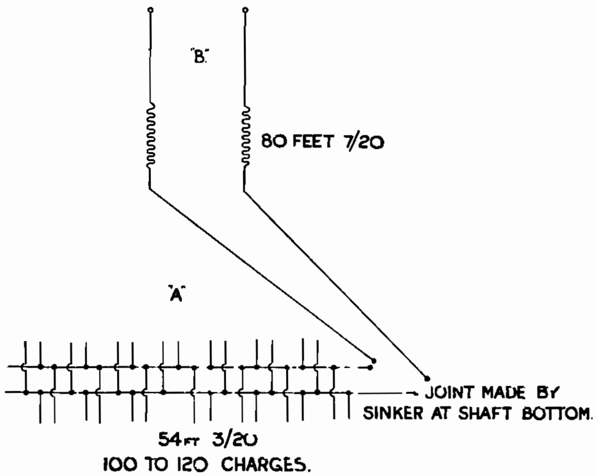
(1) The African Explosives detonator had a venthole in the side which seemed to present the possibility, on firing, of igniting the gelignite, or of permitting the access of water.

(2) Rolfes, Limited, could supply detonators with any length of wire, and any number of delays, whereas African Explosives, at the time, could not.

(3) Rolfes, Limited, offered a new inverted wax primer patented, which presented the following advantages for shaft sinking :—

- (*a*) The preparation of the wiring, detonators and primers could be completely made on the surface by an apprentice electrician, or junior handyman, in a building in which it was not necessary to store explosives.
- (*b*) Safety in handling in the shaft.
- (*c*) The position of the detonator in the primer, and the routine of charging up, ensured the placing of the primer at the bottom of the hole, with consequent recovery of the primer from the bottom of misfired holes, and
- (*d*) The number of the delay could be stencilled on the primer.

The shaft bottom sketch, Fig. 10, shows the arrangement of holes and the order of firing. No. 0 is a six-second delay, and there is a two-second interval between delays. Thirteen sets of delays are used. The primers are attached to the bus wires on the surface, in the order and at the intervals shown at the bottom of the shaft sketch. Sets are prepared, coiled up and placed in special boxes, ready for each blast. A junior handyman can prepare three complete sets in eight hours. Four sets are always kept on hand.



DETONATOR CONNECTIONS AT SHAFT BOTTOM.

FIG. 12.

The bus wires are 3/20 insulated, non-specification, and are laid along the shaft bottom. After charging up, they are connected to two 7/20 wires (B in Fig. 12) suspended from the manifold platform. These two wires are attached to a switch (C in Fig. 13) at the manifold platform by thumb screws. This switch is a two-pole 60 amp. knife switch, enclosed in a waterproof connexion box.

The cable down the shaft to this switch is a 7-core 7/20 cable and is attached to a reeling drum in the junction chamber next above. The cable from the reeling drum to the surface is the same—7-core 7/20. The advantages of using this type of cable are :—

(1) Voltage drop in the total length of shaft is comparatively low.

(2) The seventh wire serves as an earth wire for the cable, and

(3) The permanent bell cable is installed during the period of sinking and is ready for use at the completion of sinking.

The main blasting switch is located in a separate locked brick house, the key of which is kept in the shaft office and must be signed for. The blasting cable for the shift is plugged into an earth socket (E in Fig. 13) painted green. Before blasting, this cable must be removed from E and plugged into blasting socket F (in Fig. 13) painted red, which is connected with the main switch G. The blasting switch is a two-pole Ellison spring limit switch, the main feature of which is that the lever must be *held* in the *ON* position to make contact. At all other times the switch is released by the spring and the circuit is open.

The red and green lamps (HH in Fig. 13), visible from outside the building, are an additional safety precaution, and indicate the position of the plug attached to the blasting cable. The plug is always in the earth position, green, except when the sinker removes it to the blasting position immediately before blasting.

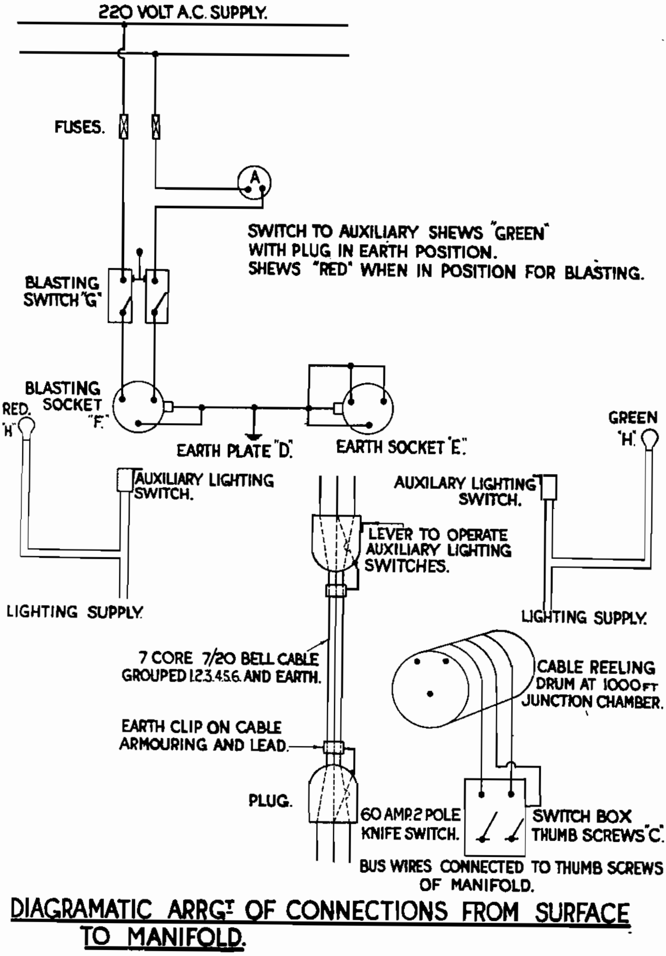


FIG. 13.

