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Belt Conveyors of the Future

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Bandanlagen der Zukunft
Transporteurs à courroie de l'avenir
Cintas transportadoras del futuro
未来のベルトコンベヤー
未来的输送带
الناقلات بالسير التي ستستخدم في المستقبل. بقلم اوه. كلوبفيل.

Summary

Belt conveyors are nowadays widely used as one of the most economical methods of continuous conveying of bulk materials over medium and long distances. Since the economy of the handling operation is dependent on many boundary conditions, including, for example, the terrain configuration, it has been found in the past that the economic performance of belt conveyor systems can be substantially improved if their alignment can include horizontal curves to adapt them to the terrain. In this way it is possible to avoid intermediate transfer points with their associated problems and cost. The incorporation of horizontal curves in combination with convex and concave vertical curves is bound to gain greatly in importance in the design of future installations. This article describes belt coveyor systems comprising one or more successive horizontal curves, including one with an overall length of about 11,000 m with four horizontal curves in succession attaining a total curved length of about 5,500 m, showing what is possible in this field of engineering. Such a system with left-hand and right-hand horizontal curves can claim to be unique and can provide a powerful impetus to the design of new installations embodying these possibilities.

1. Introduction

Belt conveyor systems are now extensively used for the efficient transport of bulk materials over long distances. The choice of this conveying method does, however, depend on the result of a comparison, in economic terms, with alternative methods:

— ropeway
— railway
— truck (road vehicle)
— pipeline
— other methods (e.g., high-speed "trains" of tubular containers powered by linear motors, more particularly the German "asbz" system).

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The following factors are of major importance with regard to the economy of a conveying system:

— capital cost
— cost of land
— operating costs
— maintenance costs
— repair costs
— operational reliability
— capacity reserve
— personnel requirements
— energy consumption.

2. Conveyor Alignment

The route alignment of the conveying system will have a great effect on most of these factors. Thus, with conventional belt conveyor systems it was only possible to apply alignments which were straight on plan, while variations in level of the terrain could, within limits, be overcome by means of concave and convex vertical curves and therefore usually did not present any major problems. However, it is often not possible to connect the material feed point (e.g., at the quarry) to the material discharge point (e.g., at the cement works) by a straight alignment, this being prevented by the intervening presence of obstacles such as mountains, roads, rivers, buildings, private land, etc. Under such circumstances the conveying route has to be subdivided into a number of conveyor sections with appropriate transfer points for passing the material from one section to the next. This arrangement, however, suffers from some serious drawbacks which affect all nine above-mentioned factors and thus has a marked adverse effect on the economy of the installation, so that in many cases it has been necessary to adopt a different method of transport instead. Especially disadvantageous is the additional capital expenditure comprising equipment and construction, the additiona operating, maintenance and repair costs, and the increased manning requirements associated with each transfer point on the conveying route.

3. Operational Reliability

Besides, the operational reliability of a belt conveying system diminishes with increasing numbers of transfer stations, and these are moreover at variance with environmental considerations, since they are liable to form a source of pollution and noise nuisance, not to mention their unattractive appearance in the landscape. Furthermore, with long overland belt conveyor systems, which are usually installed in regions with deficient infrastructural facilities, the supply of electricity to the drive motors at the transfer stations can be a serious problem — involving heavy expense, a lowering of operational reliability, energy losses and further undesirable interference with the natural environment. For all these reasons, efforts have been made to solve the problem of long-distance overland conveying without having recourse to transfer points. In cases where the length attainable by one belt conveyor is limited by the strength of the belt, it is possible to attain substantially greater lengths by providing several intermediate drives of various kinds, so that the tensile forces acting in the belt are reduced. Many theoretical and practical investigations have been carried out for this purpose, some of which are very promising. The principal reasons why belt conveyor systems are now sometimes still uneconomical and therefore not chosen, or why transfer stations have to be incorporated in the design, are bound up with the route alignment which, because of the obstructing features already mentioned, cannot be planned as a direct continuous line connecting the beginning and the end of the conveying path. It has therefore been the purpose of research and development to achieve flexible alignment for long-distance belt conveyors without entailing extra cost due to modified supporting frames, idlers, special belts or other technical features. Greater flexibility or adaptability of alignment means more particularly that, besides comprising vertical curves (concave or convex), the conveyor can be laid to horizontal curves.

