BELT CONVEYOR DESIGN CRITERIA WITHIN ANGLO AMERICAN CORPORATION

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SYNOPSIS

Belt conveyors for Anglo American mines are mostly designed within the corporation. An internal code of practice serves as a reference for the economic design of conveyors. The current design method is based on GOODYEAR but also incorporates aspects of CEMA and ISO 5048. It is similar to that used by many other designers since the early 1970's.

AAC has developed, and continues to develop, its own manufacturing and performance specifications for pulleys, idlers and steel-cord belting.

Independent design comparisons have shown that, on balance, AAC's conveyors are economically designed. Preliminary field testing shows a good correlation between measured and design powers.

1. INTRODUCTION

The Anglo American Corporation of South Africa Limited (AAC) administers various coal, diamond and gold mines. Belt conveyors are the essential bulk materials handling equipment that are common to all the mines.

Conveyors can be the most used and abused pieces of equipment on a plant. If they become overloaded they can trip out or cause spillage. Belt failure generally involves a long period of downtime which is interruptive to the plant process. Belt replacement is an expensive business. Conveyor components that are incorrectly designed or specified can lead to premature failure and often a "knock-on" effect that affects other components.

Belt conveyors for Anglo American mines are mostly designed within the corporation. Internal designs emanate from the Mechanical Engineering Department. There is a recommended code of practice for belt conveyors.

This paper describes the current design philosophy, the design methods used, and weighs the results against comparisons made by independent sources as well as some field testing.

2. AAC THE USER AND CONVEYOR DESIGNER

Anglo American uses and also designs conveyors.

The operating divisions i.e. coal, diamonds and gold, use conveyor belts extensively both underground and in surface process plants. Thus we have a wide variety of installations from which to gather operational feedback.

The Mechanical Engineering Department incorporates a Materials Handling section whose primary function is to design belt conveyors. New designs, re-designs, modifications and troubleshooting exercises are undertaken. This design section functions in close collaboration with the Project Design section where all drawings and schedules are prepared.

The Mechanical Engineering Department works closely with project engineers and mine engineers in the operating divisions. Hence the methods and criteria used have been fashioned and developed over many years with the benefit of operational experience.

3. BASIC DESIGN METHOD

Traditionally, the Anglo American Corporation used various sources for the design and supply of its belt conveyor requirements. As technology improved and engineers became bolder in their application of the equipment, the conveyors were required to operate under more and more strenuous conditions.

3.1. In the Beginning.......

In the late 1950's and into the 1960s, it was discovered that similar conveyor installations, with similar loading patterns and utilisation, but designed by different sources, were supplied with entirely different and incompatible equipment. Not only was the equipment different, but the conveyors had entirely different specifications of tension and ancillary equipment.

This led AAC to investigate a number of different methods for the design of conveyors. It was discovered that there were about as many significantly different results as there were design procedures. Many of the procedures relied almost entirely on empirical formulae and safety factors for their successful operation.

3.2. The Green Book

Arising out of this investigation, in the early 1970's, AAC compiled the green book. This book was a combination of a design code and a specification (AAC 370/1). For ten to twelve years, it formed the basis for the design of many conveyors in AAC.

The book compiled, into one document, all the standard requirements for the AAC's conveyors. It also served to bring a measure of uniformity of approach to the design of a widely varied field of belt conveyor requirements.

To cater (amongst other things) for the ever-present "Langlaagte" chute and in an attempt to cater for the kind of abuse to which many mining conveyors were subjected, the procedure made use of a design capacity that was based on oversizing the capacity by 67%. (One operating division insisted that the factor be 100%). This was ostensibly to cater for, or eliminate, spillage. Of course, this oversizing at the front end of the design had a ripple effect on the whole design, with "safety factors" being added on all along down the line. Eventually, AAC ended up with some fairly large conveyors. In addition to very large conveyors, and probably more to the point, we have a whole generation of mining engineers who have been brought up believing that the conveyor will happily carry anything that they could throw at it.

3.3. A Fresh Start

At the beginning of 1980, a start was made on the compilation of the updated AAC Code of Practice (AAC 3TP-1 310) for the design of belt conveyors, in order to try to overcome the very real shortcomings of the previous design procedure. It must be borne in mind that the old "green book" was really only valid for conveyors up to about 150 m in length. With the rapid advance in mining conveyor technology and the ever-increasing length and capacity of the belt conveyors, it became obvious that the old specification was no longer compatible with the advances being made.

The first application of the revised code of practice was on the shaft and yard conveyors for the Amcoal Goedehoop colliery project in 1982. The conveyors designed to this code have all behaved fairly predictably, with a minimum of reported problems. It can be said that those designs were successful.