An ammeter is also included in the switch circuit to indicate whether the current is flowing when the switch is in. A voltage of 220 at the surface was used when 3,000 ft. of cable were in use. When a fourth length of cable was added, making the blasting cable 4,000 ft. long, the voltage was increased to 340. Experiments on the surface have shown that a safe current to use is between 0·5 amp. and 1 amp. *per detonator*. The principal part of the detonator is a low tension bridge, covered with a pyro-technical composition. When the current passes, the bridge wire glows, ignites the composition and the subsequent flash ignites the fuse end, under pressure of gas. If the current is too low, the bridge wire will not heat up sufficiently to ignite the composition. If the current is too high, arcing occurs between the bridge terminals, the composition is exploded and the copper igniter shell bursts, releasing the gas, thereby reducing the burning rate of the fuse, and the time of the delay is altered. In case of extremely high voltage, there is danger of the exploding igniter shell igniting, or exploding, the gelignite with which it lies in contact in the charged hole.

To eliminate the possibility of induced currents in the blasting cable, the headgear and steel structures in the vicinity were earthed, also bell wires, plumb lines, ventilation pipes and shaft columns, as shown in Fig. 14. Lightning conductors were fitted to the headgear and engine rooms. The bell wires and plumb wires were overlooked in the first instance. When the shaft timbermen reported shocks from these wires during an electric storm, this omission was rectified.

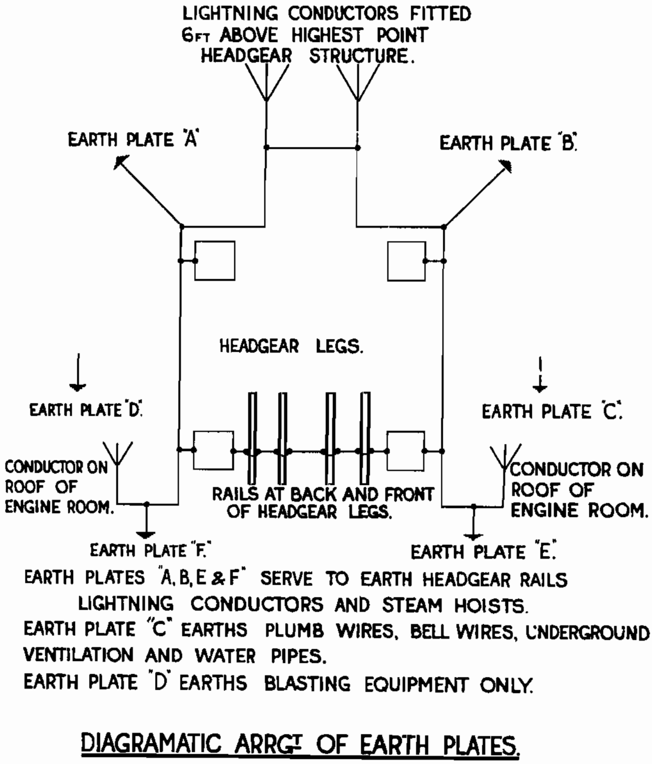


FIG. 14.

Charging up operations actually took place, on one occasion, at the height of the heaviest storm experienced during the season, with lightning apparently striking in the immediate vicinity of the headgear.

The cost of electric blasting is at present in the neighbourhood of of £4 10s. per blast, made up as follows :—

Purchased detonators	£3	16	0
Wire		8	0
Preparation of sets		5	0
Electrician's time		1	6
	£4	10	6

which is approximately 35s. more per round than with safety fuse.

The apparent advantages are :—

(1) Safety—the sinking crews and drivers are relieved of the usual tension when blasting with fuse.

(2) Less misfires—1 per cent. as against 3·3 per cent. with fuse, for 300 previous blasts.

(3) Improved breaking
(4) Less damage to shaft timber
} These two advantages indicate the difficulty of accurate timing with fuse in a large shaft.

(5) Lashing expedited—The round is so broken that the rock lies piled high in the centre of the shaft, and the outside skips can be filled to a certain extent from above.

(6) Faster charging up—A round of 100 holes can now be comfortably charged up in 30 minutes.

Before changing over to electric blasting, a full size model of the shaft bottom was laid out on the ground on the surface. Short lengths of 1 in. pipe were sunk in the ground to represent the drilled holes, and dummy electric detonators and primers prepared. The sinking crews were trained and drilled in the correct charging up procedure.

Since the record footage of 422 ft. in March was accomplished, the following are the monthly footages :—

April—285 (Pump station cross-cut and pipe raise cut.)

May —352 (Two hoists only in service—the drop valve Robey having reached its limit of wind.)

June —347 (Sinking stopped for two days while changing over to the second permanent winder.)

The depth of the shaft at 30th June was 3,560 ft.

