Winding Engines on the Croydon Goldfield: What the Documents Don't Say

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Winding engines are essential for efficient underground mining at depth. Advanced winding technology was available late in the nineteenth century, but isolated capital-starved goldfields like Croydon in North Queensland favoured small, inexpensive, and portable winders. Some documentary evidence is available on the field's winding technology but only the material remains can give a complete picture of what machinery the miners were using and why.

Croydon is a small goldfield in North Queensland's Gulf Country. Dry, hot and isolated, it presented miners with several problems during its heyday between 1885 and 1920. The technological answers to these problems were usually small-scale, suited to shallow mines on erratic ore deposits which were developed with very little capital. The winding engines employed to raise ore from these mines fitted the pattern. Small, slow and inexpensive, they lacked the technological advances becoming notable in gold mining elsewhere during this period.

Evaluating the miners' choice of technology depends on finding out exactly what technology was in use on the field in order to compare it with the range of technical options available at the time. Fortunately, documentary evidence about Croydon is plentiful. Because it was found relatively late for a Queensland mining field, it had all the benefits of an established infrastructure including a bureaucracy which left an excellent run of records on local conditions. These exist in the Queensland State Archives and overseas in the British Public Records Office and the Guildhall Library in London. As well, Croydon had four local newspapers, three of which survive in extensive runs. Local photographers, fascinated by headframes, contributed visual records. There are even two former residents who remember Croydon mining practices; one, Norman Rains, has a particularly good grasp of mining technology and remembers it in detail.

However, written sources which describe Croydon's winding engines are rare. This is no doubt thanks to the usual historical problem that some practices and machinery were so common and taken for granted that they are mentioned only in unusual circumstances, eg. the court case over maintenance of a rented engine in 1899.[1] Oral history cannot entirely fill the gap as the two oral history informants can only recall the period after about 1910. They grew up among the mines rather than working in them. Fortunately, until recently the bush around Croydon was littered with the remains of winding engines. Three field surveys of Croydon mine sites between 1983 and 1985 recorded details of these winders. In some cases this material simply confirmed what had been gathered from other sources; this of course is valuable in itself, as the historical method is a comparative one. Sometimes the physical evidence seemed to confuse the issue, raising more questions than it answered. Again, this can be valuable: history thrives on new questions. Generally, however, the information gained presented a much clearer picture of the technology in use on the field, enabling a more detailed analysis of miners' choices of winding technology.

WINDING ENGINE DESIGN

A steam winding engine is basically one or two cylinders (very large winders can have up to four) containing a piston which powers a crankshaft, which is coupled in some way to a winding drum or drums on which the mine rope is coiled. The rope goes over a pulley wheel at the top of a headframe or whip and then into a mine shaft, from which it pulls ore or bails water. It also lowers and raises miners and sends down supplies such as timber and explosives. The same tasks can be done by hand-operated windlasses or horse-driven whims and whips, but a winding engine is more efficient for big or frequent loads, or depths beyond 30 to 100 metres. Most were steam-driven for this period but electric winders were becoming more common in the early twentieth century.[2]

Winding plants have certain characteristics. First, they often have two cylinders. The problem with single cylinder winders is that steam engines have two 'dead points' when the piston is at either end of the cylinder. If the engine is stopped at a 'dead point', it will not start again without manual assistance. This can be dangerous in emergencies.[3] Two cylinders coupled to the drum and set 'at quarters' cancel out each other's dead points and are much safer. The engine can start quickly and reliably in any position. Two cylinders also mean that the winder can do without a flywheel, a heavy wheel which stores kinetic energy and helps an engine to run smoothly over the dead points. The drums can also act like flywheels to a certain extent.

Driving a winding engine is easier with reversing gear. It is not necessary; quite large engines raised by steam and lowered by gravity, slowing the descent by braking.[4] However reversing gear offered the driver more control. It also allowed more efficient running of the engines. The greatest load occurred at the beginning of a wind but as the skip or bucket travelled up the shaft, the weight of the rope lessened as it wound onto the drum so less power was required. Winding engines therefore needed considerable capacity which was wasted for much of their work. Reversing gear could be adjusted to shorten the travel of the steam valves so less steam was used as the requirement for power decreased.

Transferring the power of the engine to the winding drums could be done in a number of ways. Powerful plants intended for deep mines and heavy loads often had the drums set directly on the crankshaft; this is known as 'first motion'. Second motion machines used gearing to transfer power from the crankshaft to the drum shaft. This was usually toothed spur and pinion wheels, where a small pinion wheel on the engine crankshaft drove a bigger spur on the drum shaft.