The code was designed around the Goodyear system, which is a well tried and tested system for static conveyor design, used throughout the world. The AAC procedure goes beyond that system, though, by the fact that the secondary resistances are more fully investigated, for example, in the determination of the effective tension. The determination of the maximum tensions for the selection of the belting is based on standard mathematics, used by nearly all reputable conveyor designers.

3.4. Comparisons with Other Procedures

The AAC procedure does not differ much from the DIN 22101 and ISO 5048 procedures, rendering much the same results. It must be noted that all the static systems available to the conveyor designer are principally used to determine the effective or motive tension. All the other tensions flow from this, as well as the determination of the belt power (Figure 1).

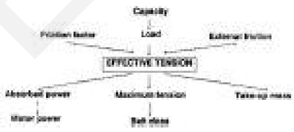


Figure 1: Static design method

Figures 2 and 3 show the comparisons of different design methods in terms of absorbed power as a function of belt length. A typical conveyor configuration was taken as a basis for comparison.

In Figure 2, the overdesign from the "green book" is immediately apparent, especially in long conveyors. A linear design system with a friction factor of 0,05 shows a similar picture but with a lower absorbed power. The present AAC procedure, using an added length factor, closely follows the linear design system with a friction factor of 0,025.

Figure 3 shows, for belts less than 200 m long, that the choice of design method is a sensitive issue.

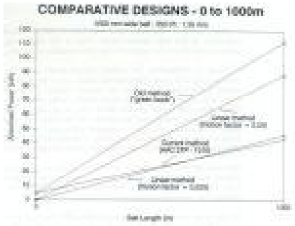


Figure 2: Comparison of Different Design Methods for Conveyors (0 - 1000m)

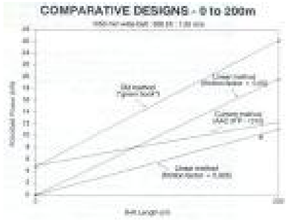


Figure 3: Comparison of Different Design Methods for Conveyors (0 - 200m)

3.5. The Specification of the Belt - The Service Factor

A major point of difference, and one that is still the cause of much argument, is the belt service factor. This is the factor applied to the maximum tension in the system for the determination of the belt class.

For ease of designation, the belting manufacturers in South Africa have standardised belt class designations based on a factor of 10. AAC has varied these factors to cater for certain known conditions, such as vulcanised splices, lap ratio (or cycle times), pulley diameters and so on. This means that a belt service factor can be as low as 7,6 for design purposes, given the proper conditions. On the other end of the scale, a factor of 12 can be utilised for conveyors with a very low lap ratio, with too small pulleys or with clipped belt joints. The next larger belt class is then selected, always subject to rationalisation within the project and plant.

For example, the actual service factors calculated at the Amcoal New Vaal colliery, built in 1983/84, showed the least value of the belt service factor at 8,13. The conveyors were all designed for a service factor of 7,6 - all the splices were specified as being hot vulcanised.

On the other end of the scale, an AAC diamond mine had the conveyors in one of the winzes designed around a service factor of 7,6. The capacity of the conveyors was stipulated as a maximum value, not to be exceeded. Not long after the conveyors were commissioned, the mine started experiencing belt breaks - not all at the splices. Investigations showed that the "feed control" devices on the conveyor did not control at all and the conveyors were significantly overloaded, with the capacity far exceeding the "absolute maximum" capacity originally specified.

On another mine, conveyors that were originally designed in 1975, for a capacity of 1800 t/h, have never exceeded 400 t/h. This results in conveyors that are grossly oversized. For example, one of the conveyors is fitted with dual 90 kW power packs, while the actual requirement, established in a recent audit, is for a single 45 kW power pack.

3.6. The Need for Good Communication

The design procedures notwithstanding, the results obtained from any system are absolutely dependent on the information provided to the designer. For example, should a conveyor be designed for a certain given capacity, the belt tensions determined will be directly influenced by that capacity, as shown in the examples above. Any increase in the capacity must invalidate the design, unless the designer is advised of the potential increase in production. For this reason, the MC design procedure allows for the application of certain oversizing factors. This means that, under certain conditions, the design capacity can be much larger than the capacity originally specified to the designer. This capacity will cater for conditions such as overloading, whether momentary, accidental or deliberate. It also attempts to cater for the normal surges that occur with any conveyor system. The oversizing factors also cater for the overloading that can occur as a result of the feed system onto the conveyor.

