KRUPP SOUTH AFRICA

CONTOUR CONVEYOR

LONG DISTANCE CONVEYOR TECHNOLOGY

DEVELOPMENT AND EXPERIENCE

Written by : T Brüwer
Presented by : R Fauerbach

INTRODUCTION

The development of stationary long distance conveyors was introduced in the early 70's with a 100km long conveyor belt system in the Sahara. The plant comprised of 11 individual conveyors, the longest measuring 11.7km. The first long distance conveyor with horizontal curves was built by Krupp in 1982 for Messrs Kali und Salz, Germany. This 1.8km long, 800m wide conveyor featured a horizontal curve radius of 1000m and transported 1000t of salt per hour.

Photo (Curved Conveyor Kali und Salz)

New fields of application for the conveyor technique were opened with the construction of a curved conveyor system in Turkey of approx 8.5km in length. This conveyor has a downhill gradient of 340m and has two horizontal curves. When loaded to approx 50% of its nominal loading capacity this conveyor generates electrical energy. Details of this system to follow later in the lecture.

Requirements to be met by Long Distance Conveyors

The introduction of the type of conveyor belt systems as described here, with steadily increasing lengths and with horizontal curves to follow the topography, created higher demands, on the drive technique, on mechanical components and last, but not least, on the belt as being the major part of the conveyor belt system.

Drive Technique

The characteristics adopted for the starting of a curved conveyor belt system are of decisive importance and place high demands on the drive technique.

While asynchronous motors are connected to the gear unit via a flexible coupling only on short conveyors with low installed capacity, this solution is no longer practical for drives with high power motors. In most applications the flexible coupling is replaced by a constant-filling coupling. This type of coupling reduces that maximum transmittable torque, ie, the starting torque, to a value that is considerable lower than the tilting point of the motor.

Extremely long conveyors with horizontal curves place considerably higher demands on the starting characteristics. On one hand attempts have to be made to minimise the forces in the belt in the horizontal curves, especially when starting an empty conveyor, while on the other hand the additional dynamic stresses during start-up or braking grow in importance and have to be minimised via an adequately controlled starting mode.

The basic solutions are practical to cope with these demands, ie, one being hydraulic, the other electrical.

Electric Drives

The requirements as mentioned above can be met for this drive version via synchronous motors but, with relatively high maintenance expenditures.

Normally, the squirrel cage motor is used in conjunction with a hydraulic starter coupling and a frequency converter.

The slipring rotor motor also represents an asynchronous engine. The only difference being that the rotor resistance, and thus the speed torque curve, can be modified by resistors which are externally switched into the circuit. Any desired starting torque can therefore be achieved by choosing the correct resistor.

For particularly difficult starting conditions the squirrel cage motor with frequency converter control represents an optimum solution. Two principle types of converters are mentioned here :

- intermediate circuit <u>voltage</u> converters, and
- intermediate circuit <u>current</u> converters

The first version permits the parallel connection of several motors to one converter. Motor and converter can be combined as desired. A torque control can be made over the total speed range. Generation of electrical energy, as well as controlled braking, can, however, only be made by providing additional equipment.

The intermediate circuit current converter does not permit the parallel switching of motors. Torque limitation is only possible to some extent. Torque limitations have to be expected in the slow speed range.

The essential advantage of converters is inherent in the fact that speed control permits the conveyor speed to be adapted in accordance with the masses to be transported - thus saving energy.

Hydrodynamical Starting Means

As mentioned previously, the squirrel cage motor with hydraulic starter coupling is frequently used as the driving element. These couplings can be grouped into constant-filling couplings and controlled couplings for conveyor drives.

Hydrodynamical couplings are composed of two nearly identical but, in most cases, not fully symmetrical paddle wheels with pure radial, axial, parallel placed paddles, forming, together with a cup, an enclosed rotating housing. This design guarantees the formation of a fully closed fluid circuit between the two wheels should an excess centrifugal force - compared to the counter centrifugal force of the second wheel - be created due to higher speed. The motor torque accelarates a fluid circuit by the pump wheel. This fluid circuit drives the turbine wheel by transmitting its flowing energy in the form of torque and transmits the torque by centrifugal force effect without any mechanical contact of the two parts.

Loading of a squirrel cage motor can be further reduced during every start-up by once underfilling the bucket chambers of during the run-up period of the motor. The motor therefore passes the range of high starting current more rapidly. The coupling torque is increased on a flat parabel during the starting of the motor and rises higher when the motor has almost attained its full speed. This is achieved by connecting a so-called retardation chamber, in addition to the bucket chamber, whereby part of the fluid is retained in the retardation chamber during motor standstill. During the run-up period of the motor the fluid from this chamber is then discharged into the paddle chamber to increase the transmitting capability of the coupling.

