



→ steeply inclined paths (along the pit wall, for instance). This precluded the C-Shaped Loop Belt profile but not the principles of operation. In-depth research sought to unify the sandwich-belt technology with the conventional conveyor technology. This resulted in an expansion of the

**TABLE 1: MAJDANPEK COPPER MINE EQUIPMENT**

Conveyor	Length (m)	Width (m)	Speed (m/s)	Capacity (t/h)	Angle (deg)	Power (kW)
T-8	811	1.2	4.34	4,000	0	1x450
T-9	361	1.2	4.34	4,000	5	2x450
High-angle conveyor	174	2.0	2.67	4,000	35.5	3x450
T-10	296	1.2	4.13	4,000	10	2x630
T-11	17	2.2	1.96	2,000	16	1x55
GD	30	2.4	0.255	2,000	0	2x110

conventional conveyor technology and ensured that all equipment is not subject to adverse loading conditions beyond its intended use.

Study of all methods of steep angle conveying found the sandwich-belt approach to be the most promising but also the least understood technologically. The BOM study sought characteristics and features, pursuant to the findings, that would ensure success. That rationalisation is revealed in the 1982 article "Evolution of Sandwich-belt High-angle Conveyors". The basis to ensure success is complete adherence to the rules of conventional conveyor technology while ensuring complete continuity of hugging on the material regardless of the conveying rate (from empty through overload with continuous and discontinuous material flow) and material size distribution. The former will ensure long life of the belting, components and the equipment while the latter ensures frictional development of the material within the sandwich, precluding material slide-back or leakage.

This paper's approach expanded the conventional

conveyor technology into sandwich-belt conveyors, ensuring that such systems would have all of the operating and maintenance characteristics of conventional conveyors and would be as widely applicable. With emphasis on the technology, rather than a particular manifestation, the paper goes on to propose five different sandwich-belt conveying methods, that, when executed according to the guidelines established, will result in success. Since the 1980s a number of successful commercial installations have been put into operation.

**OPEN-PIT SUCCESS AT MAJDANPEK**

A good example of high-tonnage high-angle conveying in an IPCC application is at the Majdanpek copper mine in Yugoslavia. The system employs an in-pit, portable crusher that is fed by a rubber belt-based rock belt feeder, a connecting in-pit conveyor and a sandwich-belt high-angle conveyor to elevate the crushed ore to the surface. An extensive study, which is discussed below, was done after more than

four years of operation. The system demonstrated the high availability and low operating and maintenance costs inherent in conventional conveyors. Indeed, it can be argued that the system proved life-saving to the mine during the most difficult period of 1992 through 1995.

At the time of conceptual planning of the Majdanpek project, the mine was already operating successful pit perimeter crushing and conveying systems for copper ore and for waste rock disposal. The in-pit system was the logical next step. The total system, as originally conceived, is shown in Figure 2 and incorporates the components described in Table 1.

- In-pit haulage of blasted ore to either of two rock belt feeders (GD);
- Two rubber belt type rock belt feeders (GD) each rated 2,000t/h, to regulate the blasted ore each to an in-pit crusher (PD);
- Two gyratory type crushers (PD), each with in-pit conveying systems (T-11, T-10) leading to one common high-angle conveyor;
- A high-angle conveyor, rated 4,000t/h, receiving primary crushed ore from both crushers and elevating it continuously up to the pit perimeter and onto an overland conveying system (T-9, T-8);
- An overland conveying system (T-9, T-8) to the ore processing plant.

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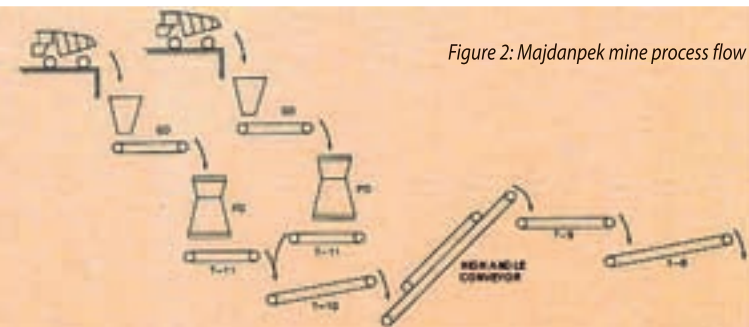


Figure 2: Majdanpek mine process flow

Majdanpek showed a total commitment to in-pit crushing and high-angle conveying, and reaped the benefits of this most effective haulage system. The result of this efficiency was a significant saving of some US\$12 million/y over the traditional truck-only haulage

system, equivalent to a 30% saving. Additionally, the mine experienced continued operations that might have otherwise shut down and improved safety due to alleviation of truck traffic.