3.7. The Current Static System

The current static design system is an extension of the system first used in 1982, with a number of enhancements and improvements being added over the years. Currently, all conveyors are designed (statically) using MC specification no. 3TP-1310. The system is on an internally-developed Lotus 1-2-3 spreadsheet-type program. The program gives results and print-outs that are geared to ease of interpretation by the structural and electrical design staff and the mechanical, project and mine drawing offices.

The design of a conveyor belt is not limited to merely determining the tensions only, but to the whole design of the conveyor system. That implies that the component parts of the conveyor be adequately and correctly specified, in order to perform the tasks required of them.

3.8. Preliminary Designs and the Field Mining Engineer

In addition to the static design, which is a detailed analysis of the whole conveyor system, there is a preliminary design system (called "PREUM) available to MC mining engineers. This (static) system is a very basic analysis that allows the mining engineers to make decisions with regard to their conveyors, prior to the designs being channelled through to the MC Mechanical Engineering Department for detailed analysis.

3.9. Conveyor Dynamic Analysis

The Mechanical Engineering Department is currently in the process of developing an in-house system for the analysis of conveyor belt dynamic transients, to cater for the accurate design of the longer and curved conveyors.

3.10. Economic Design

The yard-stick of economic design in the mining industry is low production costs achieved through the use of highly reliable equipment. This equipment must require minimal maintenance and must require the minimum number of personnel to operate and service the machines.

In order to achieve reliability, it is not necessary to overdesign equipment by providing units grossly in excess of the requirements. It is imperative to provide a well-engineered unit, sufficiently sized to cater for and absorb surge that might occur, where the transfers will not block and where the components will not fail prematurely. The MC designer strives to size the equipment objectively, bearing in mind that while the capital cost is important, reliability and ease of maintenance are equally important.

In conveyor design, considerations which prolong the life of the conveyor belt usually pay dividends in the form of enhanced reliability and reduced maintenance. As stated above, the design of the conveyor involves the correct specification of all the components in the conveyor system. This implies that the components such as the idlers, the pulleys, the power packs, the take-up, the holdback, the chutework, the belt cleaning system, the supporting steelwork and so on, must all be adequately and correctly sized, in order to achieve that goal. A major tool available to the designer in MC is the availability of a variety of in-house specifications and standards, developed over many years and based on practical experience.

4. STANDARDISATION OF CONVEYOR COMPONENTS

4.1. Pulleys

There was a time when conveyor pulleys were made of cast iron. There was also a time when the MC design office had to obtain special permission to design belts in excess of 42 inches (1050 mm) width.

With the increase in conveyor sizes and in keeping with the independent spirit displayed by AAC in the early 1970's, the design office developed a design for the conveyor pulley, utilising standard pipe diameters. While considered valid at the time (and there are still some conveyors operating today with that design of pulley fitted), the rapid and dramatic increase in conveyor usage and size led to some spectacular and catastrophic failures.

These failures led to the requirement for the total redesign of the pulleys by the Mechanical Engineering Department. The design was obviously influenced by the spectre of the failures that had occurred. This led to the use of conservative values in the basic design of the pulley. One of the bases for design was that the pulley should have an effective service life of 20 years. Another consideration was that the pulleys could be used in a number of different applications and would therefore need to be compatible with such a requirement. A third consideration was the reduction in the actual number of sizes available, to reduce spares holding.

4.1.1. The "Anglo pulley"

The result of the above development work was the "Anglo pulley - a big, heavy design that was not likely to fail, even under the most arduous conditions. Most pulley manufacturers would provide two quotations - one for the "Anglo pulley", and one for their own design, with design calculations attached.

However, these "second generation" pulleys filled an obvious gap in the industry, and served to bring a degree of sanity into the situation. The MC standard pulley diameter range is still in use today (AAC specification 371/1) and is not very different from that proposed by ISO 3684. The third generation of AAC pulleys, in the process of design and review, will follow the same basic range of shell diameters, with certain enhancements and additions.

4.1.2. Standard pulley shell diameters (mm)

(100)	315	800	(1400)
(125)	400	*900	(1600)
(160)	500	1000	(1800)
(200)	630	*1100	(2000)
(250)	*700	1250	

The standard shell diameters shown above are largely compatible with the ISO 3684 recommendations. The diameters not bracketed are currently specified, while the those shown in brackets are proposed. The smaller diameters shown, (160 and below) will probably never be used as pulleys by the MC, their diameters being close enough to the standard idler diameters to be substituted by them. The larger diameters shown in brackets are not yet incorporated in the specification proper, being proposals only, at this stage.

