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INSTITUTE OF QUARRYING

ACHIEVEMENTS THROUGH THE DRAGLINE IMPROVEMENT GROUP (DIG) IN ANGLO COAL

By

Gareth Williams
– Mine Manager, Anglo Coal – Kriel Colliery

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"Achievements through the Dragline Improvement Group (DIG) in Anglo Coal"

Author/Speaker:
Gareth Williams – Mine Manager, Anglo Coal – Kriel Colliery

Gareth Williams obtained his B Eng Hons (Mining) from the University of Auckland, New Zealand in 1988.

Gareth started with Anglo Coal, Bank Colliery as a graduate trainee in 1989 and transferred to Landau Colliery as a Pit foreman in 1991. He obtain his Mine Manager's Certificate for Coal and was promoted to Assistant Pit Superintendent at Landau Colliery prior to joining Goedehoop Colliery in 1995 as Section Manager. He became Assistant Mine Manager in 1999 returning to Bank Colliery and in 2003 he was transferred to New Vaal Colliery. Gareth was appointed as Mine Manager, Kriel Colliery as of 2004 – a position that he holds today.

He is a member of the South African Coal Manager's Association, and an Associate Member of the South African Institute of Mining and Metallurgy.

Gareth is married, has three sons, one daughter and is a keen sportsman.

1. INTRODUCTION

Anglo Coal is one of the largest private sector mining groups in the world with substantial holdings in South Africa, Australia and South America.

'Operations under Anglo Coal South Africa (A.C.S.A.) consist of eight producing mines with a combined base reserve of 1.2 billion tons'.(2) Four of these mines, namely Kriel, New Vaal, Kleinkopje and Landau have opencast operations (strip mining) and combined, have ten draglines currently continuously uncovering coal reserves.

In 2000, Anglo Coal concluded the purchase of Shell Holding Limited and acquired coal operations both in Australia and Venezuela. The Australian opencast operations, namely in Callide, German Creek, Drayton and Moura, operate with a total of seven draglines.

In 2002, the Dragline Improvement Group (DIG) started as an initiative from the Australian mines. They realized that there were areas requiring improvement, and when focused upon, would yield gains in productivity. The South African operations followed suit some six months later believing that 'two minds are better than one'.

2. WHAT IS A DRAGLINE? (3)

A dragline is a specialized piece of electronically powered mining equipment used primarily in stripping overburden to expose coal seams. Draglines, in one form or another, have been around for about 100 years. Machine sizes, bucket styles and rigging techniques have slowly evolved with improving technology over that time. The modern day coal mining dragline is a massive machine. A BE 1570W dragline, weighs approximately 3,000t and is capable of an overburden payload of over 130t. Draglines consist primarily of a large circular base, upon which revolves the large machinery housing comprising the swing, propel, drag and hoist motors and power generation equipment. The boom length can be up to 130m. The boom can be rated to hold over 200t, depending on the capacity. The standard mine site bucket volumes can range from 30 – 110m^3 in volume. The BE 1570W has a 100m boom and approximately 56-64m^3 bucket with a steel weight of 34 to 46t. This setup should shift a little over 110t of spoil per pass.

Draglines are the largest pieces of machinery on the mine site after coal treatment plants and consequently carry large maintenance and operational issues. They require close support from dozers, blasting coordinators, maintenance crews, electricians, supply and logistics personnel, field technicians, rigging and bucket maintenance crews, water trucks *et cetera* in order for the dragline to operate efficiently and be cost effective in uncovering coal.

2.1 Dragline Specifications

The typical operating specifications of a BE 1570W dragline is shown in Figure 1 and the specification list that follows.

Working Ranges and Dimensions

Clearance Radius (Rear End)	21.4m
Operating Radius	87.5m
Boom Length	99.1m
Boom Angle	38°
Clearance Height (Under Frame)	2.4m
Tub Diameter	20.1m
Dumping Clearance	45.7m
Boom Point Height	65.2m
Maximum Digging Depth	53.3m
Width (Shoe-Shoe)	28.0m
Rated Suspended Load	176t
Step Length (approx)	2.6m

Electrical Equipment

Hoist Motors	Four/Five/Six	1300hp
Drag Motors	Four 1300hp	
Swing Motors	Four 800/1045hp	
Propel Motors	Four 500hp	
MG Sets Sync. Motors (Genemotor System)	Two 3000hp	
Walking Speed	200-250m/h	