Hydrodynamical control couplings are used where specific demands are placed on the starting characteristics of conveyor drives. Two types of couplings are mentioned here, they are : the scoop trim coupling
and : the drain type coupling.

Contrary to turbo couplings with constant fluid filling, the controlled turbo couplings permit the filling degree to be modified optionally from full to empty during operation. This, in turn, permits stepless speed adjustment of the driving motor over a wide speed range when driving against different loading characteristics.

A primary side-driven pump delivers into the working chamber from the oil sump underneath the coupling through a control valve. The height of the oil level in the working chamber - and thus the transmitting capability of the coupling - is determined by the radial position of a displaceable scoop trim pipe with a bailing capacity that is higher than the pump delivery.

The fluid collected by the bailing pipe is circulated from the oil cooler to the control valve and from there it is recirculated to the coupling circuit or to the oil sump.

For DTP couplings a controlled transmission of torque is obtained by piloting a valve into the infeed flow to the working chamber. This guarantees partial filling of the coupling to adapt the coupling characteristics to the requirements in operation.

Belting

In addition to the described developments in drive technique, new horizons were opened for conveyor belts as being the major components of a conveyor belt system. This lecture concentrates on two essential fields. The first progress was made by increasing the nominal strength of steel cord belts and the second, by increasing the lifetime of conveyor splicing joints.

Today's limits for tensile strength of a steel cord belt are around 7500 N/mm^2 as attained for a belt in operation in the Prosper Mine, Germany.

Progress in belt technique as described above claims for the simultaneous advance in the splicing mode adopted for belt joints as being the weakest link in a conveyor line. Both industrial and research institutions have been working on the problem for more than 20 years of increasing the durability of a splicing joint (ie, the splicing strength during which the belt attains a lifetime of 180 000 circulations). This can be achieved by adopting new splicing techniques and different levels of thickness for intermediate rubber covers.

Calculation of Long Distance Curved Conveyor Systems

Planning of long distance conveyor belt systems, but especially the planning of horizontally curved conveyors, is facilitated nowadays by the application of modern working techniques, ie, computers and computer aided (CAD) design modes. These modern working aids permit optimum system planning, taking into consideration both technical and economic aspects.

CAD is used to show the surface topography on the terminal. This permits the optimum routing of the conveyor taking the following conditions into consideration :

- concave vertical curve radii must be selected to avoid an uplifting of the belt under all load conditions
- convex vertical curves must not fall under a particular size determined by the edge strain of the belt
- horizontal curve radii must be selected big enough to safely guide the belt under all loading conditions
- routing of the conveyor belt must involve only a minimum of building work, ie, both earth removal and filling must be optimized; bridges for the crossing of roads, valleys or rivers must be kept to a minimum.

In order to cope with all of these conditions different routings of the conveyor system must be investigated, conveyors must be calculated and the belt tension forces in critical areas must be determined. This work is required to select an optimum solution for the routing of the conveyor belt, both from a technical and from an economic point of view. This procedure is taken over by efficient computers and a simulation program which is capable of representing the exact route of the conveyor belt on the terminal, including all vertical and horizontal curves.

For the calculation of horizontally curved conveyors it is imperative that the correct positioning of the belt is guaranteed on its carrying idlers in the horizontal curves. This maintains proper functioning of the system during all operating conditions.

Compared to a straight conveyor, a curved conveyor has radial forces which are created on the inner side of the belt. These forces are due to the belt tension force which causes the moving of the belt towards the inner side.

A safe belt guidance on the carrying idlers can only be obtained by transverse forces acting on the outer side of the belt so that the sum of all these forces equal '0' when the belt is in a certain position. The forces acting on the belt are determined on one hand by the weight of the belt and the material transported, and on the other hand by the friction between belt and carrying idler. These forces can be influenced by the forward tilting and banking of the carrying idlers.

Previous lectures - amongst others also those presented during this congress - have already reported on the creation and the common effects of these forces and the possibilities of influencing them. They are therefore not specifiied here.

All of these complex factors which influence the position of equilibrium of the belt in the horizontal curve must be considered for all load and loading conditions.

Experience in Operation

Two exemplary conveyor belt systems are used to show how the theoretical design was put into practice. The first system covers a conveyor approx. 10,8km in length built in 1984 for an operation in Canada; the second system is the previously mentioned 8,5km long curved conveyor system built in 1987 for Turkey.

For both applications Krupp Industrietechnik made field measurements, partly in cooperation with the University of Hannover, to collect data on the operating characteristics of the system, especially the drives.

Union Oil - Canada

The conveyor belt system built for the Union Oil Company in Canada was commissioned in 1984. It has a length of 10'767m with a downhill gradient of approx 330m. The following illustration shows the routing of the conveyor :

Fig. (Routing - Union Oil)

The conveyor is powered by a total of three drive units. The head(front) end of this conveyor features an extended discharge pulley with two drive units at two drive pulleys. The third drive unit being placed at the tail (end of the) pulley. The second shaft end of this tail pulley is gearless and connected to a hydraulically actuated double disc brake unit.