The diameters shown with an asterisk indicate that these pulley diameters are not in the standard ISO R20 range of diameters, but fill an otherwise large gap between two standard diameters. These sizes are not preferred, but are used where necessary.

The pulley shell diameter is sized in accordance with the ISO 3684 recommendation. ISO 3684 has been adapted to form a general case, not limited to the narrow bands contained in it.

4.1.3. The pulley face width

AAC is also proposing that the pulley face widths, and by implication the bearing centers, be largely in accordance with BS 2890, adapted to the standard belt widths available in South Africa.

4.1.4. Pulley bearing centers

In the past, MC utilised two basic sets of bearing centers for their pulleys. For head and tail pulleys and pulleys enclosed in chutes, we used the "wide" centers, while "narrow" centers were used elsewhere. This was acceptable for the conveyors generally in use in the 1960's and 1970's, but has proved to be inadequate for the larger sizes of shafts demanded by today's conveyors. As a result, this aspect of the pulley design is also under review.

4.1.5. The pulley shaft diameter

There exists a very wide requirement for the pulley shaft diameters, because there is such a wide range of tensions imposed on the pulleys. (Incidentally, this was one of the major obstacles addressed in the design of the second generation AAC pulley). The current (unwritten) standard is to limit the maximum pulley diameter/shaft ratio to 3. For example, the maximum shaft diameter that may be fitted to a 500 mm pulley will be 500/3 = 167 mm. The nearest standard bearing diameter is then 160 mm.

4.2. Conveyor Idlers- Dimensional Standards

Before the advent of SABS 1313 in 1980, there existed a plethora of idler manufacturers, with little or no correlation between the various forms available. Since AAC operates so many conveyors, with such widely diverse materials being transported, it can be appreciated just how rapidly the different forms can escalate. At AAC, at least three suppliers are required to tender for equipment, whether new or replacement. With new projects, this was easy to achieve, but the picture changed dramatically when it came to spares. With the very different idler forms and sizes, the supplier of the original idlers had essentially a captive market - not an economically healthy scene at all. For this reason, AAC actively promoted the creation of SABS 1313 and still actively supports it.

South Africa was probably the first country to establish and operate a national standard for the dimensions of belt conveyor idlers and rolls. This took the form of SABS 1313, which is currently under review. Some idler forms were omitted, though, probably for very good reason, and also possibly because these idler forms were simply not considered at the time. These omissions make a conveyor designer's life difficult, since the specification of garland, picking and fixed-form suspended idlers can lead to some interesting scenarios.

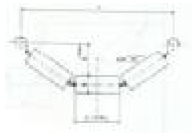
At AAC, there is an internal specification (MC 373/1) for idler performance, which details the additions and exceptions to SABS 1313, for general purpose conveyor systems. The AAC specification must always be read in conjunction with SABS 1313.

4.2.1. Garland idlers

AAC has the experience where, on one of the major diamond mines, an inclined underground conveyor with a lift of +100 m was being installed. It was discovered that the idlers (5-roll garlands) were ordered from two different suppliers. Once the installation was complete, and the belt was being pulled in, it was discovered that the center roll of maker A's idler was 200 mm lower than that of maker B's idler. The idler support structure was designed around one of the maker's idlers and the other idlers simply did not fit.

AAC has recently issued a specification for garland idlers (MC 373/2), which specifies the boundary dimensions for the rolls and the idler set form. This was done to prevent a repetition of the problem outlined above. Possibly a national dimensional standard could arise from this. (Figures 4 and 5 shows standard 3-roll and 5-roll dimensions).

35 Deg. 3-Roll Garland Idlers
Series 25x125 Nom. Dia.



Belt Width	A	B	C	D
600	920	175	240	127
750	1050	200	290	127
900	1180	230	340	127
1050	1310	260	390	127
1200	1470	295	450	127

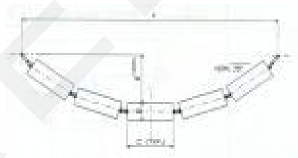
Note:

{1} Dimension 'A' shall be toleranced to ±1,0mm for dimensional test purposes only

{2} Dimensions 'C' and 'D' are in accordance with SABS 1313

Figure 4: Standard 3-roll Garland Idler Dimensions

35 Deg. 5-Roll Garland Idlers
Series 25x125 Nom. Dia.



Belt Width	A	B	C	D
1350	1865	355	300	127
1500	2050	390	340	127
1650	2185	415	370	127
1800	2320	440	400	127
2100	2660	510	475	127
2400	2940	560	536	127

Note:

{1} Dimension 'A' shall be toleranced to ±1,0mm for dimensional test purposes only

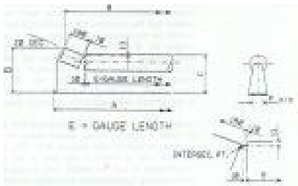
{2} Dimensions 'C' and 'D' are in accordance with SABS 1313

Figure 5: Standard 5-roll Garland Idler Dimensions

4.2.2. Picking idlers

The same sort of confusion is prevalent with picking idlers, with many different dimensions and profiles appearing. At AAC, a single dimensional standard is proposed, with individual performance standards stipulated by the project designers and consultants (Figure 6 shows a proposed standard).