Most drums were loose on the drum shaft. The driver would put the drums into gear by clutches, though winders without clutches were not unknown. Clutches could be put on the spur wheel or on the drum itself. They could be of the spur and pinion type, with the gear wheels set inside the drum, but most were jaw or friction clutches. Jaw ('dog') clutches were iron or steel discs set on the drum shaft beside the drum. They had projections which fitted into similarly-shaped recesses in a boss on the drum (Fig. 1). A lever would slide them along the

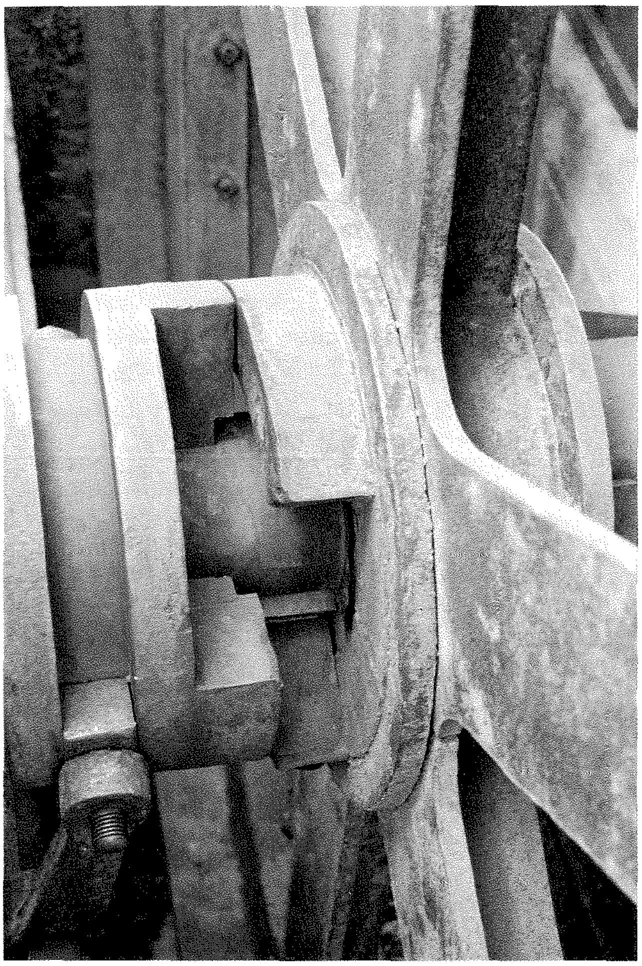

Fig. 1: Jaw clutch, Iguana Consols winder.

drum shaft until they locked into position. They were slow to use as the engine had to be jockeyed to manoeuvre them into line. Two miners in the True Blue Block endured a frightening couple of minutes when they lit the fuses for a charge of dynamite below and climbed aboard the bucket to be hauled up the shaft, only to discover that the engine was out of gear; they were fortunate to escape with minor injuries.[5] Jaw clutches could also jump out of gear or break. A more advanced method was the friction clutch, which came in a variety of designs. These were a band or a set of blocks which were forced onto a path on the drum by arms and a sliding sleeve. They acted rather like a brake in reverse, forcing the drum to move by frictional resistance. They were generally considered safer, smoother and faster to use than jaw clutches, though there was said to be a prejudice against them in Australia.[6]

The winders were stopped by admitting steam against the travel of the piston and by braking. On some the brakes were on the flywheel, a dubious practice for any other than first-motion plants. If flywheel brakes were used on geared engines, the teeth of the gear wheels could be stripped and the driver lose control of the rope. Rather, most brakes acted on a brake path built into the rim of the winding drums. The simplest was a brake shoe brought into contact with the brake path by a lever, but the area of contact was very small. A safer type was a band brake, a semicircular strap of metal attached to the engine bed in front of the drums and to a lever behind them. Pushing down the lever tightened the band onto the drum path. The brake band was lined with small wooden blocks to increase grip and reduce wear on the drum (Fig. 2). The action of the brake was assisted by brake weights in front of the drum. The area of brake contact could be further improved by carrying the brake strap the full circumference of the drum, an arrangement called a strap or disc brake. Large engines, however, used post brakes. These were two posts or heavy straps in front of and behind the drum, holding wood-lined brake shoes against the brake path. Pushing on the brake tightened the posts onto the drum.

The clutches, brakes and reversing gear were normally operated by hand or foot levers. However in larger engines the power required to operate these could be enormous – over 20 000 pounds (9 tonnes +) to brake a four-foot (122 cm) diameter drum with a full load, for example.[7] Small steam or air-driven engines were employed to do this.

There was little variation in drum design. Most were simple iron or steel reels with tall flanges to prevent the rope slipping off. Most were cast, but some were made from riveted plate; wear on the rope from the rivets no doubt made these less desirable than the cast product. The drum face could be grooved to allow the rope to settle evenly. Drums for flat winding ropes were made only the width of the rope, but for round ropes were wider and could have the rope lapping on itself. A step-up next to the drum flange was recommended so