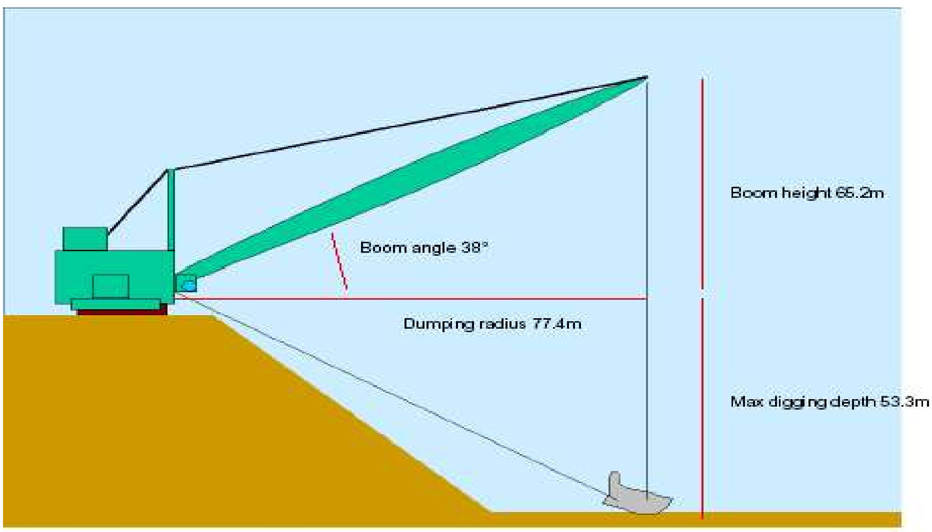


Figure 1 – Operating Specifications of a B.E. 1570W Dragline

3. UNDERSTANDING DRAGLINE PRODUCTIVITY

For most mines which use draglines, the dragline is the central focus of productivity. The mines profitability is highly leveraged towards dragline productivity and therefore, the recognition for rapid improvement is a necessity due to increased coal demands for both the export and power generation markets.

In order to fully appreciate the potential improvements that were possible within the South African dragline fleet, the newly formed D.I.G. group contracted assistance from Ground Breaking Innovations (G.B.I.) Australia.

'G.B.I. has a database from draglines all over the world and, as of June 2003, contains more than 90 million cycles spanning over 187 dragline years (Queensland - 138, New South Wales - 41, united States of America - 61, South Africa - 40 and Canada - 7)'. [4]

By entering 9 of the 10 current draglines into the database (Kleinkopje only received the fourth dragline during 2003), the relevant mines could then compare or benchmark (the continuous process of comparing organizations strategies, products or processes with those of best-in-class organizations[5]) themselves against other machines worldwide and ascertain in which areas to focus with regards to improvements and/or change.

The difference between the average of the top 10% and the average of the whole database is illustrated in the waterfall chart depicted in Figure 2. The chart clearly identifies that best practice draglines achieve higher payloads and higher dig hours, thus a concentration on payload and dig hours has the greatest potential to increase productivity.

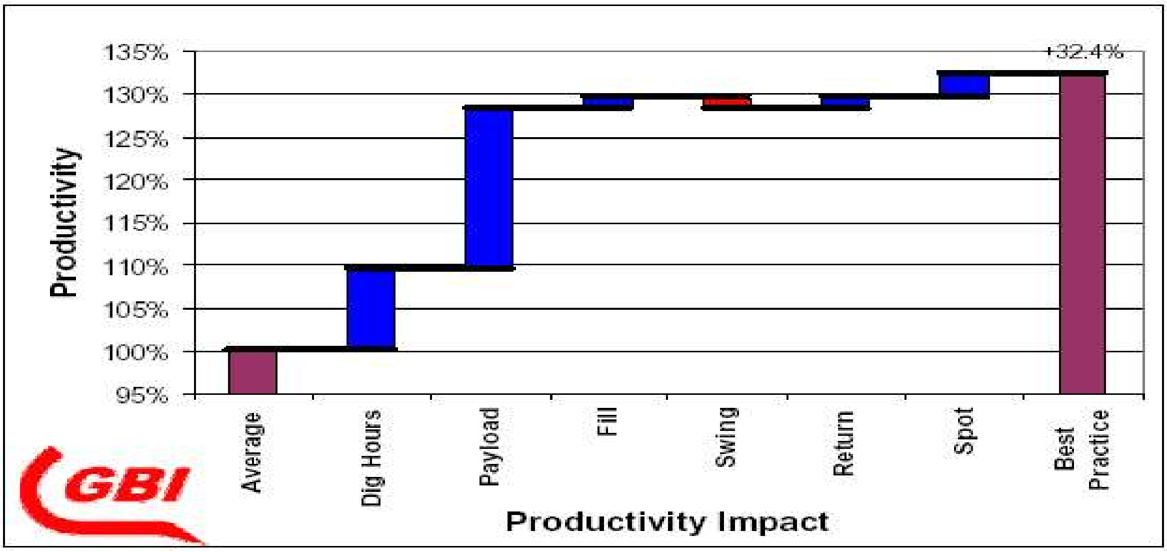


Figure 2 – Difference between Best Practice and Average

To determine the philosophy of digging, the strength of the relationship between the main productivity parameters (dig hours, payload, fill, swing, return and spot) is calculated and described as the r² value. The correlation coefficient (r²) is the relative predictive power of the model and is between 0 and 1. The closer to 1, the stronger the relationship.

The r² values relative for 250 years of dragline data are:

Payload	0.90
Dig time	0.41
Cycle time	0.09
Fill time	0.00
Swing time	0,01
Swing angle	0,02
Return time	0.01
Spot time	0.30

It is important to note the link between payload and productivity as well as dig time. These two areas once again reiterate the fact that this is where the focus should be to make rapid in-roads into improved productivity.

4. INITIAL FINDINGS

Information captured from the dragline monitoring systems (Contel x 8, ISI x 1) were sent to G.B.I. in early 2002 to ascertain their performance for the production year 2001.