Introductory Remarks by the Author : I have two reasons for presenting these notes. One is, that in March of this year Vlakfontein No. 1 Shaft achieved the world's record for one month's sinking, and it seemed likely that the method adopted and the equipment used, even if not differing greatly from present-day Rand vertical sinking practice, would be of some interest to anyone engaged in shaft-sinking. The other is, that electric blasting has been proved so satisfactory for vertical shaft-sinking from the surface that an exchange of ideas on the method of its use may lead to its universal adoption for this type of work, and to its further application to development work, with a possible improvement in working conditions in so far as safety and efficiency are concerned.

I should like to draw your attention to several features of the shaft-sinking operations described in the notes that may be of special interest —in the first place, to the dimensions of the shaft : six compartments, each 11 ft. by 6 ft., with a cross-sectional excavation area of 600 sq. ft., in this respect the biggest shaft on the Rand.

Secondly, to the fact that with three winches, one double-drum and two single-drum, and sinking buckets, the shaft was sunk at an average rate of only 142 ft. per month for five months. The two outside compartments not being served, cleaning was slow and timbering difficult. Only two blasts per 24 hours could be obtained. A preferable equipment would have been six single-drum winches. Cleaning would have been faster, timbering easier and safer, all compartments could have been equipped and blasting could have taken place on three shifts in the 24 hours. It is probable that an average rate of 200 to 240 ft. per month could have been obtained. The one objection to the single-drum winch arrangement is that 18 engine drivers are required.

The point is that in the first 12 months, during the erection of the permanent headgear and permanent hoists, a shaft can be sunk to a depth of nearly 2,000 ft., under favourable conditions, with temporary equipment, purchased locally.

Thirdly, in so far as world record breaking is concerned, I should set the par, or standard scratch of the month's run at 465 ft., or an average of 5 ft. per blast. An average of 4·54 ft. per blast for 93 blasts was obtained at Vlakfontein. This could have been improved on, as suggested in the notes, if the ground had permitted of faster drilling, and if all hoists could have operated 3-ton skips, instead of 3, 2½ and 2 tons, as described.

It is difficult to conceive of faster sinking than an average advance of 5 ft. every eight hours. In a shaft narrower on the short axis than Vlakfontein, filling of the skips from all sides is not possible, and cleaning out is slower, even than in proportion to the tonnage to be cleaned. Skips, smaller than 3-ton, are filled so quickly that the proportion of the time they are on the bottom to the time that they are travelling is too low. Larger skips might mean too high a lashing lift, and the time to fill would be exhausting.

If the skips are not all of the same size, the different hoists get " out of step," *i.e.*, three skips may be at the bottom at the same time, and there is not sufficient room for the maximum number of boys to lash.

If the shaft is deeper than 3,000 ft., the travelling time of the skips increases the lashing period, but between 2,000 ft. and 3,000 ft. the time taken to raise a skip to the tip allows a breathing spell for the lashers, which seems to permit them to work at the necessary high pressure for four hours.

As far as the drilling period is concerned, if the round can be drilled over in under an hour and a quarter not much is gained, as this period is required for swinging setts, permanent guides, hoist and rope examinations, etc. If the holes for a 5 ft. round could be drilled in an hour to an hour and a half, then sufficient time remains for cleaning. If drilling is slow, the length of the round is fixed by the balance of time required to clean it out.

In connexion with the timbering, the comparatively close-set centres, 6 ft. 9 in., required the swinging of two setts every 24 hours. The width of the shaft made the use of stage planks on the short axis of the shaft difficult and cumbersome, and these were dispensed with. Short stage planks between dividers were used only for placing studdles and corner posts in position. To install two complete setts daily, in the time available, without mishap and without interfering with the drilling operations, is something of an accomplishment, and the procedure is therefore given in considerable detail, for those who may be interested.

As far as the electric blasting is concerned, I should first like to make acknowledgements to Mr. Hebbard, of Rand Leases, for his advice and guidance. I believe that he can claim to have pioneered, or at least restarted, electric blasting in sinking large rectangular shafts from the surface on the Rand.

There is no question but that the extra cost is fully justified. The advantages of blasting 100 or more holes from the safety of the shaft bank, as compared with the operation of lighting that number of fuses at the bottom of the shaft, and getting away in a hurry, are obvious.

The number of misfires, owing to improvements in the manufacture of the detonators, has now dropped to about 1 per 500 holes. The timing of a large round can be so perfectly controlled that breaking is definitely improved.

I submit samples of Rolfes and African Explosives electric detonators. The differences are :—

1. The Rolfes igniting bridge is a low tension bridge, while the African Explosives detonator requires about double the current, I understand, to ignite it.

2. The gas is released in the African Explosives detonator, and confined in Rolfes.

3. Rolfes use ordinary sinking fuse with a burning rate error of 6 per cent., while African Explosives use a special fuse with a similar burning rate, but a marginal error of 3 per cent.

4. Rolfes supply an inverted wax primer made under a patented process claimed to seal without damaging the bent fuse. African Explosives, until recently, have been unable to supply a satisfactory inverted primer. On page 21, paragraph 2, of their "Report on Investigation into the Properties of Explosives and their Behaviour in Boreholes" they say: "As these tests showed that the difficulties of waterproofing the sharply bent fuse of the primers had not been overcome satisfactorily, it was decided not to deliver any inverted inert primers for test on the mines but to refer the matter to the fuse manufacturers for suggestions."

The use of this inverted wax primer with electric detonators in shaft-sinking has proved entirely satisfactory, and some of the reasons for its use at Vlakfontein are indicated in the notes.

Shaft-sinking costs and details of permanent equipment I have withheld, as the shaft is still being sunk.

