# Sandwich Belt High Angle Conveyors
# 2007 - Progress to Date

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**SUMMARY**

First introduced in the early 1950's, as "Conveyor with Cover Belt", Sandwich Belt High-Angle Conveyors have progressed significantly both technically and commercially.

Sandwich belt high-angle conveying systems use two smooth surfaced rubber belts that hug the conveyed bulk material, in a sandwich between them, along the carrying path. The hugging pressure develops the material's natural internal friction, successfully conveying it along any steep incline up to vertical.

The Loop Belts of the 1970's, a significant technical advance, demonstrated vertical conveying, at unlimited capacity, with all conventional conveyor equipment. Loop belts have been at the heart of the revolution in self-unloading ship systems.

Dos Santos Sandwich Belts of the 1980's extended the success and capabilities of the Loop Belts beyond the C-Profile to widely varying conveying paths of C-Profile, S-Profile and combinations thereof. This work included the landmark publication "Evolution of Sandwich Belt High-Angle Conveyors"; the first rigorous theory and rationalization of the Sandwich Belt High Angle Conveyors in the conventional conveyor technology. The Snake Sandwich High-Angle Conveyor, a natural extension of the Loop Belt, was the preferred Dos Santos System however other successful variations included systems using fully equalized pressing rolls.

Throughout the 1980's, 1990's, and into the first decade of the 21st century many successful applications have demonstrated the versatility, capability and reliability of the sandwich belt systems. 2005 and 2006 saw a surge in Snake Sandwich High-Angle Conveyor installations. These represent repeat business in diamond mining and in steel making. The latest unit, a fully mobile ship loader is the ultimate in versatility.

The first half of this writing retraces the history and development of the Sandwich Belt High-Angle Conveying systems. The second half deals with the latest Snake Systems and their special characteristics that make them ideal for the applications.

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## INTRODUCTION

High angle conveying, particularly vertical conveying, by bucket elevator, is as old as civilization. The open trough belt conveyor, on the other hand, is relatively modern. Introduced in the 19th century, using cloth or leather belts on wooden troughs, the modern troughed belt conveyor was advanced in the early 20th century when reinforced rubber belts were troughed on two or three-roll idlers. The rolls were equipped with anti-friction bearings, maximizing roll life while minimizing travel resistance. The troughed belt conveyor quickly gained prominence because of its high reliability and low maintenance costs. By the mid 20th century troughed belt conveyors dominated the high volume haulage duties at mines, processing facilities and at transfer terminals. Despite the limitations in incline angles troughed belt conveyors have dominated high volume elevating duties, typically requiring four times the length to achieve a given lift. This has required much additional excavation in open pit mine applications, additional valuable space at transfer terminals, expensive structure and building space at processing facilities and costly dock length at ports. In some cases multiple switch backs with multiple transfers begin to defeat the advantage of the simple troughed belt conveyor.

## COVER BELTS OF THE 1950'S

The late 1940's and early 1950's saw the introduction of the first steep conveyor with cover belt. In the lignite fields of Germany such a system (see figures 1 & 2) was installed at the bucket wheel boom of a bucket wheel excavator in order to increase the machine's cutting height without increasing the boom length [1]. This system inspired many other variations of conveyors with cover belts, in Germany, throughout the 1950's [2,3]. The various systems are described more fully in Dos Santos and Frizzell [6]. Though these systems revealed much that would be useful in later developments there were no lasting successes. By the end of that decade all such systems were abandoned in favor of the simpler and more reliable open troughed belt conveyor, despite its incline angle limitations.

During this time the first mathematical model was developed for sandwich type high angle belt conveyors.

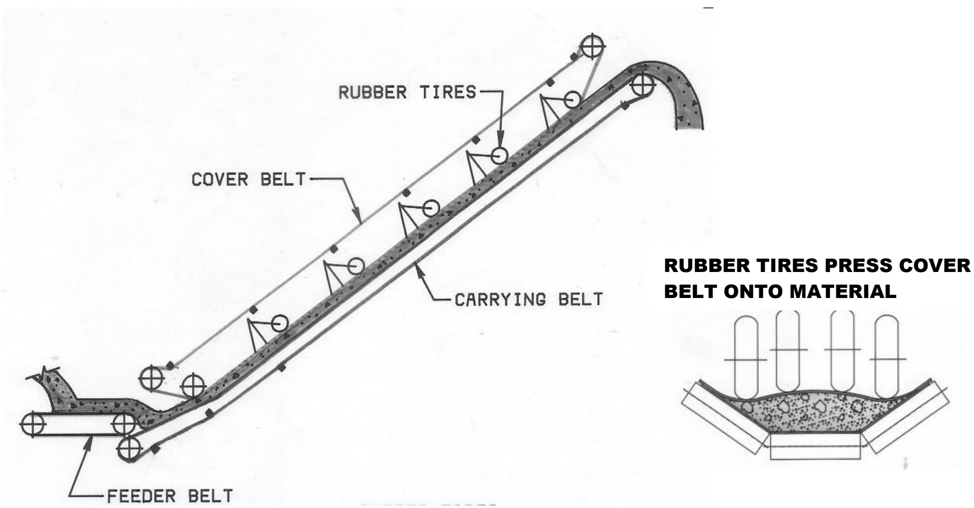



Figure 1: Steep Conveyor with Cover Belt-Schematic

## THE FIRST MATHEMATICAL MODEL

Conventional belt conveyors offer a most economical method for transporting bulk materials at recommended inclination angles up to 12° to 18° for most common materials. Internal friction development and the induced dynamics of the moving conveyor belt limit the conveying angle. Higher angles approaching the internal friction angle could be achieved by reducing the dynamic effects. The inclination angle cannot, however, exceed the angle of internal friction of the material at the free surface.

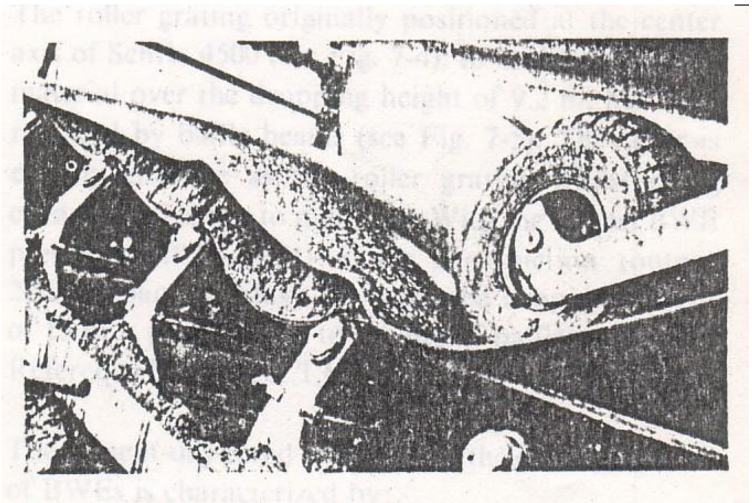
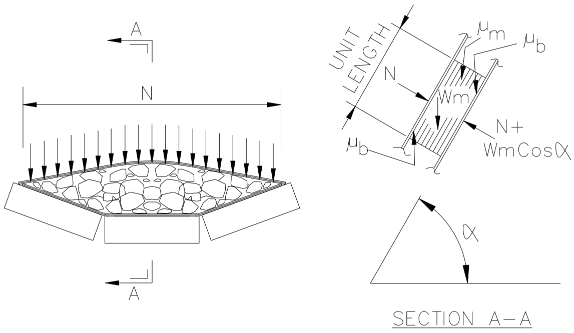


Figure 2: Steep Conveyor with Cover Belt-Photo

Conveying angles beyond the angle of internal friction can be achieved by a cover belt which, when pressed against the material, will create a hugging action to prevent sliding at the contact surface.

