MODERN CONTINUOUS HAULAGE SYSTEMS AND EQUIPMENT

1995

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The favorable economics of conveyor based haulage, especially in moving large volumes, has long been acknowledged. This has given impetus to significant developments over the last two decades in conveying systems and equipment. Such developments have resulted in improved equipment and system reliability, versatility and mobility.

The present article presents conveyor systems and their variations. Long conveyors of various profile and plan layout are considered along with various typical support systems. Horizontally curving, two-way and booster driven conveyors are included. High Angle Conveyors - HAC®s are reviewed, citing their wide and varied application. HAC® units throughout Southern Africa are described. Finally, several important advances in idler and in pulley design are presented.

1. Introduction

The economics of hauling large volumes of bulk materials continuously, with conveyors, has long been acknowledged. Continuous mining and conveyor based haulage systems have had worldwide use since beginning of the twentieth century. Conveyor haulage has been dominant in underground coal mines, potash, soda ash, and salt mines, since the 1950's. The conventional drill, shoot, load methods of mining consistently resulted in a conveyable product. The later introduction of continuous miners and early longwall systems dictated, that for economic reasons, conveyor systems were the answer to underground haulage.

Some surface mining of soft, unconsolidated ores and overburden, such as the German lignite fields, has also seen extensive use of large continuos mining machines and conveyor haulage systems.

In general, however, surface mining has not been in soft unconsolidated materials. Typically, surface mining has required blasting of the face and loading by large bucket rope shovels, backhoes, front-end loaders, push dozers, etc. Trucks have dominated haulage in these cases. Only recently have conveyors begun to dominate in the long haul and high lift duties of surface mines. The key to conveyorized surface mines has been the development in the late 1970's and throughout the 1980's of high capacity mobile and portable crushers to reduce mined materials to a conveyable size.

Important developments in conveyor systems were prompted by the needs, in underground applications; to install and relocate conveyor lines quickly; to extend or retreat the conveyor lines in order to stay proximate to the mining machines. This resulted in modularization of drive, take-up, loading, and belt storage units and decoupling these from the intermediate conveyor line. The conveyor line could thus be made in components light enough to be manhandled.

The developments in underground ultimately were adapted in above ground overland conveyors. On the other hand, very significant developments in high angle conveyors were prompted by the need for the most direct conveying path from open pit mines. These are now being applied to underground mines and tunnels and are revolutionizing vertical shaft haulage.

The number of longwall mining systems, in underground coal mines, increased dramatically throughout the 1980's and into the 1990's. This promises to continue throughout the remainder of this decade. The high production rates of the longwall systems, reaching peaks to 3000 tph in some cases, made the capacity of previous conveyor systems inadequate. Where 42 inch belts were previously considered adequate for the large mines, today's haulage systems require 48, 54, 60 and even 72 inch belts to handle the increased production. Other implications of the longwall systems will be discussed further.

Conveyor systems and components have matured over the past fifteen years, reaching high technological levels due to advanced analytical techniques using computers. The result is that reputable conveyor companies can now use advanced analytical techniques to offer a wide variety of conveyor systems suitable for many haulage duties previously considered out-of-bounds to conveyors.

2. Longhaul and high lift conveyors

The longhaul conveyor is an attractive alternative to trucking and rail haulage. Conveyor lengths have increased dramatically over the years and lengths exceeding 20 km are no longer uncommon. Such systems have been made possible by steel cord belts of ever increasing strength exceeding ST 5000, various forms of starting control for very high power conveyor drives exceeding 5000 kW, by quality conveyor components and by the computer based analytical techniques to predict accurately the tension variations and power requirements under the various load conditions. Table 1 lists some long conveyor systems provided by Continental Conveyor & Equipment Company of Winfield, Alabama, U.S.A.

Fig. 1. Horizontally curving conveyor in tunneling project.

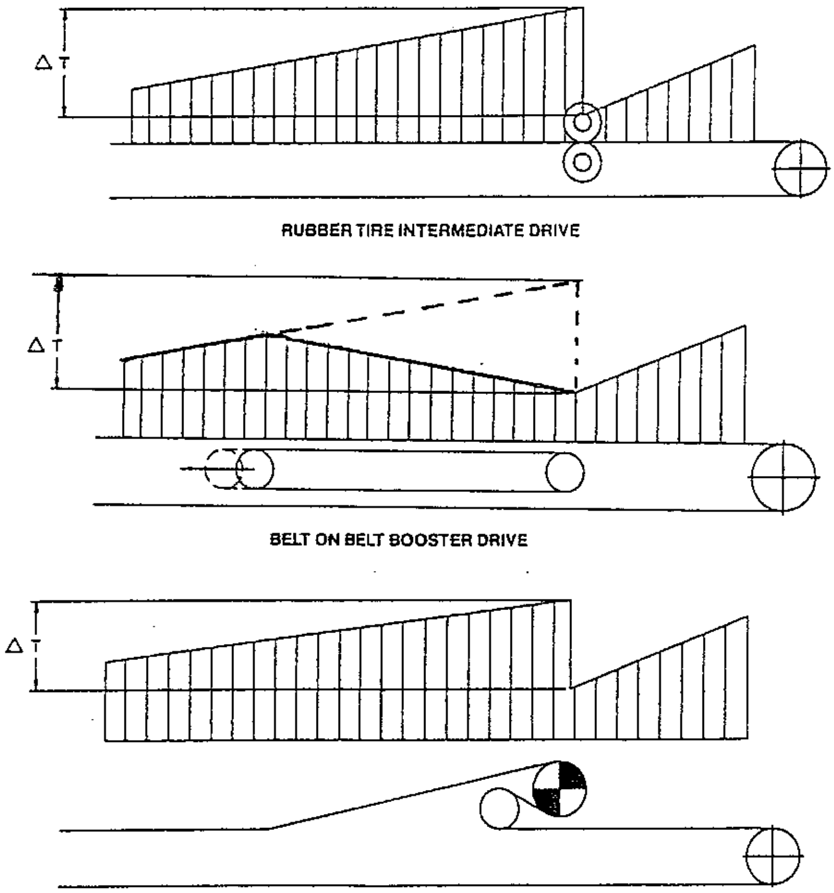

Fig. 2. Basic principle, three types of intermediate drives; rubber tire, belt on belt, fixed tripper.

2.1 Horizontally Curving Conveyors

Due to modern analytical and control methods using high speed computers, it is now possible to accurately predict operating belt tension and tension variations throughout the profile of any long conveyor. This, along with tension control by automatic take-up means and by controlled starting and running of drives, permits the design and operation of long conveyors with vertical and horizontal curves along the profile. Accurate knowledge of the tensions allows proper tilt of the idlers to offset radial pull of the belt and allows accurate determination of belt wander during operation. In above ground applications, horizontally curving conveyors can permit long single flights around obstacles, such as rugged terrain, limited right-of-way, structures, etc., that would otherwise require multiple conveyor flights and an equal number of transfer points. In underground mining, horizontally curving conveyors are being used to follow tunnel boring machines (TBMs) to haul away the muck. In general, the tunnel path has many horizontal curves which the conveyor follows without transfer. After tunneling is complete, such conveyors may be operated in reverse to deliver fresh concrete, for tunnel lining as the conveyor is retracted. Fig. 1 illustrates a horizontally curving conveyor in tunneling.

