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Basic Design of the Bucket Wheel Excavator for the Goonyella Mine

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Grundlegende Konstruktionsmerkmale des Schaufelradbaggers für den Goonyella Tagebau
Conception de base de l'excavateur à roue à augets pour la mine de Goonyella
Diseño básico de la excavadora de cangilones para la mina de Goonyella

グーニエラ炭坑のバケットホイール掘削機の基本設計

贡耶拉矿场杓轮挖掘机的基本设计

التصميم الأساسي لحفارة الدواليب ذات القواديس الخاصة بمنجم جونيلا

Summary

Overburden stripping at Goonyella Mine has already reached the stage where draglines alone cannot handle the depth or achieve the production targets required without the aid of additional (pre-stripping) equipment. Currently, a fleet of twelve scrapers is being used for this purpose but long-term planning indicates an ever increasing need for pre-stripping, to such an extent that more sophisticated, more efficient systems will be required early into the 1980s.

Investigations of options available for this pre-stripping showed a continuous system, i.e. Excavator-Conveyor-Spreader, would be the most attractive. This would mean introduction of entirely new plant types and related operating methods to the Central Queensland mines. Similar systems have operated for many years in Victoria and overseas, however, these existing systems are in deposits much less consolidated than those at Goonyella. Soil investigations suggest a continuous system will meet some of the most arduous conditions yet encountered by this type of plant. Consequently, extensive investigations have been made to judge whether a suitably designed Bucket Wheel Excavator (BWE) could be obtained for Goonyella, and, this being so, in drawing up the specification of the machine and associated transport and disposal units.

1. Introduction

The open cut coal mines managed by Utah Development Company (UDC) in Central Queensland use the dragline stripping system, as developed in North America, to expose the coal seams. The coal is excavated by a heavy duty shovel and loaded into wheeled transport. To date, typical overburden (O/B) depths are 35—45 m and even with the high rehandle rate necessary at these depths, stripping with draglines is highly efficient (Runge, 1979). However, the coal seam dips at some 5° and the corresponding increase in O/B depth as mining progresses necessitates increased rehandle by the draglines. Stripping by draglines alone would then become inefficient and at depths over 45 m a tandem system for stripping is required.

The options open to UDC for pre-stripping included:

scrapers; shovels and trucks; a semi-continuous system using shovels, crushers and conveyors; and a fully continuous system.

Scrapers are being used at present for auxilliary stripping, but the greater the depth of O/B the further the spoil has to be moved in order to maintain stable slopes, and wheeled transport begins to lose its advantage in favour of conveyors. The semi-continuous system would have the advantage of conveyors and would be applicable if extensive blasting and crushing at the operating face were necessary. However, much of the upper layers of O/B at Goonyella can be very sticky, which would prejudice shovel and crusher productivity.

Investigations to date suggest less than 25 % of the O/B to be pre-stripped will be too hard for a BWE, but could be blasted to a lump size suitable for handling by conveyors. The majority of the O/B appears suitable for BWEs, although harder than that in most of the open cuts where BWEs have been applied satisfactorily. Its occasional high stickiness poses severe design and operating problems.

UDC were aware there had been some costly mis-applications of BWEs in hard deposits, and therefore undertook digging resistance tests to confirm suitability for the BWE application. The results of these and other judgements suggested a suitably designed BWE could be applied and the decision was made to proceed on the basis of a continuous system. Specifications for the main plant units were issued late in 1977 and orders placed progressively in 1978. The system is expected to be in service in 1981.

2. Present Goonyella Operations

The Goonyella Mine became operational early in 1971 and is designed to produce $4.5 \cdot 10^6$ tonnes of coking coal annually. The Goonyella Middle seam is being mined at present. Its thickness ranges from 6—10 m and it yields a high quality, hard, medium volatile coal. Present operations use the extended bench method of dragline stripping; shovel and trucks are used for the mining and hauling of coal. Both coal

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and O/B are blasted prior to digging. The coal is hauled out of the pits up ramps and roadways to a crushing and screening plant. The ramps are established in gaps left in the spoil heaps. The present overburden stripping fleet consists of:

2 Bucyrus Erie 1370W draglines (45 m^3 bucket)
2 Bucyrus Erie 1350W draglines (34 m^3 bucket)
1 Marion 8050 dragline (45 m^3 bucket)
5 Caterpillar D9 bulldozers (one to each dragline)
6 Caterpillar 657B scrapers
2 Caterpillar 633C scrapers
1 Caterpillar 633 scraper
3 Caterpillar 631B scraper
2 Caterpillar D9 bulldozers

It has been estimated that the existing dragline fleet can economically strip 45 m of O/B and maintain sufficient reserves of uncovered coal to meet current production targets. At depths greater than 45 m the operating cost of the dragline system rises and the rate of uncovering coal drops because of the high rate of rehandling necessary and generally lower productivity (Runge). Eventually the cost of rehandling would be at least as high as a pre-stripping system. This situation has led to the decision to pre-strip in those areas where the O/B depth exceeds 45 m.

3. Future Operations

As referred to in 1 above, of the options open to UDC for the pre-stripping system the continuous type was selected. The dragline system will remain for main stripping for the time being and hence the new system will have to integrate satisfactorily with the existing one.