The findings of the exercise were that the South African machines performed at 19,2% below the database average and that the Anglo Coal Australian draglines were 21% more productive than their South African counterparts.

Becoming 'world best' suddenly became an over optimistic goal but the movement towards industry average and then the top decile become highlighted targets.

Exercise Rank (10)	Dragline	ANNUAL OUTPUT (T) VS. RSL		TARGET IMPROVEMENTS	
		Res. (vs DB)	Rank (150)	Top Priority	Second Priority
1	BH BE1350W	+14.4%	36	Payload (16%)	Swing Time (4%)
2	DR BE1370W	+2.3%	64	Payload (15%)	Dig Time (4%)
3	CA M8750	-5.3%	82	Payload (15%)	Swing Time (6%)
4	KR55 BE1570W	-7.9%	92	Payload (17%)	Dig Time (12%)
5	NV49 BE1570W	-10.3%	99	Payload (22%)	Dig Time (16%)
6	NV45 BE1570W	-16.7	116	Payload (22%)	Dig Time (16%)
7	KK10 BE1300W	-17.9%	121	Payload (19%)	Dig Time (14%)
8	CC M8050	-18.8%	124	Payload (22%)	Fill Time (5%)
9	NV51 BE1570W	-21.6%	132	Payload (24%)	Dig Time (21%)

10	KK50 BE1570W	-22.1%	134	Payload (18%)	Dig Time (14%)
11	KK33 BE1570W	-26.7%	141	Payload (28%)	Dig Time (15%)

Table 1: Summary of Anglo Coal 2001 Dragline Results with Targeted Improvements

5. DEVELOPMENT OF AN IMPROVEMENT PLAN

On receipt on the database information from G.B.I., representatives from three South African mines travelled to Australia to ascertain why such differences in productivity exist.

In May 2002, it was agreed between the four South African mines that all efforts would be directed towards payload and dig time.

Note: Subsequent to this initial trip, two additional trips have taken place enabling a total of 21 operational staff to visit Australian operations and suppliers as well as reciprocal visits to South Africa by Australian staff.

Figure 3 highlights the areas that inter-relate with maximizing payload and digging time.

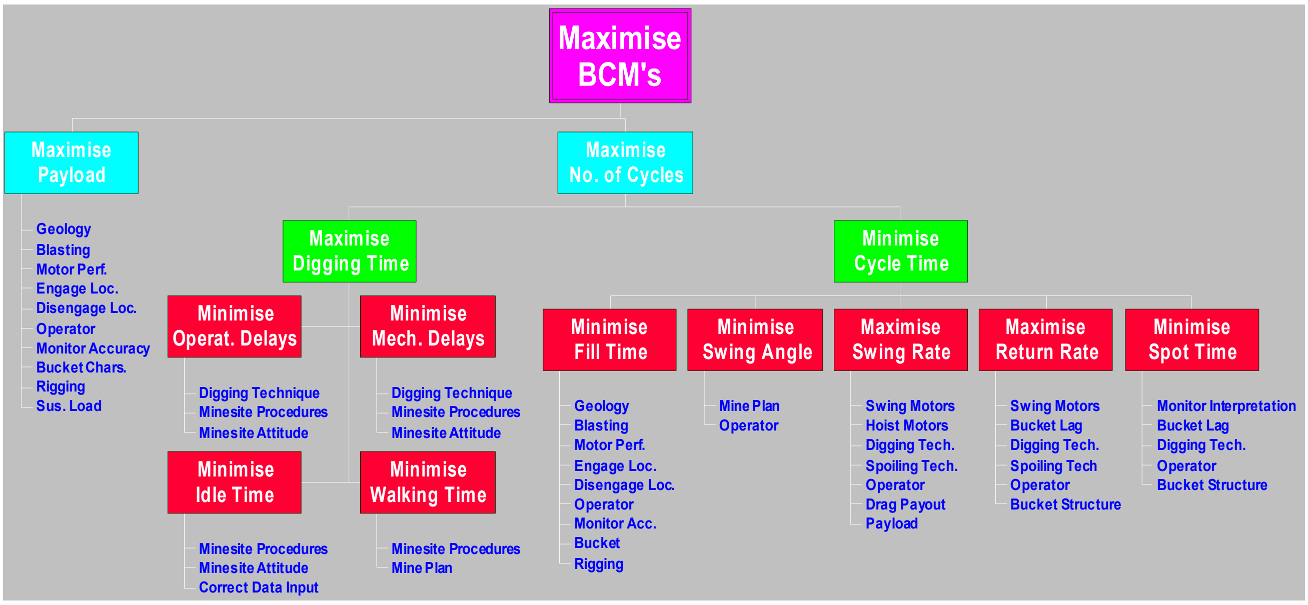


Figure 3 – Dragline Productivity model

6. IMPROVED PAYLOAD

All draglines have a rated carrying capacity referred to as Rated Suspended Load (R.S.L.). This is based on the combined weight of the bucket (empty), the fill material placed into the bucket and the associated rigging.

The following issues were investigated;

i) bucket characteristics
ii) changes in rigging
iii) overloading of R.S.L.