Fig. (Conveyor Scheme - Union Oil)

The 4-pole 4kV short circuit motors of a nominal capacity of 600HP = 448kW are the main members of the drive unit. These motors have hydrodynamical couplings and microprocessor control to permit a run-up of the drive units at controlled torque and within certain limits.

The main technical data can be taken from the following illustration:

Fig. (Conveyor Belt - Union Oil)

The concept adopted for control provides for the regulation of the delivery of oil to the individual nozzles of the couplings. This controlled oil delivery causes a time dependent increase of the torque transmitted by these couplings after idle start-up of the associated motor and permits the compensation of deviations from the theoretical value curve by means of a two-position control.

The investigations on the stationary and non-stationary operating characteristics of the system dealt : with the power transmission in the drive units; with the amount of the resistance to motion in the conveying route; as well as with the starting and braking characteristics of the entire system.

The results of these investigations can be found in various publications. It should be mentioned here, however, that the operating characteristics of the system corresponded with the parameters set up during the planning phase and that the non-stationary behaviour could be improved by the changing of the basic settings at the hydrodynamical coupling and at the brake.

Fig. (Conveyor Belt System - Union Oil)

From this illustration you can get a good impression of the conveyor belt system.

Long Distance Conveyor Denis

A long distance conveyor approx 8,8km in length and with a downhill gradient of approx 330m was commissioned in 1987 in Western Turkey. This conveyor was routed over several upgrades and downgrades and has two horizontal curves overlapping with the vertical curves.

Fig. (Conveyor Routing - Denis I)
Fig. (Conveyor - Denis I)

This system transports 1000t of coal per hour over on a 1000mm wide belt at a speed of 4,5m/s. The steelcord belt St 1800 with 6mm covers on the carrying side and 5mm covers on the running side also moves over 3-roll carrying idlers with 15° troughing and 2-roll return idlers with 15° troughing. The top strand idlers are spaced 2m (apart), while the return strand idlers are spaced 6m (apart). In certain downhill areas the carrying idlers were spaced more closely (together) in order to reduce belt sag due to to the sloping force of the load on the belt.

This conveyor is powered by two 350kW motors which are arranged at two drive pulleys at the tail end of the conveyor system.

Fig. (Conveyor Scheme Denis I)

The motors used (normal squirrel cage motors) are controlled by intermediate current circuit converters. The use of these drive units have the following advantages :

- In order to avoid inadmissable high belt tension forces, especially in areas with convex vertical curves and horizontal curves, it was necessary to start the conveyor at constant acceleration, irrespective of its loading
- For similar reasons it was necessary to constantly brake the conveyor, irrespective of its loading
- From a loading of approx 50% of nominal load, the drives generate electrical energy which is recirculated into the current network
- For inspection purposes a creeping speed of approx 15% of the nominal speed had to be guaranteed.

High demands were also required of the braking characteristics of the conveyor system. A controlled hydrualic disc brake with three brake calipers was installed at the tail end of the system. This brake allows for the conveyor system to be stopped at constant retardation speed, irrespective of its loading, should the drives fail.

Under normal operation the conveyor is braked down to 10% of its nominal speed via the frequency-controlled drives. The disc brake then engages and stops the conveyor. In case of voltage failure or a fault in the driving system, the disc brake brakes the conveyor at constant deceleration, irrespective of its loading. To maintain this function the braking unit incorporates a control unit as well as its own independent voltage supply system. The memory of the control unit has a speed/time input. A signal indicating the speed of the motor shaft is converted to the belt speed and compared with the stored speed/time characteristic as the momentary value. If necessary, the required braking torque can be influenced by the raising or lowering of the hydraulic counter-pressure at the brake calipers.

Once the conveyor has stopped, the hydraulic counter pressure drops completely and the entire braking torque can be used as the holding moment.

Should the brake control system fail, the mechanical braking moment is slowly raised by the retarded continuous lowering of the hydraulic counter pressure. This grants the advantage of the entire braking torque not being suddenly applied and therefore, even in emergency situations, prevents inadmissable high belt tension forces.

The conveyor belt system is equipped with a controlled take-up winch. It was necessary to control the pre-tension forces since the stresses inside the belt may vary strongly due to the non-uniform distribution of load on the belt.

Example :

When starting the empty conveyor, the belt tensile force attains its maximum value during the run-up of the belt to drive pulley 1. However, when loaded, this force reaches its maximum when the belt leaves drive pulley 2.

Bearing this in mind, three ranges of control are provided for the take-up winch.

- while the conveyor is at a standstill, the belt is slackened and the pre-tension in the belt is at a low level
- prior to start-up, the belt is pre-tensioned to a value which ensures maximum transmission of the starting torque. This value is then kept constant during the entire starting procedure
- the pre-tension is reduced after completion of start-up and kept at a constant level during all load conditions.