A wide range of continuous systems is available. For instance BWEs are built from small standard units of only 50 tonnes mass to gigantic units of 13,000 tonnes and daily outputs of 240,000 m^3 (bank). Machines in the large ranges are capable of digging up to 50 m above and 15 m below transport level and even greater vertical ranges are possible by use of multiple bench operations (Rasper, 1975).

Planning for the pre-stripping system at Goonyella was based on continuing production to the year 2000. By this time the O/B depth will average more than 90 m, and if the lower 45 m of this were allocated to draglines, about the same depth would eventually have to be taken out by the pre-stripping system. The total pre-stripping requirement builds up to some $22.5 \cdot 10^6$ m^3 (bank) per year during the 1980s. However, this assumes final (steep) highwall slopes being reached in 1999/2000. If production beyond 2000 were contemplated, higher outputs would be needed, not only from inherently deeper overburden, but also because flatter overall batter angles would be needed to ensure pit stability, that is, the pre-stripping benches would have to be advanced further ahead of the dragline benches.

Theoretically one BWE alone with a daily output of 80,000 m^3 (bank) would be capable of $22.5 \cdot 10^6$ m^3 (bank) annually. Such a large unit would of course necessitate conveyors with widths of 2.4 m or more and a correspondingly large spreader. The system would represent a large capital investment and a high operational risk for several reasons. Firstly, the only comparable heavy duty machines in this size range are in Ekibastus, Siberia and are not readily available for inspection. Others have not been proved in hard digging. Secondly, the six pits at Goonyella stretch over 18 kilometres and the use of one BWE alone would necessitate frequent changes of site to balance the respective dragline operations in the various pits. A correspondingly complex conveyor and disposal system would be involved. Thirdly, the intention is to superimpose pre-stripped overburden on the dragline spoil heaps. Such spoil piles do not have the capacity to receive efficiently pre-strip spoil at such a high rate over a limited area.

When initial planning was undertaken by Rheinbraun Consulting (RC) in 1975 (Peretti, 1976) it appeared two "standard" heavy duty machines with digging heights of up to 15 m and masses of 500 tonnes each would suffice. However, subsequent information on the O/B indicated the "standard" machines might not be robust enough and the low digging height could necessitate additional conveyors. Also, the parameters set for the RC feasibility limited highwall depth to only 75 m. After consideration of the various alternatives UDC opted for three individual systems, each with a nominal annual output of $7.5 \cdot 10^6$ m^3 (bank). The excavator would have an overall digging range of 33 m. The programme is such that if the first unit were installed by early 1981 sufficient operating experience could be gained before it would be necessary for the second and third systems to be ordered. Three systems would also give a desirable degree of flexibility, and procurement of the first system has proceeded on this basis.

The disposition of the existing dragline system and the new continuous system is diagrammatically shown in Fig. 1. The basic BWE unit would have a digging range of up to 25 m above and 11 m below the transport level, and some variations in these heights would accommodate the nominal 33 m strip. The conveyor system would initially have three simple flights and the O/B would be transferred by a crawler-mounted tripper with 20 m transfer boom to a crawler-mounted spreader with 35 m connecting conveyor and 60 m discharge boom. The spreader would be capable of high dumping to a height of 23 m as well as deep dumping. The details for these three basic plant units and the main parameters which were considered in specifying and developing their designs were developed following the completion of a detailed study of the Goonyella O/B in 1977.

4. Nature of the Goonyella Overburden

4.1 Basic Details

Typically the coal seam (the Goonyella Middle) sub-outcrops some 15 to 30 m below surface. The seam is 6 to 10 m thick and dips to the east at some 5°. Weathering up-dip of this location renders the coal unsuitable for coking. Strike length of the mine is about 18 km.

Within the zone for pre-stripping the O/B consists of Tertiary sands and clays and minor gravels, with occasional boulder beds between 5 to 15 m deep overlying unconformably Permian sandstone, siltstone, claystone, and occasionally thin coal beds with associated carbonaceous claystone.

In the Tertiaries very stiff to hard, moist clays dominate, with minor dense beds of clayey sand, river wash with hard rocks up to head-size, occasional weathered boulders of sandstone, siltstone and claystone.

The Permian rock types include weathered rock fragments forming the coarse fraction and clay minerals forming the rock matrix and cement. Most sandstones contain between 30 % to 50 % clay minerals. The important exception to this