TABLE 1. SELECTED LONG HAUL/HIGH LIFT CONVEYORS BY CONTINENTAL CONVEYOR & EQUIPMENT COMPANY

Company/Location	Material Rate (t/h)	Belt Width (mm/in.)	Length (m/ft.)	Type System	Year
Texas Municipal Pwr Auth/Tex	Lignite/1636	1219 (48")	6497 (21315')	4 flights	1982
B.C.Coal Ltd./British Columbia	Coal/1000	1219 (48")	4428 (14528')	2 flights	1982
Centex Corp./Texas	Sand/545	762 (30")	1646 (5400')	3 flights	1981
Dalcan Constr./British Columbia	Rock/909	914 (36")	3048 (10000')	10 flights	1980
Black Butte Coal Co./Wyoming	Coal/2727	1524 (60")	5294 (17370')	5 flights	1980
S.J. Groves Co./Utah	Fill/3182	1067 (42")	21123 (69300')	18 flights	1979
Utah Power & Light Co./Utah	Coal/1091	1067 (42")	1585 (5200')	2 flights	1978
Drummond Coal Co./Alabama	Refuse/454	914 (36")	1219 (4000')	2 flights	1976
Drummond Coal Co./Alabama	Coal/545	1067 (42")	1463 (4800')	2 flights	1975
Dolet Hills Mining/Louisiana	Lignite/909	1067 (42")	11218 (36803')	4 flights	1985
Morrison-Knudsen/Chicago, IL	Limestone/1089	914 (36")	6522 (21400')	3 flts,7 horiz crvs	1989
Jersey Miniere/Gordonsville, TN	Zinc Ore/227	914 (36")	1591 (5219')	1 flight slope belt	1993
Pequiven/Venezuela	Phspht Rock/735	762 (30")	2279 (7477')	6 flights downhill	1993
Drummond Coal Co./Alabama	ROM Coal/4990	1828 (72")	1356 (4450')	1 flight. 5968 kW	1993
Perini Corp./Chicago, IL	Tunnel Muck/1266	914 (36")	13986 (45885')	2 flts,8 bstrs,17 crvs	1993
Eighty-Four Mining/Eighty-Four,PA	ROM Coal/6700	1828 (72")	7622 (25000')	11 flights	1993
Drummond Coal/Colombia	Coal/2721	1524 (60")	1652 (5420')	2 flights	1994
CBPO/California	Alluvial Fill/1089	914 (36")	4633 (15200')	6 flights	1995
CBPO/California	Rock Fill/2177	1219 (48")	3200 (10500')	4 flights	1995

2.2 TWO-WAY CONVEYING

Two-way conveying (i.e. conveying material on both strands of the belt, running in opposite directions) with many loading variations is also made possible by modern analytical techniques. Two-way overland conveyors are especially useful in conveying mined ore to the processing plant on the upper belt strand and returning the tailings, on the bottom strand, for disposal at the mine area. In coal mine to power plant systems the two materials may be coal and ash respectively.

2.3 INTERMEDIATE BOOSTER DRIVEN CONVEYORS

Theoretically, booster drives permit design of conveyors of unlimited length utilizing belts of modes strength. Such a system utilizes linear drives spaced at intervals along the conveyor length. The belt tension which tends to increase along the conveyor length is relieved by the driving tension exerted by the booster drive. In this manner maximum belt tension is controlled and the conveying system can be driven by several drive stations of modest power rather than a single drive station of very high power.

Three different approaches to intermediate drives (Fig. 2) have reached commercial status. The first system utilizes driven rubber tires at the underside of the belt edge, and non-driven rubber tires at the topside. The belt edges are pressed between the tires and friction driven.

The second system consists of an endless driving belt on which the main conveyor rests. The booster belt is typically 154 mm (6 inches) narrower than the main belt but uses drive and carrying components which are standard conveyor hardware and typically interchangeable with other such components at the main belt. This system also imparts its driving tension to the main belt by frictional development but no added pressure is imposed beyond the normal load of the main belt under varying conditions from empty to full. The length of the booster belt is thus determined for the drive power transmitted and within the design parameters of the system. Fig. 3 illustrates the typical configuration of a belt on belt booster driven system for underground haulage.

The third system, illustrated by Fig. 4, is the tripper type intermediate drive. It has emerged dominant and promises to be the system of the future. Besides simplicity of hardware, requiring only a drive station (no additional belting, tail, take-up system), it permits monitoring the belt tension forward of the booster drive by use of load cells. The feed back in turn permits control of the booster drives for continual optimal belt tension distribution along the belt profile. This system has proven ideal in facilitating complex horizontally curving conveyor systems.

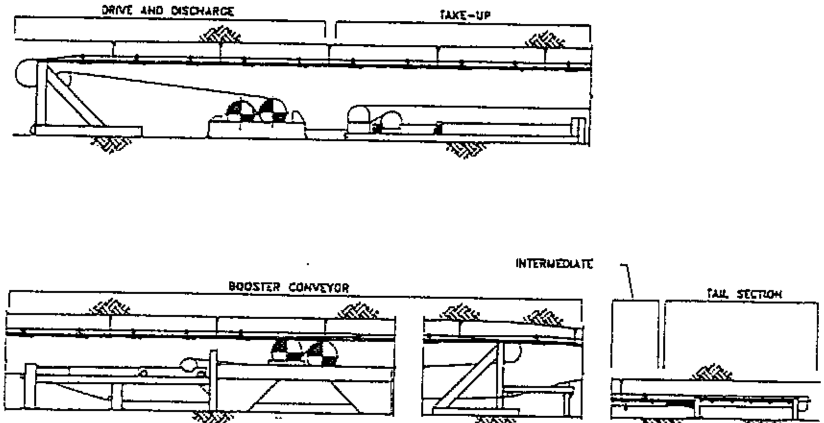

Fig. 3. Belt on belt type booster driven conveyor for underground mine.

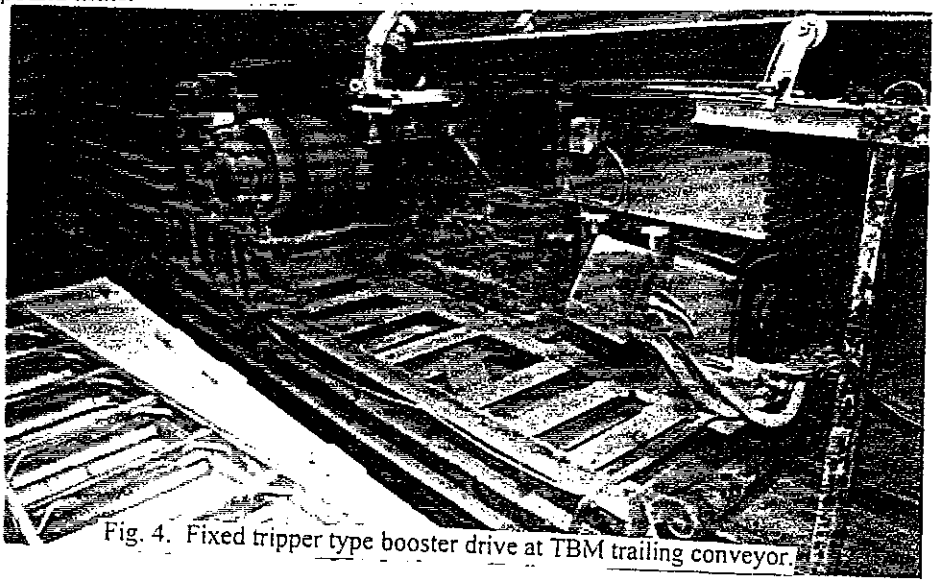

Fig. 4. Fixed tripper type booster drive at TBM trailing conveyor.