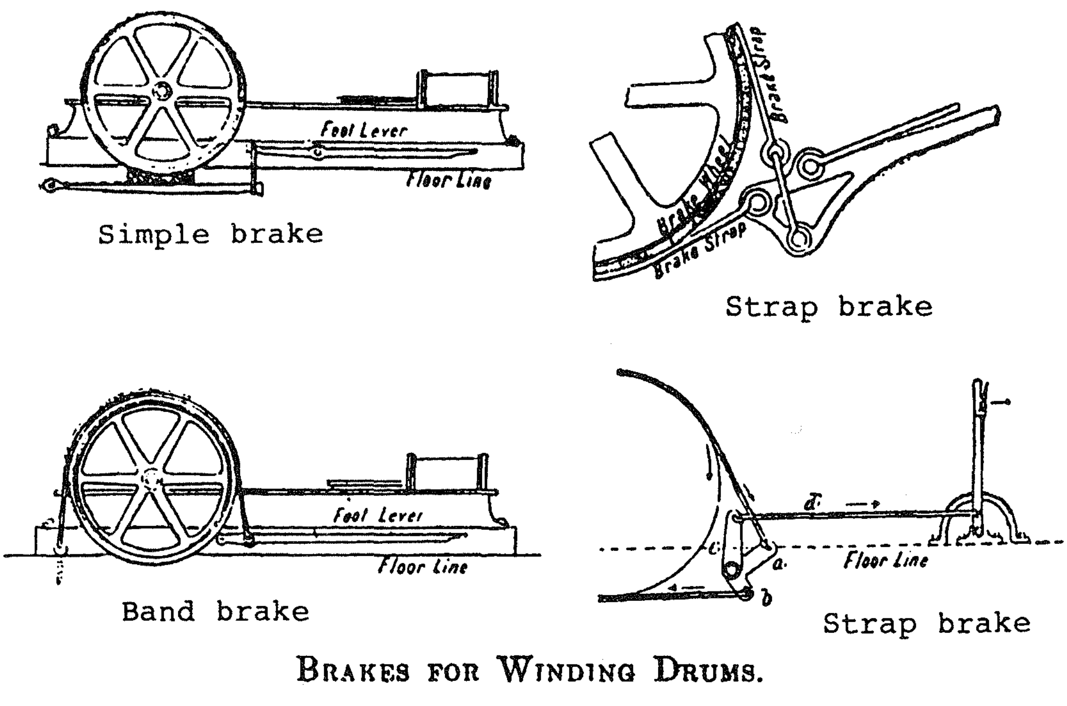

Fig. 2: Winding drum brakes. (Queensland Government Mining Journal, 15 September 1902:457).

the rope lapped smoothly. The only unusual type was the conical drum, a development which may have been borrowed from clock-making.[8] It was designed to even out the load on the winder; two conical drums tapered in opposite directions, one raising and one lowering, would distribute the load evenly on the drum shaft. However it appeared to lose favour in the early twentieth century.[9]

For maximum flexibility, it was better to have two drums set loosely on the shaft. A single winding drum could be used to wind two buckets or skips by turning the middle of the rope around the drum and having a load attached to each end. One end of the rope would come off under the drum, the other over. However winding could only take place from the same level in the mine. Two drums which could be wound independently of each other could raise from any level while still retaining the benefits of balanced winding, ie. using the weight of the descending bucket or skip to assist the ascending load.

The final requirement for a winding engine was an indicator to show the engine driver the depth of the skip or bucket. The two main kinds were the dial and the barrel. The dial was a round face with a needle indicator, driven by some kind of gearing or pulley from the drum, crankshaft or the drum shaft. Alternatively the needle could move up and down a vertical board. Markings on the dial indicated the depth reached. Unfortunately these indicators were not very sensitive or precise, because the needle travelled so little in relation to the travel of the rope.[10] A better device was the barrel, a vertical drum which turned on its axis and had a spiral groove engraved around it. The pointer travelled in the groove and was driven by gearing from the drum. Because the path of the indicator was much longer it gave a better picture of where the skip or bucket was in the shaft.[11]

WINDING ENGINES AT CROYDON

There was a wide variety of winding engine designs incorporating – or lacking – these basic components. As there are few contemporary descriptions of Croydon winding engines, it is the surviving plant which provides most information on what Croydon miners used. All of the plant is, of course, incomplete due to vandalism and recycling of parts, so some details are not available for individual machines.

The first winding engines to arrive on Croydon were small steam winches or donkey-engines of a type common on ships. A small engine with a vertical boiler and one or two cylinders would power a single winding drum; all were mounted on an iron frame. They were usually only three to eight horsepower but had the advantages of being compact and easily transported. At first most of Croydon's had only one cylinder. Indeed two cylinder winding engines – double winding gear – did not predominate on the field until after 1899. The Inspector of Mines complained of the 'many little worthless single cylinder engines' on the field.[12] However they were quite suitable for small-scale workings with little capital available for development. Nearly all were first imported for bailing out Croydon's endless supply of underground water rather than for ore raising, so safety considerations were not as important.

The field survey found three still on site: the Golden Gate 3 & 4 South, the Mountain Maid, and the King of Wallabadah. The latter is very small, has only a single cylinder and is described by the Inspector of Mines in 1891 as being six horsepower.[13] Including boiler, the whole plant measures only 171 x 89 centimetres at the base and 200 centimetres high (Fig. 3). The winders at the King and the Mountain Maid have their cylinders set at a 45 degree angle, while that at the Golden Gate has two horizontal cylinders. All worked the drum by toothed spur and pinion gear but insufficient evidence has survived to precisely work out the gear ratio.[14] That at the Golden Gate appears to be geared down 5:1, ie. there are five revolutions of the engine crankshaft for every one drum