For a cohesionless material one can idealize the situation as shown in Figure 3. The material is idealized as closely spaced parallel layers.




$\alpha$ = Conveying Angle

$\mu_m$ = Coefficient of friction for bulk material on bulk material

$\mu_b$ = Coefficient of friction for bulk material on belt

N = Normal lineal hugging load exerted by the top belt

Wm = Lineal weight of bulk material

Figure 3: Sandwich Belt Model # 1

If the cover belt is free to follow the material as it slides back, sliding will occur when the tangential component of the material weight exceeds the frictional forces which resist it or:

$$\text{Wm} \sin \alpha > (\text{N} + \text{Wm} \cos \alpha)\, \mu \tag{1}$$

where:

$\mu = \mu_m$ or $\mu_b$ whichever is smaller.
Wm, $\alpha$, N, $\mu_m$, $\mu_b$, are as defined in Figure 3.

To achieve an inclination angle $\alpha$, a normal lineal hugging load, N, must be exerted by the top belt such that:

$$\text{N} \geq \text{Wm}\left(\frac{\sin\alpha}{\mu} - \cos\alpha\right) \tag{2}$$

If the top belt is driven with the bottom belt, resisting the motion of the material at the interface, then material will begin to slide back when:

$$\text{Wm} \sin \alpha > (2\text{N} + \text{Wm} \cos \alpha)\mu \tag{3}$$

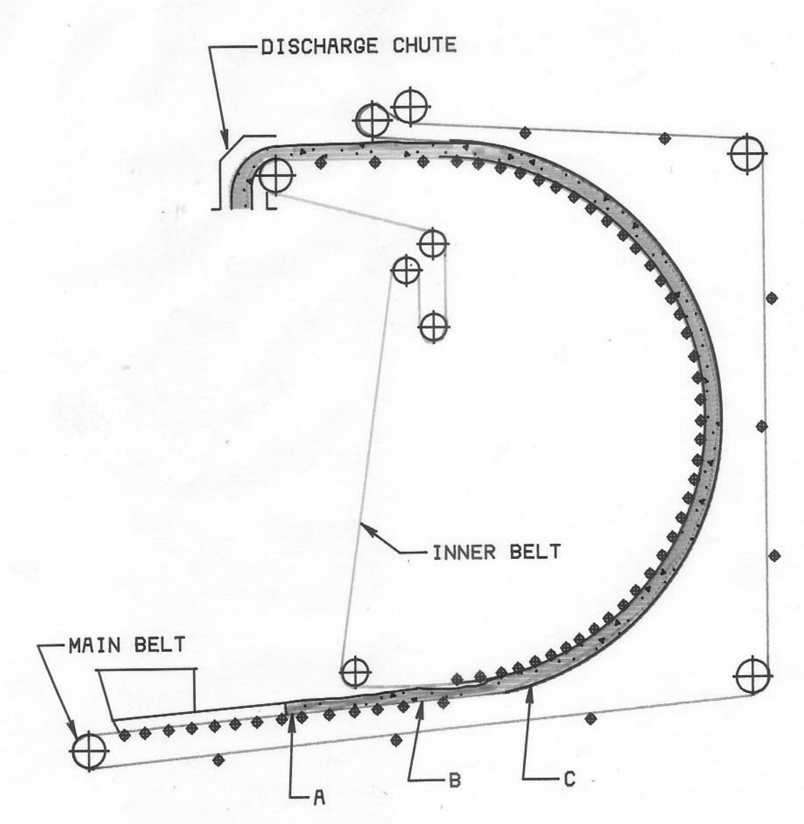
To achieve an inclination angle $\alpha$;

$$\text{N} \geq \frac{\text{Wm}}{2}\left(\frac{\sin \alpha}{\mu} - \cos \alpha\right) \tag{4}$$

The above equation shows that the normal hugging load, N, needed to prevent backsliding is only half of that required in the previous case (see Equation 2).

N is the normal component of the lineal weight of the cover belt plus the additional pressure imposed on the cover belt. The second set of equations, 3 and 4, clearly show that the required hugging load is much less if both belts are driven at the same speed.

**LOOP BELTS OF THE 1970'S**



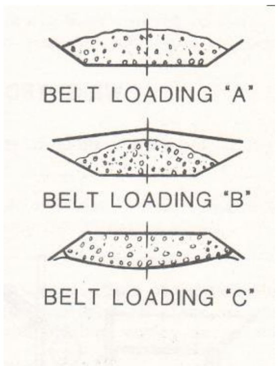




Figure 4: Loop Belt-Schematic

The 1970's saw resurgence in high angle conveying concepts particularly in sandwich belt systems. The most successful, the Loop Belt [5] elevator was developed for self-unloading ships. Part of the complete self-unloading ship system the loop belt handled the elevating duties from the gathering hold conveyors (running along the ships inner bottom) to the discharging boom conveyor (on the ship's deck). Loop belts demonstrated very high volumetric rates (10,000 t/h plus), utilizing very wide belts (to 3000 mm) at high belt speeds (5 m/s plus). The Loop Belt profile could be tucked up against the aft wall of the aft most hold or could be accommodated within the engine room, thus minimizing the displacement of cargo capacity. The Loop Belt features included:

1. The use of all conventional conveyor equipment including smooth surfaced rubber belts that could be continuously scraped clean

2. Unlimited conveying rates with wide belts at high belt speeds
3. Exploiting the inherent belt tension, with an engineered profile, to derive a natural radial hugging pressure on the conveyed material. The hugging pressure is to develop the material's internal friction so that slide back does not occur at any high-angle including vertical conveying


Figure 5. Loop Belt-Photo

The Loop Belt carrying profile consists of a tensioned inner belt which is supported against closely spaced troughing idlers and an outer belt which wraps itself around the conveyed material hugging it against the troughed inner belt. Each belt exerts a radial load against the curved profile according to the equation:

$$P_r = \frac{T}{R} \qquad (5)$$

where:

T = Belt tension at the point, along the conveyor profile
R = Radius of curvature corresponding to belt tension T
$P_r$ = The corresponding lineal load induced by the belt of tension T

The radial load induced by the outer belt must produce the pressure that will hug the conveyed material firmly against the inner belt and develop its natural internal friction so that material slide back cannot occur at any high angle.

Merits of the Loop Belt concept are undeniable and the inspiration for the modern successes in sandwich belt high angle conveying. Technical rationalization and execution left much to be desired. Though highly and widely marketed there was little disclosure by the developers on the technical basis for the system.