H. J. Hebbard : Some notes on electric blasting as carried out in No. 11 Shaft, Rand Leases, which is a seven-compartment rectangular shaft, are submitted.

I cannot claim to have pioneered electric blasting, as the Crown Mines have used this form of firing in their sub-shafts for many years. I understand that the number of holes in their shafts would amount to approximately 50 per round with only one blast per day, therefore no difficulties were presented in connecting the wires in the shaft bottom.

In large shafts the time taken to make, say, 224 connexions in a comparatively short period with three blasts per day, presented a difficulty, which, if not overcome, would have made electric blasting prohibitive. I can only claim, in some measure, to have organized electric blasting, to enable the period of charging up to become faster or more expeditious than the ordinary fuse firing.

Electric Blasting Arrangements at No. 11 *Shaft, Rand Leases.*—No. 11 is a rectangular shaft of seven compartments ; six of these are skip-ways, the inside dimensions being 8 ft. by 5 ft., and the seventh is equipped with a cage for installing columns, cables, etc., and is served with a single-drum 200 h.p. geared electric hoist. The inside dimensions of this compartment are 8 ft. by 7 ft. 6 in. The overall length outside of timbers is 43 ft. 6 in., and the width is 9 ft. 6 in., which requires an excavation of 45 ft. by 11 ft. equivalent to 495 sq. ft.

Pending the installation of the two permanent Ward-Leonard winders, sinking for the first 1,000 ft. was accomplished by means of two 100 h.p. electric winches which necessitated the use of electric shot firing. When the permanent hoists were put in commission, it was decided to discard electric firing in favour of fuse firing, on account of the higher cost of the former.

After sinking for two weeks by means of fuse firing, the shaft being in a very hard "Hornblende Porphyrite" dyke at the time, it was noticed that the shaft timbers were being damaged to such an extent that the bottoms of the timbers, especially the dividers, were almost completely rounded, notwithstanding the fact that the holes were charged with the same amount of explosive as when using electric shot firing ; whereas with the electric firing, the bottoms of the timbers were only peppered. After consideration, it was decided that the advantage of having sound timbering in the shaft outweighed the disadvantage of the extra expense incurred by the use of electric firing, and we reverted to this method accordingly.

Before giving a description of the electric firing arrangements and the routine followed, it would be as well to discuss the advantages and disadvantages of the system.

Advantages (1) The safety of all persons concerned in the blasting operations is definite by reason of the fact that they are all on the surface when the firing switch is closed.

(2) Little damage is done to the timbers.

(3) The timing of the blast is perfect, ensuring the best results. With fuse firing in a confined space, as in the shaft bottom, mistakes are liable to be made in timing owing to confusion, due to the large number of fuses in the shaft bottom.

(4) The tension and excitement during the lighting up period in fuse firing, particularly in a wet shaft, is eliminated, and thus the possibility of not lighting some of the holes is non-existent.

(5) Less time taken in charging up. The round can be charged in 30 minutes.

(6) Owing to the short length of fuse between the electric and firing detonator, the danger of misfires owing to " cut-offs " is greatly minimized, and the possibility of the explosive burning is also reduced, as the fuse does not run the full length of the hole as in fuse firing. (Misfires average approximately 1 per cent.)

(7) Misfires are easily detected by the wires projecting from the hole.

Disadvantages (1) The electric firing system is more expensive.

(2) The cut and sump must always be located approximately in the centre of the shaft, as the African Explosives Company supply only 10 delays.

(3) With the instantaneous detonator, the cut must not be drilled too flat, otherwise the shaft timbers may be damaged.

Description of Electrical Arrangements and Routine followed at Blasting Time.—The power supply is taken from one 15 K.V.A. 2,100-500-volt single phase transformer, reserved exclusively for blasting. This is located in the basement of the main winder room, no one but authorized persons having access thereto. Power is led from the transformer to the firing box situated at the shaft head by 230 ft. of ·0225 cable, two legs of which are common, armour earthed to main earth.

The firing box, made of wood, contains the actual blasting switch, of the two pole constant pressure type, earth plug and blasting plug. From this box the blasting cable is led down the shaft to the nearest surveyor's plumbing station, cut in the south end of No. 7 compartment, the cable being extended 600 ft. at a time to one of these stations as sinking proceeds. (Note.—Levels are cut at 200 ft. intervals down the shaft from the 17th Level.) This cable is a special screened core with earth core, 3-core construction, but two legs are joined to provide a straight circuit, and it is clamped at 30 ft. intervals down the shaft and terminates in a box with a three-pin socket located on the platform. (Note.—This cable is left in the earth plug in the blasting box and only detached and plugged into the blasting plug just before the firing switch is closed.)

At the above-mentioned plumbing station an adjustable length of cable is situated, consisting of a small drum reeled with approximately 600 ft. of twin Vicma rubber-covered cable; the drum end, carrying a three-pin plug, terminates in a three-pin socket. The drum extension cable is Vicma rubber-covered twin 7/·036, and the final section Vicma with four 7/·036 leads attached.

The whole of this section of the equipment can be considered permanent, and it is subjected to a daily examination, the result of which is recorded.