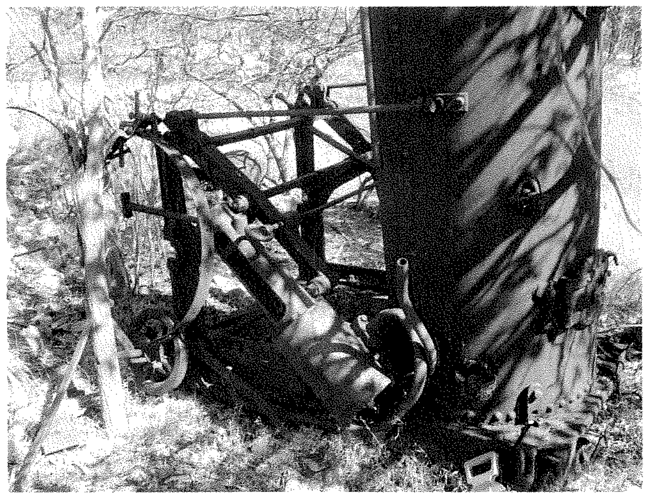

Fig. 3: Winch, King of Wallabadah.

revolution. On the Mountain Maid machine, the gear teeth are set directly on the drum; at the 3 & 4 South, separate gear wheels have been employed. A band brake is in evidence for the Mountain Maid machine, and a strap brake appears to have encircled the missing drum at the King of Wallabadah plant. All three had the two valve eccentrics on the crankshaft which indicate reversing gear. Only one, the Mountain Maid plant, has evidence of a clutch but this does not preclude the others having them. All are set on solid metal engine beds which also incorporate the vertical boiler base, though the Mountain Maid engine's boiler is missing.

These plants would have been slow, inefficient and underpowered but they were also compact, easy to transport and erect, and simple to use.[15] Their components were basic but adequate: band or strap brakes, reversing gear and second motion gearing. The only question over them is the existence and type of clutch or indicator. Other sources suggest that an indicator may have been too advanced for these engines: Maclaren remarked caustically on the prevailing prejudice against indicators on Croydon. Drivers relied on marks on the rope, usually a twist of hemp, to warn them when to stop. These marks could easily be stripped and at least one overwind resulted from this practice.[16] Given the slow winding speeds normal for Croydon, however, this omission is not as serious as it would be for deep mines employing fast winding.

Another type of plant commonly imported to Croydon in the 1880s for winding was the portable engine. These consisted of a multitubular boiler on wheels with the engine mounted on top or underneath. A variation was the semi-portable, without wheels. They were usually more powerful than the winches, 10–14 horsepower, and their boilers were more efficient than the usual type of vertical boiler. They were also more likely to use devices such as steam jackets around the cylinders to keep them warm. This lessened condensation and allowed the steam to work more efficiently in the cylinder. They also sometimes had compounded cylinders. High pressure steam would be fed into a smaller cylinder and then exhausted into a larger cylinder, of a size sufficient to produce the same power as the smaller. This double use of the steam was perhaps the most important nineteenth-century innovation in steam technology for increasing efficiency.

Unfortunately, portable engines were highly valued for all kinds of uses so only one used for winding is still *in situ*, at the Homeward Bound, and it has been badly damaged. Richardson shows how a portable engine can be set up with a semi-independent winding plant, driving it through spur and pinion wheels geared 1:6 or 1:8 and using a clutch on the drum (Fig. 4).[17] The plant at the Homeward Bound has the remains of a single drum with a spur wheel (141 centimetres diameter) attached, but there is no other indication of the relationship

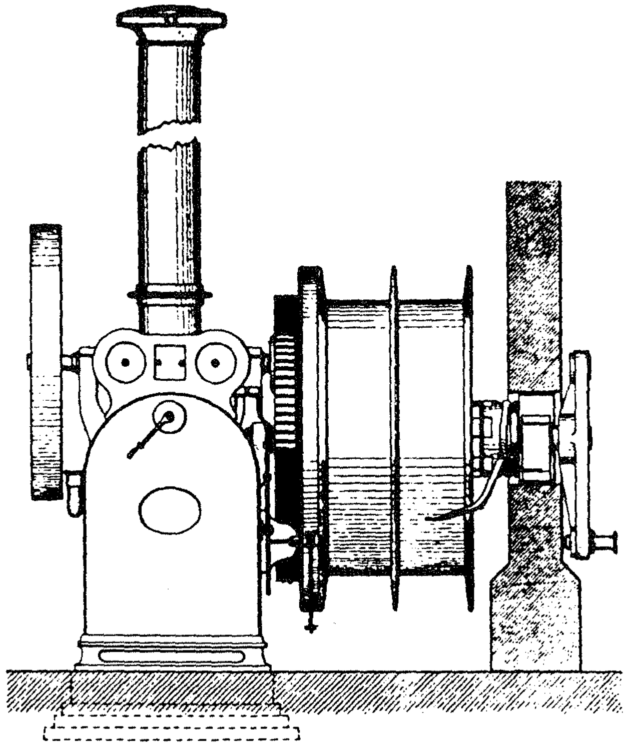

Fig. 4: Portable engine driving a winding drum and pump crank. (Richardson, 1873:Plate 62).