6.1 Bucket Characteristics:

Most buckets used in the South African industry were made to last as they were protected by excessive wear plates due to the common understanding that bucket life must be maximized. Observations in Australia indicated that a bucket change, when organized, only takes four hours and unless damaged, the repair costs are insignificant. Major changes have now resulted in buckets with reduced wear packages and have been built to suit the associated ground conditions. Buckets used to be maintained with wear packages designed to make it last four months of digging in an operation which was heavily focused on reducing blasting costs. This philosophy has radically changed to buckets, maintained and designed, to work as effectively as possible in material that has been blasted for optimal fill. These packages have also been designed to assist with the flow ability of the material into the bucket by adding smooth liners with jointing/welding along the same planes as material flow direction. The old philosophy that one bucket suits all has now been abandoned, for example; New Vaal Colliery has three different buckets that each individually out perform the other depending in what ground they dig.

Other assumptions previously made were that all buckets of the same size must dig the same. Information gained now indicates that the digging characteristics of a bucket depends on its weight, centre of gravity, associated rigging, attack angle of the teeth to the fill material and engage distance from the machine. Figure 4 indicates different dig characteristics of four similar buckets in similar ground conditions.

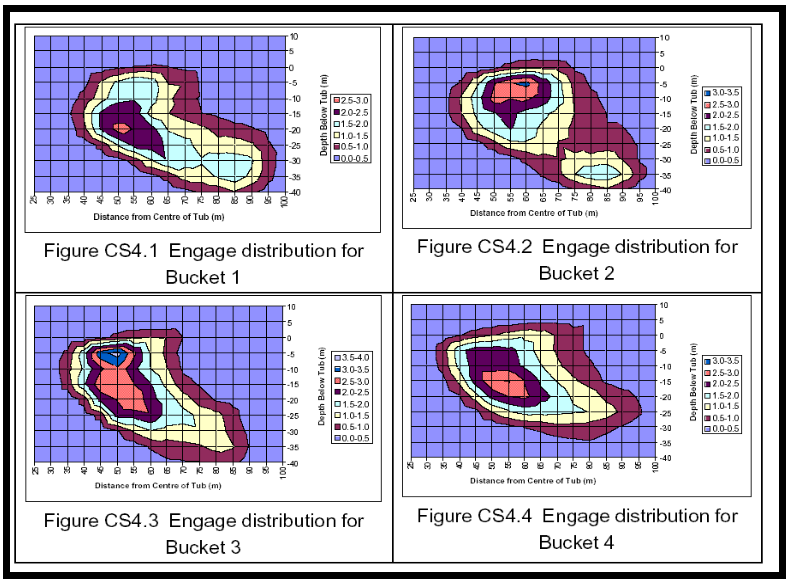


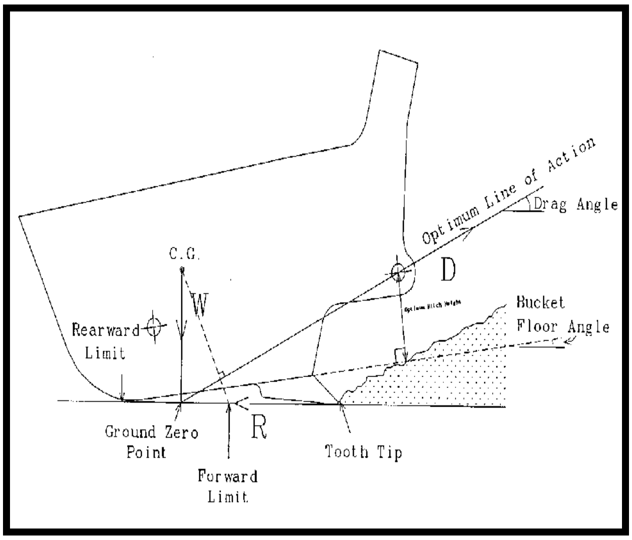
Figure CS4.1 Engage distribution for Bucket 1

Figure CS4.2 Engage distribution for Bucket 2

Figure CS4.3 Engage distribution for Bucket 3

Figure CS4.4 Engage distribution for Bucket 4

Figure 4 – Spoil movement charts for similar bucket dimensions



Due to the removal of unwanted steel from around the bucket (sometimes in excess of seven tons), it was now found that the draglines became under loaded hence the challenge became to add the additional weight back into the bucket - in payload. An additional seven tons per swing creates a quick gain of 6 – 8% in productivity, however some mines had to increase the size of the bucket for this to materialize. New Vaal and Kleinkopje Collieries removed steel from a 56m3 Esco bucket and managed to increase its capacity to 62m3 without changing the R.S.L.

6.2 Changes to Rigging:

Using the same methodology as light weight buckets, investigations revealed that alternative rigging packages also service the Australian industry. Due to the size of this market, active competition is readily available, however in South Africa only one maybe two rigging suppliers had been utilized. Persistence from D.I.G. personnel have enabled the manufacture of a lighter and stronger design of hoist and drag chain (Rhino Rigging) and this is currently on trial at Kriel Colliery whereby a possible eight tons can be removed and added back into payload. A 50 % improvement in life cycle has been achieved with this rigging during the trial.

Another change in rigging is the angle in which the bucket is carried to the spoil pile known as carry angle. South African draglines have continued over the past years with a belief that one angle (22^{O}) suits all. However, Kleinkopje Colliery now continues to trial differing angles for changing pit dimensions. Most operations in Australia vary this angle up to 35^{O}.