The final section, consisting of 40 ft. of Vicma with four leads, 60 ft. long, 7/·036, completes the wiring. This section is examined daily on the surface by the electrician who attaches a tab with his initials, certifying that it is in order. This daily examination of cables may appear to be extravagant, but should there be a fault in the line during the night period, one can conceive that with no electrician on hand, the blast may be delayed an hour or two, which would throw the sinking routine out of stride, which is a costly business. As the bottom section of wire is subject to maltreatment through travelling, covering plugs are provided to eliminate faults as far as possible. A ring support, attached to the top of the trailing cable, is supplied so that the cable can be attached to a hook fastened to the shaft timbers. This obviates the necessity of winding the cable round the hook and possibly causing damage to the wires.

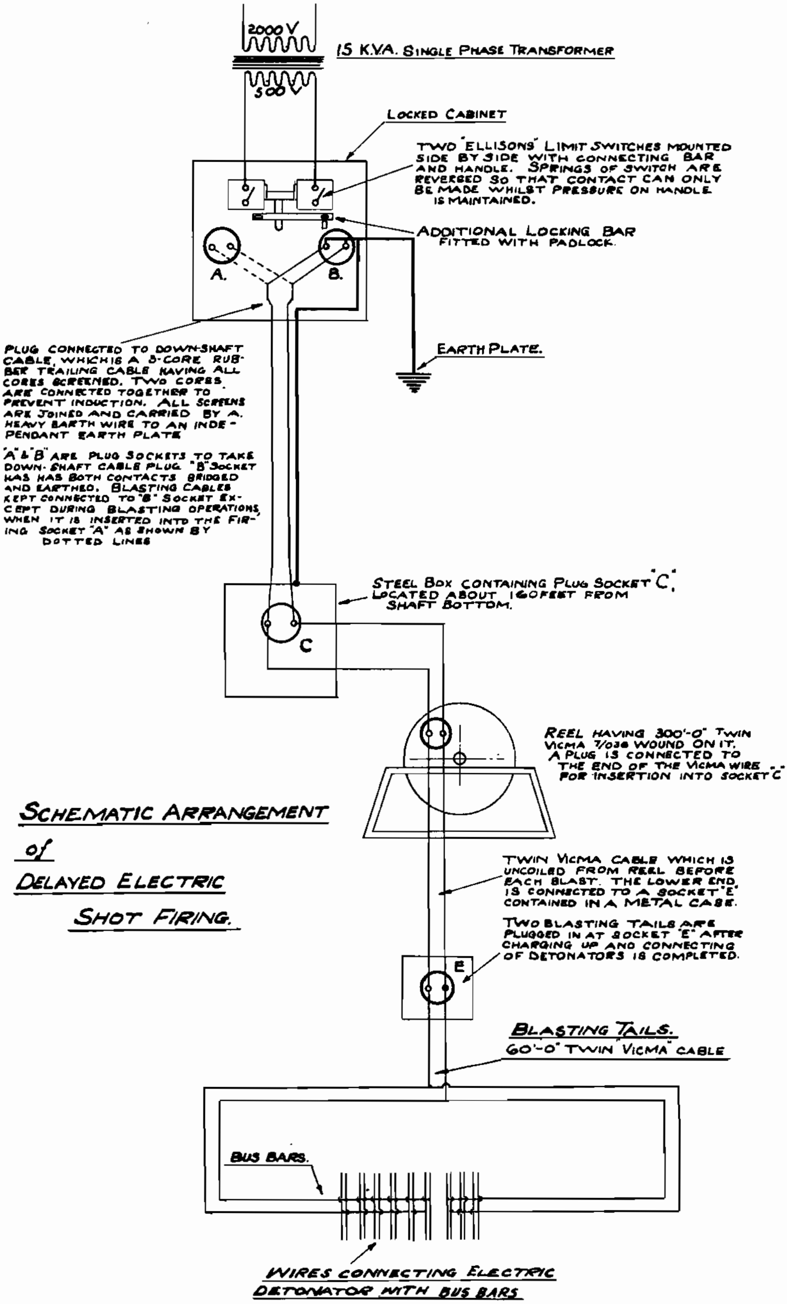
To ensure against inadvertent firing at any time, both the blasting box and the actual blasting switch are locked. The keys are retained by the banksman, and are only released on signature to the helper who carries them during the charging up operation. A duplicate set of keys is retained by the master sinker.

The helper, on coming to the surface for powder, obtains from the banksman the blasting box key and the switch key for which he signs. He then proceeds to examine the switch and plugs to ensure that they are in their correct positions. With the powder, he takes the certified set of bottom leads and proceeds to the platform, and hangs his trailing cable on the hook provided. He then goes to the shaft bottom and starts charging up.

The bus bar is stretched along the long axis of the shaft with 10 delays on either side of the centre where the instantaneous detonators are located.