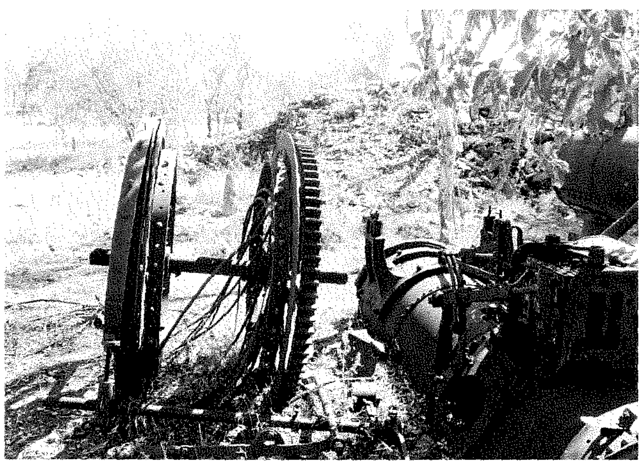

Fig. 5: Homeward Bound winding plant.

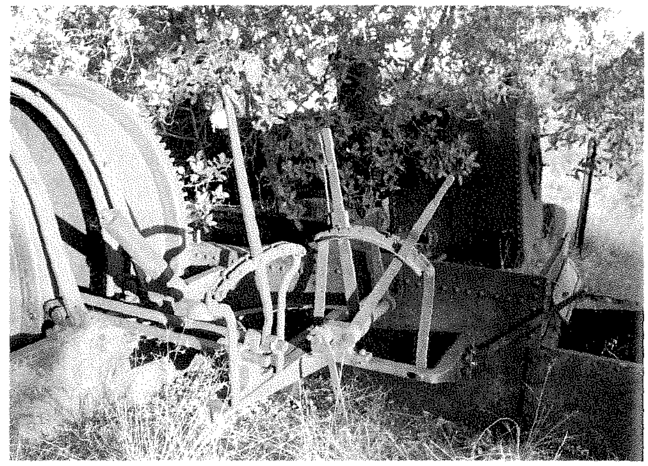

Fig. 6: Prospector's plant, Golden Gate 3&4 South underlie shaft.

Fig. 7: Prospector's plant, Golden Gate 10 North.

between the engine and the drum. The engine, which is probably semi-portable, has a single cylinder and reversing gear. There was a strap brake on the drum, actuated by a foot lever. There is no sign of a clutch or indicator (Fig. 5). At very slow speeds and using only one drum, a clutch would not be necessary.

The scarcity of physical evidence for this kind of winding arrangement could reflect its decreased popularity after the 1890s as other types of winders became available. It would certainly be an acceptable method of ore raising or bailing for shallow mines, but would not have the power or the stability to wind large loads from deep shafts. It would also be safer if there were two cylinders on the engine. Its main advantages would have been its portability and efficiency.

A large group of winders at Croydon consists of prospector's plants, with one or two drums and two cylinders set on a common frame and powered by a separate boiler. A characteristic of this class is that the engine bed is shaped like a tank, which can be partly buried or filled with stones or water to weigh it down (Fig. 6). This means it does not need wood or concrete foundations. There are five scattered around the Golden Gate, one at the 3 & 4 South underlie shaft, two at the 10 North, one near Vile's Block, and the last at an unidentified mine. The two smaller plants, at the 10 North and the unidentified mine, have the normal pattern of cylinders placed either side of the whole plant. They have disc cranks. The three largest have the cylinders together and off to one side of the winding plant; here the cranks are U-shaped (Fig. 7).

Only one of the plants has a single drum. Three have double drums, while the larger plant at the 10 North has one drum divided into two by a middle flange. This would make i less flexible than winders with independent double drums Curiously, the drums on the three larger plants are all the sam diameter: 172 centimetres including the flange. The smaller 1 North machine has drums 124 centimetres diameter; like th other small plant, its drums have been made of sheet iro rather than cast.

Gearing and clutch arrangements vary. Two winders, at th 10 North and 3 & 4 South, have spur wheels on the side of th drum nearest the engines. The gear ratio for the 10 North pla