Although Continental Conveyor pioneered the development of rubber tired type intermediate drives, with installation of two important systems of this type (Table 2), the market trends in North America have led to shifting emphasis towards the belt on belt type and the tripper type systems. Continental Conveyor's largest market in North America is in the underground coal mines. These have traditionally employed conveyor systems which utilize standard drive units typically in the single or dual 150 to 224 kW (200 to 300 HP) range with typical belt working strength ratings of 107 to 143 kg/cm (600 to 800 PIW), based on 10 to 1 safety factor against breaking. One standard belt, typically of multi-ply or of solid woven fabric, is chosen to meet the requirements of all mine conveyors and is inventoried for use throughout the mines.

Increased use of longwall systems over the last decade has resulted in higher production from larger areas, thus requiring larger and longer main line and slope conveyors. The maximum belt tensions at main line and slope belts often exceed the working strength rating of the selected inventory belt. This presents the following options: *a.)* selecting and stocking non-standard belt (sometimes requiring steel cord belting); *b.)* breaking the conveyor into multiple flights (thus incurring as many material transfer points); or *c.)* boosting the main conveyor with intermediate drives. The strong aversion to steel cord belting and the difficulty in splicing (does not permit mechanical splicing) and the strong desire to keep belt inventory simple, precludes *a.)* as the solution. The belt on belt type booster drive offers the best solution requiring no material transfer points. Simplicity and added tension control with the tripper type booster drives often overshadows the disadvantage of material transfer making it the most popular solution.

2.4 CONVEYOR SUPPORT STRUCTURES

Intermediate conveyor structure has evolved over the years with the significant advances coming from underground mine systems. Fig. 5 illustrates the variety of support arrangements available today. The wire rope system, the most economical, was pioneered by Continental Conveyor & Equipment Company for underground coal mines. It may be roof hung from rock anchored chains or floor mounted on cross-ties and posts. This system has also found wide use in above ground overland conveyor systems. The portable rigid structure is an alternate approach to the wire rope structure with parallel applications.

The continuous stringer type supports have been used widely for the bulk of plant, yard, and dock applications while table sections have been popular in surface mine application. The basic table section on steel sleepers with connecting shifting rail has long been used in shiftable conveyor systems in surface mines. The support truss is most popular when conveyor lines must be elevated far above the ground.

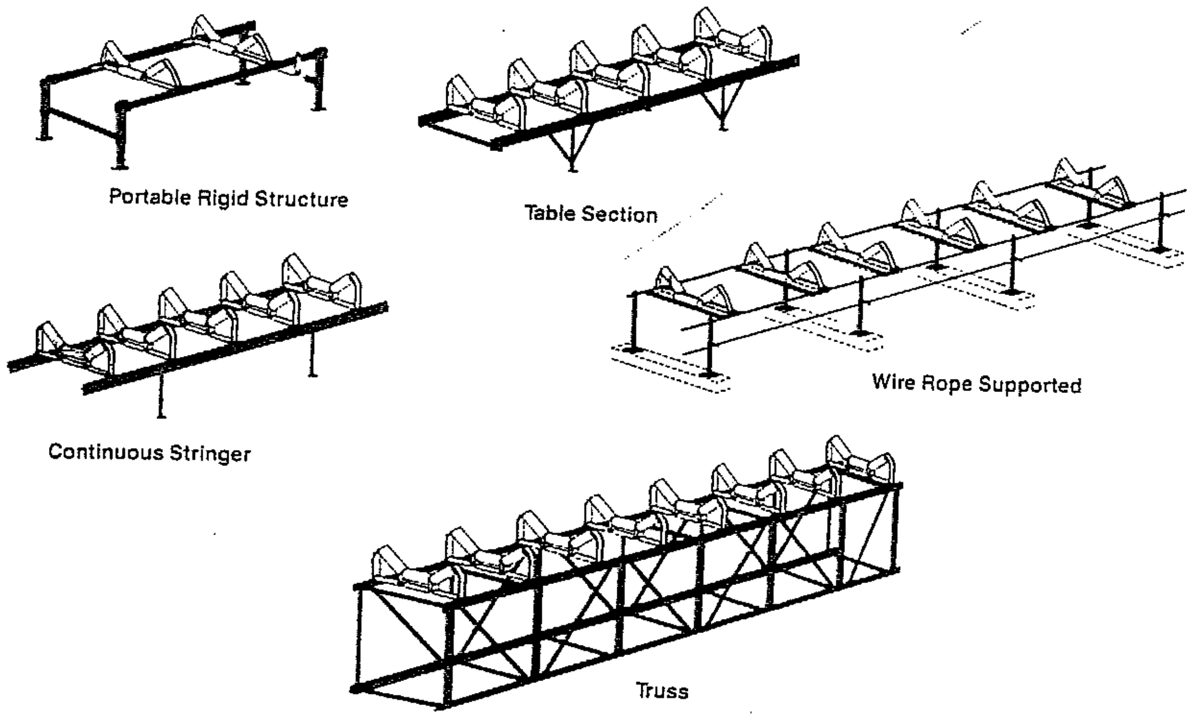

Fig. 5. Five types of support structure for conveyor.

Table 2. Selected Single Flight Booster Driven Conveyors by Continental Conveyor & Equipment Company