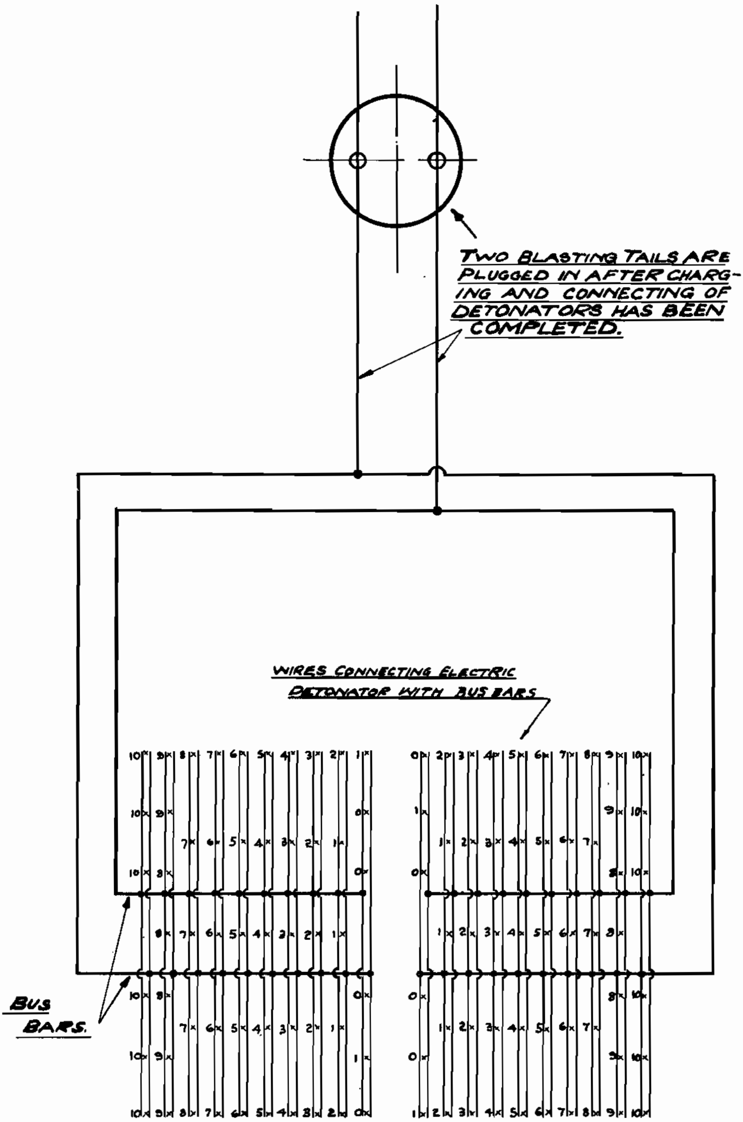
Charging up is started from each end of the shaft, working towards the centre. This avoids any scrambling over the holes which have been charged, and thus there is little danger of disconnecting or disarranging the wires. The primer cartridge is placed in the bottom of the hole followed by the required amount of gelignite, and is finally tamped.

Having charged up, the helper attaches his lead wires to the extreme ends of the bus bars, clears the shaft bottom, and proceeds to the lowest platform where he plugs in the trailing cable. He is then raised to the platform at the end of the permanent cable, where he again plugs in, and is finally raised to the surface. The skips are cleared and put in mid-shaft, after which the sinker unlocks the blasting switch, removes



2000 V
500 V
15 K.V.A. Single Phase Transformer
Locked Cabinet
Two "Ellisons" Limit Switches mounted side by side with connecting bar and handle. Springs of switch are reversed so that contact can only be made whilst pressure on handle is maintained.
Additional Locking Bar fitted with padlock.
A.
B.
Earth Plate.
Plug connected to down-shaft cable, which is a 5-core rubber trailing cable having all cores screened. Two cores are connected together to prevent induction. All screens are joined and carried by a heavy earth wire to an independant earth plate
"A" & "B" are plug sockets to take down-shaft cable plug. "B" Socket has has both contacts bridged and earthed. Blasting cables kept connected to "B" Socket except during blasting operations, when it is inserted into the firing socket "A" as shown by dotted lines
Steel Box containing Plug Socket "C", located about 160 feet from shaft bottom.
C
Reel having 300'-0" twin Vicma 7/036 wound on it. A plug is connected to the end of the Vicma wire for insertion into socket "C"
Schematic Arrangement of Delayed Electric Shot Firing.
Twin Vicma cable which is uncoiled from reel before each blast. The lower end is connected to a socket "E" contained in a metal case.
Two blasting tails are plugged in at socket "E" after charging up and connecting of detonators is completed.
E
Blasting Tails.
60'-0" Twin "Vicma" cable
Bus Bars.
Wires connecting electric detonator with bus bars

Fig. 15.



SCHEMATIC ARRANGEMENT of DELAYED ELECTRIC SHOT FIRING.

FIG. 16.

the blasting plug from earth, and plugs into blast. (Note.—The blasting plug is painted red and the earth plug green.) He then closes the main switch. After the blast the sinker replaces the blasting plug to earth, locks the switch and box, then hands the key to the banksman.

The relieving sinker proceeds underground, disconnects the two plugs—the one at the base of the permanent cable and the other for the trailing cable. The trailing cables are sent to the surface.

Written instructions have been given to the banksmen to the effect that they are responsible at all times for the keys, and can only allow them out of their charge on signature from either the helper or the electrician who examines the blasting equipment.

A log book has been provided, and specific electricians are appointed to examine, one hour before blasting, the Neon earth detector installed in the blasting system. The result of each examination is recorded in the book.

One hundred and ten detonators are used every blast, and by actual test, the detonators have exploded with $\frac{1}{2}$ volt. The makers state that one volt is ample. We do not agree with this for shaft sinking conditions, and consider that 500 volts are necessary for 110 to 120 detonators.

The electric detonators are supplied by African Explosives, and, with the exception of one consignment, have proved satisfactory. The failure was attributed to the waterproofing applied by the makers, which set up corrosion with the metal of the detonator, allowing water to enter the vent hole.