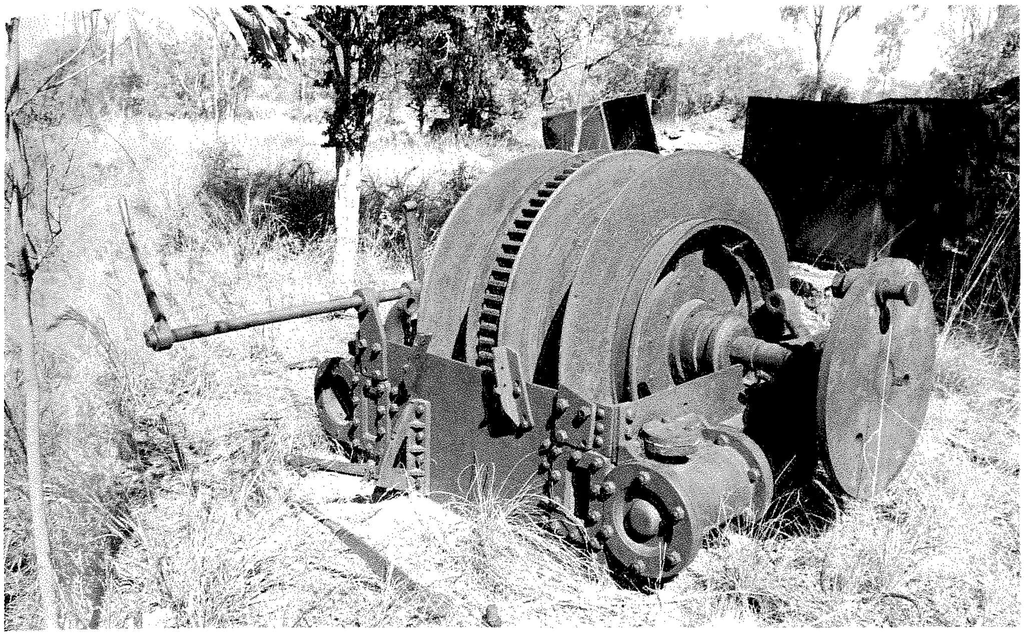

Fig. 8: Small winding plant, Golden Gate 10 North.

is around 5:1. Jaw clutches act directly on the drums. The smaller plant at the 10 North has two drums separated by the gear wheel, and the gear ratio is around 1:4. The drum shaft has been extended on the western side and supports a pump crank (Fig. 8). The other small plant has one drum driven by a spur wheel; the clutch, unusually, works on the pinion on the crankshaft. It is on a tank-shaped metal foundation but unlike the others, sits on a solid surface on the top of the tank rather than being in it. Attached to the front is a long hollow rectangle made of I-beams which appears to have been bolted down to buried timber bedlogs. It may have provided more stability against the pull of the rope. This plant was powered by a vertical boiler while the larger 10 North machine and the 3 & 4 South plant have multitubular semi-portable boilers.

All five plants have jaw clutches, reversing gear using double eccentrics on the crankshaft, and band brakes actuated by a foot lever. None have indicators. While not as portable as the winches and mobile engines, they could be transported fairly easily and would be eminently suited to small mines emerging from the early prospecting stage. As few Croydon mines actually graduated beyond this level it is not surprising that prospecting plants are so relatively common on the field.

The remaining class of winders consists of larger stationary plants on concrete or wood foundations. They were installed for continuous work, either bailing or raising stone, by mines which were developed enough to afford them. Two are bailing plants: one at Morgan's Block, which formed the main drainage shaft for the busy Golden Gate area, and the other at the Rip and Tear, which provided water for the Croydon Quartz Crushing Company's mill. Others are at the Golden Gate Consols underlie shaft, at 1 700 feet (around 520 m) the longest shaft on the field; the Croydon Consols pump shaft; and the Iguana Consols, intended to be Croydon's last deep prospecting shaft.

The Morgan's Block machine consists of two loose winding drums 171 centimetres in diameter, made from sheet iron and set on concrete foundations. The winding plant appears to have been driven by a separate engine beside it, of which only the concrete foundations and bedbolts remain. This is an unusual layout for a large plant. Each drum was put into gear by a jaw clutch on the drum shaft, but no other indication of how power was transferred from the engine is extant. The plant has been badly vandalised.

The plant at the Croydon Consols shaft also has two drums, 145 centimetres in diameter, with a large (187 centimetres diameter) spur wheel on the eastern side of the drum shaft. Two cylinders, neither of which remain, were placed at each end of the crank shaft. There is a reversing lever still in place. The drums each have a jaw clutch and a band brake. The whole is set on a metal frame which must have been bolted at some stage to timber bed-logs.

The Rip and Tear winder is larger; its drums are 152 centimetres in diameter, put into gear with jaw clutches. It also has a substantial flywheel of 220 centimetres diameter. There is only one crank, implying a single cylinder (now missing) between the winding plant and the colonial boiler beside it. The presence of two valve rod eccentrics on the crankshaft shows that it reversed. The stroke was about 20 inches; the gear ratio is about 1:3:5. Both drums appear to have had band brakes. The winding plant sat on a heavy metal beam frame, which must have been bolted down to timber bedding. This may have been the winding plant made in 1896 from a 18 horsepower battery engine and a cheap set of drums, put together with reversing gear made by the local foundry.[18] The eclectic origin would explain the unusual layout.

The Golden Gate Consols winder and its colonial boiler were made locally by the Croydon foundry, Stuart and Mackenzie, so it is described well by contemporary sources. On its completion the newspaper reported it as an 18 horsepower plant with two cylinders, double loose drums of five feet (152.4 cm) diameter and 'the usual brake and clutch gear'. The engine crosshead guides were of the hollow or trunk type and there were extra-large bearings and rubbing surfaces for better wear.[19] It was set on 'elevated concrete foundations'.[20] The plant was christened 'The Captain' with the aid of champagne.[21] The physical evidence adds the fact that the drums were made of sheet iron, not cast, the gear ratio would have been around 4:1, and the 'usual brake and clutch gear' were band brakes and jaw clutches.