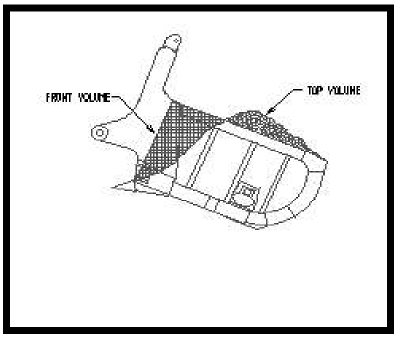


Figure 5 – Loss of fill due to incorrect carry angle

Other rigging initiatives include the trials of plasticized dump ropes at New Vaal Colliery, which the Australian mines have taken back with them to implement as a potential means to increase rope life. Initial trials indicate almost a doubling of dump rope life when using the plasticized rope at a cost increase of only 50%. Further improvement can be achieved by installing 'U-bolts' to prevent the untimely 'knocking out' of bolts during dig time.

Ground engaging tools (G.E.T.) in most overseas operations were found to be user friendly due to the higher cost of labour and a multitude of ideas are currently in place across all collieries. Trials include bolt-on teeth / shrouds, two piece teeth and the removal of welded keeper plates with 'lock-bolts'.

Pins have been re-designed incorporating a safer locking system which make use of bolt instead of 'hammering-in' wedges.

6.3 <u>Overloading of R.S.L.</u>

Based on the information from the G.B.I. database, the largest difference in dragline productivity was that on average, the Australian machines were 12 % overloaded compared to the South African counterparts that were 2 % under loaded. Callide Colliery had assistance from Monash University in determining the effects of overloading on the boom. Following discussions with Monash and other institutions that monitor dragline booms under similar loading conditions, a careful decision was undertaken to begin overloading various machines whilst monitoring the increased productivity and any change in machine reliability. To date the net result is improved productivity, for example New Vaal Colliery has replaced one 56m3 bucket for a lightweight 64m3 bucket which has averaged a 12 % overload – see increased bucket fill in figure 6. The same mine now continues a program to refurbish their older buckets to larger, lighter versions.

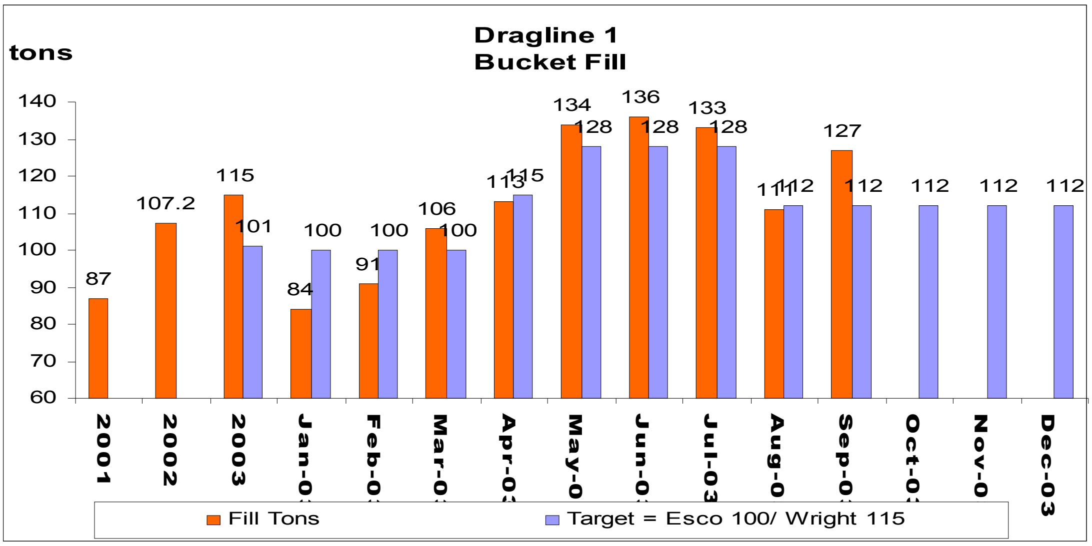


Figure 6 – Effects of 64 m3 bucket at New Vaal Colliery 2003

Overloading of machines remains a topical subject within the group, however the quickest way to improve productivity ranking in the G.B.I. data base is to simply put more material in the bucket. 'For a 20 % increase in payload, there is an approximate 10 % increase in stress along the boom cords. For an incremental increase in stress of 10 %, there is a possible reduction of machine life of at least 25 %.'(6) Anglo Coal South Africa is currently costing the exercise to place strain gauges onto one of its machines to understand the effects of overloading and to ascertain what percentage becomes acceptable.

6.4 **Improved Blast Results**:

On examination of typical Australian fill material, the investment into higher blast ratios result in lower bucket and rigging costs. Kleinkopje Colliery continues to track the progress of different blast patterns, explosive type and powder factors for different material types. Similar trials also continue across the group together with the explosive suppliers whom also keep abreast of world developments. The importance of blasting and its affect on dragline productivity has now been incorporated into another improvement group namely (B.I.G.), Blasting Improvement Group.