Company/Location	Material Rate	Belt Width	Length (m)	Type System	Booster Drives	Other Drives	Year
1. Kaiser Stl/NM	Coal/2727	1219 (48")	2499 (8200')	Rubber Tire	4@ 149 kW	Hd Dr@298kW	1974
2. Brewster Phpht/FL	Carry Phpht/2309	1372 (54")	4426 (14520')	Rubber Tire	11@149 kW	Hd Dr@149 kW	1977
	ReturnTailings/1291			Two-Way Conv.			
3. Eastern Assc.Coal/WV	Coal/1545	1219 (48")	2149 (7050')	Belt on belt	1@373 kW	Hd Dr@373 kW	1987
4. Amer.Elec.Pwr/OH	Coal/1818	1219 (48")	2865 (9400')	Belt on belt	1@187 kW	Hd Dr@373kW	1988
5. Amer.Elec.Pwr/OH	Coal/1818	1219 (48")	2774 (9100')	Belt on belt	1@187 kW	Hd Dr@373 kW	1988
6. Amer.Elec.Pwr/OH	Coal/1451	1219 (48")	3292 (10800')	Belt on belt	1@448 kW	Hd Dr@448 kW	1989
					1@224 kW		
7. Cyprus Emerald/PA	Coal/3629	1829 (72")	3089 (10135')	Belt on belt	1@373 kW	Hd Dr@746 kW	1989
8. Cyprus 20 Mile/CO	Coal/2722	1524 (60")	921 (3020')	Belt on belt	1@298 kW	Hd Dr@896 kW	1989
9. Cyprus Empire/CO	Coal/2722	1524 (60")	1219 (4000')	Fixed tripper	1@597 kW	Hd Dr@597 kW	1989
10. Drummond Coal/AL	Coal/1633	1067 (42")	2737 (9000')	Fixed tripper	1@298 kW	Hd Dr@298 kW	1989
11. So.Utah Fuel/UT	Coal/2085	1372 (54")	5700 (18700')	Fixed tripper	1@896 kW	Hd Dr@896 kW	1989
12. Utah Fuels Skyline/UT	Coal/1633	1219 (48")	2438 (8000')	Fixed tripper	1@671 kW	Hd Dr@896 kW	1989
13. Mingo Logan/WV	Coal/4264	1829 (72")	3048 (10000')	Fixed tripper	1@746 kW	Hd Dr@746kW	1990
14. S.A.Healy/TX	Tunnel Muck/689	762 (30")	5395(17700')	Fixed tripper	2@149 kW	Hd Dr@298 kW	1992
15. Perini Corp/IL	Tunnel Muck/1266	914 (36")	8888(29160')	Fixed tripper	5@186 kW	Hd Dr@373kW	1993
16. Perini Corp/IL	Tunnel Muck/1266	914 (36")	5098(16725'	Fixed tripper	3@186 kW	Hd Dr@373 kW	1993
17. Consol Coal-Bailey/PA	Coal/1996	1219 (48")	2657 (8716')	Fixed tripper	1@448 kW	Hd Dr@448 kW	1994
18. Consol Coal-Enlow/PA	Coal/1996	1219 (48")	2512 (8240')	Fixed tripper	1@448 kW	Hd Dr@373 kW	1994
19. So.Utah Fuel/UT	Coal/1633	1219 (48")	4267 (14000')	Fixed tripper	1@671 kW	Hd Dr@896 kW	1994
20. Drummond Coal/AL	Coal/6078	1829 (72")	3109 (10200')	Fixed tripper	1@896 kW	Hd Dr@896 kW	1994
					1@448 kW		
21. Martin City Coal/KY	Coal/1905	1219 (48")	1515 (4972')	Fixed tripper	1@448 kW	None	1994
22. CBPO of America/CA	Alluvial Fill/1200	914 (36")	671 (2200')	Fixed tripper	1@224 kW	Hd Dr@448 kW	1995
23. CBPO of America/CA	Rock Fill	1219 (48")	671 (2200')	Fixed tripper	1@448 kW	Hd Dr@896 kW	1995
24. BHP Australia Coal	Coal/3500	1600 (63")	2300 (7546')	Fixed tripper	1@650 kW	Hd Dr@650 kW	1995
	Coal/2500	1400 (54")	2000 (6562')	Fixed tripper	1@650 kW	Hd Dr@650 kW	1995
	Coal/2500	1400 (54")	2000 (6562')	Fixed tripper	1@650 kW	Hd Dr@650 kW	1995
25. South Bulga Colliery	Coal/2500	1400 (54")	2200 (7218')	Fixed tripper	1@750 kW	Hd Dr@600 kW	1995

3. High Angle Conveyors - HAC®

One of the most significant advances in conveyor technology, the High Angle Conveyor - HAC®, was introduced by Continental Conveyor in June 1983. The system has matured and proven its worth over the years in widely varying applications. High Angle Conveyors - HAC®s, are proven versatile systems for elevating or lowering materials continuously at steep angles to 90°. Widely varying industries have exploited the benefits of HAC®s. Materials handled include coal, refuse, coarse copper ore (-250 mm), hot clinker, municipal sludge, wood chips, gypsum, slag, excavated earth, various grains and RDF (refuse derived fuel - garbage). Throughput rates vary from 0.27 to 4250 t/h. The conveying profiles vary widely and elevating heights range from 3.66 m to 183.5 m.

HAC®s have found application in coal mining, preparation, power and synfuels, in various minerals and metals mining, in municipal waste treatment, rapid transit projects, pulp and paper mills, cement plants, and transshipment of grain.

Table 3 lists the main parameters of various systems. Figs. 6 - 13 illustrate some select HAC units. Seven of these are in operation in Southern Africa, (Figs. 9, 10, 12).

3.1 THE SANDWICH BELT PRINCIPLE

The Continental HAC® represents evolution to the latest state-of-the-art in sandwich belt high angle conveying. The sandwich belt approach employs two ordinary rubber belts which sandwich the conveyed material. Additional force on the belts provides hugging pressure to the conveyed material in order to develop sufficient friction at the material to belt interface so that sliding back will not occur at the design conveying angle. An ample belt edge distance is provided to insure a sealed material package during operation even when normal belt misalignment occurs. A comprehensive treatment of force interaction can be found in Dos Santos and Frizzell [3].

The Continental HAC® consists of a carrying conveyor belt which is supported on closely spaced troughing idlers and a floating cover belt which is softly pressed onto the conveyed material by closely spaced, fully equalized, pressing rolls. The required material hugging pressure varies according to the conveying angle, material characteristics and the dynamics of the system. The hugging pressure device is, therefore, designed for specific requirements of the application with provision for field adjustments.

3.2 ADVANTAGES OF CONTINENTAL CONVEYOR SANDWICH BELT HAC®

The Continental Conveyor HACs can take on various profiles and offer many advantages over other systems including:

Simplicity of approach: The use of all conventional conveyor hardware.

Virtually unlimited in capacity: Conventional conveyor components permit high conveying speeds. Available belts and hardware to 3 m (120 in) wide make possible capacities greater than 13,608 t/h (15,000 tph).

	Company/Location	Materal . Rate (t/h)	Conveying Angle (°)	Elevating height (m)	Length (m)	Belt Width (mm)	Belt Speed (m/s)	Drives kW top/bottom	In Operation
1.	Demo Unit/Winfield, AL, USA	Various.To 2,903	30 to 60	7.9 to 19.5	35.0	1524	0 to 6.1	75/112	1983
2.	Triton Coal Co./WY, USA	Coal 2,540	60	32.9	56.7	1524	5.33	149/224	1984
3.	Majdanpek Mine/Yugoslavia	Copper ore/4,000	35.5	93.5	173.7	2000	2.85	450/900	1992
4.	Coal Company/Western USA	Coal/2.903	35	29	61.9	1829	4.57	149/224	1987
5.	Granite Constr.Co./CA,USA	Ex. Earth/272	90	31.7	39.9	914	1.6	22.4/22.4	1988
6.	Waste Treatment Co./NY,USA	Sludge/.272	90	3.66	8.6	610	0.3	0.0/2.2	1989
7.	Boise Cascade/WA,USA	Wood chips/173	53	32.6	49.3	1219	2.03	22.4/22.4	1989
8.	Coal Prep Plant/Eastern USA	Raw coal/1,089	49	21.9	40.2	1372	2.79	56/56	1990
9.	BethEnergy Mines/WV,USA	Clean coal/726	90	76.2	90.2	1372	2.79	112/112	1991
10.	Boise Cascade/WA, USA	Wood Chips/65.3	90	15.5	31.4	914	2.03	7.5/7.5	1991
11.	Valley Camp of Utah/UT, USA	Raw Coal/1,089	65	30.7	44.2	1372	3.56	93.2/93.2	1990
12.	Island Creek/VA,USA	Coal Refuse/454	To 41	174.8	454.2	914	2.34	186/186	1992
13.	Steel Cement/Australia	Gypsum,Slag/50	90	16.2	37.8	600	1.67	7.5/7.5	1991
14.	Kimberly Clark/Canada	Wood Chips/229	53	22.9	40.5	1219	2.03	18.6/18.6	1991
15.	Cape May Co./NJ,USA	Compost/40.3	90	9.0	17.5	762	1.27	0.0/11.2	1991
16.	Cape May Co./NJ,USA	Compost/40.3	90	13.0	31.8	762	1.27	0.0/11.2	1991
17.	Shipping Co./Mexico	Grain/584	90	18.9	27.4	1524	4.06	56/56	1991
18.	Shipping Co./Mexico	Grain/1,361	90	22.0	181.0	1829	4.06	112/112	1993
19.	Coal Co./WV,USA	Clean Coal/544	90	16.1	69.4	1372	2.79	37.3/75	1991
20.	Shipping Co./Mexico	Grain/907	65	30.7	44.2	1372	3.73	75/75	1993
21.	Gleason-Pequiven/Venezuela	Phspht Rock/668	-35.5	Drop 34.0	113.0	914	2.29	0/93.2	1992
22.	Cementos Veracruz/Mexico	Hot Clinker/715	35	41.3	198.9	1219	1.73	56/112	1992
23.	Mid-West Conveyor/FL,USA	Coal/1,814	48	14.2	57.0	1829	3.56	75/112	1992
24.	U.S.Gypsum/NY,USA	Gyp Rock/363	90	36.6	48.5	1067	1.52	37.3/37.3	1992
25.	The Conveyor Co./WI,USA	Sludge/9.1	90	6.5	15.6	610	1.22	0.0/7.5	1992
26.	Mountain Coal Co./CO,USA	Raw Coal/1,361	51	22.6	44.2	1524	3.56	75/93.2	1992
27.	Mountain Coal Co./CO,USA	Raw Coal/272	35	15.0	37.5	1219	1.27	11.2/14.9	1992
28.	Taulman Sys./Canada	Compost/81.6	90	20.0	36.3	762	1.78	11.2/11.2	1992
29.	Montague Sys./WY,USA	Coal/1,950	57	59.4	90.8	1829	3.66	186/298	1993
30.	Turris Coal Co./IL,USA	Coal/1,361	90	102.0	113.0	1524	4.57	298/298	1993