In-Line Type Picking Idlers



Belt Width W	A	B	Slotted Holes	C	D	E	F	Clearance Belt Edge to Roll Edge
750	990	922	14x25	265	315	546	100	93 Approx
900	1144	1074	14x25	265	315	698	100	94 Approx
1050	1296	1226	14x25	265	315	850	100	95 Approx
1200	1448	1380	14x25	265	315	1004	100	97 Approx
1350	1600	1532	14x25	265	315	1156	100	98 Approx
1500	1752	1684	18x30	285	335	1308	150	99 Approx
1650	1904	1836	18x30	285	335	1460	150	100 Approx
1800	2058	1988	18x30	285	335	1612	150	101 Approx
2100	2362	2294	18x30	285	335	1918	240	102 Approx
2400	2668	2596	18x30	285	335	2222	240	103 Approx

Wing rolls 125 Nom. Dia. Series 25
Center roll 150 Nom. Dia. Series 30
With spherical roller bearings (Which may be specified as a rubber impact roll. In which case Dim. C.as Max will increase by 10mm)
E = [1,017 (W - 300) + 87.14] Approx.
For tolerances see SABS 1313

Figure 6: Proposed Standard for Picking Idlers

4.2.3. Fixed form suspended idlers

AAC only occasionally specifies this type of idler. However, where they have been specified it is plain, from different formats offered by the various suppliers, that there is a need for some dimensional standard. This will hopefully be addressed by the SABS and the Conveyor Manufacturers' Association in the future.

4.2.4. Dimensional standards

A dimensional standard should be seen as just that - a standard group of dimensions to ensure compatibility. The performance requirement for a particular piece of equipment must vary as often as there are different requirements for each user. For this reason, we believe that the performance specification for a particular component should be the responsibility of the user, in order to satisfy his own unique set of needs. To create a very tight set of performance specifications at the national level will serve to downgrade the generally high standard of conveyor equipment used. Smaller operators, who have perhaps not so stringent performance requirements, will simply circumvent or ignore such a specification, to the ultimate detriment of the conveyor industry as a whole.

At AAC, the performance specifications that are issued are generally to meet a specific need, where there is no other specification available to satisfy local requirements. We are not averse to using the BSI, DIN or ANSI, if any one or all of those bodies has a specification to suit our needs. AAC is very much aware of the cost of re-creating specifications and does not believe that it needs to do so.

4.3. Conveyor Belting

At the end of the 1960's, the MC design office started investigating a uniform (or standard) approach to the description and specification of the conveyor belt itself. Working in conjunction with the SABS, a private specification was drawn up, where the belt was given a class number, which referred to the belt strength. The designation still maintained the concept of strength per ply, as was common at that time. This specification was very much a bridging document between the old "anything-goes type of specification and the national specifications, SABS 971, SABS 1173, and SABS 1366.

There is no supplement to the national specification for plied belting or solid-woven type belting at MC. However, there have been some interesting experiences with steel-cord belting.

For example, on one colliery, the belting for an overland conveyor was supplied in a certain format; (number of cords, cord diameter, cover thicknesses and strength rating). Came the requirement for replacement and the belting was specified by strength rating only, and with a different supplier this time. Of course they did not match. The replacement belt had a different number of cords, they were of a different diameter and the covers were slightly different. It is a tribute to the mining engineers, their staff and the belting vulcanising team, that the two different constructions were successfully spliced.

In another case, the belting supplied for a particular overland conveyor system had a class designation of ST850. This was because of the cords available at the time. Ever since then, that particular mine has had to pay a premium for replacement belting, whether large or small amounts are ordered, because the belting is "non standard".

For the above reasons, in 1986, AAC developed an internal specification for steel-cord belting (AAC 377/2). This stipulates, in a scientific way, the number and maximum diameter of cords related to belt width and strength, the breaking strength of the cords, the nominal belt widths and the minimum cover thicknesses (Table 1). The specification also dictates the range of belt classes utilising steel-cord belting. Once again, the preamble to the specification stipulates that the document lists additions and exceptions to the national specification, and does not supersede it.