### HIGH-ANGLE VS CONVENTIONAL

While the Majdanpek mine example clearly shows the advantage of IPCC over conventional truck haulage out of open pits, it does not offer a comparison between high-angle conveying and conveying at conventional angles. Of course, the much smaller footprint and elimination of haulage



This system, utilising truck haulage only in the pit, precluded the need to otherwise triple the truck fleet over a four-year period, saving the mine significant initial capital and later fuel costs over subsequent years. It furthermore precluded large haulage ramps (needed to alleviate traffic congestion) up the face of the pit, thus reducing the overburden removal requirements. Haulage ramp requirements were reduced by 4km, 3.5km of which are under continuous ascent.

Key elements of this in-pit system are, first, a high-angle conveyor that permits direct haulage from within the pit along the steep wall and a rock belt feeder that meters the face blasted ore into the in-pit primary crusher. More details of the high-angle conveyor are summarised in Table 2, while Figure 3 shows the high-angle conveyor in the background, with the rock belt feeder in the foreground.

In 1992, immediately after start-up of the system, the Majdanpek mine, like the rest of Yugoslavia, experienced a period of great difficulty and uncertainty, and from 1992 to 1995, due to the political climate, Majdanpek experts alone had to handle procedures that were the system designer's expertise. However, Majdanpek experts demonstrated their resourcefulness and ingenuity, bringing the system quickly into production, making the adjustments deemed necessary and building in-house those parts required for back-up and/or replacement.

Initially, the system experienced typical starting pains with production hours falling somewhat below the scheduled hours for the year 1992. However, by 1993, scheduled and actual production hours were nearly the same and by 1994, actual system hours exceeded the planned hours. Actual hours continued to exceed planned in subsequent years. Accordingly, system availability improved during the same time period from 84% in 1992 to 86% in 1994.

### TABLE 2: MAJDANPEK HIGH-ANGLE CONVEYOR SPECIFICATIONS

Material conveyed	Copper ore
Density	2.08t/m <sup>3</sup>
Lump size	250mm max
Conveying angle	35.5°
Conveying rate	4,000t/h
Belt width	2,000mm
Belt speed	2.85m/s
Elevating height	93.5m

#### Drives

Top belt	450kW
Bottom belt	2 x 450kW = 900kW



Mn
Manganese 25
6.40 7.06
Fe
Iron 26
6.93 7.65
Co
Cobalt 27
7.48 8.26
Ni
Nickel 28
8.05 8.90
Cu
Copper 29
8.64 9.57
Zn
Zinc 30
9.25 10.26
Ga

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→ roads, and the associated unproductive excavation, are obvious benefits.

A high-angle conveyor versus conventional conveyor comparison was performed in a different example – the case of elevating bulk material to silos of increasing height. The reader is referred to the paper “The Cost/Value of High-angle Conveying” for the complete details of this study. The study compared four different conveying paths to each of five different (increasing) silo heights: a conventional conveying path, at 15° and three alternate high-angle paths at 45°, 60° and 90° (vertical). The results of that study are summarised graphically in Figure 4.

Though the pricing comparison is pursuant to Dos Santos International’s uniform design and pricing philosophy, the study presents the results in the form of an index. Any reader can then normalise this cost comparison according to their own buying and/or selling experiences and policies.

The graph shown clearly conveys the point that the use of high-angle conveyors in high-lift, high-capacity applications will yield the most cost savings in capital expense, and in total investment. The cost of the vertical DSI Snake Sandwich system is only 60% of the conventional conveying system when elevating to a 76m-high silo.

The great cost differentials between the conventional 15° slope conveyor and the sandwich-belt conveyors are due to the great difference in structural steel requirements. The steel in this case includes all truss spans, bents, terminal framing, covers, access walkways and stairways, chutes, etc.