Poor execution included:

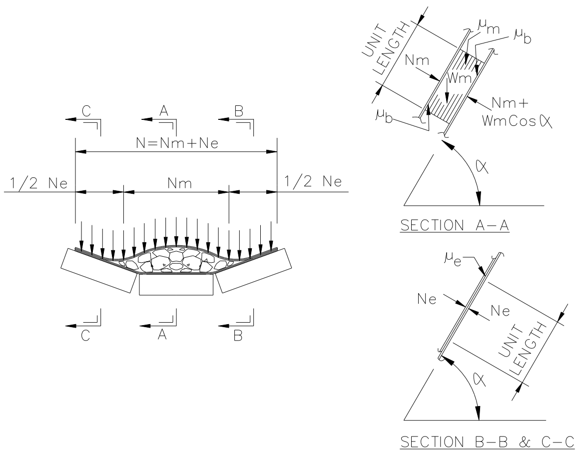
1. Poor (short) transitions that damaged the belts and splices
2. Abrupt breaks at the carrying profile, particularly at the sandwich entrance, that:
    a. Buckled and damaged the belts and splices
    b. Overloaded the local idlers requiring special-super idlers with live shaft rolls
    c. Jammed the conveyed material hard into the inner belt and idlers.

Though likely well understood by its developers the Loop Belt's technology basis was never disclosed to the public and complete technical rationalization awaited the Dos Santos advances of the 1980's.

**THE SECOND IMPROVED MATHEMATICAL MODEL**

Though never disclosed by the developers of the Loop Belt the typical material cross-section between the carrying belts did not nearly fill the space between the belts leaving much material free edge distance. This called for an improved mathematical model that reflected the actual carrying cross-section. Such a model was first presented in 1980 and published in Dos Santos and Frizzell [6].

The Belt Sandwich model, illustrated in Figure 3 is instructive but not accurate. It assumes that the cover belt contacts only the material, but the edges do not touch the carrying belt. Lateral movement of the cover belt during operation will cause the edges to bear, intermittently, on the carrying belt, losing a portion of the hugging load directly to the carrying belt and support idlers, while uncovering the material at the other edge. Realistically, a minimum edge distance is required so that the material is always covered and does not spill out. The cross-sectional filling of the sandwich type conveyors must be controlled to assure large edge distances, and thus, a sealed envelope.




$\alpha$, $\mu_m$, $\mu_b$, N, Wm are as defined for Sandwich Belt Model #1

Nm = That portion of N which bears directly on the conveyed material

Ne = That portion of N which bears directly on the edges of the bottom belt

$\mu_e$ = Coefficient of friction at the interface of the top and bottom belts

Figure 6: Sandwich Belt Model # 2

A more realistic model, Figure 6, illustrates the actual interplay of forces. The minimum normal hugging load, Nm, that must be exerted on the material, to prevent backsliding, if both belts are driven, is expressed by equation 6. This follows from equation 4.

$$(\min)\mathrm{Nm} = \frac{\mathrm{Wm}}{2}\left(\frac{\sin\alpha}{\mu} - \cos\alpha\right) \tag{6}$$

If only the bottom belt is driven, then the drag that is exerted on the material, by the top belt, must be developed between the top and bottom belts at the edges, as expressed by equation 7.

$$(\min)\ \mathrm{Ne}\ \mu_e = (\min)\ \mathrm{Nm}\ \mu \tag{7}$$

The minimum required total normal load, N, can be expressed by combining equations 6 and 7 to obtain equations 8 and 9.

$$(\min)\mathrm{N} = (\min)\mathrm{Ne} + (\min)\mathrm{Nm} = \left(\frac{\mu}{\mu_e} + 1\right)(\min)\mathrm{Nm} \tag{8}$$

$$\text{(min)N} = \left(\frac{\mu}{\mu_e} + 1\right)\frac{\text{Wm}}{2}\left(\frac{\sin\alpha}{\mu} - \cos\alpha\right) \tag{9}$$

If the hugging pressure on the cover belt is distributed evenly across the belt width, then;

$$\frac{Ne}{N} = \frac{2\ Edge\,Dist.}{Belt\,Width} \tag{10}$$

So that the required "edge Distance" per side, to satisfy equation 7 can be determined by setting Ne=N-Nm and combining with equations 8 and 10 to produce equation 11.

$$Edge\,Dist. = \frac{Belt\,Width}{2\left(1 + \frac{\mu_e}{\mu}\right)} \tag{11}$$

If $\mu = \mu_e$, then the required Edge Distance per side is ¼ belt width. If contaminants or fine grains of material lubricate the edges, then $\mu_e$ may be much less than $\mu$. If $\mu_e = \mu/2$ then Edge Distance per side equal to 1/3 belt width is required to transfer the needed drag from the bottom belt edges to the top belt and material interface at the center. Effectively only 1/3 belt width is used to carry the material.

Actual internal friction coefficients vary at the material/belt surface interface, from less than 0.6 to above 0.9. Some very fine materials tend to fluidize and have no internal friction. These cannot be conveyed. Wider variation occurs at the belt edges, depending on the degree of wetness and contamination. Friction coefficients can vary from less than 0.1 to above 0.5.

Drag transfer at the edges is not necessary if the hugging pressure over the material is twice that determined in equation 6 or if both top and bottom belts are driven. Driving both belts is in general the better solution since it avoids the need for higher hugging pressures that will cause greater loads on the conveyor components. Driving both belts also results in higher possible lifts, since the tension capacity of both belts is exploited, and there is no differential stretch or movement between the two belts.

**DOS SANTOS SANDWICH BELTS OF THE 1980'S**

Throughout the 1970's haulage by troughed belt conveyors made significant inroads into open pit mines and quarries. The cost advantage of conveyor haulage, compared to truck haulage, especially in the elevating duties, gave rise to in-pit crushing systems. Such systems either completely eliminated in-pit truck haulage or limited it to the mine face proximity maintaining maximum flexibility in dispatching. Thus in-pit crushing was required to reduce the hauled material to a conveyable size. In the case of ore haulage the primary crusher is moved into the pit from the pit perimeter. For waste haulage an in-pit primary crusher is required solely for the sake of haulage by conveyor.

This trend of reducing haulage costs with belt conveyors prompted the US Bureau of Mines to take it to the next level. The Bureau recognized the incline angle limitations for open troughed belt conveyors and the cost of accommodating the limitations. At the end of 1979 the US Bureau of Mines funded a major study entitled High Angle Conveyor Study [7]. The Study ran from August of 1979 to December of 1981. A more descriptive title would have been "In-Pit Crushing and High Angle Conveying Systems versus Truck only Haulage Systems in Open Pit Mines".

As a key participant in this Study this author had the opportunity to study broadly the many various high angle conveyor systems and their applications at that time. The various systems included the Cover Belts of the 1950's and the Loop Belts of the 1970's. It was clear to the writer that the Sandwich Belt Concept would prove to be the most suitable and economic for high volume haulage of coarse materials from open pit mines. It was equally clear that this concept was the least understood technologically and the complete technological basis had to be developed and demonstrated. This became a mission of the writer.