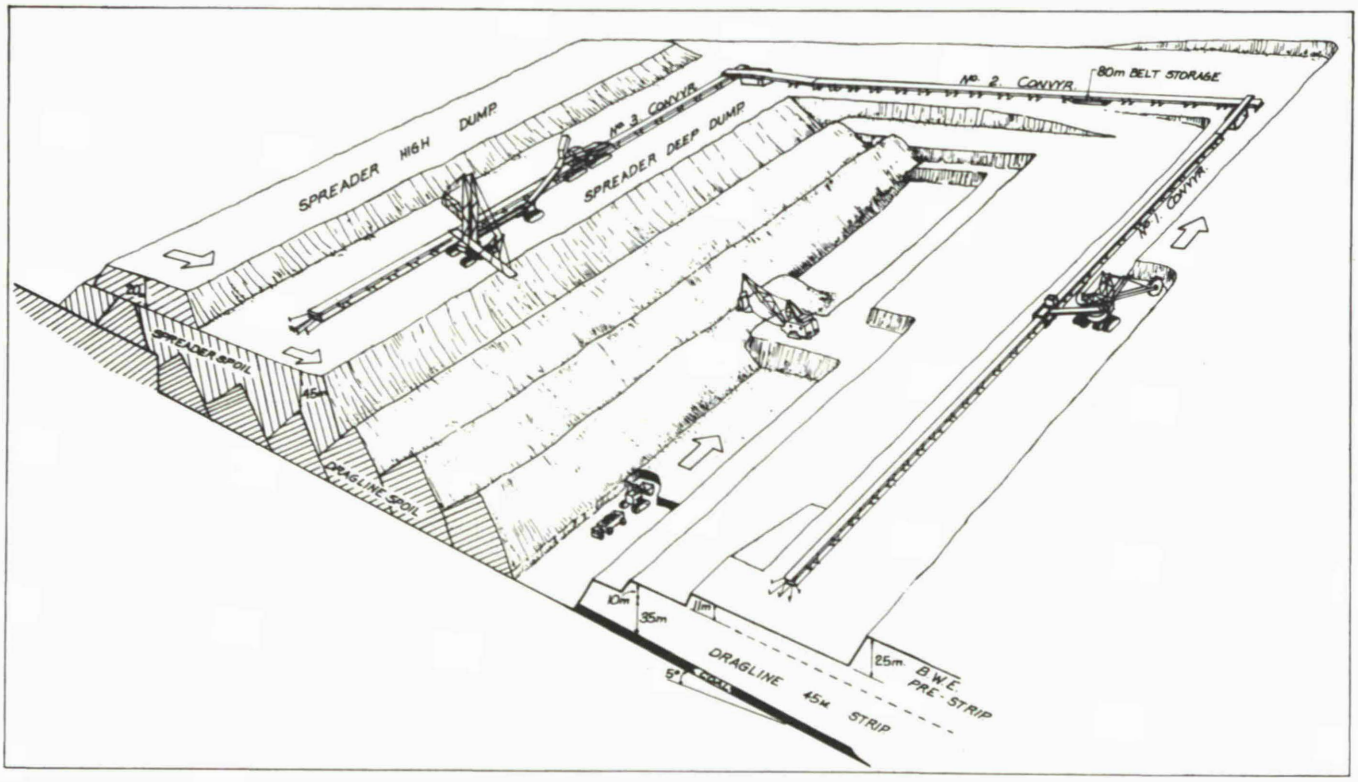

Fig. 1: General arrangement of pre-stripping system in relation to existing operations

is where carbonate minerals form the cement, the effect of which is to increase rock hardness and strength significantly.

4.2 Batter Stability

The mix of the various materials which form the Goonyella O/B necessitates blasting for excavation by draglines. Blasting aggravates the deposit's natural tendency to instability and highwall and spoil dump failures have been a continuing problem. This has increased the need for pre-stripping in order to lower dragline operating faces.

Highwall failures are mostly caused by slip planes dipping into the pit; spoil failures are primarily caused by weakened spoil material. In the mid 1970s a joint study was undertaken by CSIRO and UDC (Boyd, Komdeur and Richards, 1978) to determine the relationship between depth of rock weathering and stability. This study involved extensive large core drilling and the opportunity was taken concurrent with this (in 1976—77) to carry out digging resistance tests on the various rock types.

4.3 Digging Resistance

In any O/B system the behaviour of the material at each point in its movement from the undisturbed operating face to the disposal point, where it must become a stable O/B dump, strongly influences the design of each plant unit within the system. While this may be axiomatic many of the misapplications of BWEs have occurred through an ignorance of, or an ignoring of, the need to relate closely the nature of the deposit to the design of the plant (Winzer 1976, Rodgers 1976).

For the BWE the first consideration is design of the wheel and its drive to ensure it will be able to separate the hardest of materials from the operating face at a steady rate of output, with high reliability and without undue wear and tear. For this the designer needs to know the digging resistance and characteristics of the O/B. Various methods of determining this have evolved and usually design of the drive power and digging parts of the wheel are based on a number of factors. In an open cut such as Goonyella which has long existing operating faces it is possible to cut pit-wet samples from beneath the dry surfaces and make laboratory tests on these. However, it is also necessary to determine characteristics of the material remote from the operating faces which will be dug some years hence. Core drilling gives a ready means of such checks.

Among the methods frequently used for measuring digging resistance are the O & K Wedge Test, unconfined compressive strength tests, and the Protodjakanov method.

The Protodjakanov method is used in East Germany but did not appear to be of sufficient value to the Goonyella investigation, although some samples were sent to Freiberg for testing. Drilling and testing was carried out as follows:

Initial — 50 mm diameter open-hole drilling with rock type and weathering recorded from cuttings. "Hardness" was related to drilling performance.

Intermediate — a grid of 50 mm diameter core holes with samples taken at 1.5 m intervals for compressive strength testing.