The belt of an ordinary conveyor, with a fabric carcass or steel wire cables enclosed between rubber covers, rests without lateral restraint on its idlers and can thus adapt itself freely within wide limits to the forces acting upon it. In such conventional installations without horizontal curves, provided that the supports and pulleys are correctly adjusted, the belt tension does not adversely affect the running of the belt, while variations in tension due to starting, braking, partial loading, etc., have practically no effect on belt running either. On the other hand, if there are horizontal curves in the conveying path alignment, the belt tension will produce horizontal force components acting inwards, i.e., towards the centre of curvature (Fig. 1), and thus tending to shift the belt in that direction. The magnitude of these inward forces will depend on the following factors:

— the initial belt tension adopted
— the tensile forces required in the belt under specific operating conditions
— the tension additionally produced by the weight of the belt itself
— the horizontal radii of curvature adopted in the design
— the spacing of the idlers

In order to ensure satisfactory belt running despite the inward radial forces, counteracting forces for equilibrating them have to be produced. This can be achieved by setting in the idlers at a suitable angle and/or "superelevating" the inner edge of the belt in the curve (Fig. 2). These measures will, in conjunction with the belt and its weight when running under load or empty, produce force components directed outwards, i.e., away from the centre of curvature, enabling good belt guidance to be achieved even on horizontal curves.

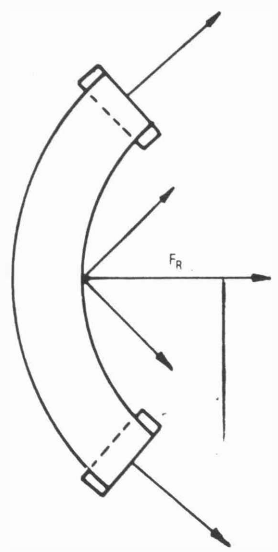

Fig. 1: Force components due to belt tension in belt systems comprising horizontal curves

It is not difficult to see that the components of the belt tension forces will vary to a greater or less extent with the difference in level on ascending or descending gradients, so that it will be necessary to consider each operating condition individually in order to take full account of all the requirements. A substantial proportion of the belt guiding forces which are developed by the idlers in co-operation with the belt will depend on the frictional forces (and therefore the coefficients of friction) between belt and idler, so that it is very important to know the actual magnitudes of the friction coefficients and their tolerances under all conditions of conveyor operation. This is especially relevant when it is con-