During the first year of operation evaluations were made centering around the following major items :

- the behaviour of the belt in horizontal curves

- the behaviour of the drives under different load conditions and under non-stationary operating conditions
- the braking characteristics of the system.

The behaviour of the belt in horizontal curves, ie, the belt off-tracking in horizontal curves under various load conditions corresponds fully with the theoretical values established, avoiding any special measures to be taken for lateral belt deviation.

For the first time it was possible to make evaluations on frequency-controlled drives. The derived findings were of significant importance :

1. For a twin-pulley drive with frequency controlled motors, the speed difference between the two pulleys has to be considered for control.
2. Under slow speed (in the range of 0-5% of nominal torque) instantaneous torques are created which can be avoided by intermediate pulsation.
3. In the case of a conveyor with steep downgrade routing, the loaded belt starts automatically once the brake is released. The starting of the drive then has to be made in such a way that the drives generate a torque only after synchronisation of the speeds of belt and drives.

These findings could be considered from the beginning for all subsequent conveyor systems with similar drive techniques.

Fig. (Conveyor Belt Denis I)

This illustration very clearly shows the difficult terrain which, in this particular case, is an extremely long downhill route with a right horizontal curve at the end.

Summary

This lecture was aimed at highlighting the problems of long distance conveyors, especially the curved versions. Special demands set for their design were explained.

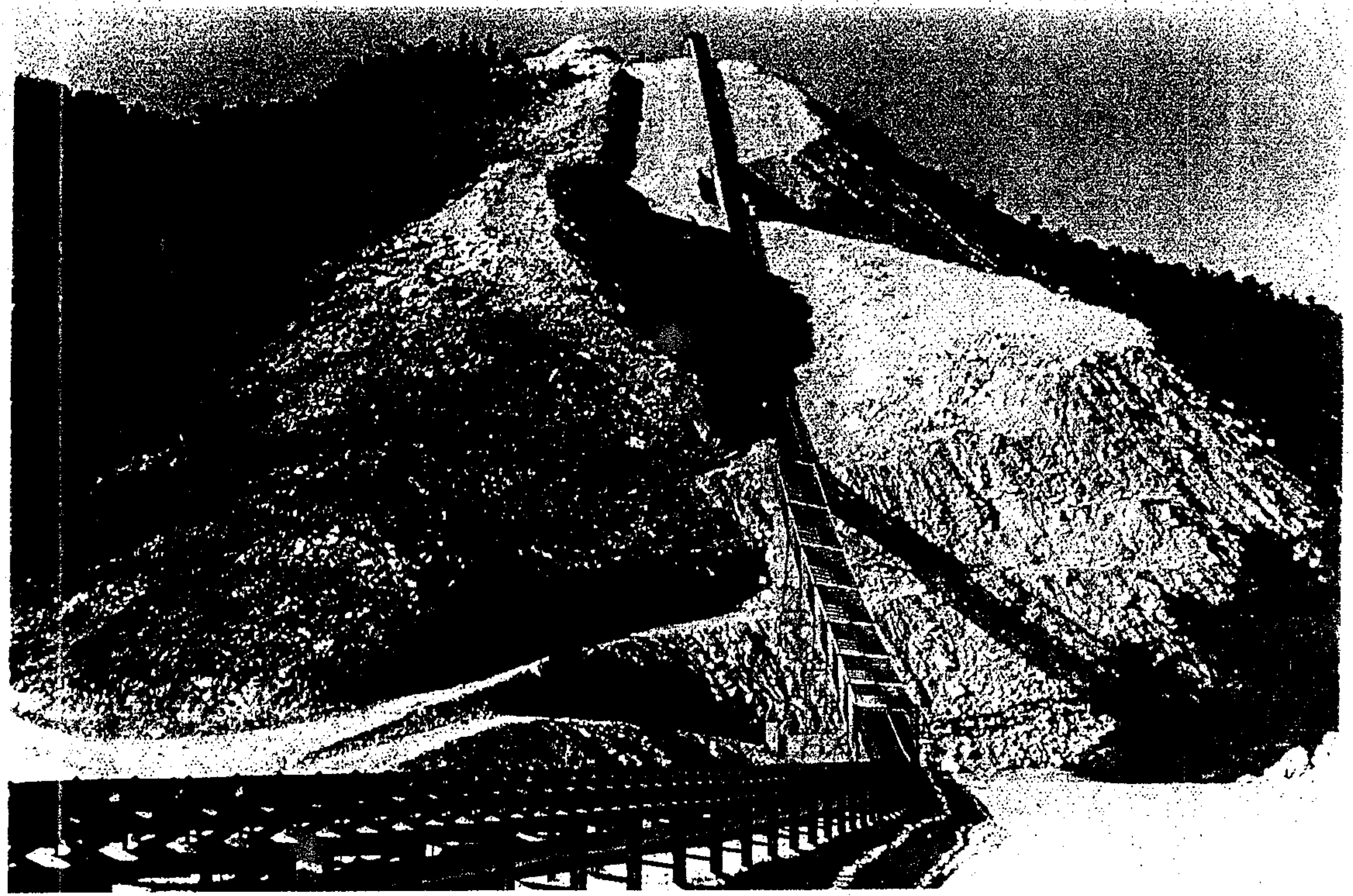
A short overview was given on the possibilities of different drive concepts, ie, electrical and hydrualic drives. The development in the belting field of was - purposefully - focused on very briefly; this topic being left to the specialists of the relevant companies.