This fact is indeed true for most of AAC's specifications. The intention is to enhance the accepted specifications to suit AAC's unique requirements, not to prescribe globally.

Class	Thickness of cover mm	Steel cords	
		Cord spacing mm	Max diameter mm
ST500	5.0	17.5	3.5
ST630	5.0	15.0	3.5
ST800	5.0	17.5	4.3
ST1000	5.0	15.0	4.3
ST1250	5.0	12.5	4.3
ST1600	5.0	17.5	6.3
ST2000	5.0	13.5	6.3
ST2500	6.3	20.0	8.6
ST3150	7.0	20.0	9.6
ST4000	8.0	20.0	10.6
ST5000	9.0	20.0	11.8
ST6300	10.0	20.0	13.2

TABLE 1: EXTRACT FROM AAC SPECIFICATION 377/2 - STEEL-CORD BELT

AAC specification 377/2 goes on to say,

- "Cords in any one length of conveyor belt shall be from one source of supply."
- "Where more than one length (see SABS 1366; clause 3.5.1) of belting is supplied for a specific conveyor belt installation, each length shall have cords of the same diameter and shall be sourced from one supply."

The nominal belt widths allowed in the AAC specification are as follows:
750, 900, 1050, 1200, 1350,1500, 1800, 2100 and 2400 mm. Greater widths may be specified as the need arises.

This specification is designed to assist the designer and user of the conveyor belt, in the proper and repeatable selection of both new and replacement steel-cord belting.

5. RATIONALISATION OF PLANT BELTING/MAJOR COMPONENTS

When a complete plant is being designed from concept through to detailing, each conveyor is designed separately, using the ideal sizes of components such as belting, drives, pulleys etc. In a complex plant, this means that there would be a wide variety of component sizes, which would lead to a large and expensive spares holding, in addition to the lack of interchangeability in times of crisis. Hence a rationalisation of major components is often carried out at the design stage. This means that a few selected component standards are used throughout the plant. This is especially true for conveyor belting which can constitute up to 50% of the total capital cost of an installation.

Rationalisation can be considered from the point of view of different areas. A single, geographically isolated plant may be rationalised to suit its own needs. A group of mines in a localised region may be the object of rationalisation. Invariably, this process involves specifying components of a higher duty than the optimum. This looks like "over-design , but the economies of reduced spares stockholding against the increased capital costs of the installation will guide final decisions.

As an example, Table 2 shows a diamond mine project (before and after rationalisation). A subset of 900 mm wide conveyors is shown. The required classes of the 13 belts range from 177 to 949. 12 belts were rationalised to class 800, whilst the last was chosen to be class 1000. Because of the wide range of design capacities, there was a wide range of required powers and no rationalisation of power packs was made here.

Table 3 shows the rationalisation of 1200 mm wide belting underground at another diamond mine. These 8 conveyors all have similar lengths, lifts and design capacities, hence the belting was easy to rationalise to class 1000. However, the required powers ranged from 94 kW to 147 kW. All 8 power packs were rationalised to 160 kW installed power.

When extensions or modifications are made to an existing plant, the component standards already in use dictate the narrow range to be used in the design of the extensions.

TABLE 2: SUMMARY OF RATIONALISED EQUIPMENT -900 mm WIDE BELTING. DIAMOND MINE PROJECT

Conveyor No.	Length m	Lift m	Design Capacity t/h	Belt Speed m/s	Belting			Power kW		
					Width mm	Class				
						Required	Installed	No	Required	Installed
RCX-1-18	465	-0.6	900	2.2	900	413	800	1	56.5	75
RCX-2-18	779	34.3	900	3.1	900	949	1000	2	94.7	110
RFX-1-18	164	17.4	540	2.1	900	177	800	1	56.6	75
RFX-2-18	31	3.3	540	2.0	900	177	800	1	19.4	22

RFX-3-18	189	37.8	540	2.1	900	700	800	1	90.7	90
RJX-1-18	251	4.1	700	1.9	900	436	800	1	54.6	55
RKX-1-18	454	-0.6	532	2.3	900	296	800	1	43.4	55
RKX-2-18	1150	12.5	532	2.1	900	796	800	1	104.9	110
KX-2-18	157	7.9	532	2.3	900	257	800	1	37.7	45
KX-3-18	644	10.1	532	2.0	900	554	800	1	71.3	75
RCZ-1-18	47	6.6	900	2.9	900	251	800	1	42.8	45
RCZ-2-18	32	3.7	300	1.0	900	231	800	1	13.1	15
RKZ-1-18	48	6.7	532	2.0	900	219	800	1	26.9	30