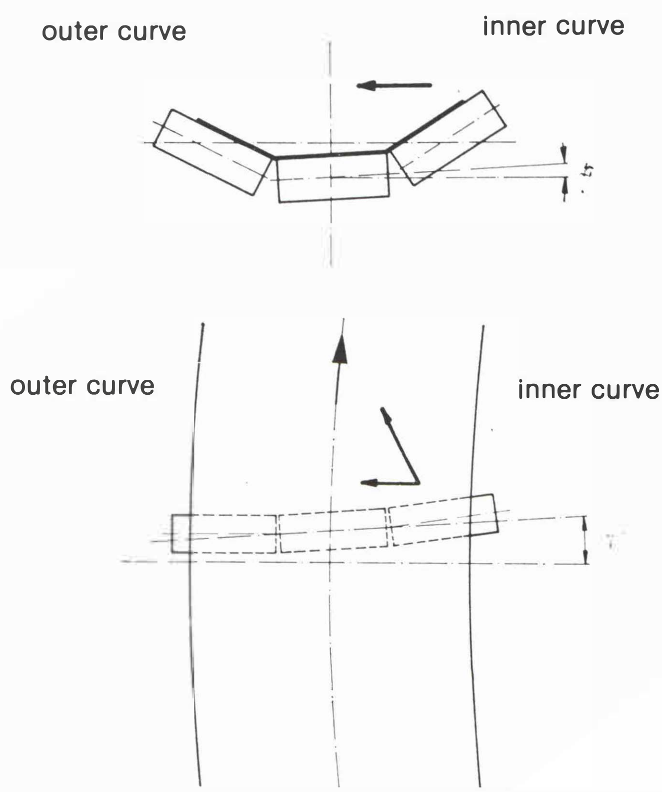

Fig. 2: Positioning of idlers

sidered that overland belt conveyor systems have to function properly under a wide variety of weather and environmental conditions: rain, sunshine, frost, wind, snow, extremely high temperatures, etc. These not only affect the friction developed between the belt and the idlers, but also have a great effect on the elongational behavior of the belt, as well as on its elastic properties including those of the covers, so that, for example, the running resistance and deformability are liable to vary considerably.

In designing a belt conveyor system comprising horizontal curves the correct layout of the route alignment with regard to vertical curves is also very important, as the radii of these last-mentioned curves must be correctly suited to the quality and strength of the belt as well as to the horizontal curve radii, the idler spacing, the belt running speed, etc. With a conveyor system comprising several consecutive horizontal curves in both directions, it may occur that various conditions are superimposed upon one another, so that precise knowledge of the individual parameters is essential to ensure that the installation will indeed function satisfactorily and reliably. Correctly designed belt conveyor systems with horizontal curves are no different from ordinary belt conveyor systems (without transfer points) as regards their reliability, manning requirements and running costs. It is for this reason that they are so superior to systems with transfer points particularly in terms of economy.

4. Conveyor Systems

Below some installations are described which were designed and commissioned by the writer especially with respect to the horizontal curves and which have run for years, partially in continuous 24-hours' operation.

1. Belt conveyor system for potassium salt (Fig. 3)
   Length of system: 850 m
   Width of belt: 650 mm
   Speed of belt: 1.78 m/sec.
   Handling capacity: 200 t/h
   Difference in level to be overcome: + 1.35 m
   Belt quality: EP 800/3 5:2
   Horizontal curve radius: 1,400 m
   The route alignment of the conveyor is shown in Fig. 4
   The reason for having a horizontal curve was the presence of works buildings, roads and railway lines.

Fig. 3: Belt conveyor system for potassium salt

2. Belt conveyor system for potassium salt (Fig. 5)
   Length of system: 1,232 m
   Width of belt: 1,000 mm
   Speed of belt: 3.35 m/sec.
   Handling capacity: 800 t/h
   Difference in level to be overcome: + 187 m
   Belt quality: St 2000 8:6
   Horizontal curve radius: 1,400 m
   Drive power rating: 600 kW
   The route alignment of the conveyor is shown in Fig. 6
   The reason for having a horizontal curve was the presence of works buildings and a waste tip.