The Loop Belts of the 1970's, well executed, compliant to the rules of good conveyor practice, including proper transitions and continuity in profile, offered all of the desired features for efficient vertical haulage at high volumetric rates. The shortcoming for general inclined applications is the carrying profile, which is always C-shaped. A first step in solving the profile problem was the introduction of the S-shaped Sandwich Conveyor. Including all of the positive features of the Loop Belt the S-Shape conveyor introduced a point of curvature reversal, at the carrying profile, reversing the functions of the two belts that make up the load carrying sandwich. The area around the point of curvature reversal is now commonly known as the inflection zone. Up to the inflection zone the profile and features are not different than a well executed Loop Belt. The tensioned upper belt is supported against closely spaced inverted troughing idlers while the lower belt wraps itself around the conveyed material hugging it against the troughed upper belt. Each belt exerts a radial load against the curved profile according to equation 5. Beyond the inflection zone the belt functions are reversed with the tensioned lower belt being supported against closely spaced upright troughing idlers while the upper belt wraps itself around the conveyed material hugging it against the troughed lower belt. Continuity of material hugging through the inflection zone is crucial and this is achieved by fine tuned field adjustments at vari-troughing idlers.

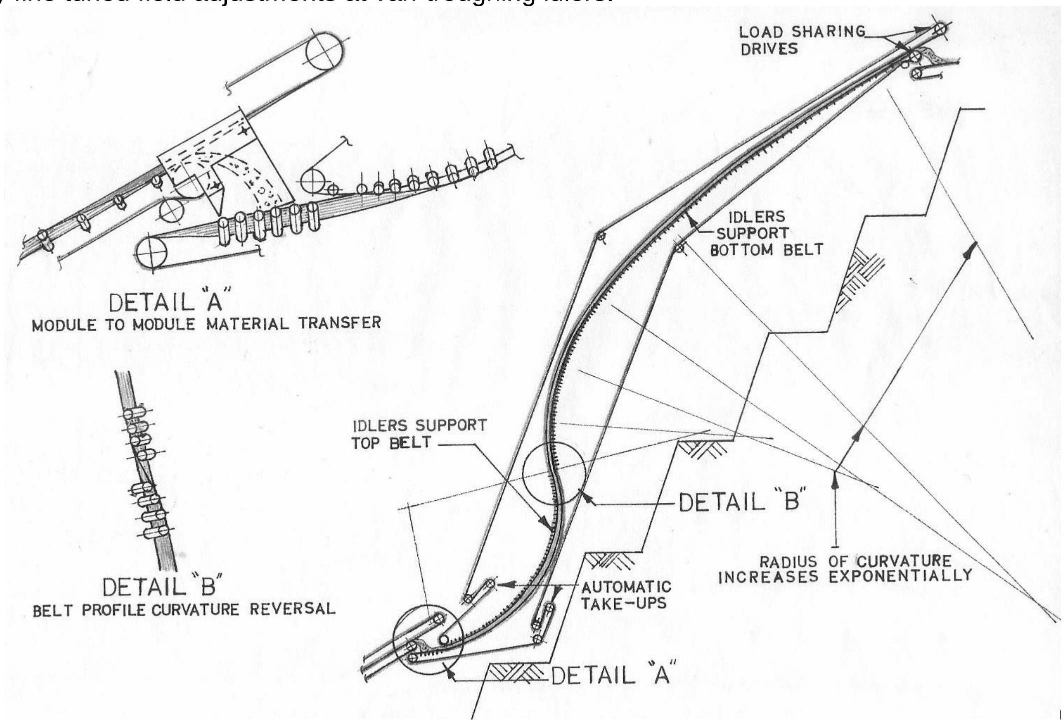



Figure 7: S-Shape Sandwich Conveyor–Schematic

The logical next step in developing a better, more versatile high angle profile, the Snake Sandwich High Angle conveyor introduced a multitude of inflection zones so that the alternating convex curves of the carrying profile fit nicely within a compact structural system such as a box truss or twin beam frame.

These systems, logical extensions of the Loop Belts of the 1970's, included all of the positive features without the profile limitations. They feature smooth surfaced rubber belts that can be continuously scraped clean and all conventional conveyor equipment and components. When rationalized in the conventional conveyor technology they can be expected to demonstrate the performance characteristics of conventional conveyors, that is high reliability and availability and low operating and maintenance costs. At the conclusion of the US Bureau of Mines Study the Snake Sandwich High-Angle Conveyor was chosen as the preferred system for high volume haulage of coarse materials from open pit mines.

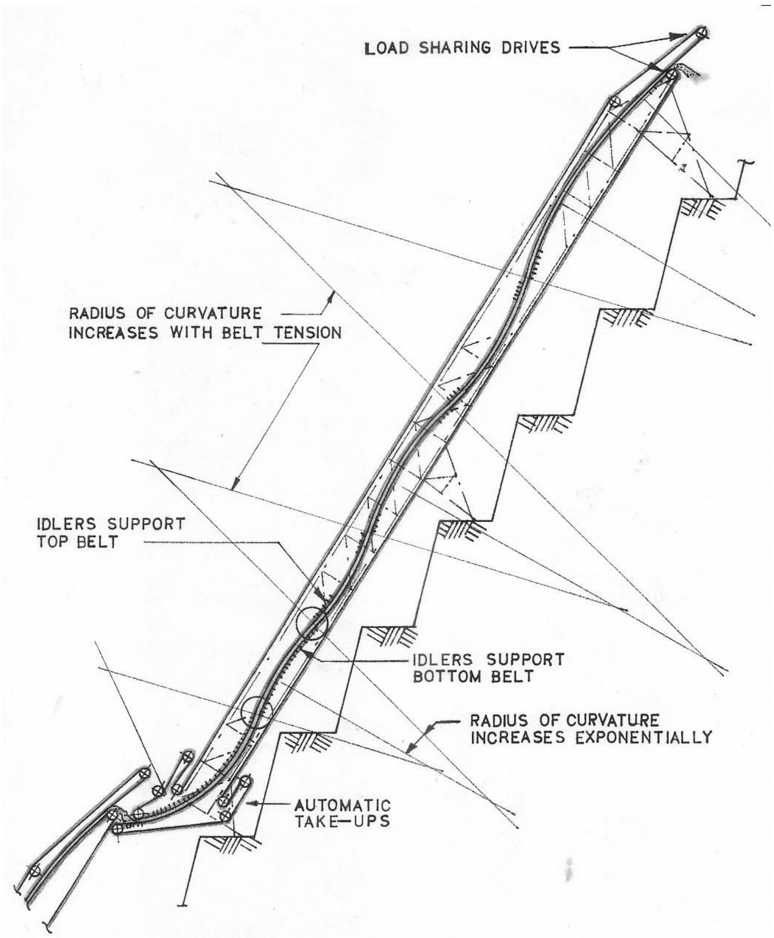


Figure 8: Snake Sandwich Conveyor-Schematic

The US BOM Study also included a complete rationalization, by the writer, of the Sandwich Belt High Angle Conveyor technology with some other embodiments including a mechanically pressed sandwich belt system, with fully equalized pressing rolls, and a pneumatically pressed sandwich belt system. The former (see Figure 9) was further developed and successfully commercialized by J.A. Dos Santos in the employment of a major conveyor manufacturer until 1997.

The complete technical development and rationalization has been published, most notably in the 1982 landmark article, "The Evolution of Sandwich Belt High-Angle Conveyors", by Dos Santos and Frizzell [6]. Many additional publications since 1982 have documented the technical and commercial progress in sandwich belt high angle conveying [11-20]. In the year 2000 publication "Theory and Design of Sandwich Belt High Angle Conveyors According to The Expanded Conveyor Technology" [11], the rationalization is returned to the realm of the conventional conveyors in order to expand and generalize the broader technology. The interested reader is referred to the extensive list of referenced publications.