It is also worth noting some non-cost factors for comparison. The high-angle conveyors require less real estate and less spatial volume. A cost can be associated with the displaced projected area when considering the additional excavation and occupation of what may otherwise be usable space.

### SAFETY AGAINST SLIDE-BACK

Safety against material slide-back is a very important factor in any materials-elevating system, particularly in mining applications. Such a consideration might lead the more conservative to erroneously choose

the conventional conveyor as the safe solution. However, at any of the more than 100 sandwich-belt conveyors designed pursuant to the ‘expanded conveyor technology’, slide-back has never been an issue. Safety against slide-back is inherent in a sandwich-belt conveyor system because the induced hugging pressure is pre-determined. On the other hand, there are many documented cases of conventional conveyors that experienced slide-back failures at incline angles of 15°, 16° and 17°. Indeed, to achieve equal safety against material slide-back, conventional conveying angles would be limited to less than 12° even with coal and crushed rock.

### INSTALLATIONS

While Snake Sandwich high-angle conveyors have been under-utilised in open-pit mining, there are a number of other examples of their successful implementation throughout industry, including installations in mine processing plants. A few examples are detailed below.

#### Aceralia steel mill, northern Spain

Table 3 lists the technical data for a Snake Sandwich high-angle conveyor that began operation in July 2003 at the Aceralia steel mill, near Gijon in Asturias, Spain. The actual installation is shown in Figure 5. The Snake is part of an expansion to the coal grinding facilities for the carbon injection to the existing and new blast furnaces and 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.

#### De Beers Snap Lake and Victor, Canada

Table 4 describes the specifications for three Snake units that are part of the major Victor open-pit diamond mine in northeastern Ontario, Canada and are shown in Figure 6. The Snakes, with their small footprint, conserve precious building space in the processing plant whose housing has to protect the facilities from the harsh northern Canadian environment and, in turn, protect the environment by greatly reducing the heated area of the facility. Victor is the second Canadian mine to exploit the space-saving Snakes.

The previously-completed Snap Lake diamond mine in the Northwest Territories (also owned by De Beers) is the first completely-underground diamond mine in Canada and utilised two Snake Sandwich high-angle conveyor units. These Snap Lake units are shown in the title photo of this article. Both projects began full production operations in 2007 and both handle kimberlite.

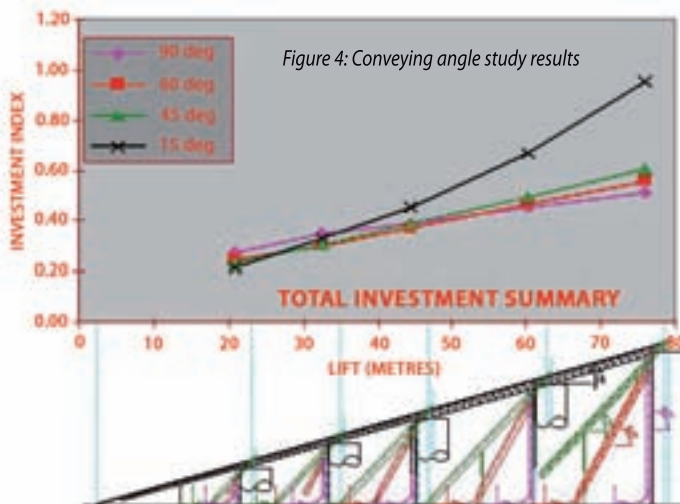


Figure 4: Conveying angle study results

### TABLE 3: SPANISH STEEL MILL HIGH-ANGLE CONVEYOR SPECIFICATIONS

Material conveyed	Coal
Density	0.8t/m <sup>3</sup>
Lump size	-50mm
Conveying rate	250t/h
Conveying angle	75°
Belt width	1,200mm
Belt speed	2.29m/s
Elevating height	35,100mm
Length	45,065mm
<b>Drives</b>	
Top belt	30kW
Bottom belt	30kW