TABLE 3: SUMMARY OF RATIONALISED EQUIPMENT -1 200 mm WIDE BELTING. DIAMOND MINE - WINZE CONVEYORS

Conveyor No.	Length m	Lift m	Design Capacity t/h	Belt Speed m/s	Belting			Power kW		
					Width mm	Class				
						Required	Installed	No	Required	Installed
21	264	65.8	800	2.2	1200	1000	1000	2	102.0	160
22	340	84.9	800	2.2	1200	999	1000	2	127.5	160
23	349	84.9	800	2.2	1200	999	1000	2	127.9	160
24	322	80.3	800	2.2	1200	999	1000	2	121.4	160
31	349	84.4	800	2.2	1200	999	1000	2	126.9	160
32	246	59.7	800	2.2	1200	962	1000	2	94.4	160
33	400	99.7	800	2.2	1200	997	1000	2	147.3	160
34	342	85.3	800	2.2	1200	998	1000	2	128.1	160

6. INDEPENDENT DESIGN COMPARISONS

In response to suggestions of "over-design" , a number of independent audits of various AAC designs were arranged. A selection of operating conveyors in AAC were taken and reputable designers, outside AAC, in the conveyor belt industry, audited MG's designs based on their own methods. The results are shown below.

6.1. Comparison 1.

This conveyor has the following parameters:

Material.....Diamond ore
Capacity.....900 t/h
Length.......465m
Lift.........-0.6m
Belt Width...900mm
Speed........2.2 m/s

One auditor was chosen: designer A. The results are summarised in Table 4 below.

TABLE 4: RESULTS OF DESIGN COMPARISON 1.

	AAC	A
Absorbed power (kW)	45.3	50.3
Effective tension (Te) (kN)	21.0	23.2
T1 tension (kN)	31.0	36.9
T2 tension (kN)	10.0	13.7

AAC'S absorbed power is 5 kW (10%) lower than the auditor's value.

6.2. Comparison 2.

The second design comparison was made with a long overland conveyor that incorporates vertical and horizontal curves. The audit was carried out by designer B. The parameters are as follows:

Material.....Coal
Capacity.....1200 t/h (design)
Length.......1745m
Lift ....-3.5
Belt Width...1200m
Speed........3.5 m/s

Table 5 shows the comparisons of power and tension for a capacity of 2400 t/h.

TABLE 5: RESULTS OF DESIGN COMPARISON 2

	AAC	A
Absorbed power (kW)	375.5	434.6
Effective tension (Te) (kN)	106.9	117.0
T1 tension (kN)	140.0	136.3
T2 tension (kN)	33.1	19.4

AAC's absorbed power of 375 kW is 14% lower, and effective tension of 107 kN is 9% lower than the auditor's values.

6.3. Comparison 3.

This conveyor has the following parameters:

Material.....Coal
Capacity.....3112t/h
Length.......103m

Lift.........18m
Belt Width...1800 m
Speed........2,6 m/s

The essential design parameters were given to four independent designers (C,D,E and F). The results are summarised in Table 6 below.

TABLE 6: RESULTS OF DESIGN COMPARISON 3.

	AAC	**C**	**D**	**E**	**F**
Friction Factor	0.022	0.017	0.02	0.02	0.219
Absorbed Power (kW)	227.4	197.5	204.0	200.0	206.0
Effective tension (Te) (kN)	83.6	72.6	74.4	73.1	70.9
T1 tension (kN)	115.7	109.5	102.0	136.0	111.8
T2 tension (kN)	32.1	36.9	27.5	57.0	40.6
Belt class	800	800	800	800	800

AAC's friction factor (0,022) is higher than the average; however, AAC considers designer C's factor of 0.017 to be rather low. Although designer E's T1 and T2 tensions are significantly different than his colleagues, AAC'S effective tension, and hence absorbed power, is 15% higher than the average. The belt class selected showed no differences. Incidentally, the belt class was rationalised to class 1250.

6.4. Discussion

In Figure 1, absorbed power is determined by effective tension, which, in turn, is determined by 3 factors, viz, the friction factor (encompassing idler friction, belt flexure resistance, material resistance and pulley inertia), the load (from the belt capacity) and the external friction (from rappers, scrapers, ploughs, trippers and skirts etc). Hence effective tension is an important central parameter to compare different design methods.