In the initial stages of sinking, the electric detonators with primers attached were connected to the bus bars by the sinker in the shaft bottom. This proved to be extremely slow, the process taking about two hours due to the care which had to be taken to make a minimum of 224 connexions with good contact. This has since been superseded by the present method. The electrician connects the detonators to the bus bar in their correct sequence, and the completed bus bar is handed to an authorized person for attachment of the primer cartridges. The primer cartridges are made up and dipped ready for transport underground, this operation taking place in the approved house.

The primer cartridges, attached to the bus bar, are transported underground in wooden boxes specially provided; each delay of five primers is secured in a sample bag which is clearly marked with the number of the delay.

The headgear and all adjacent tracks have been bonded and earthed to the main shaft earth. The down shaft blasting cable has been earthed to a separate independent earth to eliminate any possibility of induced currents.

The cost of electric blasting amounts to about £4 11s. 0d. per blast, which includes the cost of installing the equipment, and exceeds the cost of fuse firing by 41s. per round.

W. Allen : Mr. Vail deserves our thanks on his complete and clear description of the details attending the swinging of setts. As far as I know this subject has not previously been treated with the same thoroughness in any technical paper despite the very important part it plays in shaft-sinking. The operations require the highest degree of organization, care and skill, not only to ensure speed and accuracy but also to win the confidence of the drilling crew working beneath, against injury from falling material, thus enabling full concentration on drilling.

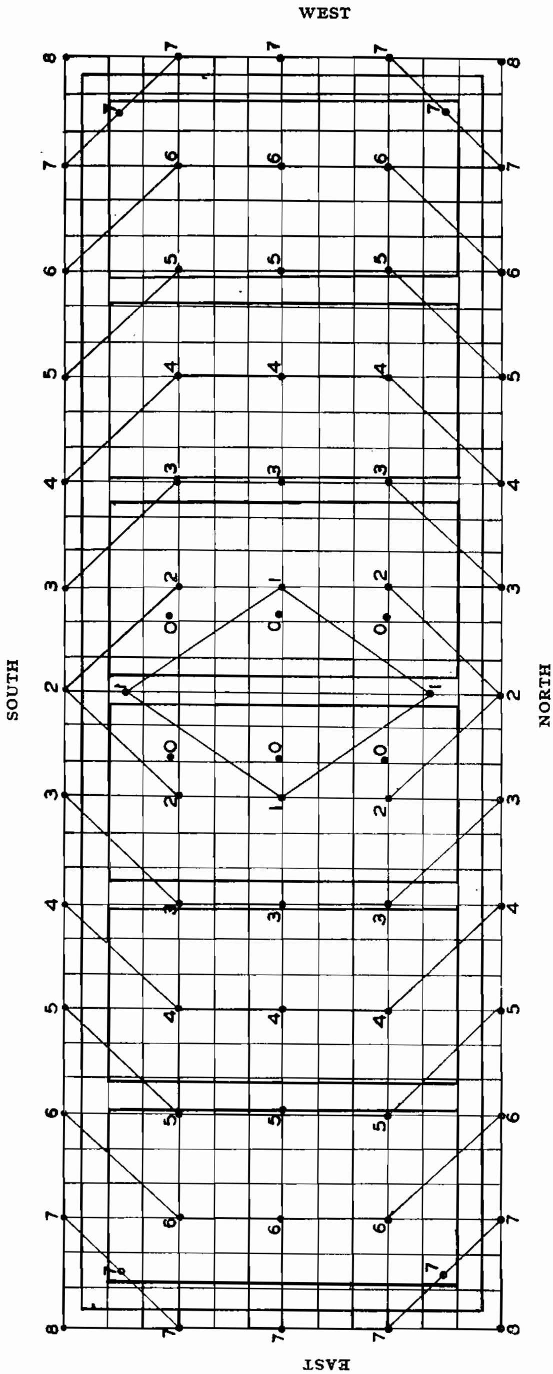
I have not seen any cost figures for the Vlakfontein sinking, but it is reasonable to assume that they will emphasize the need of speed. The overall charges on a large sinking shaft vary little from month to month whether the footage be small or great. These would probably be in the neighbourhood of £12,000 and, if the shaft attains its ultimate depth one month earlier, this sum is saved, in addition to which the earlier development of the mine is made possible.

These features are fairly widely recognized, but there are instances where it would appear that parsimony in the provision of proper sinking equipment has caused losses in shaft delays much in excess of the price of better equipment.

As regards electric blasting one precaution, that of keeping skips off the shaft bottom while charging up, has not been mentioned by Mr. Vail, and though it is undoubtedly practised at Vlakfontein and elsewhere, the matter is worthy of attention. At No. 2 Shaft, Venterspost, while drilling was in progress at a depth of approximately 300 ft. a flash of lightning struck the headgear and quite a severe shock threw natives off the machines. One bucket was touching the wet bottom of the shaft at the time, and it can only be surmised that the current travelled the hoisting rope.

I attach a plan (Fig. 17) of the shaft bottom showing the position and order of firing of holes in the round used for electric blasting at Venterspost. This was copied from Mr. Vail's layout with small changes. It will be noticed that the advancing banks of shots in the case of Vlakfontein form a Vee. It was felt in arranging our layout that if a misfire occurred next to the apex of the Vee, the latter would be over-heavily burdened.