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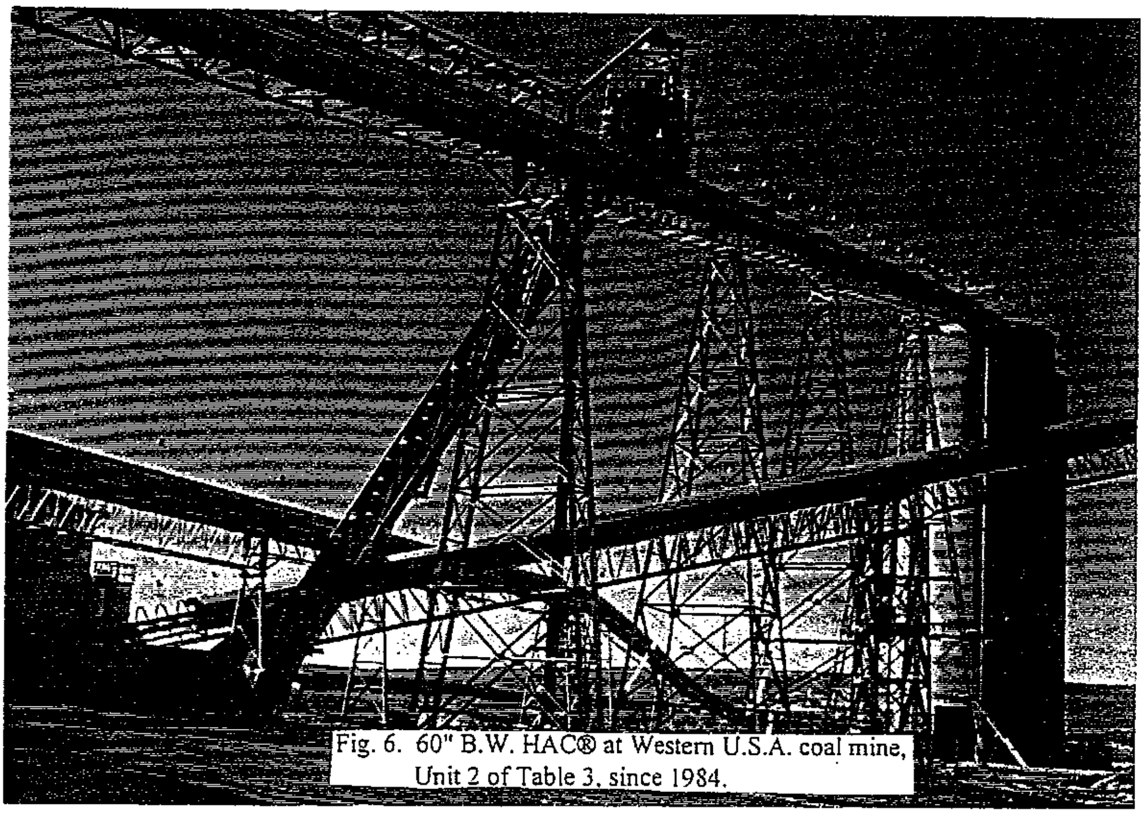

Fig. 6. 60" B.W. HAC® at Western U.S.A. coal mine, Unit 2 of Table 3, since 1984.

31.	Sasol/South Africa	Coal/400	90	13.3	39.3	1200	2.2	30/30	1993
32.	Sasol/South Africa	Coal/400	90	13.3	40.3	1200	2.2	30/30	1993
33.	Sasol/South Africa	Coal/400	90	13.3	43.4	1200	2.2	30/30	1993
34.	Sasol/South Africa	Coal/600	90	13.3	40.3	1350	2.6	45/45	1993
35.	Sasol/South Africa	Coal/600	90	13.3	40.3	1350	2.6	45/45	1993
36.	Bechtel/NV, USA	Gold Ore/689	60	28.9	58.4	1219	1.65	37.3/56	1993
37.	Perini/MA,USA	TBM Muck/1,266	90	70.1	83.8	1372	3.56	186/186	1993
38.	Palm Beach Res./FL,USA	RDF/45.3	45	23.8	40.2	1372	1.15	0/16	1993
39.	Colver Pwr Plant/PA,USA	Coal/260	55	28.3	60.4	762	2.29	22.4/22.4	1994
40.	Colver Pwr Plant/PA, USA	Coal/260	To 60	48.5	75.0	762	2.29	30/37.3	1994
41.	Butterley Engr./Ripley,U.K.	Various/To 49	90	9.0	11.3	500	2.5	3/3	1993
42.	Lehigh Cement Co./AL,USA	Raw Feed/227	90	30.0	60.0	914	2.8	22.4/30	1994
43.	A&A Roofing/AK,USA	Coal/136	90	13.8	41.4	1067	1.51	11.2/14.9	1994
44.	Butterley Eng./Zimbabwe	Coal,Pyr/7	90	16.0	68.3	500	.75	0/6	1994
45.	LTA,Iscor/South Africa	Iron Ore/4,250	53.5	17.5	43	1800	3.12	220/220	1994
46.	Palm Beach Res./FL,USA	RDF/45.3	45	23.8	40.2	1372	1.52	0/15	1994
47.	Fording Coal Co./Canada	Coal/200	90	17.4	34.3	914	2.8	22.4/22.4	1994
48.	FMC Corp./PA,USA	Anth.Culm/272	75	23.4	48.8	914	2.2	30/30	1995
49.	FMC Corp./PA,USA	Anth.Culm/272	75	20.1	70.7	914	2.2	30/30	1995
50.	Coal Prep Plant/WV,USA	Coal/317	33	15.2	31.1	914	2.29	0/37.3	1994
51.	Mid-West Conveyor/TX,USA	Pet.Coke/635	72.5	26.2	53.0	1372	2.67	56/75	1994
52.	Binghamton Johnson/NY,USA	Compost/84	90	22.6	38.1	762	1.78	11.2/11.2	1994
53.	Great No.Paper Co./ME,USA	Wood Chips/146	60	8.5	16.3	1067	2.03	0/22.4	1994
54.	Air Products & Chem./PA,USA	Coal/1,814	90	73.9	97.1	2134	4.06	336/336	1998
55.	Air Products & Chem./PA,USA	Coal/227	45	16.7	119.8	914	1.65	30/30	1998
56.	Air Products & Chem./PA,USA	Coal/227	45	50.4	88.8	914	1.65	30/30	1998
57.	Boise Cascade/WA, USA	Wood Chips/435	50	32	98.2	1524	2.94	56/56	1995
58.	Duke Fluor Daniel/NC, USA	Pebble Lime/91	90	44.1	53.2	762	2.03	18.6/18.6	1995
59.	Cleveland Cliffs/MI, USA	Iron Ore/136	41	5.2	17.7	762	.76	0.0/11.2	1995
60.	Cleveland Cliffs/MI, USA	Iron Ore/136	41	5.2	17.7	762	.76	0.0/11.2	1995
61.	Commonwealth Edison/IL, USA	Coal/635	45	38.1	69	1219	3.05	75/75	1995
62.	The Conveyor Co./GA, USA	Sludge/5	60	2.3	9.7	610	.30	0/2.2	1995
63.	The Conveyor Co./LA, USA	Sludge/5	60	1.6	13.8	610	.3	0/2.2	1995