Progress in the Dos Santos Sandwich belts has continued since the early 1980's with many installations demonstrating the principles, fulfilling the prophecy. Figure 10 illustrates some select profiles of the many installations, illustrating the versatility of the system.

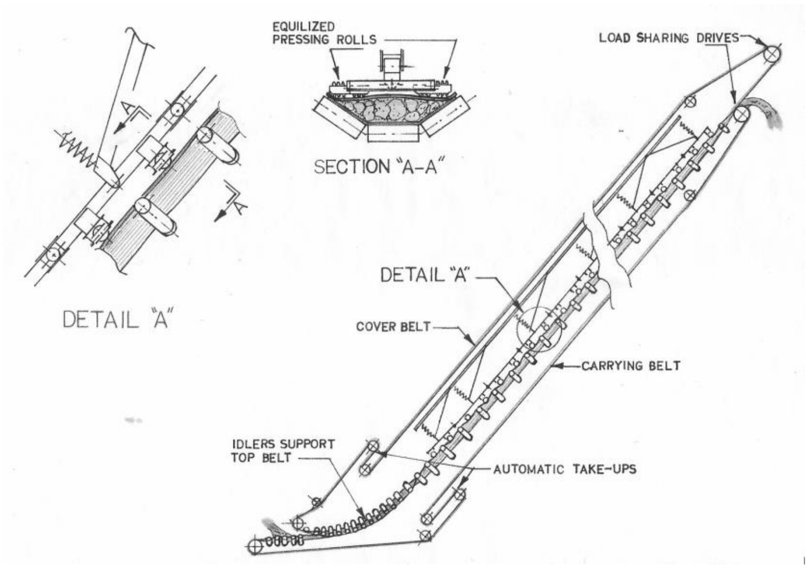



Figure 9: Mechanically Pressed Sandwich Conveyor - Sketch

## 1997 RETURN TO THE HEART

Principles of the Snake Sandwich High Angle conveyor system were demonstrated in all of the Dos Santos installations including many units of S-Shape profile. Until 1997, due to certain conflicts, the US BOM preferred high-angle conveying system remained dormant. The Snake Sandwich system was brought to the forefront at the founding of Dos Santos International in July of 1997. Since then Snake Sandwich High-Angle conveyors have been installed at mining facilities including iron, copper-zinc, diamonds, at steel mills including coal pulverizing, iron making and specialty steel making, at pulp and paper mills and at port facilities.

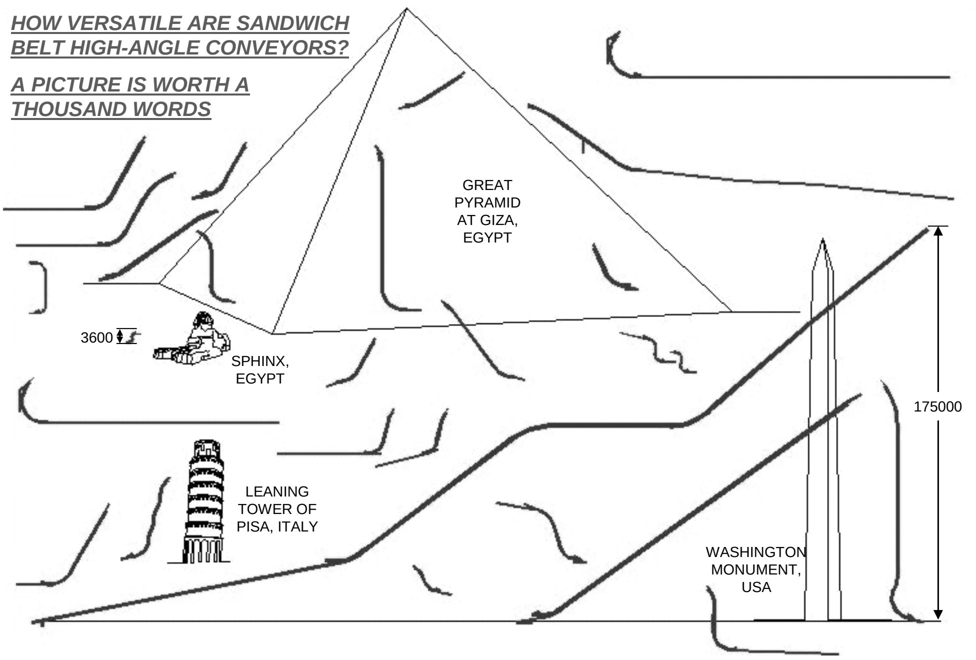



Figure 10: Select Profiles Dos Santos Sandwich Belt High-Angle Conveyors

## STEEL MILL IN NORTHERN SPAIN

Table 1 lists the technical data for the Snake Sandwich High-Angle Conveyor that began operation in July of 2003, at the Aceralia Steel Mill, near Gijon, Asturias, Spain. Figure 11 illustrates the features.

The Snake is part of an expansion to the coal grinding facilities for the carbon injection to the existing and new blast furnaces. The Snake elevates the total raw coal through-put to a transfer where a bifurcated chute, with flop gate, allows directing the coal flow to the old or to the new grinding facilities.