Final — based on the results of the above a wider spaced grid of 150 mm diameter core holes was drilled. Holes were continuously cored in the pre-stripping range and 30 cm samples taken at 3 m intervals, or whenever a change of rock type or weathering occurred. These samples were subjected to the O & K Wedge Test.

The O & K method was developed by Orenstein & Koppel of Lübeck, West Germany (O & K). The procedure is illustrated in Fig. 2. This is drawn to show the test carried out on the 150 mm drill cores at Goonyella. With larger samples taken close to the operating face it is usual and possible for them to be shaped to 150 mm cubes, but the principle of the testing on cylindrical corings is the same. For laboratory purposes the standard wedge, with dimensions as shown at A of Fig. 2, is mounted in a compression testing machine. For field testing at Goonyella a portable rig as shown at B of Fig. 2 was used.

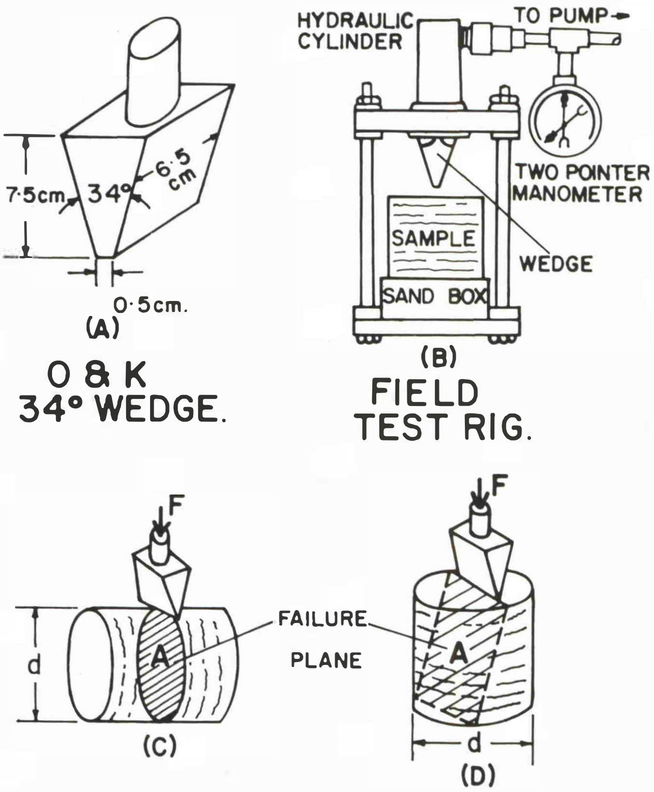

Fig. 2: Test rig and details: O & K wedge digging resistance tests

The wedge is first pressd into the centre of the sample as shown in C of Fig. 2 and parallel to the bedding planes. The test as shown in C yielded two further samples each approximately 15 cm dia. by 15 cm long. Each of these was then subjected to the test as shown in D of Fig. 2 in which the wedge was applied normal to the bedding planes. For each test the force F at which splitting occurred was recorded on a pressure gauge and the depth of penetration of the wedge and the area of the surface as split were measured.

The tests yielded two sets of results for Specific Cutting Force. One of these was related to the area of splitting and was expressed as Ncm^{-2} with the symbol K_A. The other related to the length of the wedge and expressed as Ncm^{-1} with the symbol K_U.

In addition to the wedge test on the 150 mm core samples, specific compressive strength normal to the bedding planes was also measured and compared with the results of similar tests on the 50 mm sample. They tended to be lower, showing the effect of sample size. The results in these cases were also expressed as Ncm^{-2} with symbol C_A.

UDC classified the rocks according to their increasing degrees of hardness into six classes:

(i) Clays — extremely weathered rock
(ii) Highly weathered rock
(iii) Moderately weathered rock
(iv) Slightly weathered rock
(v) Fresh rock
(vi) Calcareous material (slightly weathered to fresh)

The O & K wedge test appeared to be the most applicable and results of these tests were used in evaluation of digging resistance and as a basis for determining productive performance of the proposed BWE.

It should be noted the method of application of these measurements to dimensioning of buckets and teeth and drive of a wheel is largely empirical. Correlation between wedge test measurements and compressive strength test results and actual cross-section cut by the bucket is usually qualified by a multiplication factor applied by the designer and dependent on his judgement of likely problems in digging the various materials. This judgement is based not only on the test results but from a qualitative comparison between the deposit under consideration and others where BWEs have been successfully and unsuccessfully applied. Whilst the task for the designer for an open cut mine such as Goonyella having long, exposed faces and a large diameter programme, is less difficult than for a deposit in virgin ground with only a limited number of small diameter drill cores available, many preliminary enquiries were answered with the suggestion that the only way to determine "diggability" of the O/B was to install a BWE for test purposes or airfreight 300 kg lumps of overburden to Europe for testing.

This was not possible and the evaluation of likely behaviour of the various rock types and application of the digging resistance tests results had a dominant influence on plant design philosophy and detailed specifications as explained below.