New trends in modern conveyor technology were explained via two examples of built systems, ie, the long distance conveyor Union Oil in Canada and, the long distance conveyor Denis I in Turkey. The results of evaluations undergone during operation of these two systmes were briefly presented.

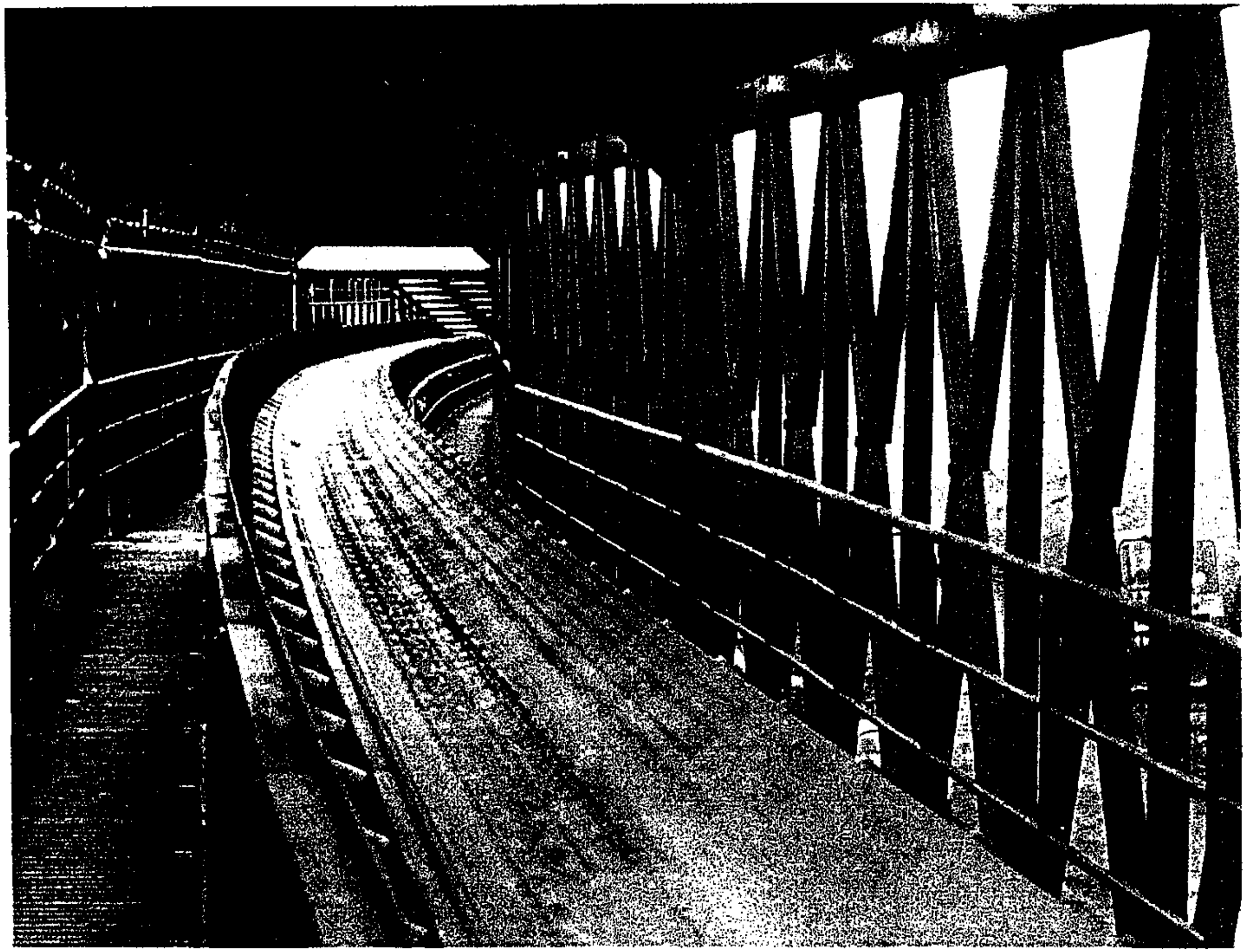
Krupp Industrietechnik

Contour Conveyor
Long Distance Conveyor Technology