7 IMPROVED DIG TIME

Dragline operations overseas boast average dig time exceeding 500 hours. However in 2001, some South African machines were achieving less than 440 hours, averaging 12 % less digging time.

Generally dig time is affected by

i) operational delays: shift change, cable work, blasting, dozing, pad work etc
ii) engineering delays: mechanical and electrical delays, bucket work, rope work, breakdowns, maintenance etc

The common thread to maximizing dig time is to ensure that all dragline staff are well trained and work together to reach common achievable targets.

7.1 **Operator training**:

Through interactions with G.B.I., operator training has been contracted out over the last two years to assist all operators / training staff to keep abreast of latest digging techniques. Such changes have allowed draglines to have two different digging areas at one time hence the elimination of unwanted dozer wait. The simple technique of covering the cable with half a plastic pipe has allowed digging through 360^0 without cable damage as well as blind side spoiling. Most important was the re-introduction of continuous feedback to all operators with respect to their performance and how they rank against other. Figure 7 is an example whereby this report is shown on all draglines however only each operator knows what number relates to his own performance. Operator comparisons of the K.P.I's (Dig Hrs, Payload, Fill, Swing, Return and Spot time) allow for continuous comparison between operators. Those under performers receive one on one discussions in order to assist in their continuous performance.

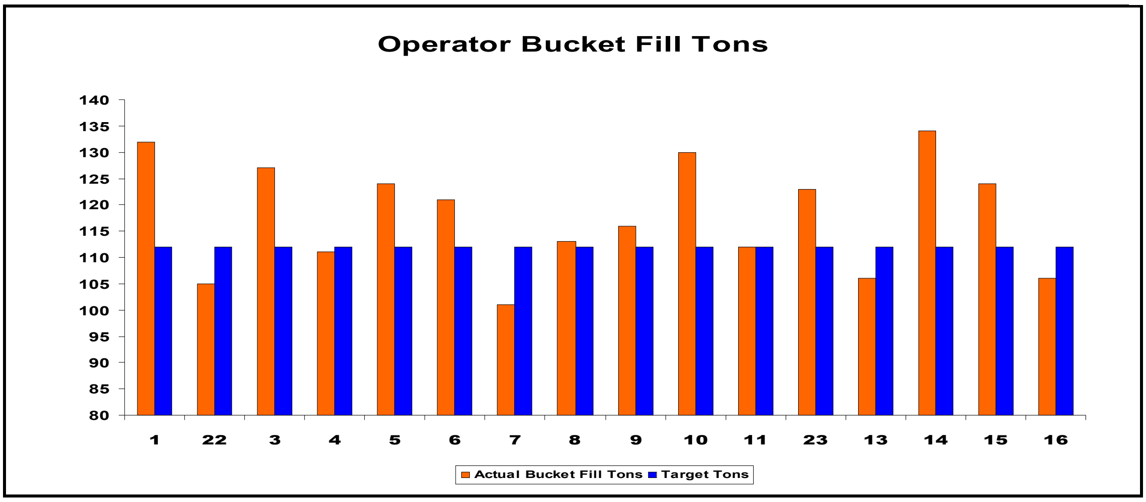


Figure 7 – Operator Fill tons, September 2003, New Vaal Colliery

Historically most operations in South Africa only had one trained operator per team, hence the expectancy that he would work productively for his entire seated shift, some shifts being 12 hours in duration, whereas most overseas operations share the digging shift between at least two multi-trained personnel. This change was introduced to only one dragline at New Vaal colliery in 2003 and the saving in operational delays is depicted in figure 8.