5. Basic Design Philosophy

The specifications for the units associated with the pre-stripping system were the first UDC had issued for this type of plant and a prime objective was to ensure the highest degree of man safety and plant reliability. A vital consideration for many Australian mining projects is that they are in remote locations with limited mechanical and electrical engineering workforce and maintenance personnel. These people must of necessity be versatile and are frequently masters of improvisation but they cannot be expected to be completely up to date with some of the maintenance techniques required for sophisticated electrical equipment nor can they be expected to keep in service mechanical items which are not of first-rate quality and simplicity. Where mining operations are in densely populated areas, such as the Rhineland, West Germany, specialists can be obtained in a matter of hours, but in Australia it may be several days before a specialist can be brought from, say, the Pilbara region to the Bowen Basin. These considerations, and the very arduous duty expected from the studies of the deposit, caused the specifications to be such as to give emphasis to the need for safe, simple, robust, high-quality plant components. The following examples are typical of the way this attitude permeated drafting of the specifications and the subsequent negotiations with tenderers to work up safe and reliable designs.

5.1 Structure

It was anticipated the machines, i.e., BWE, spreader and tripper would be of East or West German design. Over nearly 50 years these countries jointly, and then separately, have developed advanced and comprehensive codes for the design and construction of large machines. By the use of a wide range of Load Assumptions for different degrees of operational severity of loading, and sophisticated strength and stability analyses, their machines can work safely to high permissible stresses. As a control of this practice, it is mandatory in both countries for the design to be audited progressively by a government accredited Proof Engineer (Independent Expert). The UDC specifications provided for such an appointment and an eminent West German engineer was engaged to check the designs.

The material used and the actual manufacture also are subject to approval of the Independent Expert (I.E.) and he normally makes a personal inspection before the plant is cleared for operation.

5.2 Mechanical Items

The life rating to be expected from plant of this nature is equivalent to 100,000 hours of full load operation of the BW drive. The aim of those who drafted the UDC specifications was to call for life ratings where appropriate with the object of some 20 calendar years without significant "wear and tear" mechanical breakdowns. A typical example of this is that specified for gears. All bearings are to have a life rating of 75,000 hours at input to the gearbox of the most arduous combination of torque and speed when the drive motor is operating at full output. Tenderers were given the option for gears to be designed to AS61 (i.e. BS436) and kindred standards or the AGMA standard. For the former case the expected running hours with full load rated output of the drive motor applied at each side of teeth of each gear wheel were specified. These hours were selected according to the frequency of operation of the drive and, for instance, 100,000 hours for both wear and strength were given for the BW, whereas for the BW hoist only 26,000 hours was stated. For variable elevation conveyors 26,000 hours was nominated, whereas for fixed elevation conveyors (and this also applied to the main, long conveyors) the figure was 52,000 hours. Other qualifications were applied to ensure reductions in these hours were not introduced by application of zone factors and other means.

Where the tenderer opted for AGMA he was required to use the curves of flank life C_L and root life K_L which provided for a diminution of these factors up to not less than 10^9 cycles of tooth contact. The gears were to be classified for reliability at "Fewer than one Failure in 100" and the appropriate value of C_R was, in any case, to be not less than 1.0. Also, appropriate overload factors C_0 were to be applied to deal with such conditions as starting torque and shock and in any case are to be not less than 1.25. Tenderers were also required to show that provisions would be taken to have the elasto-hydro-dynamic (EHD) oil film thickness maintained under full load in the gearboxes and were to state what the minimum values of film thickness would be.

Table 1: Comparison of heavy duty BWEs

		O & K 1340	O & K 1355	O & K 1367
		Athabasca	Neyveli	Goonyella
BW Diameter	m	12.5	10.5	12.25
Bucket Capacity l_1		1900	1400	1300
Ring Space Capacity l_2		550	800	1000
Number of Buckets	S	14	10	10
Number of Pre-cutters		0	10	10
Discharge Range	buckets/min			
HIGH		53	65	48
LOW		26.5	65	16
Cutting Speed Range	m/s			
HIGH		2.48	3.57	3
LOW		1.24	3.57	1
Bucket Wheel Drive	kW	2 x 500	2 x 750	2 x 600
Basic Digging Force	tonnes	35.0	36.4	34.7
Belt Width	mm	2200	2000	1800
Belt Speeds	m/s	4.7	4.5	2.5/4.2
Ground Pressure	kPa	160	131	127
a. BW outreach	m	21	31.3	36
b. Discharge boom outreach	m	35	30	40
A. Max. height to centre of BW	m	17	26	25
T. Max. range below transport level	m	10	8	11
Ballast	tonnes	220	270	270
Mass Ready for Service	tonnes	1725	2170	2230
Total Installed Power	kW	3000	3750	3200

5.3 Electrical Equipment

Electrical equipment for the system will be to the same high standard as the structural and mechanical components. Electrical supply is the one common denominator in the whole system, particularly from the point of view of control. Interlocking of conveyor drives and other operational functions are essential.

The conveyors must be started and stopped in sequence and under controlled conditions, otherwise flooding and blocking of chutes would occur. Such interlocking and sequential control are commonplace in similar installations throughout the world. Where the Goonyella installation differs electrically from most other operations, is as follows:

5.3.1 Bucket wheel drive — 2 x 600 kW DC motors

DC motors provide an appropriate means of speed and torque control to a degree not possible with the simple AC alternatives. "Cascade" and other AC speed control systems lack the range of speed control and efficiency of the DC motor control and also require provision of heat dissipation and additional equipment for start-up.