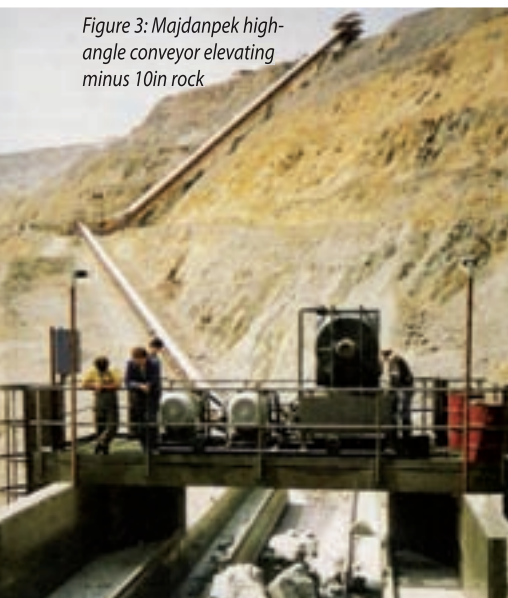
#### Snake ship loader, Port of Adelaide, Australia

A mobile 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 manoeuvrability. Australia’s first Snake ship loader elevates a variety of high-value ores from trucks to ship. Materials for export are trucked to the dock and dumped onto a special feeder. The ore is

Figure 5: Coal handling Snake Sandwich conveyor in northern Spain



Figure 3: Majdanpek high-angle conveyor elevating minus 10in rock



**TABLE 4: DE BEERS VICTOR DIAMOND MINE, SNAKE SANDWICH HIGH-ANGLE CONVEYORS FOR KIMBERLITE**

Conveyor	S1	S2	S3
Density	1.6t/m <sup>3</sup>	1.6t/m <sup>3</sup>	1.6t/m <sup>3</sup>
Lump size	-28mm	-28mm	-6mm
Conveying rate	422t/h	381t/h	185t/h
Conveying angle	60°	49.5°	49.5°
Belt width	1,067mm	1,067mm	1,067mm
Belt speed	2m/s	2m/s	1m/s
Elevating height	11,886mm	18,508mm	18,508mm
Length	33,282mm	67,581mm	65,981mm
<b>Drives</b>			
Top belt	29.83kW	29.83kW	18.65kW
Bottom belt	29.83kW	29.83kW	18.65kW

rationalisation and have demonstrated the performance characteristics of conventional conveyors. At the described Majdanpek copper mine in Yugoslavia, a system installed at the end of the 1980s as part of the IPCC system, the high-angle conveyor demonstrated its suitability for the coarse ore elevating duties directly up the mine wall. Performance over a five-year period demonstrated a saving of US\$12 million/y and reduced the truck fleet requirements by two-thirds

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.

The mobile Snake is carried on a tripod of twin rubber tyres. Each set of twin tyres is mounted at a vertical kingpin. The rear tyres are powered by hydraulic motors and are steerable. The front tyre sets are designed to be rotated to positions parallel to the ship loader's length for to-and-fro travel and to manoeuvre in a perpendicular direction for side travel, or perpendicular to an axis with the rear tyres for a slewing motion. Thus, without repositioning, the Snake can set up to travel in any direction.

### SUMMARY

Complete rationalisation of sandwich-belt conveyor technology into conventional conveyor technology was achieved in the period 1979 to 1982. Many successful sandwich-belt steep and vertical conveyors have been built pursuant to that

compared with a truck-only haulage system. Despite this proven success, other mines have not followed suit and DSI believes there is great potential for improved performance and profits from these systems that has remained untapped.

Other studies and installations have also demonstrated the cost savings with sandwich-belt high-angle conveyors. The latest DSI Snake Sandwich installations, such as those in Canada's diamond mining industry, continue to demonstrate their suitability for elevating mined products. These have also demonstrated harmony with the environment, imposing a minimal footprint (both physical and environmental) and consuming minimal energy.

Figure 6: High-angle Snake Sandwich conveyor, De Beers' Victor diamond mine



**TABLE 5: AUSTRALIAN SNAKE SHIPLoader**

Material conveyed	Various ores
Density	2.4t/m <sup>3</sup>
Conveying rate	1,000t/h
Conveying angle	50°
Belt width	1,200mm
Belt speed	2m/s
Elevating height	21,805mm
Length	56,656mm
<b>Drives</b>	
Top belt	55kW
Bottom belt	55kW

### References

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