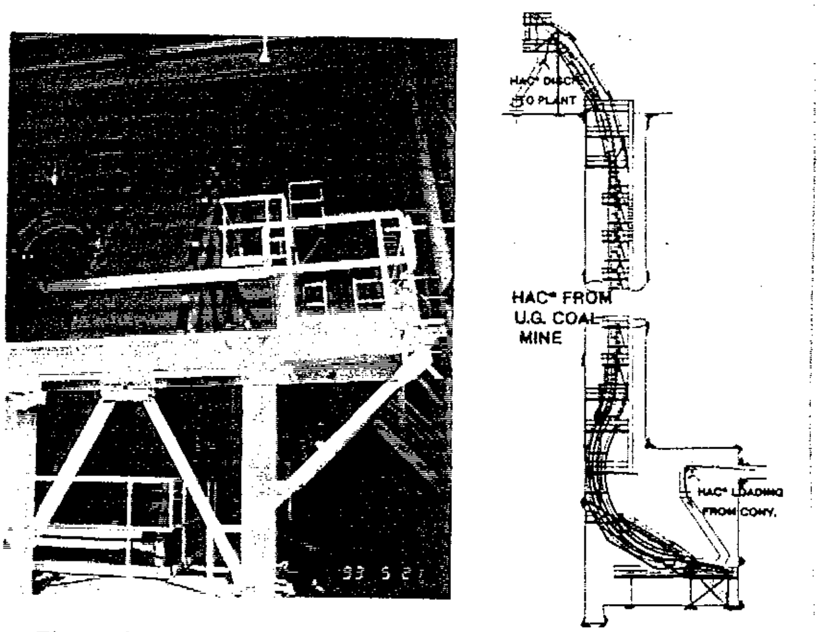

Fig. 7. 60" B.W., 340' lift HAC® in U.S.A. underground coal mine, Unit 30 of Table 3.

High lifts and high conveying angles: Lifts to 305 m (100 ft.) are possible with standard fabric belts and single flights of greater lifts are possible with steel cord belts. High angles to 90° are possible.

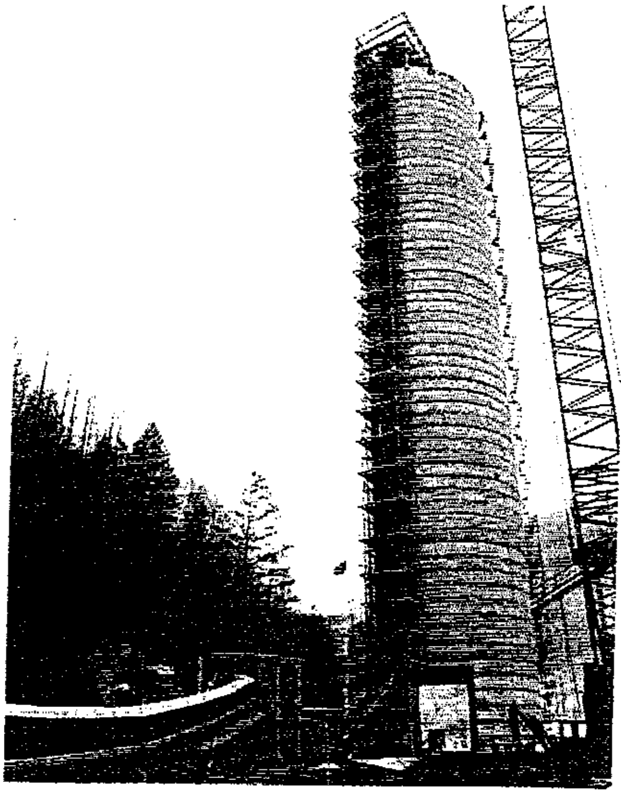

Fig. 8. 54" B.W. HAC® at Eastern U.S.A. coal prep plant, Unit 9 of Table 3.

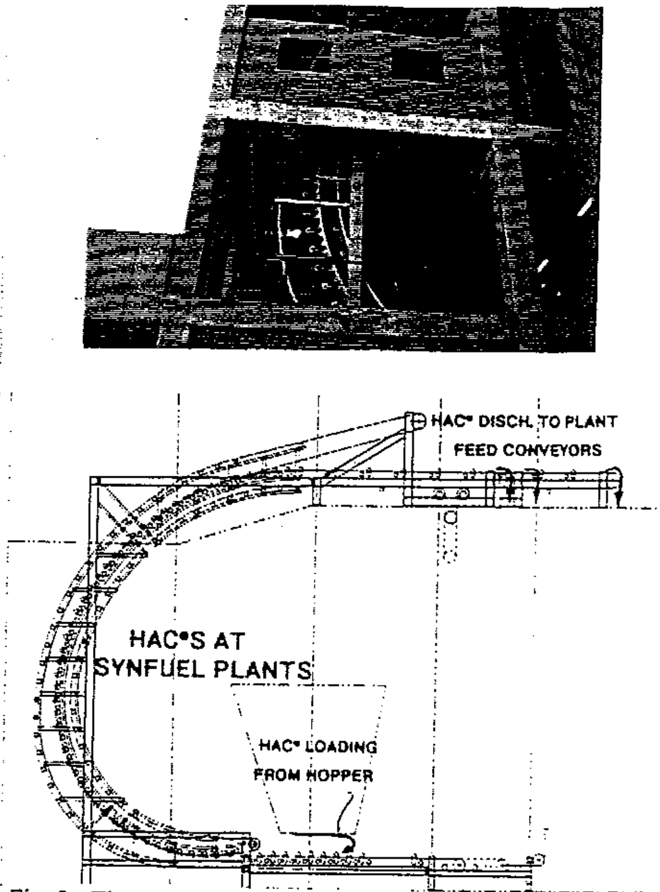

Fig. 9. Three (3) 1200 mm B.W. HAC®s, two (2) 1350 mm B.W. HAC®s, at synfuel plants, South Africa, Units 31 through 35 of Table 3.