Weight and cost of DC motors, with no real need for a wide speed range, have not favoured DC in most BWE applications. However, use of aluminium piping and remote ventilation have enabled DC motors of comparable weight to the AC motors to be designed for the Goonyella machine.

5.3.2 Pole-changing motors

Full and half-speeds have been specified for all main machine and trunk conveyors. Variable speed couplings permit a range of speeds to be used for a conveyor installation but the range of speeds is limited by, again, considerations of efficiency and heat dissipation. Pole-changing motors, although not in common usage, are considered to present the best solution to the speed range problem. On board the machines the motors will be squirrel-cage AC motors and on the conveyors resistor controlled, wound rotor motors.

5.3.3 22 kV power supply

Draglines, drills and shovel already in use at Goonyella are fed at 6.6 kV. The larger motors on the pre-stripping equipment will be 3.3 kV. However, due to the length of trailing cable that would be required and with the necessary derating for layers on cable drums, the supply to the mobile machinery has been selected at 22 kV. The 22 kV trailing cables will be designed for a rated capacity of 3 MVA to accommodate possible, future machinery such as mobile belt conveyors.

5.4 Manufacture

As a follow-up to quality design, specifications called for stringent and well-controlled manufacturing processes and these are to be subject to inspection by UDC as well as by the contractor.

5.5 Testing

Goonyella lies some 200 km north of the Tropic of Capricorn and its shade temperature ranges from —7 °C to + 45 °C. This and other climatic details were given in the specifications and the main objective of workshop and field testing was to ensure that plant components could give sustained operation under these conditions. This meant that for units such as gearboxes and electric motors, works testing was required to be carried out in "hot boxes". Furthermore the practice often followed by some manufacturers of extrapolating results from smaller units was to be avoided and as far as practicable components were to be given tests before delivery equivalent to full load.

Particular attention was given to the quality of metals both by chemical, physical and detailed ultrasonic testing.

6. Basic Plant Unit

6.1 Bucket Wheel

As explained in Section 3 the annual output for the initial system was planned at $7.5 \cdot 10^6$ m^3 (bank) and the BWE is to have an overall range of 33 m. From these main parameters and the batter stability characteristics of the deposit the basic hourly outputs were developed.

In some mining circles much emphasis is placed on plant availability rather than the more realistic aspect of utilisation. While individual units in a system may have high availability, the overall system might not have high utilisation. A major influence is the total number of hours worked annually and obviously a system working one shift 5 days weekly will have higher inherent utilisation than one on 3 shifts 7-day continuous operation. The latter is planned for the Goonyella operations and of the 8,760 hours available annually the planned hours of full operation was taken at 5,000. This utilisation of some 57 % is consistent with continuous systems throughout the world and it has been explained (Winzer, 1976) that utilisation of a continuous system is really no worse than a remote dumping system with wheeled transport.

The outcome of this consideration was a nominal 1,500 m^3 (bank) hourly. The UDC specification called for this output to be guaranteed over a test period of one month. Tenders were invited from major BWE manufacturers most of whom had built BWEs for heavy digging. Most of the offers were capable of being developed into what could be expected to be a suitably designed machine for Goonyella. However, the machine finally selected was the O & K 1367 and it is dealt with here as a typical example of how a tenderer and client can develop a design prior to the contract ad without shifting the responsibility for the performance from the tenderer (contractor).

At the time the Goonyella tenders were under consideration a system with a similar hourly and annual capacity had commenced operation at Yallourn (Rodgers & Mitchell, 1978). The BWE for this sytem is a well engineered and versatile machine with high output potential and should prove to be well suited to the Yallourn conditions. However, the digging at Goonyella will be much harder than in the Latrobe Valley; hence the BWE, and in particular the BW drive, will need to be more powerful. The latest heavy duty machine readily available for comparison is the O & K No. 1340 which commenced operation at the Fort McMurray Mine (Athabasca) of Great Canadian Oil Sands Ltd. (GCOS) in Canada late in 1976 (Winzer, 1976). This is a custom-built unit designed to dig glacial drift in temperatures ranging from + 40 °C to —40 °C and to load to 150 tonne back-dump trucks. It is shown in Fig. 3. As well as 1340, a group of three heavy duty O & K machines Nos. 1355-56-57 were under construction at Neyveli, India and the first of these went into operation late in 1978.

Fig. 3: O & K 1340 BWE at Athabasca

Neither 1340 nor 1355 were readily applicable to Goonyella — because of the inherent differences between the three deposits — but they served some useful comparisons in working up the design for No. 1367.

The design ordered for No. 1367 is illustrated in Fig. 4 and the main dimensions are set out in Table 1, which also gives some basic comparisons between the three other machines referred to above.