The MG basic design method, based on Goodyear, uses a friction factor of 0,022 as well as an "added" length of 60 m. For underground conveyors less than 150 m long, the friction factor is 0,03 and the added length is 40 m. The friction factor is a critical parameter, and the Goodyear value of 0,022 has been based on extensive experience. However, it has to be an average value to cater for varying conditions e.g. different idler stiffnesses, the pressure of skirt seals, the adjustment of the belt cleaner etc. The friction factor is most sensitive on shorter conveyors of, say, less than 50 m in length.

ISO 5048 has a wider range of friction factor i.e. from 0,016 to 0,03 with a recommended value of 0,025. ISO 5048 gives the designer scope to reduce the primary friction factor if the secondary resistances are specified more accurately. As an extension to the Goodyear method, AAC specifies secondary resistances conservatively.

The standard factors, which the AAC design method incorporates, are not rigidly applied. Deviations are allowed for particular conditions. As an example, for a short (10 m) reversible shuttle conveyor, with full length skirts, a "linear" design method would be used (no added length) with a friction factor of 0,05.

Overloads are more likely to occur on shorter conveyors and the results of such overloads are far more significant. Thus, shorter conveyors are designed for a greater overload margin.

7. RESULTS OF FIELD TESTING

Further comparisons were done where motor current and weighmeter readings were taken for conveyor belts that were designed in-house. Table 7 shows a summary of the results and Figure 7 shows the comparative conveyor powers - actual vs design.

Figure 7: Comparison of Conveyor Powers

TABLE 7: SUMMARY OF CURRENT READINGS AND CAPACITY

Conv	Cap t/h		Length m	Amps α	P.F.	Eff %	Power kW		
	ACT	DES					ACT	DES	INST
R4	1100	1056	71.1	48	0.9	95	39.1	38.6	55
R8	1000	1056	183.3	50	0.95	95	43.0	46.1	55
M1	250	200	34.0	1.5	0.8	95	1.1	3.3	4
M2	250	200	34.0	3.5	0.8	95	2.5	3.3	4
103	--	110	875.0	65	0.8	95	44.9	44.3	2 x 55

Conveyors R4 and R8 were being operated very close to the design capacities. The actual powers consumed were 1% lower and 7% higher than the design powers, respectively.

Ml and M2 are small conveyors and were being operated at a 25% overload compared to the design capacity of 200 t/h. The powers consumed were significantly lower than the design values, and significantly different between themselves, in percentage terms. However, such "over-design" is insignificant when the 4 kW motors are considered in the context of the total installed power in the plant.

Although the actual capacity of conveyor 103 was not determined, the motor powers show a good correlation per motor.

8. CONCLUSIONS

The current conveyor design method is based on GOODYEAR but also incorporates aspects of CEMA and ISO 5048. An internal code of practise serves as a reference for the economic design of conveyors.

AAC has developed, and continues to develop, its own manufacturing and performance specifications for pulleys, idlers and steel-cord belting.

Independent design comparisons have shown that, on balance, AAC's conveyors are economically designed. AAC believes that the yard-stick of economic design is low production costs achieved through the use of highly reliable equipment. Units must be well-engineered in which the capacity well be sufficient to absorb surge that may occur. The determination of conveyor design capacity and the rationalisation of plant being are important issues.

Preliminary field testing shows a good correlation between measured and design powers

9. Acknowledgements

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10. REFERENCES

Specifications

AAC 370/1	: Belt Conveyor Standards (May 1974)
AAC 371/1	: Conveyor Pulleys and Shafts
AAC 373/1	: Belt Conveyor Idlers and Rollers
AAC 373/2	: Garland Conveyor Idlers and Rollers
AAC 377/2	: Steel-cord Reinforced Conveyor Belting
AAC 3TP-1310	: Recommended Code of Practice for Belt Conveyors
BS 2890	: Specification for Troughed Belt Conveyors
CEMA	: Belt Conveyors for Bulk Materials
DIN 22101	: Belt Conveyors for Bulk Materials
Good Year	: Handbook of Conveyor and Elevator Belting
ISO 3684	: Conveyor Belts - Determination of Minimum Pulley Diameters for Belt

Conveyors

ISO 5048	:	Belt Conveyors with Carrying Idlers
ISO R20	:	Series of Preferred Numbers
SABS 971	:	Fire-Resistant Textile Re-Inforced Conveyor Belting
SABS 1173	:	General Purpose Textile Re-Inforced Conveyor Belting
SABS 1313	:	1980: Conveyor Belt Idlers and Rolls
SABS 1366	:	Steel-cord Re-Inforced Conveyor Belting