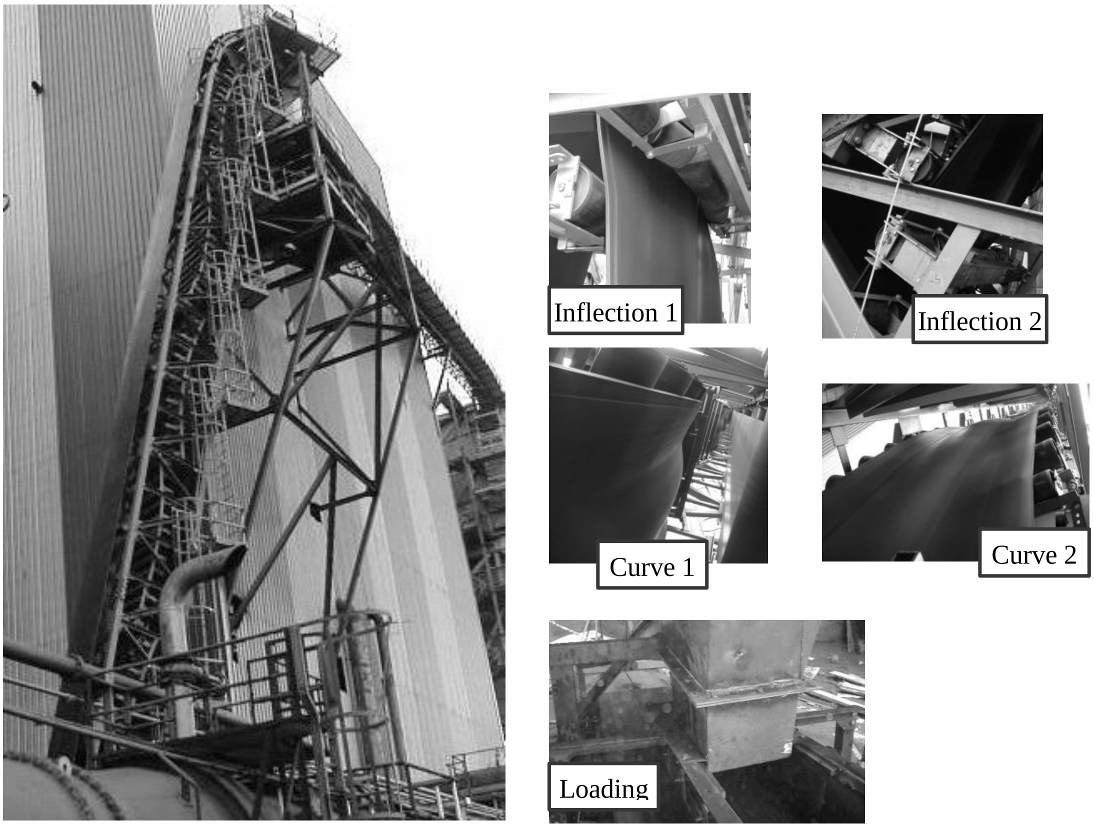



Figure 11: Snake Sandwich High-Angle Conveyor, Northern Spain

**Table 1. Snake Sandwich Conveyor**
**at**
**Steel Mill, Northern Spain**
- Technical Data -

| | |
|---|---|
| Material | - Coal |
| - Density | - 0.8 t/cu-m (50 PCF) |
| - Size | - 50 mm (2”) minus |
| Conveying Rate | - 250 t/h (276 STPH) |
| Conveying Angle | - 75 degrees |
| Belt Width | - 1200 mm (47”) |
| Belt Speed | - 2.29 m/s (450 FPM) |
| Lift | - 35,100 mm (115’) |
| Length | - 45,065 mm (148’) |
| Snake Drives | |
| - Top Belt | - 30 kW (40.2 HP) |
| - Bottom Belt | - 30 kW (40.2 HP) |

## IRON MINE IN NORTHERN MICHIGAN, USA

Table 2 and Figure 12, describe the Snake Sandwich System at a Northern Michigan iron mine facility. Operation began in August of 2001. This unit is the fourth Dos Santos Sandwich belt system at the facilities. Of the four, the Snake features the highest production, the highest incline angle and the fastest belt speed.

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Part of an employee driven process improvement, the Snake re-circulates 40% already crushed ore mixed with the incoming coarse ore. The re-circulate facilitates more efficient crushing of the coarse ore. This improvement is said to substantially reduce the net cost of crushing.

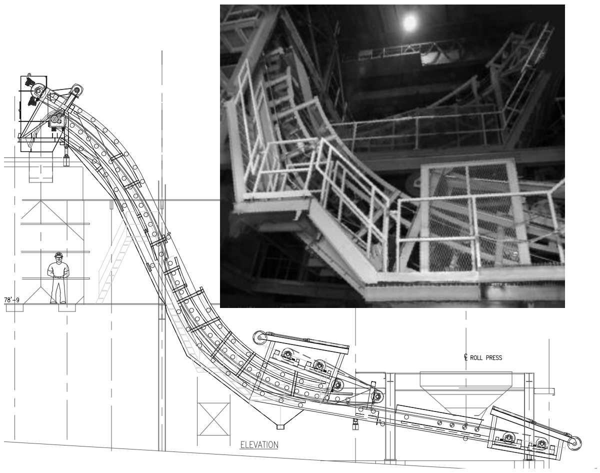


Figure 12: Snake Sandwich High-Angle Conveyor, Northern Michigan

**Table 2. Snake Sandwich Conveyor at Iron Ore Mine, Northern Michigan, USA**

| | |
|---|---|
| Material | - Iron Ore |
| - Density | - 2.4 t/cu-m (150 PCF) |
| - Size | - 2 mm (.08”) minus |
| Conveying Rate | - 793 t/h (780 LTPH) |
| Conveying Angle | - 65 degrees |
| Belt Width | - 1067 mm (42”) |
| Belt Speed | - 2.29 m/s (450 FPM) |
| Lift | - 11,522 mm (37.8’) |
| Length | - 21,489 mm (70.5’) |
| Snake Drives | |
| - Top Belt | - 29.8 kW (40 HP) |
| - Bottom Belt | - 37.3 kW (50 HP) |

**STEEL MILL, EASTERN CANADA**

Part of the specialty steel making process, the Snake of Table 3, Figure 13, elevates the high value additives to the elevated charging bins. This system is unique in handling so many materials which are so different from each other. Seven different chemical sources range from light coke to heavy manganese. These range in bulk density from 0.64 to 4.16 t/m$^3$ (40 to 260 PCF) and in size from granular to 76 mm (3”) heavy rock. Productive operation began at the end of 2006. Commissioning was completed in February of 2007.

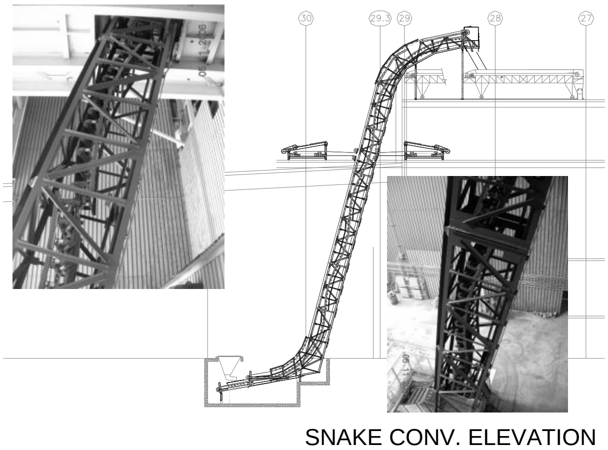


Figure 13: Snake Sandwich High-Angle Conveyor, Eastern Ontario, Canada

**Table 3. Snake Sandwich Conveyor at Eastern Canada Steel Mill**

| | |
|---|---|
| Material | - Various |
| - Density | - 4.16 t/cu-m (260 PCF) |
| - Size | - 75 mm (3") minus |
| Conveying Rate | - 188 t/h (200 STPH) |
| Conveying Angle | - 70 degrees |
| Belt Width | - 914 mm (36") |
| Belt Speed | - 1.02 m/s (207 FPM) |
| Lift | - 35,235 mm (115.6') |
| Length | - 48,768 mm (160.0') |
| Snake Drives | |
| - Top Belt | - 18.64 kW (25 HP) |
| - Bottom Belt | - 18.64 kW (25 HP) |

**DIAMOND MINE, NORTHERN CANADA**

Tables 4, 5, 6 and Figures 14 and 15 describe three Snake units which are part of a major diamond mining project in Northern Canada. The Snakes conserve precious building space and structure that must protect the processing facilities from the harsh Northern Canadian environment. These units are part of a second Canadian Mine to exploit the space saving Snakes. An earlier diamond mining project, by the same owner and consultant utilized two (2) Snake Sandwich High-Angle Conveyor units. Both projects will start-up production in 2007 and 2008.