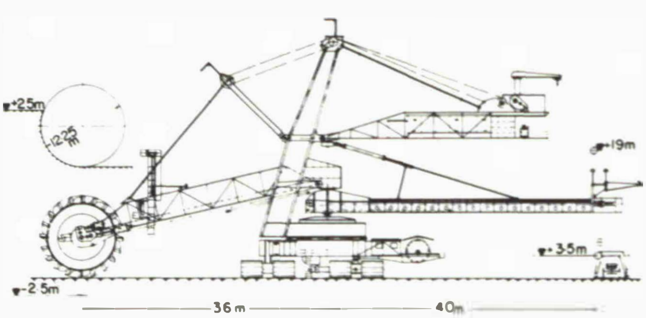

Fig. 4: O & K 1367 BWE for Goonyella

6.1.1 Bucket wheel head and bucket wheel drive

The nominal hourly output of 1,500 m^3 (bank) is to be maintained in the weathered clays, which at times can be extremely sticky, and it was realised and agreed that lower guarantees would suffice in the harder and more abrasive types of O/B. At the extreme, where material will have to be blasted, lumps up to 0.5 m^3 would have to be handled by the whole system. For this condition belt speeds will be lowered.

In the Goonyella system in order to attain the annual output the wheel must be proportioned to handle the sticky O/B and in the case of 1367 this is attained by large, roomy buckets (Volume I_1) and by having the ring space (Volume I_2) twice the size of the normal German convention (Rodgers & Mitchell, 1978). With these proportions and a speed variation control, the digging rate can be varied so that O/B is not packed firmly into the bucket but can "float" in the bucket and ring space and so discharge more readily. Also, with these proportions, when free-flowing material is met, both I_1 and I_2 can be filled to overflowing and high production can be maintained. However, an upper limit needs to be set on production rate to minimise the risk of excessive spill and blockages at the conveyor transfers of the system. This was set at 6,600 m^3 (loose)/h. At an assumed swell factor of 1.5 this is equivalent to 4,400 m^3 (bank) or nearly three times the guaranteed output, and is a measure of the conservative rating used in the Goonyella planning. It also indicates how a wheel of the 1367 proportions has a good deal of reserve capacity and can cope with a wide spectrum of digging conditions and O/B variations.

The close relationship between the batter slopes and block widths has been explained (Rodgers, 1976) and for Goonyella the stability investigations suggested that 45° at 25 m would be the norm for the standing side batter and for the same height 50° could be tolerated for the front batter. The zone allocated for No. 1367 will vary in heights between 20 and 25 m above the conveyor transport level. It was also realised that to attain the hourly and annual outputs the wheel diameter would need to be in the order of 11 m and in order to optimise the frequency of conveyor shifting the block width should be a nominal 40 m at the 25 m face height. From these considerations it appeared that the BW outreach should be between 36 and 38 m. Once the order of the BW outreach and the block width were known, it was then apparent the discharge boom would be of the order of 40 m. Its hoisting equipment and clearances to the BWE top structure should enable it to load to conveyors standing up to 11 m above the BWE operating level. With these basic proportions, variation in face conveyor grading would enable No. 1367 to command its nominal 33 m strip. It and the associated transport and disposal equipment would also have sufficient electrical reserve capacity to enable it to operate with a mobile slewing conveyor (bandwagon).

Having determined the basic proportions of the BWE the next main consideration was the BW drive. The digging resistance tests and comparison with other heavy duty machines indicated that a cutting speed of 2 m/s and a force at the bucket cutting circle of the order of 35 tonnes, would be needed for digging the more difficult material. An overall drive efficiency of 85 % was assumed and from this the following simple formula was derived for the relation between the cutting force P and the kilowatts output of the BW drive motor s, viz:

$$P = 0.0867 \times \text{kW} \div V.$$

where kW = kilowatts input to bucket wheel drive when drive motor(s) are at maximum torque without overload, V = cutting speed in m/s at the bucket wheel cutting circle and 0.0867 = 85 % x 0.102 (the conversion factor of kW to tonnes). (For wheels with multiple speeds the largest value of kW $\div$ V is to be used).

With the nominal 35 tonnes for P this gave 800 kW at 2 m/s and as it was desired to dig at 3 m/s in soft and free-flowing regions, 2—600 kW (i.e., 1200 kW total) motors were nominated. It was also considered the wheel speed would need to be reduced to 1 m/s to prevent excessive loading and impact on the transport system when handling blasted material. This would be readily obtainable with a DC drive or with an extended version of an AC "Cascade" system. The capacity of the drive for 1367 thus became comparable with those of 1340 and 1355 and of course resulted in a very heavy bucket wheel head. DC motors were chosen in preference of AC for the BW drive.

A major influence on the design of the BWE as a whole is the moment of the BW and its boom about the boom pivots. The greater this moment, the stronger and, therefore, the heavier the machine must be. The outreach from the slew axis to the outer lip of the cutting circle influence the dimensions of the top cut and consequently block width and batter slopes. Also, consideration must be given to the slope of the BW boom conveyor in the highest and lowest digging position and to the angle of the transfer chute from the bucket to the BW boom conveyor. Thus the BW outreach and hence the length of the BW boom has to be integrated with the wheel diameter, and in this case rather than choose a 37 m boom with 11 m wheel O & K opted for a 12.25 m wheel and 36 m boom, the larger wheel diameter giving better clearance angles. Permissible "foreland", or advance per terrace cut, needs to be considered also (Rodgers, 1976).