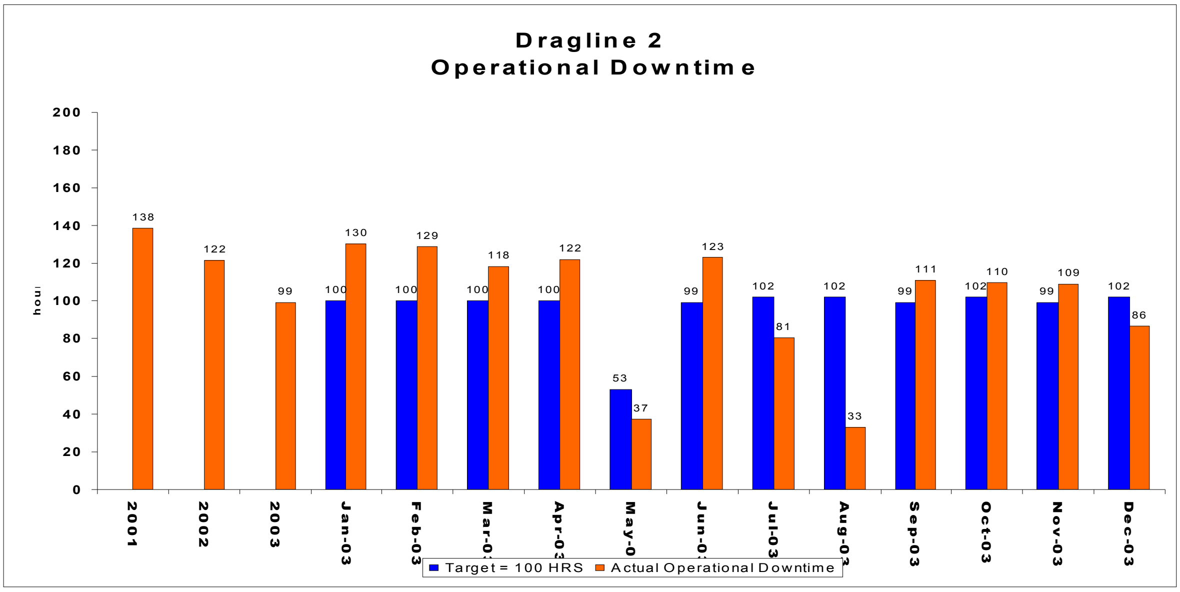


Figure 8 – Reduction in operation downtime due to additional operator

Another technique introduced by Jenson and Curtis (an American dragline consultancy currently working at Moura Colliery) is the positioning of a web camera on the highwall, that through time lapse photography acts as a training tool for operators on tub positioning. Landau Colliery is currently working with C.S.I.R. Mining to introduce this technology into the South African collieries.

7.2 Engineering Maintenance:

Reduced unnecessary time spent on the machine results in increased dig time. Changes in past philosophies brought back from Australia are

- i) removal of welded keeper plates changed out with lock bolts reducing the amount of welding required during service intervals
- ii) hard facing of wear plates / teeth have resulted in increased life
- iii) better maintenance scheduling has allowed increased intervals between downtime without adversely affecting machine reliability

Improved condition monitoring and inspection techniques together with risk assessments have lengthened the major shutdown frequency for the A.C.S.A.dragline fleets. True focus on dragline availability together with detailed cost sensitivity for all aspects of maintenance was evident at Australian operations. This has allowed the shutdowns to be based on a target of 25 000 hours compared to that of 6 000 hours in South Africa. Supplier involvement is crucial overseas in order to retain business due to the size of industry however the feeling within South Africa was that sole suppliers determine both the cost and willingness to assist. Anglo Coal South Africa has, for the last year, begun Heavy Mining Equipment (H.M.E.) meetings with Bucyrus Erie that in order to improve productivity, the challenge must be accepted by all role players.

7.3 Technical services training:

An area whose importance has traditionally has been undervalued. However, with the purchase of available software such as Drag2000 and Dragsim, the South African operations are becoming more dependent on computer planning instead of 'highwall discussions'. These simulations are also used as operational instruction tools for spoil placement, walk routes, extended bench and rehandle profiles.

8 LATEST RESULTS

In the results for 2003, the South African fleet improved productivity by 6.0 % (figure 9) with four of the nine machines improving by > 10 %. The productivity gap between the two fleets (A.C.S.A. and A.C.A.) has reduced from 21% in 2001 to 8 % in 2003 however four machines still remain in the lower quartile. As indicated in Figure 10, dig time and payload remain the key focus areas for improved dragline productivity. However various overseas mine sites have recently become concerned that excessive overloading is affecting machine reliability.