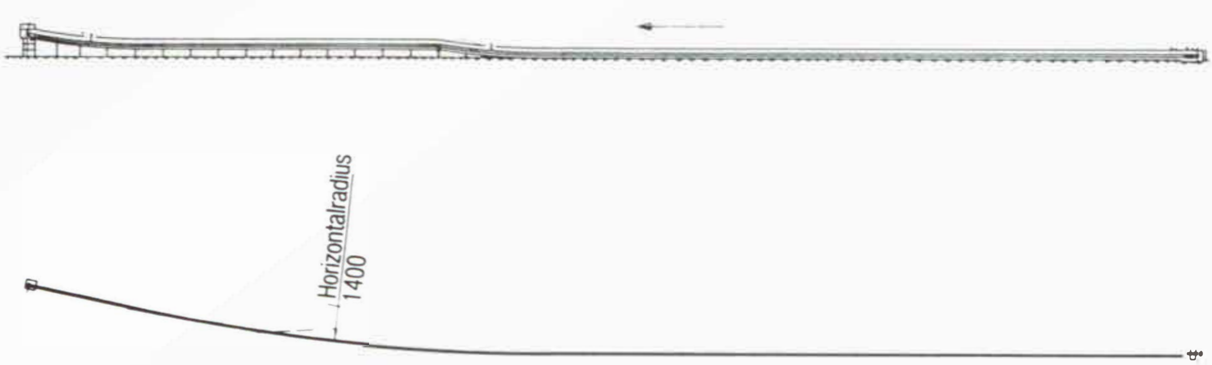

Fig. 4: Alignment of the conveyor shown in Fig. 3

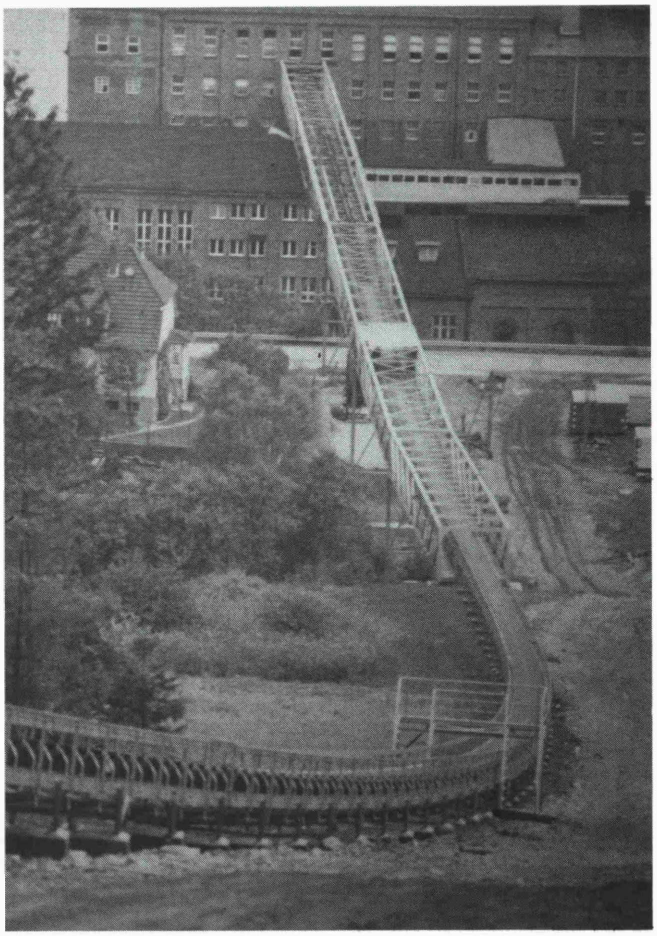

Fig. 5: Belt conveyor system for potassium salt

Fig. 7: Belt conveyor system for lime-stone

3. Belt conveyor system: 719 m (Fig. 7)
   Width of belt: 1,000 mm
   Speed of belt: 2.1 m/sec.
   Handling capacity: 800 t/hour
   Difference in level to be overcome: —37.1 m
   Belt quality: EP 500/4 4:2
   Horizontal curve radius: 1,400 m
   The reason for having a horizontal curve was that an existing belt conveyor system without horizontal curve had to be extended to a new feed point which could not be reached except with the aid of an additional transfer point or a horizontal curve (Fig. 8).