The largest winding plant ever on the field was the 25 horsepower machine imported by the Waratah Consols Co., a British company. It was far too large for the company's small unproven mine and it comes as no surprise that its maker, John Donald of Glasgow, was on the mine's board of directors.[22] The winder and its 30 horsepower Cornish boiler were moved around the field until ending at the Iguana Consols prospecting shaft.[23] The winder was described in 1917 as having some relatively advanced features. A steam trap, unique on Croydon, prevented condensation in the steam pipes from reaching the cylinders. The engine could be made condensing or non-condensing by adjusting a valve; condensing the exhaust steam assisted the action of the engine and saved water.[24] The

Fig. 9: Flywheel and helical gears, Iguana Consols winding engine. Dial indicator on left.

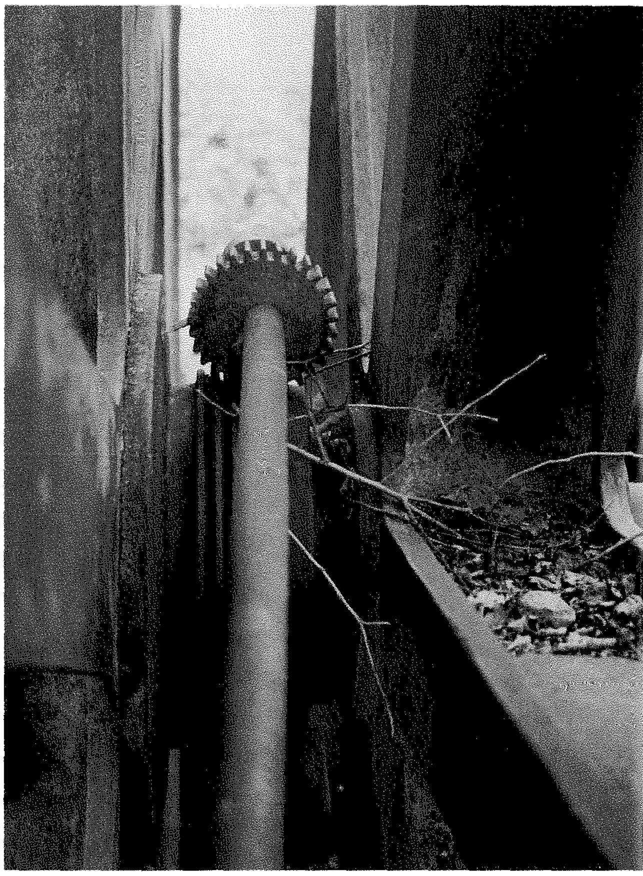

Fig. 11: Indicator drive mechanism, Iguana Consols.

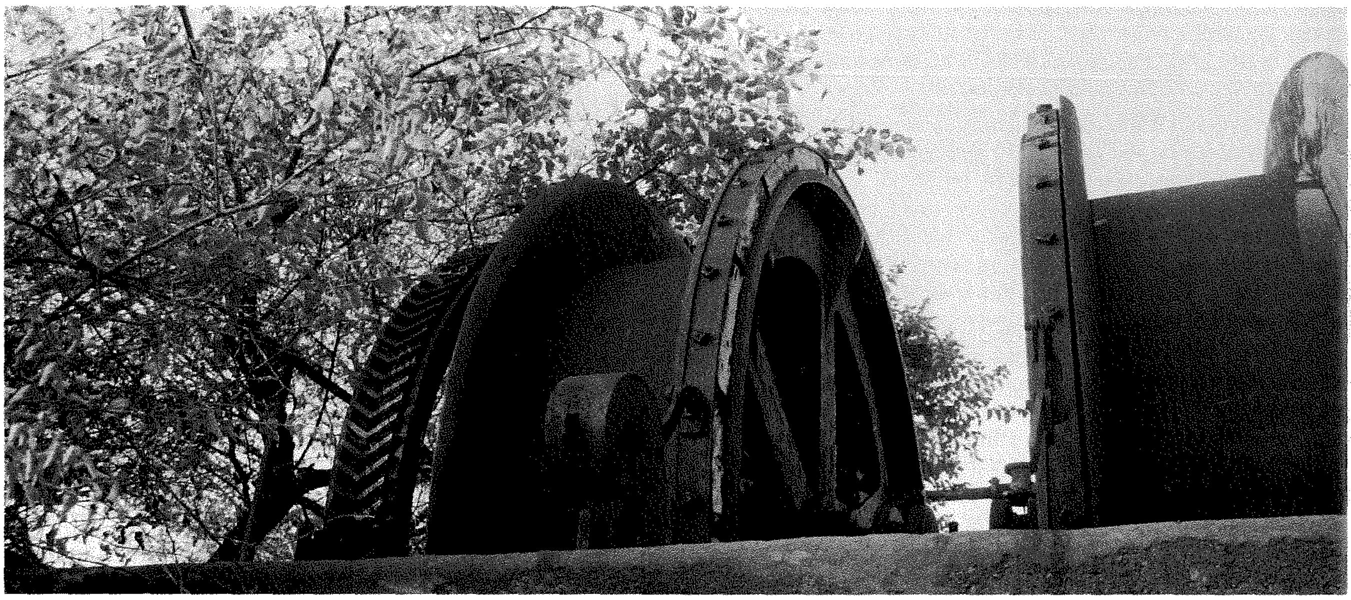

Fig. 10: Brakes and brake weight, Iguana Consols.

surviving plant is in a good state of preservation, lacking only its reversing levers of the major components.