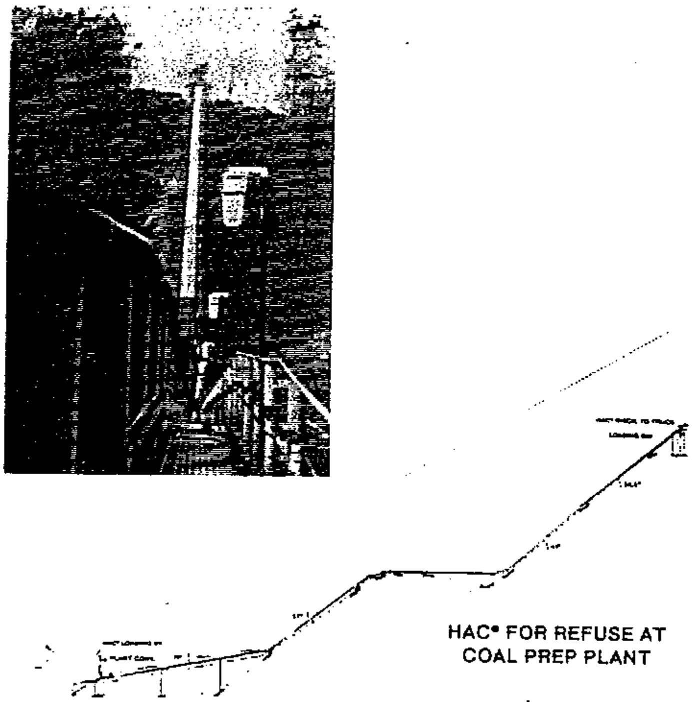

Fig. 11. 36" B.W. HAC®, 454 m long, elevating refuse at Eastern U.S.A. coal prep plant, Unit 12 of Table 3.

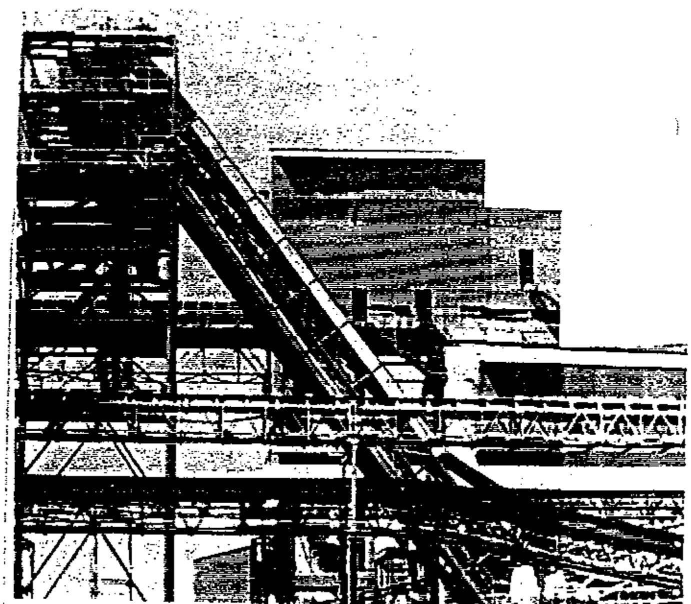

Fig. 10. 1800 mm B.W. HAC® at iron ore mine, South Africa, Unit 45 of Table 3.

Flexibility in planning and operation: The Continental Conveyor sandwich belt lends itself to a multi-flight conveying system as well as to a long single run system. The HAC® unit may be shortened or lengthened or the conveying angle may be altered according to the requirements of a new location. High angle conveying modules may be mounted on rails, rubber tires or crawler type transporters or may be equipped with walking feet for optimal mobility.

Belts are easily cleaned and quickly repaired: Smooth surfaced belts allow continuous cleaning by belt scrapers or plows. Smooth surfaced belts present no obstruction to quick repair of a damaged belt by hot or cold vulcanizing.

Spillage free operation: The material is sealed between the carrying and the cover belts. Well centered loading and ample belt edge distance results in no spillage along the conveyor length.

The wide use of longwall systems in the 1980's has required upgrade or replacement of the existing conveyor lines to keep up with production. In deep coal mines this has resulted in choking at the main haulage shaft where existing skip hoists cannot meet the increased production requirements. This has created great opportunities for high angle conveyors throughout the 1990's.

Fig. 13 shows variations of a proposed multi-flight HAC system (complete with service hoist) to elevate ore 1396 meters. It features 1219 mm (48") wide belts running at 2.54 m/s.

The economics of shaft haulage by HACs are extremely compelling compared to skip hoist systems.

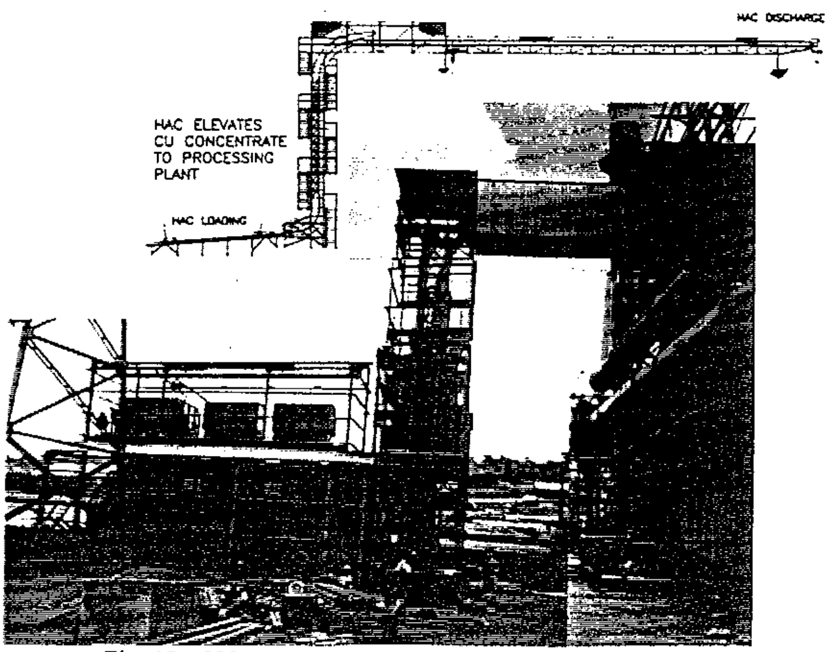

Fig. 12. 500 mm B.W. HAC®, elevating copper/zinc ore, Zimbabwe, Unit 44 of Table 3.

4. Conveyor Components

Reliable, productive conveyor systems are totally dependent on reliable and efficient components. Most important of these are the idlers that support the conveyor line and the pulleys that drive, bend and take-up the belt line. Progressive development in these areas has been ongoing since the Company's beginnings in 1960.

4.1 IDLERS

Continental Conveyor idlers have been recognized for superior quality throughout the industry for many years capturing a large per cent of the North American market. In 1987 the Company introduced an improved design in the heavy duty idler class (Fig. 14) featuring triple labyrinth and lip seals, 19.1 mm (.75 in) tapered roller bearings, and "end pointed" (tapered) shafts.

Most significant of these improvements, the "end pointed" shaft, is a tapered, hollow shaft measuring 31.8 mm (1.25 in) diameter at center drawn to 19.1 mm (.75 in) at the bearing. The result is a very rigid shaft which permits exploiting the very high load rating of the 19.1 mm (.75 in) tapered roller bearing. It is this feature which gives the new idler improved load rating and earns for it the name "H-Plus".