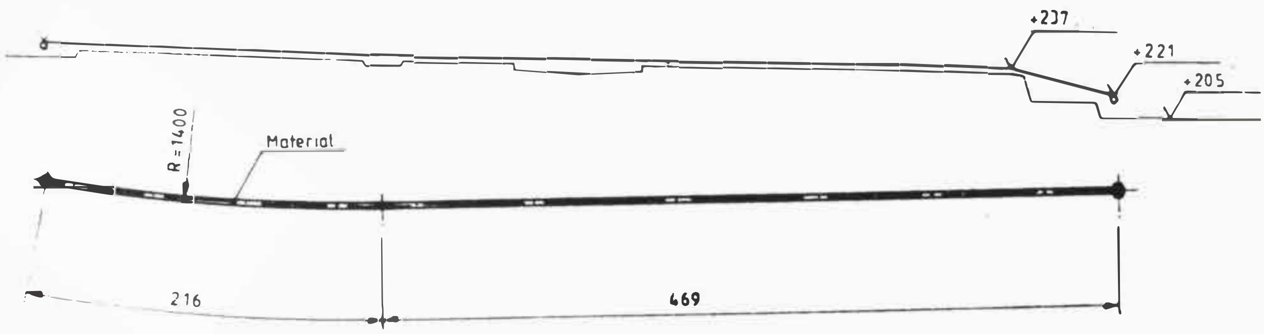

Fig. 6: Alignment of the conveyor shown in Fig. 5

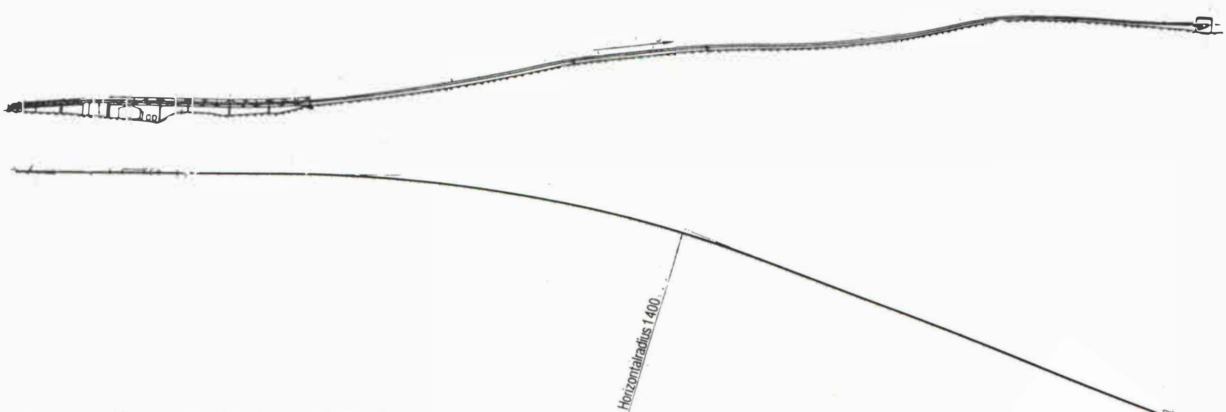

Fig. 8: Alignment of the conveyor shown in Fig. 7

4. Belt conveyor system for cement in 50 kg sacks (Fig. 9)
   Length of system: 231 m
   Width of belt: 650 mm
   Speed of belt: 0.63 m/sec.
   Handling capacity: 2,000 sacks/h
   Difference in level to be overcome: 0
   Belt quality: EP 400/3 3:1
   Horizontal curve radius: 3,000 m
   The reason for having a horizontal curve was the presence of buildings and works roads.

The installations described here were in all cases constructed with normal idlers and support structures and have given trouble-free service since they were commissioned.

Because of the great experience in the field of the horizontal curve technique for conveying installations, the writer engineered the curves of a conveyor belt with a length of more than 11,000 m with 4 horizontal curves. The supplier of the entire conveying installations was Messrs. R.E.I., Paris; the installation was built by Messrs. CGE Alsthom. Operator of the plant is Messrs. Sté. Le Nickel in New Caledonia.

New Caledonia is an island in the South Pacific, approximately 1,500 km from Australia and approximately 20,000 km from Germany. According to the actual knowledge New Caledonia has approximately 25 % of the entire world reserve of nickel ore. Actually, approximately 10 % of the world production of nickel comes from New Caledonia.