6.1.2 BWE conveyors

1.8 m belt width was selected as the appropriate balance with wheel proportions. The belts will be supported by 5-roll impact idlers in the loading zone and 3-roll 40° idlers in the main length of the conveyors. In the loading zones 5-roll plain steel impact idlers are to be used spaced at 400 mm; but there are some reservations as to whether these will prove to be as satisfactory under Goonyella conditions as 3-roll steel or rubber disc idlers. For this reason the frame and the chutes at the tail ends of conveyors are to be designed for ready modification to suit the 3-roll idler configuration.

The normal belt speed will be 4.5 m/s but in order to cope with the sharp and heavy blasted material this can be reduced to the half speed of 2.25 m/s, a feature not only in the BWE but throughout the whole system. Also, to prevent belt damage by sharp, heavy lumps impact tables are to be installed at transfer points. Naturally these would very quickly cause blockages when handling sticky materials and hence the impact tables will be retractable.

In order to improve belt tracking, even with steel cord belts, drive pulleys are to be crowned.

6.1.3 Ground pressure

Because of the high clay content of the Goonyella deposit and its inherent instability, it was considered that ground pressure on the BWE should be low enough to minimise the risk of bogging of the crawlers and was set at an average based on the operating weight of < 125 kPa, with a maximum of not more than 200 kPa. These ground pressure measurements are taken on the convention of distance between the crawler end tumblers with the take-up tumbler in the mid position. Even so, the risk of bogging cannot be overlooked and the crawlers steering system and underframe are to be designed so that the machine can travel with full steering with the crawlers on one side bogged to a depth of 0.8 m. The crawlers also have to be powered and proportioned for a grade of 1:20 in operation and 1:10 when changing sites.

6.1.4 Power supply

Whereas 1340 and some machines in Europe have a separate cablecar, No. 1367 has followed the Australian practice of having a large cable drum mounted on the BWE underframe. This helps to make the BWE fully independent of other plant and tends to minimise manning requirements. For the Goonyella system, a central feed point is contemplated on the 2.5 km face conveyor and the drum on the BWE itself will accommodate 1,500 m at a supply voltage of 22 kV.

6.1.5 Load assumptions

The basic design code for 1367 will be the West German Basis for Calculation of Large Open Cut Machines (the B.G.)

and related codes and standards. The current version of this code is 1960. UDC became aware that revisions and upgrading are in progress and provision has been made to incorporate these revisions into the 1367 design. For example, under the BG the theoretical live load is based on the bucket contents l_1 and half the ring space contents l_2, but for 1367 a higher figure, from the maximum normal cross-section of load on the BWE conveyors, has been taken. This results in a nominal live load of 14,000 tonnes/h to which the structure are to be designed, compared with some 10,000 tonnes/h at the nominal peak load of 6,600 m^3 (loose).

7. Australian Manufacture

The highest practicable Australian participation in its projects has been an objective of UDC and was applied again in this case. The result was that only some specialised mechanical and electrical items and those which the contractor insists on making overseas will need to be imported. A high percentage of the machines and conveyors will be made in Australia. However, as indicated in Section 5, the design parameters for the machines are higher than hitherto and much of the structures are of plate with maximum use of welding. This type of steelwork is expected to be of a higher standard than the highest quality of bridge steelwork and the contractors' detailed welding instructions have been audited by UDC and local welding authorities to ensure a close integration of the best of German and Australian welding practices. This approach has been carried back to the design stage, where the drawings are required to have full size details of welds rather than symbols only, so that the designers intentions can be made clear to the welder on the shop floor or in the field.

Close cooperation has been achieved between the local steel suppliers (BHP), UDC and the contractor to ensure that plates of the required quality will be produced by local mills. As with earlier machines of this type steel to AS1204-350-L15 will be used in lieu of the German St52-3 for plates up to 30 mm thickness and above this size the local equivalent of the low sulphur German OK400 will be used. AS1204-250-L15 is to be the equivalent of the German steel St37.

In terms of contract value the percentage of Australian manufacture will be 56 for the BWE, 67 for the Spreader, 72 for the Tripper and 80 for the conveyors. Of necessity, most of the design has to be carried out overseas and this reduces the Australian content on a contract basis, but as far as work in Australian shops is concerned the percentages are higher than the figures stated above.

8. Conclusions

The Goonyella pre-stripping system marks a new venture into heavy duty O/B stripping by a BWE system but only broad details have been given here because of the length limitations on this paper. As with most new systems teething troubles can be anticipated in the early stages of this operation. However, as explained herein a systematic approach has been made, firstly to try to understand the nature of the deposit and then to develop plant design parameters to suit the deposit.

This was followed by the issue of performance and engineering standards and specifications, and then discussion with each of the competitive tenderers; and finally close discussions with selected tenderers prior to placing contracts. It is also intended close and continuous communication be maintained with the contractors until the end of warranty periods. This will not shift any responsibility to the client but will rather help the contractors to develop the optimum plant for this application. Such user input is worthy of application in most mining ventures and readers are commended to the following quotations:

"No mining operation is a piece of cake" ... and ... "Good mining equipment is only constructed in cooperation between manufacturer and user". (Winzer, 1976).

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