Referring to the swinging of setts, the method in use at No. 1 Shaft, Venterspost, has one small difference from that used at Vlakfontein. Hemp spreading ropes are dispensed with. The slings used to raise the lower ends of the wall plates into position are passed over the back of the wall plates of the bottom sett and under the dividers and attached to the wall plates. By this means these slings both spread and raise the wall plates to the correct position and the hanging bolts are hooked together. The other ends of the wall plates are fitted on the surface with two $\frac{3}{4}$ in. wire rope slings fitted with a $1\frac{1}{8}$ in. eyebolt at each end. One eyebolt is put into the hanging bolt hole adjacent to the hanging bolt hole used for swinging the wall plates into the shaft. The slings are lowered with the wall plates and as they pass the bottom sett a native catches hold of the fore end of the sling and inserts the eyebolt in the corresponding hanging bolt hole in the bottom sett. When both



Each Square = 1 Square Foot.

FIG. 17.

slings are fixed the wall plates are lowered and the short slings spread the wall plates and hold them in the correct position to enable the hanging bolts to be hooked together. These $\frac{3}{4}$ in. wire rope short slings are made the length to conform to the distance between wall plates.

T. C. A. Meyer.—The methods followed seem to coincide broadly with the usual shaft-sinking practice on the Far East Rand. Water conditions in the shaft did not appear to offer any serious set-backs, and to those of us who have to sink through water-bearing strata, it is gratifying to know that there are dry shafts in the district.

Mr. Vail does not give any particulars as to costs of sinking to date; it would be interesting to know these figures when the first stage of sinking has been completed.

In describing electric blasting practice at Vlakfontein, Mr. Vail gives his reasons for preferring electric blasting to fuse blasting, and for using Rolfes delay action detonators in preference to those offered by the African Explosives and Industries, Ltd. I agree with him in most of his reasonings, and I am giving figures showing in detail the average resistance and the minimum current required to ignite delay action fuses of the two makes at present available.

At this stage I should like to mention that I do not consider that the two types of electric delay action detonators at present on the market are ideal in construction, and I am looking forward to the day when the detonator itself will have incorporated in it the time delay. Such detonators are in use in other countries.

RESISTANCE OF "SQUIBS" WITH 14 FT. LEADS.

	Rolfes.	*A.E.& I.*
No. of circuits tested	58	60
Mean Resistance (Ohms)	2·04	1·37
Highest Resistance (Ohms)	2·15	1·55
Lowest Resistance (Ohms)	1·95	1·27

MINIMUM CURRENT REQUIRED TO FIRE SQUIB.

ROLFES.		A.E. & I.	
No. TESTED: 58.		No. TESTED: 60.	
Current in Amperes.	Percentage of Squibs Fired.	Current in Amperes.	Percentage of Squibs Fired.
·25	66·0	·4	80·0
·27	29·0	·45	8·3
·29	5·0	·475	1·7
		·5	0·0
		·55	5·0
		·6	1·7
		·65	3·3
	100·0%		100·0%
Minimum safe current to fire squib. = ·3 amp.		Minimum safe current to fire squib. = ·7 amp.	

In a model round on the surface, 100 Rolfes detonators were connected in parallel to bus bars in the same way as for a blast underground, and a measured current of 40 amps. was passed, giving ·4 amp. per detonator ; all detonators fired.

This experiment was repeated ten times ; there were no misfires.

Mr. Vail uses 220 volts for firing, and now he has stepped up the voltage to 340.

From dimensions of leads given by him, I have calculated and give below the resistance of the circuits used at Vlakfontein for 2,000 ft., 3,000 ft. and 4,000 ft., and the corresponding currents and power consumed.

Circuit.	Calculated Resistance in Ohms.	Calculated Firing Current.	Calculated Firing Current per Detonator.	Calculated K.V.A. Consumed.	Voltage Applied.
2,000 feet	2·08	105·8	1·06	23·28	220
3,000 feet	2·87	76·7	·77	16·87	220
4,000 feet	3·67	59·9	·60	13·18	220
4,000 feet	3·67	92·6	·93	31·48	340

It will be seen that for a given voltage the current per detonator varies with each advance in depth, and decreases as the depth increases : the power consumed also varies and decreases with depth.

In order to keep the current per detonator and the power consumed as nearly constant as possible per blast, it will be necessary to transmit power down the shaft at as high a voltage as possible and as low a current as possible, and transform somewhere in the shaft to a predetermined lower voltage and higher current.

At Rietfontein (No. 11) the following scheme, which works satisfactorily, has been adopted. Transmit at 500 volts to a junction chamber, and transform here to 50 volts at the firing transformer ; from the firing transformer transmit at 50 volts to the bottom through a fixed length of wire, which is usually wound on a reel and unwound as the shaft advances.

By this method the resistance of the secondary circuit (the firing circuit) is kept at a constant figure of 1·25 ohms, giving at 50 volts a firing current of 40 amperes for the round. (This gives a current strength per detonator of just over ·4 amperes and a power consumption of 2 K.V.A.)

The shaft can be sunk for fully 400 ft. before the blasting transformer need be moved lower down.

By altering either the voltage of the firing transformer or the resistance of the leads from the firing transformer to the manifold platform, the distances between the firing transformer and the shaft bottom can be regulated to suit any set of conditions desired.

In the circuit from the surface to the firing transformer, forming as it does the primary circuit, a smaller current will be carried, thus, for a given size of transmission cable, the voltage drop will be correspondingly less.

In our case the percentage drop in voltage will not exceed 6 per cent. for 3,000 ft. of shaft sunk, using 3-core 7/20, and as the safety margin on the current per detonator is over 30 per cent., the small drop in voltage in the primary circuit will not affect seriously the current in the secondary circuit. This drop can be made correspondingly less by using heavier gauge cable.

24th July, 1936.