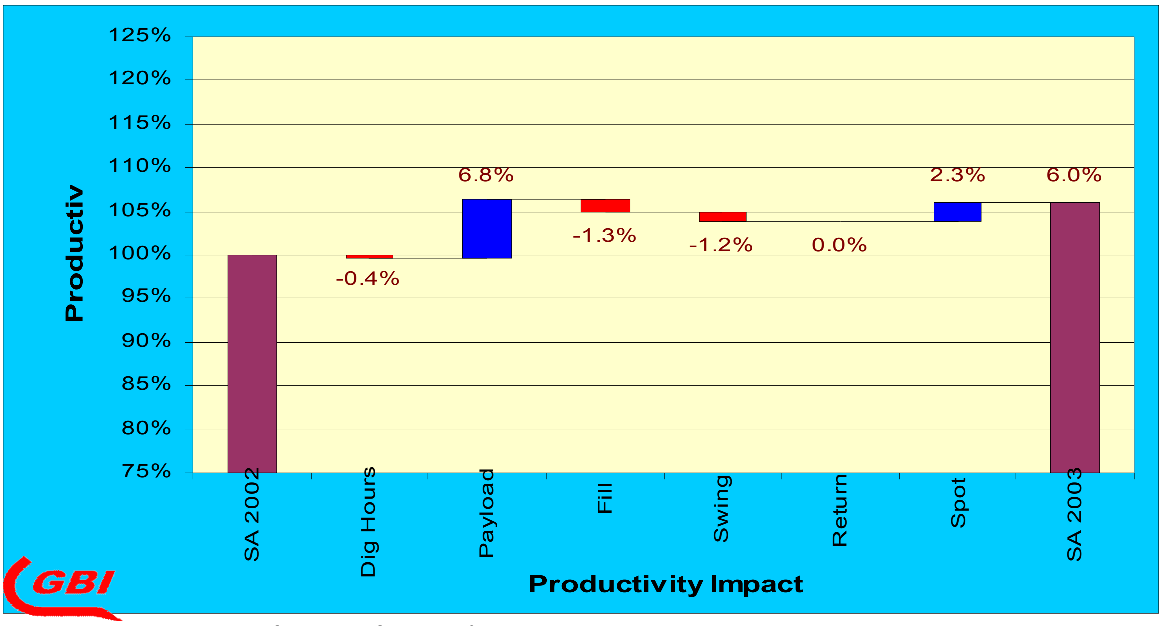


Figure 9 – Productivity Gains in South African draglines 2003 vs 2002

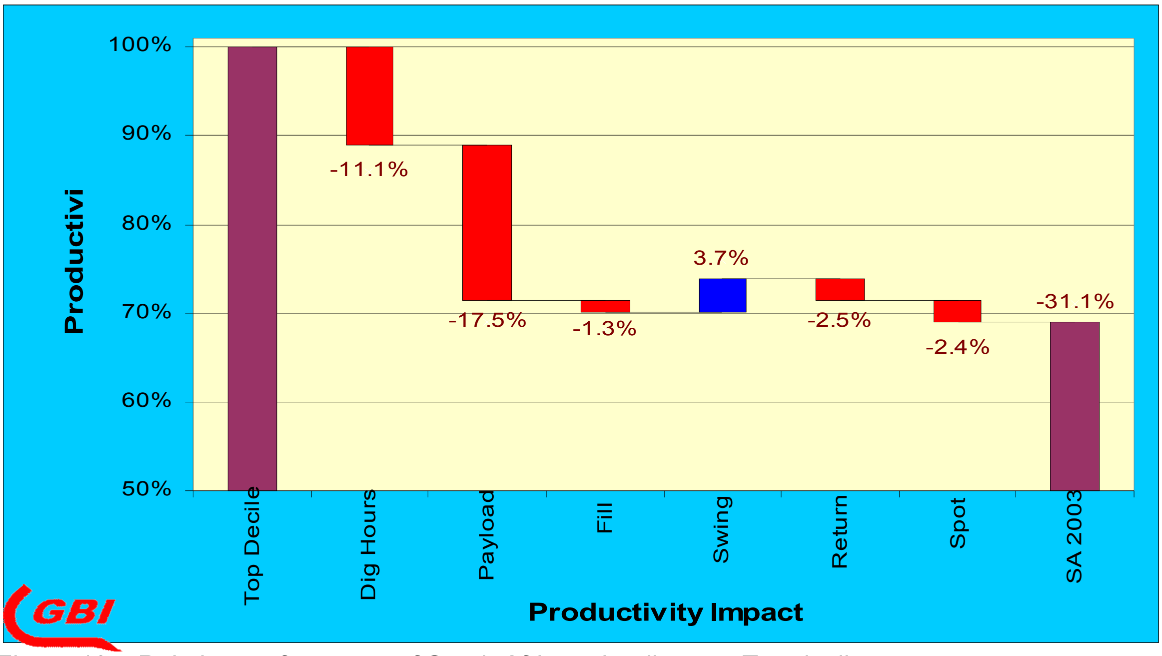


Figure 10 – Relative performance of South African draglines vs Top decile

9 DIFFICULTIES AHEAD

There have been a number of problems encountered as changes have been introduced;

9.1 Lack of expertise

In order for the D.I.G. group to bring new ideas to the relevant mines, most can only explain the concept as few operators have been exposed first hand. This has resulted in the company hiring expertise from Australia with most mines gaining one or two weeks of training per year. The cost evaluation of bringing an overseas operator across for an extended period is still being debated.

Planning expertise has also been identified as a problem with most technically skilled personnel opting for a production environment as this traditionally has been the quicker route to promotion. This problem continues and has historically been hampered by the low number of mining graduates opting for work in the coal industry.

9.2 Assistance from suppliers

Due to the size of the dragline market within the country, most suppliers have been able to demand set prices for limited ware with little scope for change. With the formulation of the H.M.E. meetings, an increased involvement from suppliers is being experienced of late. One bucket manufacturer is beginning trials on material flowability into dragline buckets as a post graduate project and another is willing to explore the possibility of designing buckets within the country for South African conditions.

9.3 Overloading of bigger buckets

Most opencast mines within South Africa have relatively shallow conditions with a multi-layered overburden. These material types can alter considerably in density, hence a bucket designed in shale for a 10 % overload, may yield an overload in excess of 30 % in clays or wet sand. An example is New Vaal, whereby the sand, whether wet or dry, has a huge change in density. The longer term effects of overloading on machine reliability are still not understood and until the introduction of strain gauges, remain an educated guess.

10 CONCLUSIONS

Benchmarking is the continuous process of comparing an organization's strategies, products, or processes with those of best-in-class organizations. It is intended to help employees learn how such organizations achieved excellence and then set out to match or exceed them. The G.B.I. database has exposed all Anglo Coal opencast operations to information that has never been previously available and has highlighted areas requiring considerable productivity improvement.

Due to the formation of the D.I.G. group and the opportunity for members to travel to Australia and learn from our sister operations, dragline productivity improvements of 5 %, 11 %, and 6 % for the past three years, has enabled most of the operations within Anglo Coal South Africa to increase output with reduced unit cost.

The challenge to get machines into the top decile is still an achievable target without sacrificing machine reliability and this focus must remain by continually updating the ranking information.

The D.I.G. group remains the change agent for South African dragline productivity and should continue this work by training those in these business units. Supervisors whom continually conduct reviews of their performance areas are already seeing the positive results and by countering traditional thinking, will achieve the breakthrough results required for world class productivity.

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