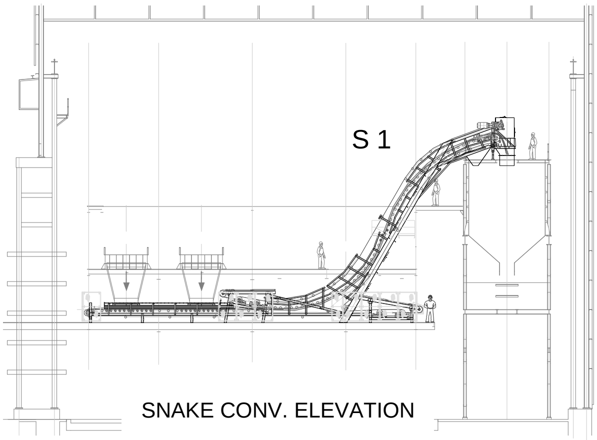


Figure 14: Snake Sandwich High-Angle Conveyor S 1, Northern Ontario, Canada

| Table 4. S 1 Snake Sandwich Conveyor at Northern Canada Diamond Mine Project | |
|---|---|
| Material | - Kimberlite |
| - Density | - 1.6 t/cu-m (100 PCF) |
| - Size | - 28 mm (1.1”) minus |
| Conveying Rate | - 422 t/h (465 STPH) |
| Conveying Angle | - 60 degrees |
| Belt Width | - 1067 mm (42”) |
| Belt Speed | - 2 m/s (394 FPM) |
| Lift | - 11,886 mm (39.0’) |
| Length | - 33,282 mm (109.2’) |
| Snake Drives | |
| - Top Belt | - 29.83 kW (40 HP) |
| - Bottom Belt | - 29.83 kW (40 HP) |

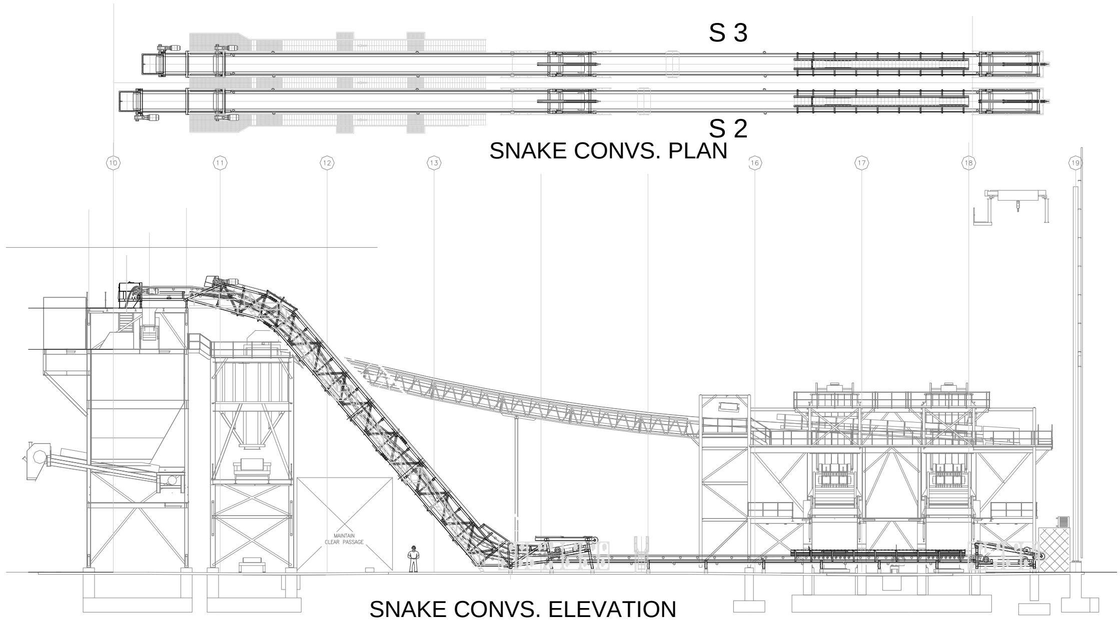


Figure 15. Snake Sandwich High-Angle Conveyors S 2 and S 3, Northern Ontario, Canada

| Table 5. S 2 Snake Sandwich Conveyor at Northern Canada Diamond Mine Project | | Table 6. S 3 Snake Sandwich Conveyor at Northern Canada Diamond Mine Project | |
|---|---|---|---|
| Material | - Kimberlite | Material | - Kimberlite |
| - Density | - 1.6 t/cu-m (100PCF) | - Density | - 1.6 t/cu-m (100PCF) |
| - Size | - 28 mm (1.1”) minus | - Size | - 6 mm (1/4”) minus |
| Conveying Rate | - 381 t/h (420 STPH) | Conveying Rate | - 185 t/h (204 STPH) |
| Conveying Angle | - 49.5 degrees | Conveying Angle | - 49.5 degrees |
| Belt Width | - 1067 mm (42”) | Belt Width | - 1067 mm (42”) |
| Belt Speed | - 2 m/s (394 FPM) | Belt Speed | - 1.0 m/s (197 FPM) |
| Lift | - 18,508 mm (60.7’) | Lift | - 18,508 mm (60.7’) |
| Length | - 67,581 mm (221.7’) | Length | - 65,981 mm (216.5’) |
| Snake Drives | | Snake Drives | |
| - Top Belt | - 29.83 kW (40 HP) | - Top Belt | - 18.65 kW (25 HP) |
| - Bottom Belt | - 29.83 kW (40 HP) | - Bottom Belt | - 18.65 kW (25 HP) |

## SNAKE SHIP LOADER, PORT OF ADELAIDE, AUSTRALIA

A Snake Sandwich High-Angle Ship Loader offered the space saving solution for loading Panamax class ships at a limited dock space. The compact structure of the Snake Ship Loader facilitates optimal maneuverability.

Australia's first Snake Ship Loader elevates a variety of high value ores from trucks to ship. Data Table 7 summarizes the design parameters while Figure 16 shows the machine in operation. Materials for export are trucked to the dock and dumped onto a special feeder. The ore is fed continuously and uniformly onto the mobile Snake's receiving chute. The Snake Ship Loader elevates the bulk over the ship's deck to the hatch where it is discharged into the ship's hold. At the Snake's discharge, a special telescoping chute, with rotating, pivoting spoon, facilitates even and complete filling of the holds.

Figure 16: Snake Ship Loader, Port of Adelaide, Australia

**Table 7. Snake Sandwich Conveyor Shiploader at Port Adelaide, Australia**

| | |
|---|---|
| Material | - Various Ores |
| - Density | - 2.4 t/cu-m (150 PCF) |
| Conveying Rate | - 1000 t/h (1102 STPH) |
| Conveying Angle | - 50 degrees |
| Belt Width | - 1200 mm (47") |
| Belt Speed | - 2 m/s (394 FPM) |
| Lift | - 21,805 mm (71.5') |
| Length | - 56,656 mm (185.9') |
| Snake Drives | |
| - Top Belt | - 55 kW (74 HP) |
| - Bottom Belt | - 55 kW (74 HP) |

The mobile Snake is carried on a tripod of twin rubber tires. Each set of twin tires is mounted at a vertical kingpin. The rear tires are powered by hydraulic motors and are steer-able. The front tire sets may be rotated to positions; parallel to the Ship Loader's length for to-and-fro travel and to maneuver; perpendicular for side travel; or perpendicular to an axis with the rear tires for a slewing motion. Thus, without repositioning, the Snake can set up to travel in any direction.