Developments and Experience

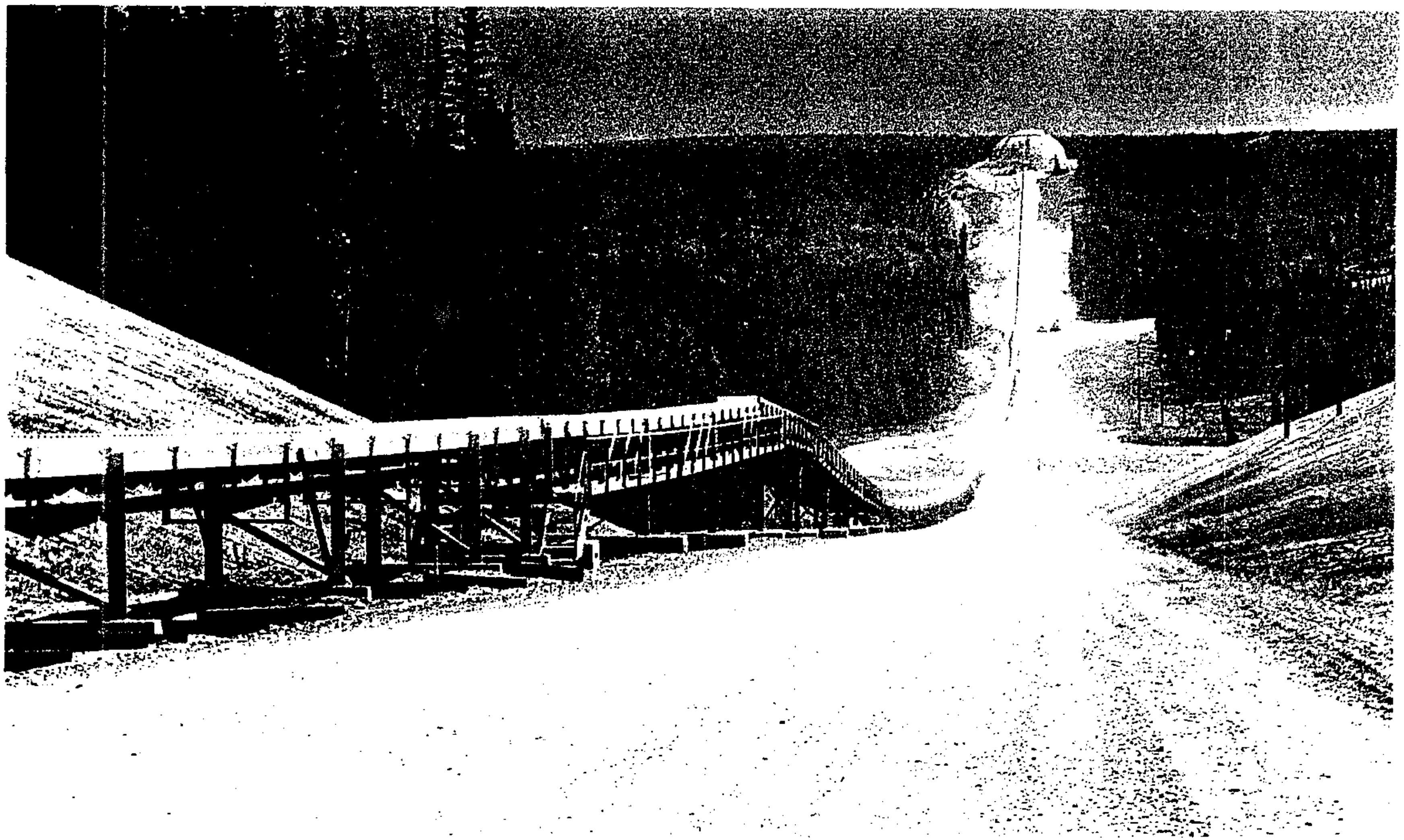
T. Brüwer



FV 32 T. Brüwer	Belt Conveyor Denis I	KRUPP



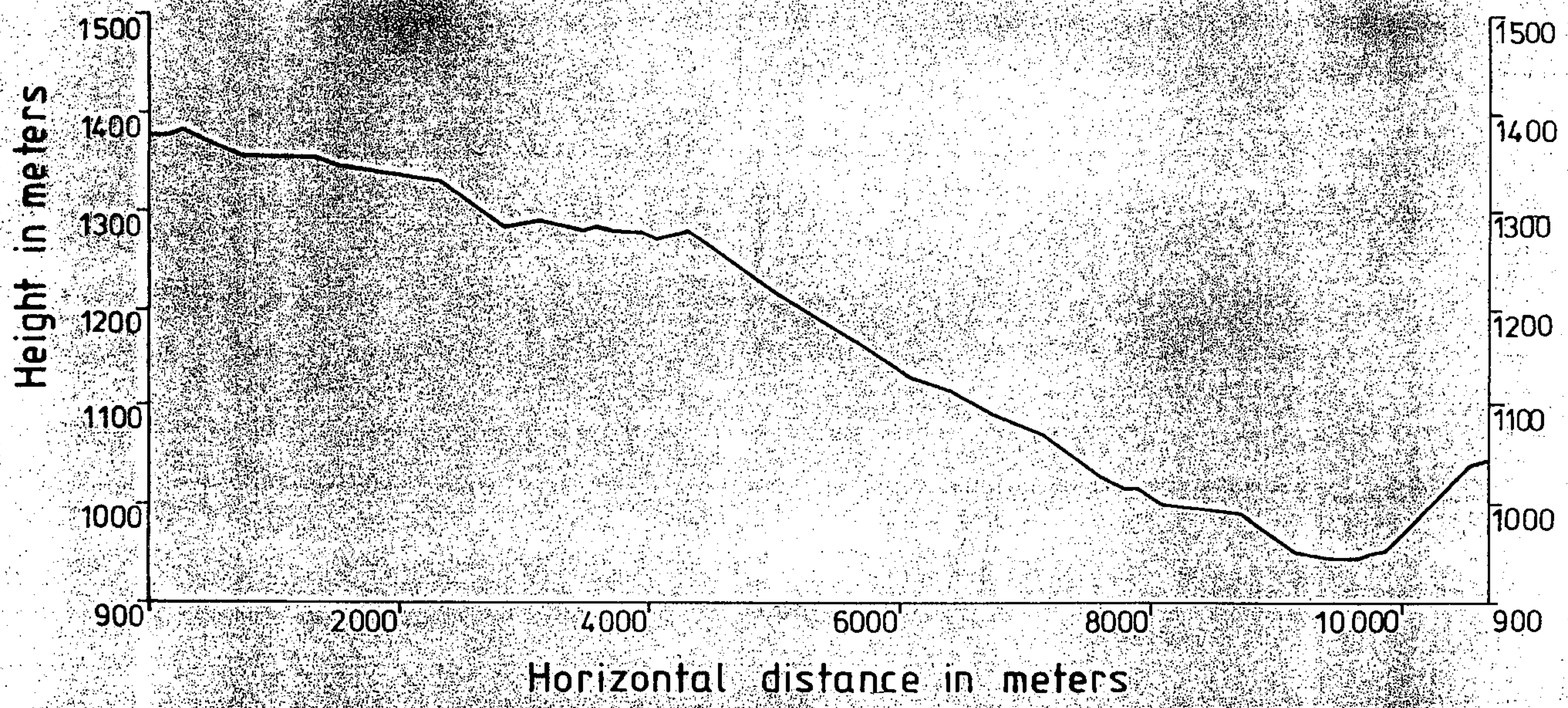
FV 32 T. Brüwer	Curved Conveyor Kali und Salz	KRUPP