The winder has two drums 222 centimetres in diameter (170 centimetres without flanges) sitting between the two cylinders. The plant has disc cranks and reversing gear. A 180 centimetres diameter flywheel is set on the western side of the crankshaft. Power is transferred to the drums by helical gears, ie. spur and pinion wheels which have V-shaped teeth (Fig. 9). There are jaw clutches on the inner side of each drum, the usual pattern for double drum winders. Wood-lined band brakes are applied by foot treadles and assisted by round brake weights at the front of the drums (Fig. 10). Two unusual features are the automatic oiler attached to the valve rod of the western engine, and two dial indicators, one for each drum. The indicators work off a small toothed wheel turned by a thread which was cut into an extension of the drum boss (Figs. 9, 11). They were the only indicators found on a Croydon winding engine during the field studies.

Despite their larger size and more solid foundations, these machines do not differ much from the prospecting plants. Band brakes, dog clutches, slide valves, reversing link gear and spur and pinion gearing are common to both groups. The drums are invariably double drums loose on the shaft, as one would expect in a larger mine working from several levels.

It is probably more instructive to consider what these plants do not have. On other fields in the same period, the biggest mines might have first motion winders with friction clutches, post brakes, compound engines, more efficient valves such as drop or Corliss valves, and brake, clutch or reversing engines.[25] Not even the winder at Plant's shaft, the deepest on the field at 1 300 feet (nearly 400 m), had any of these features. Mining on Croydon may not have justified most of them. Most of the nineteenth-century innovations in winding were for fast speeds, great depths and large loads. Depth did not warrant them for Croydon; apart from Plant's and the Golden Gate Consols, most mines were no deeper than around 500 feet (150 m). Croydon rarely had the large loads because its quartz reef orebodies were small and patchy in value. The average output of ore for a good mine was 60 tons a week, the maximum 300. Except for Morgan's Block, even bailing water was intermittent. Speed and efficiency were therefore sacrificed in the interests of saving capital by purchasing cheap, often second-hand, plant. Working capital was a resource that was usually too scarce on the field to waste on advanced machinery for unproven and unpredictable lodes. Prudently, most mine owners preferred to use it to explore and develop their leases.

CONCLUSION

The evidence presented by the winding plant around Croydon indicates a definite pattern in the machinery preferred by mine owners. Most were easily transported, an important consideration on patchy lodes when a few unprofitable crushings might spell doom for a party of undercapitalised miners. Portable plant could easily be sold or moved to the next venture. They used a basic, cheap technology suitable for small or medium sized mines: jaw clutches, band brakes, second motion gearing, simple steam engines, link reversing gear, and slide valves. Double drums and two cylinders were preferred but not considered essential. Indicators were obviously thought a luxury and there appears to be a prejudice in favour of flywheels which were unnecessary on two cylinder engines. No doubt miners stayed with this pattern because it was familiar, tried and tested; however they were not averse to innovation, as demonstrated in other areas such as milling practices. In the case of winding engines, the alternatives were simply not considered suitable for the prevailing conditions of small undercapitalised mines on unpredictable lodes.

NOTES

1 *Croydon Golden Age*, 7 March 1899.

2 *Journal of the Chemical, Metallurgical and Mining Society of South Africa* 7,5:152 and 8,11:28.

3 A good driver can stop the engine off dead centre, ready to start. Pers. comm. Jack Connell January 1995.

4 This included the giant 4 000 horsepower *Superior* at the Calumet and Hecla copper mine in Michigan, in 1881. It was thereby able to drive six winding drums, nine compressors, pumps, man engines, and a crushing mill. Watkins, 1978–1979:19.

5 Queensland State Archives, Mining Warden's Office (MWO) 14A/35, Warden's Court Cases, depositions concerning accident, True Blue Block, 4 November 1895.

6 McCulloch and Campbell-Futers, 1912:2–3, 306, 312–313.

7 McCulloch and Campbell-Futers, 1912:313–314.

8 Burstall, 1965:132–133.

9 eg. Hoover, 1909:129.

10 Godfrey, 1900:7.

11 Maclaren, 1901:7.

12 Inspector of Mines, *Annual Report of the Queensland Department of Mines*, 1891:126.

13 Warden's Report, *Annual Report of the Queensland Department of Mines*, 1891:45.

14 The gear wheels of the King of Wallabadah's winder are missing but there are two sets of bearings in the frame, for the engine crankshaft and the drum shaft.

15 Interview with Norman Rains, 5 December 1986.

16 Maclaren, 1901:7; Queensland State Archives, MWO 14A/35, Warden's Court Cases, 14 October 1896 No. 167.

17 Richardson, 1873:168–171.

18 *Croydon Mining News*, 22 October 1896.

19 *Croydon Mining Record*, 17 July 1903.

20 *Croydon Mining News*, 31 July 1903.

21 Interview, Norman Rains, 18 June 1986.

22 Stock Exchange Company Report for Waratah Consols, 25 March 1895, Guildhall Library, London.

23 *Croydon Mining News*, 1 February 1902, 1 March 1902.

24 *Queensland Government Mining Journal* 15 August 1917: 391–392.

25 Corliss valves existed on winding engines of the period though they were in fact better suited to steady work such as that of marine engines.

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