The Snake Ship Loader began productive operation in January of 2007. On start-up, some problems did arise. The system loads high value ores for export. Of these, ilmenite (titanium ore) has proved most difficult. This heavy, fine grain, dry material proved difficult to hug continuously without movement in the sandwich. The ore tended to spread and to leak from the belt edges even at low rates, less than 300 t/h. Elevating other non-mag ores was successful at all conveying rates up to and beyond the design rate.

Drawing from previous extensive experience with very dry materials we knew that we could improve the belt's grip on the conveyed ilmenite by moistening the belt surface. This has the effect of improving the belt surface/material interface with minimal actual moistening of the product. We set up a make-shift wet brush system at each belt, wetting the belts through draped cloths on the belt edges. This system was then fine tuned to minimize the belt moistening that was required to arrest the material spreading; to convey the material successfully at higher rates approaching the design rate. We achieved increased rates, without leaking, with increased moistening, up to about 78 % of the design rate. We stopped short of the full 1000 t/h because we perceived excessive wetting requirements. Calculations afterwards revealed that the added moisture was insignificant for the volume of material and was not likely to raise the overall moisture content a tenth of a percent.

In any case we are making adjustments to the equipment to improve the continuity of hugging through the full high-angle carrying length so that the full design rate can be achieved with the difficult ilmenite.

At this writing (April, 2007) modifications and adjustments are under way.

**SUMMARY AND CONCLUSIONS**

Evolution of Sandwich Belt High Angle Conveyors from the "Cover Belts of the 1950's" through the "Loop Belts of the 1970's" led to the "Dos Santos Sandwich Belts of the 1980's". Most important for the latest developments is complete development of the technology basis and rationalization in the conventional conveyor technology. This technology basis was published in the 1982 landmark article, "Evolution of Sandwich Belt High-Angle Conveyors".

Since the early 1980's the Dos Santos Sandwich Belts have demonstrated success in the market place displaying the claimed capability and versatility, fulfilling the prophecy; "such high angle systems, rationalized in the conventional conveyor technology, will have the operating characteristics of conventional conveyors, that is high reliability and availability and low operating and maintenance costs".

## REFERENCES


[1] Rasper, E. L., The Bucket Wheel Excavator, Development, Design Application. *Series on Bulk Materials Handling, vol. 1, 1975, No. 2, Trans Tech Publications, Clausthal, Germany,* 1st ed., 1975.

[2] Rasper, P., Bank / Steiloerdern in deutschen Braunkohlentugebaue (Elevating Belt Conveyors for Lignite Open Pit Mining in Germany). *Deutsche Hebe-und Foerdertechnik in Diente der Transportrationalisterung, Dec. 1958, pp. 25-29.*

[3] Gaertner, E., Entwieklungstendenzen in der Geraete-und Foerdertechnik der rheinischen Braunkohlentagebaue (Development Trends of Machines and Material Handling Techniques in the Rheinbraun Open-Pit Mines). Braunkohle, Waeme Und Energie HEFT 11/12, 1955, pp. 226-241.

[4] Vierling, A., Die Keilband-Forderanlage, ein neues Mittel zum Steilen Foerdern von Massenguetern. *Braunkohle HEFT 11, March 1953, pp.161-169.*

[5] Stephens-Adamson, The Stephens-Adamson Loop Belt Elevator. Belleville, Ontario, Advertisement.

[6] Dos Santos, J.A. and Frizzell, E.M., Evolution of Sandwich Belt High-Angle Conveyors. CIM Bulletin. Vol.576, Issue 855, July 1983, pp. 51-66.

[7] Mevissen, E.A., Siminerio, A.C. and Dos Santos, J.A., High Angle Conveyor Study by Dravo Corporation for Bureau of Mines, U.S. Department of the Interior under BuMines Contract No. J0295002, 1981, Vol.1,291 pages, Vol.II,276 pages.

[8] Frizzell, E. M., E. A. Mevissen, and A. C. Siminerio. 1981. Trucks versus High-Angle Conveyor Haulage in Open Pit Mines. *Mining Congress Journal - October.*

[9] Conveyor Equipment Manufacturers Association-CEMA. 1994. Belt Conveyors for Bulk Materials - Fourth Edition.

[10] Goodyear Handbook of Conveyor and Elevator Belting. 1982. The Goodyear Tire and Rubber Company. Akron, Ohio.

[11] Dos Santos, J.A., Sandwich Belt High Angle Conveyors according to The Expanded Conveyor Technology.
Presented at the SME-AIME Annual Meeting, Denver, CO, 1999, published in proceedings
Published in Bulk Solids Handling, Vol. 20 (No. 1), January/March 2000, pp. 27-37

[12] Dos Santos, J.A., Sandwich Belt High Angle Conveyors - Applications in Open Pit Mining,
Presented at the 1983 AMC (American Mining Congress) Mining Convention, San Francisco, CA, Sept 11-14, 1983, published in proceedings.
Presented at the SME-AIME Fall Meeting, Salt Lake City, UT, October, 1983, published in proceedings.
Published in Bulk Solids Handling, Vol. 4 (No. 1), March 1984, pp. 67-77

[13] Dos Santos, J.A. and Stanisic, Z. "In-Pit Crushing and High Angle Conveying in Yugoslavian Copper Mine.
Presented at the Mining Latin America, Int. Mining Convention, Nov. 17 - 21, 1986, Santiago, Chile, published in proceedings
Published in International Journal of Surface Mining 1, 1987, pp. 97-104

[14] Dos Santos, J.A., Sandwich Belt High Angle Conveyors - Broad Horizons.
Presented at CoalTrans '86, Amsterdam, The Netherlands, June 10-12, 1986, published in proceedings

Published in Bulk Solids Handling, Vol. 7 (No. 2), April 1987, pp. 229-239

[15] Dos Santos, J.A., High Angle Conveyors-HAC's, A Decade of Progress Yields a Rock Solid Future. Bulk Solids Handling, Vol. 10 (No. 3), August 1990, pp. 267-270

[16] Dos Santos, J.A., Continuous Haulage in the 1990's. World Coal, UK, April 1993, pp. 24-31

[17] Dos Santos, J.A., Continuous Vertical Haulage.
Presented at Mine Hoisting '93 Confernce, Royal School of Mines, London, UK, June 1993
Published in Bulk Solids Handling, Vol. 13 (No.3), September 1993 (6 pages)
Published in Mining Technology, London, UK. September 1994, pp. 238-243

[18] Dos Santos, J.A., HAC®s - Elevating Gold.
Presented at Randal Gold Conference- 1996, Lake Tahoe, NV, USA, published in proceedings
Published in Bulk Solids Handling, Vol. 16 (No.3), July/September 1996, pp.361-366

[19] Stanisic, Z and Dos Santos, J.A., In-Pit Crushing and High Angle Conveying at Copper Mine Majdanpek - Performance to Date, Future Expansion.
Presented at Fifth International Symposium on Mine Planning and Equipment Selection, São Paulo, Brazil, October 22-25, 1996,
Published in proceedings, by A. A. Balkema, Rotterdam, 1996, pp. 487-491
Published in Bulk Solids Handling, Vol. 17 (No. 1), January 1997 (5 pages)

[20] Dos Santos, J.A., The Cost/Value of High Angle Conveying.
Published in Bulk Solids Handling, Vol. 18 (No. 2), April/June 1998, pp.253-260
Published in World Mining Equipment, Vol 22, (No. 7), September 1998, pp. 46-49

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