Fig. 10 shows the layout of this installation which transports ore from a quarry — which is inside the country — to a harbour. The installation leads through wood and grassland and crosses rivers without any infrastructure. If it had not been possible to include horizontal curves in the alignment, four transfer stations would have been needed, for it would not have been practicable to adopt a straight alignment direct from the feed point to the final discharge point. This was prevented by the presence of mountains, rivers, native

Fig. 9: Belt conveyor system for sacks of cement

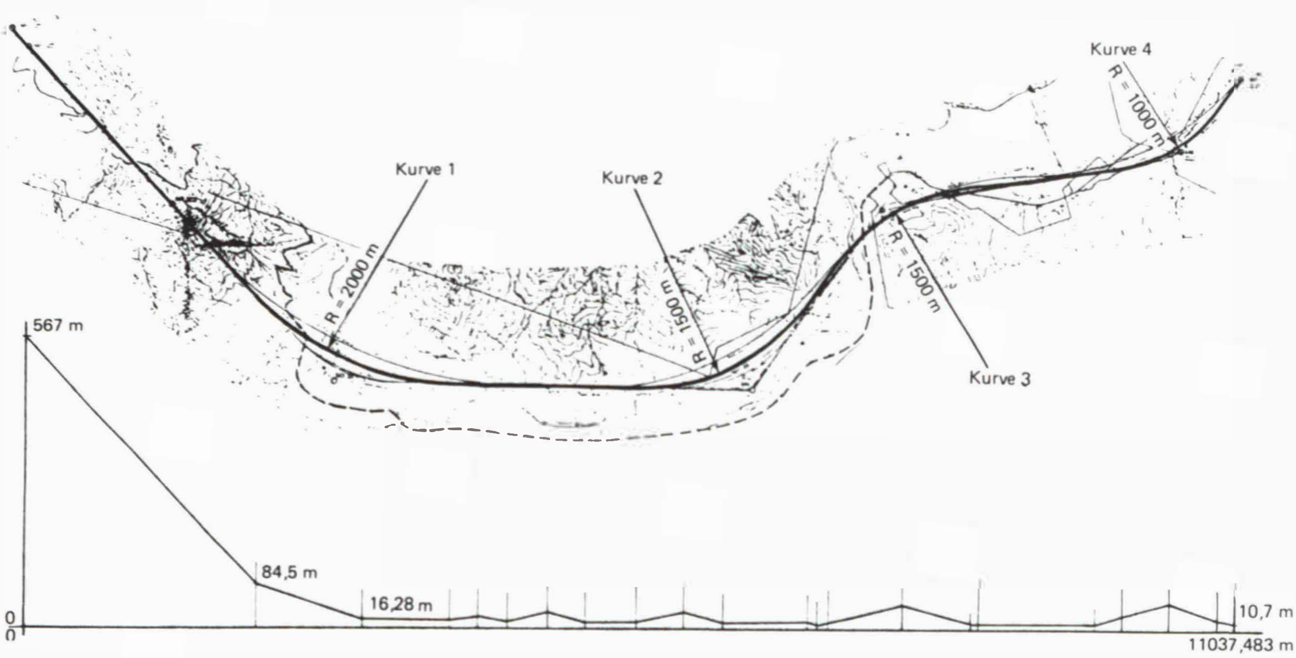

Fig. 10: Alignment of an 11 km long belt conveyor system comprising four horizontal curves

settlements and reservations which had to be bypassed. Besides, one transfer station would then have had to be located in a river and another on the site of an old native burial ground. Such sitings would have called forth protests from the local population so that the construction of the system would probably not have been possible at all. In any case, substantial extra expenditure in terms of direct capital cost would have been incurred. Furthermore, the cost of laying on the necessary electricity supply in such entirely undeveloped country would have been quite considerable, not to mention the expense of additional control equipment. Besides, the maintenance of transfer stations, some of which could be reached only via large detours or indeed not all (during periods of heavy rain) without the construction of access roads on embankments, would have required the services of many men and vehicles in order to ensure reliable and satisfactory operation of the conveyor system. In such a region, where skilled labour is locally almost unobtainable, this would have presented major difficulties.