4.2 PULLEYS

A significant pulley development effort took place at Continental Conveyor between 1982 and 1985. This effort included extensive analysis of shaft and end disc interaction including classical elastic analysis and strain gage monitoring of stresses throughout the end discs. This effort resulted in modification of classical analysis techniques to include empirical data and resulted in a new patented Continental Conveyor pulley design, "fabricated turbine end disc", which provides variation in end disc thickness consistent with the flow of stresses.

5. Summary and Conclusions

The present article has discussed some significant developments in conveyor systems and components technology.

The advent of high speed computing has made possible analysis of complex conveying systems and has permitted non-complex design of systems to suit a wide variety of applications. The high angle conveyor has added a new dimension to continuous haualge. Conveying systems have become extremely adaptable. The significant cost savings have never been denied. With the introduction of the HAC®s in the 1980's and continued development into the future, possibilities for conveyor based haulage look more promising than ever before.

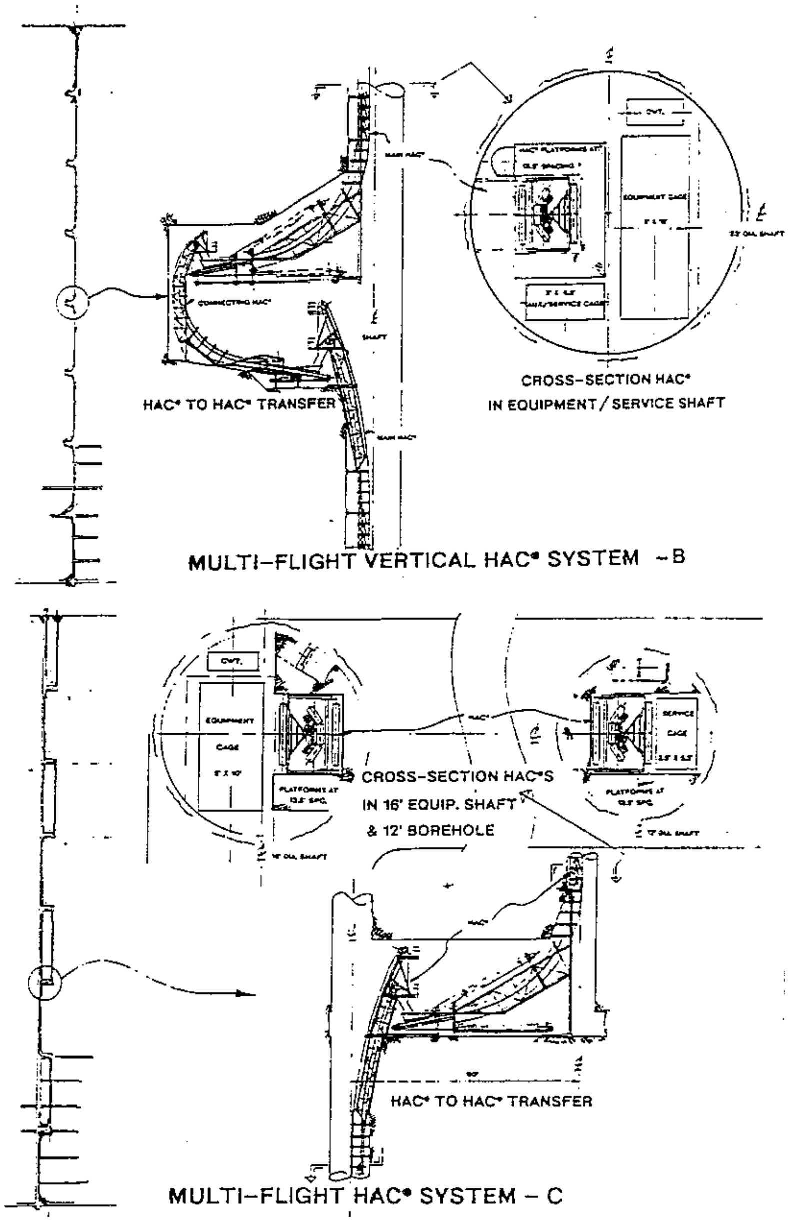

Fig. 13. Two variations of multi-flight HAC®;
System B single shaft,
System C with additional boreholes.

6.0 References

1. Continental Conveyor & Equipment Company, Conveyor Systems: Company brochure.

2. Continental Conveyor & Equipment Company: Conveyor Idler Roll Performance Study, Fall 1986; Study Report.

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

4. Dos Santos, J.A.: "Sandwich Belt High Angle Conveyors - Applications in Open Pit Mining". *Bulk Solids Handling,* Vol. 4 (1984) No. 1, pp. 67-77.

5. Dos Santos, J. A.: "High Angle Conveyors - HAC® From Mine to Prep Plant and Beyond", West Virginia Coal Mining Institute, 1991 Spring Meeting in Morgantown, West Virginia, May 9 - 11, 1991.

6. Dos Santos, J.A.: "HAC® Continuous Vertical Haulage", presented at Mine Hoisting '93, Royal School of Mines, London, U.K., June 28-30, 1993.

7. Key, J.A.: "Continental Conveyor & Equipment Company - A Profile", *Bulk Solids Handling,* Vol. 2 (1982) No. 3, pp. 617-618.

8. Scott, D. W. and Dos Santos, J.A.: "American Mining Congress, Coal Convention 1992, Cincinnati Conventio· Center in Cincinnati, Ohio, May 3-5, 1992.

9. Wise, Robert J. and Alspaugh, Mark: "The Design and Operation of Underground Conveyors Utilizing Intermediate Booster Drives with D.C. Motors and Controls", Conveyor Belt Engineering for Coal and Mineral Mining Industries, Society for Mining, Metallurgy and Exploration, Inc., Littleton, CO, 1993.

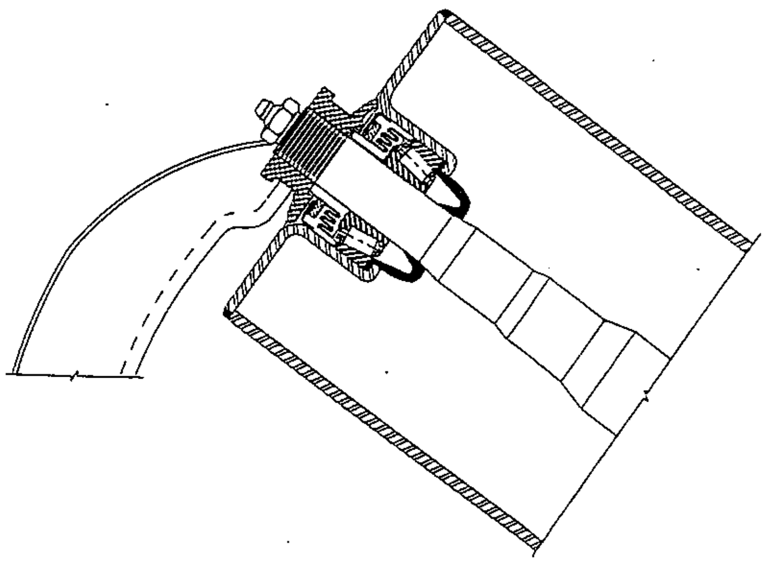

Fig. 14. "H-Plus" idler roll featuring triple labyrinth, lip seal, tapered roller bearing, end pointed hollow shaft.