Indeed, in view of these problems the installation, which has been designed to do the work of about 60 trucks, would have been virtually impracticable in economic terms. Besides, each transfer point involves belt wear and is a potential source of technical trouble, especially with the inhomogeneous material to be handled, characterized by particle sizes ranging from mud-like fineness to lumps of 250 mm, both dry and wet. The handling capacity is 520 t/hour.

Besides the extreme conditions of the material itself, the weather conditions likewise vary over a wide range, from very dry with ambient temperatures of 40 °C (and upwards) to tropical rains with high wind velocities.

The conveyor with its four horizontal curves is powered by a motor at its feed point and descends an overall vertical distance of about 560 m to its discharge point 11 km away. The required drive power is about 800 kW for no-load (idle) running and about —800 kW in the most unfavourable conditions of loading. This wide range in power requirements in itself indicates what widely varying forces occur in the various curves. Besides, the conveyor had to be designed to cope with any loading condition of the belt in the curves. A further complication was that all the horizontal curves also comprised vertical (concave or convex) curves.

On a long-distance conveyor system of this kind the braking and acceleration of the belt movement are of major importance. More particularly the braking has to comply with certain minimum requirements because, for example, in the event of an emergency stop there must not be too much run-out before the belt actually comes to a standstill.

The radii adopted for the three left-hand and the one right-hand horizontal curves are as follows: The first curve is 1,700 m long and has a radius of about 2,000 m; the corresponding figures for the other three curves are 1,500 m/1,500 m, 1,200 m/1500 m, and 1,000 m/1,000 m. Balancing the forces is achieved in the upper and lower strands of the belt by superelevation and skewing the idlers, no additional measures for belt guiding — such as side rolls, belt training devices, etc. — being needed.

The first part of the alignment, about 2,500 m, is straight and steeply downhill, followed by about 8,500 m comprising only relatively minor differences in height, but including 5,500 m of horizontally curved alignment.

The speed of the belt can be varied up to a maximum of 3.6 m/sec. It is 800 mm wide and of St 2500 quality. A disc brake system is fitted.

The installation has a tubular framework with a diameter of 273 mm which is supported about every 9 m.

The belt of the installation is tensioned by means of a tension tower at the end of the installation which has a height of approximately 30 m and which is equipped with a counterweight of 500,000 N. A belt tension of 130,000 N in the area of the discharging station is guaranteed by means of corresponding rope guiding of the 4 suspension ropes.

The drive unit with a motor of 800 kW rating and a gear with a reduction of i = 27.27 is installed at the material feed which is located inside the country as already mentioned. The diameter of the drive drum is 1,250 mm. A brake pulley is installed on the shaft of the drive drum. The drive — a 3-phase motor which is stabilized in speed — enables further to the stepless adjustment of speed also the possibility of energy recovery.

The installation of the brake has only been made for that case that the electrical provision fails. The brake is adjusted hydraulically to attain a retardation of the conveyor belt which is as equal as possible.

Fig. 11 is a view of the steeply descending portion from the material feed point into the first horizontal curve. The next five photographs show parts of the horizontal curves. The transition between the third and the fourth curve is shown in Fig. 17. This belt conveyor was brought into continuous operation at the beginning of 1980.

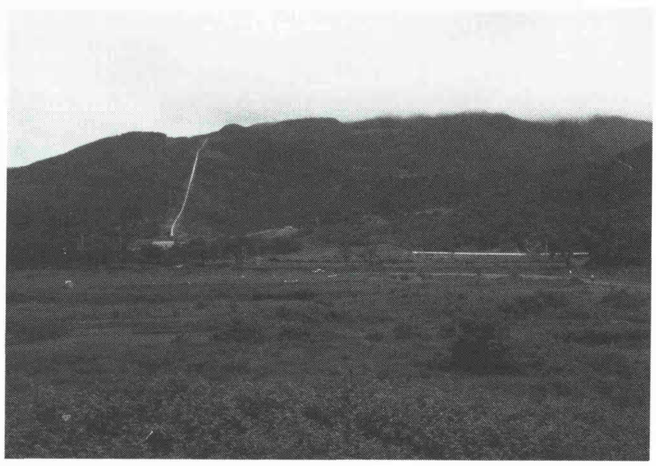

Fig. 11: View of the steeply descending portion of the conveyor shown in Fig. 10 together with the first horizontal curve

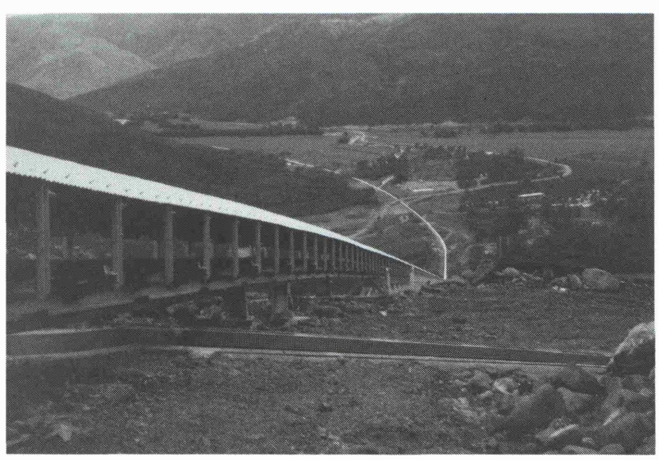

Fig. 12: Descending portion and start of first horizontal curve

Fig. 13: First horizontal curve

Fig. 14: Second horizontal curve

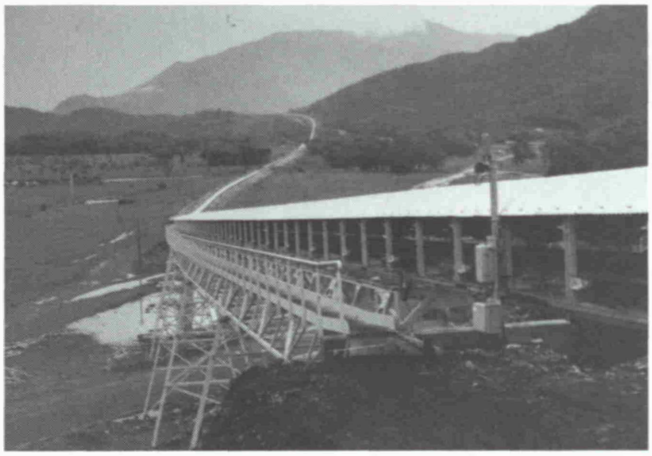

Fig. 15: Third horizontal curve

Fig. 16: Fourth horizontal curve

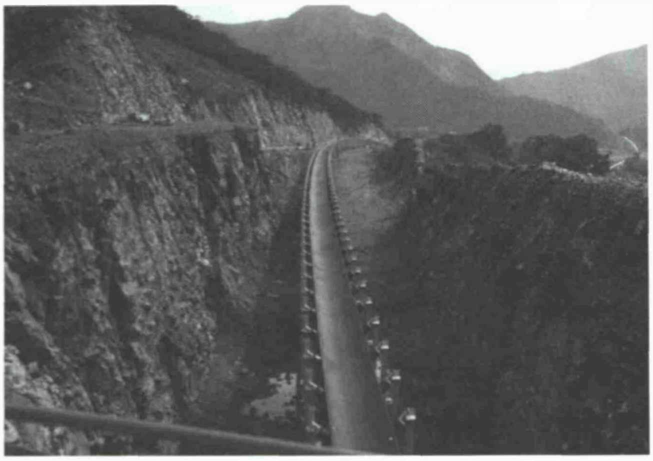

Fig. 17: View from the fourth horizontal curve, in the "upstream" direction, towards the third horizontal curve

Drawings and Photos: Author and Beumer KG, Beckum.

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