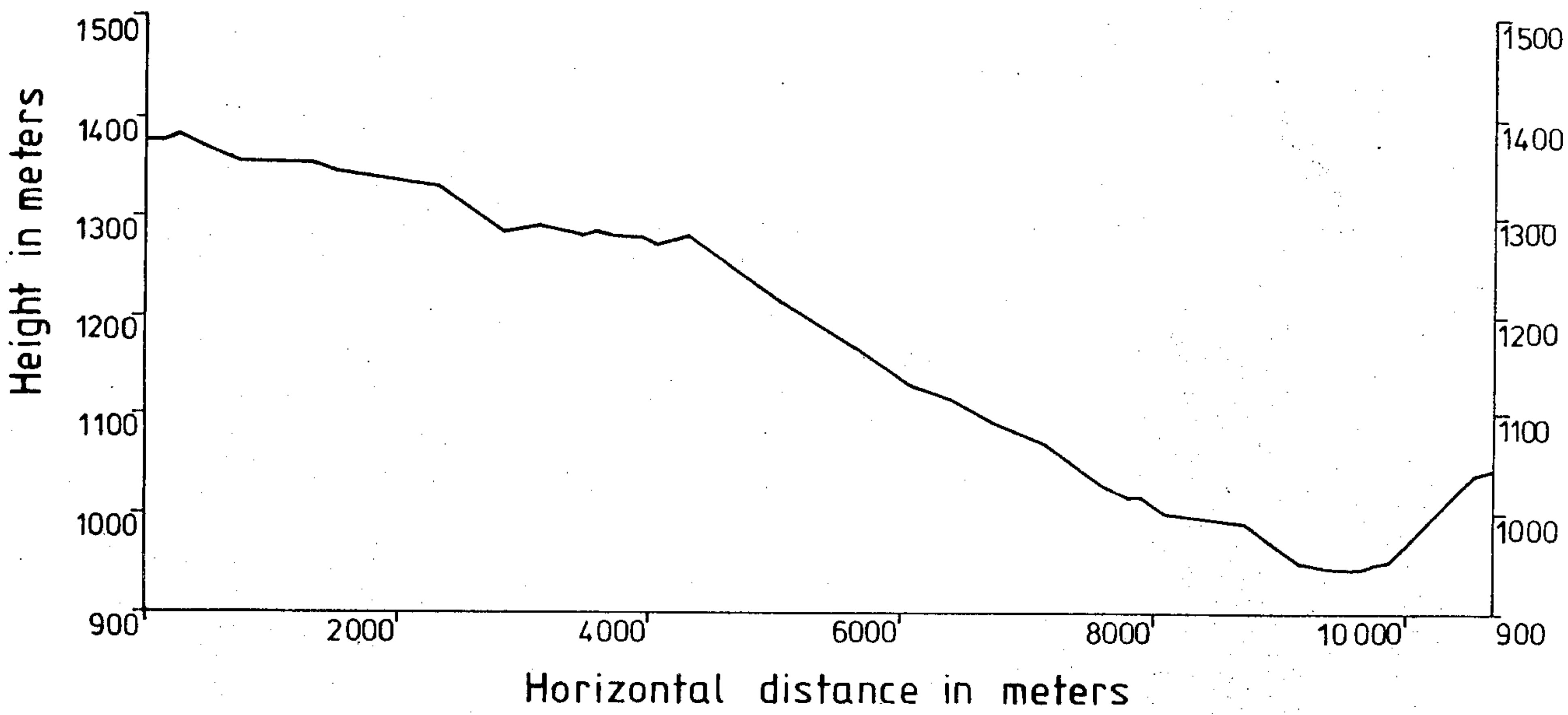
FV 32
T. Brüwer

Belt Conveyor System Union Oil

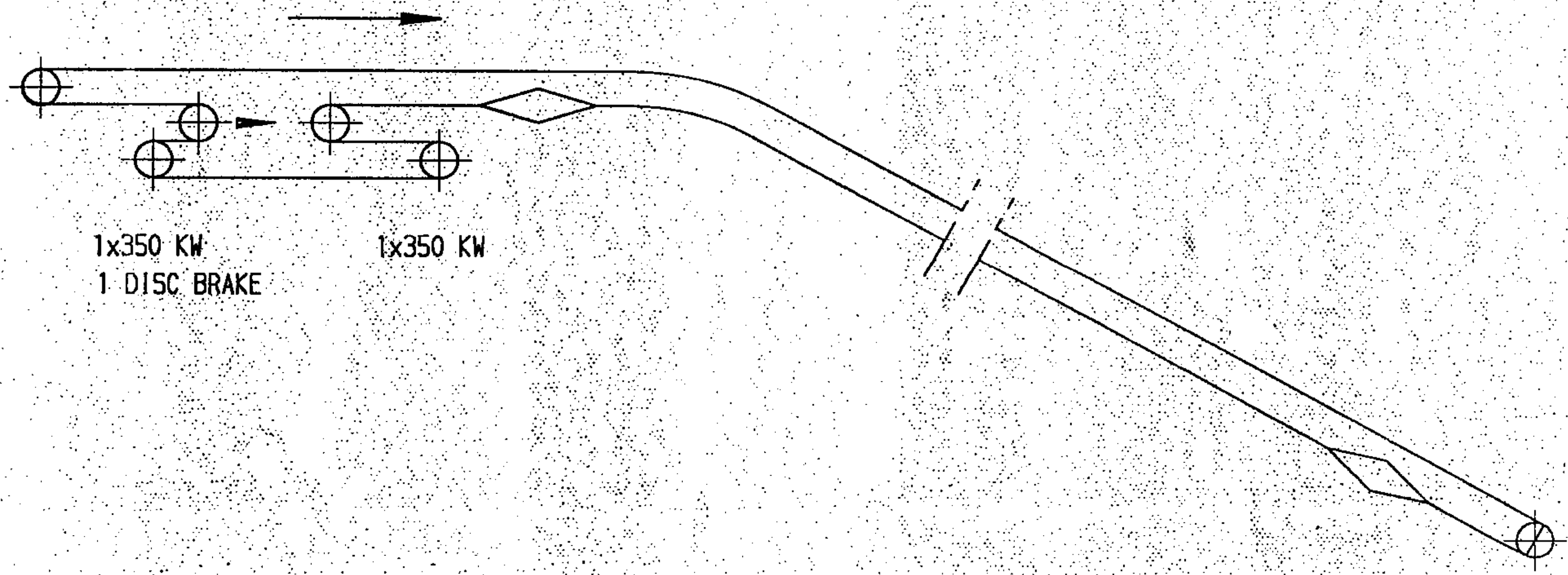
KRUPP



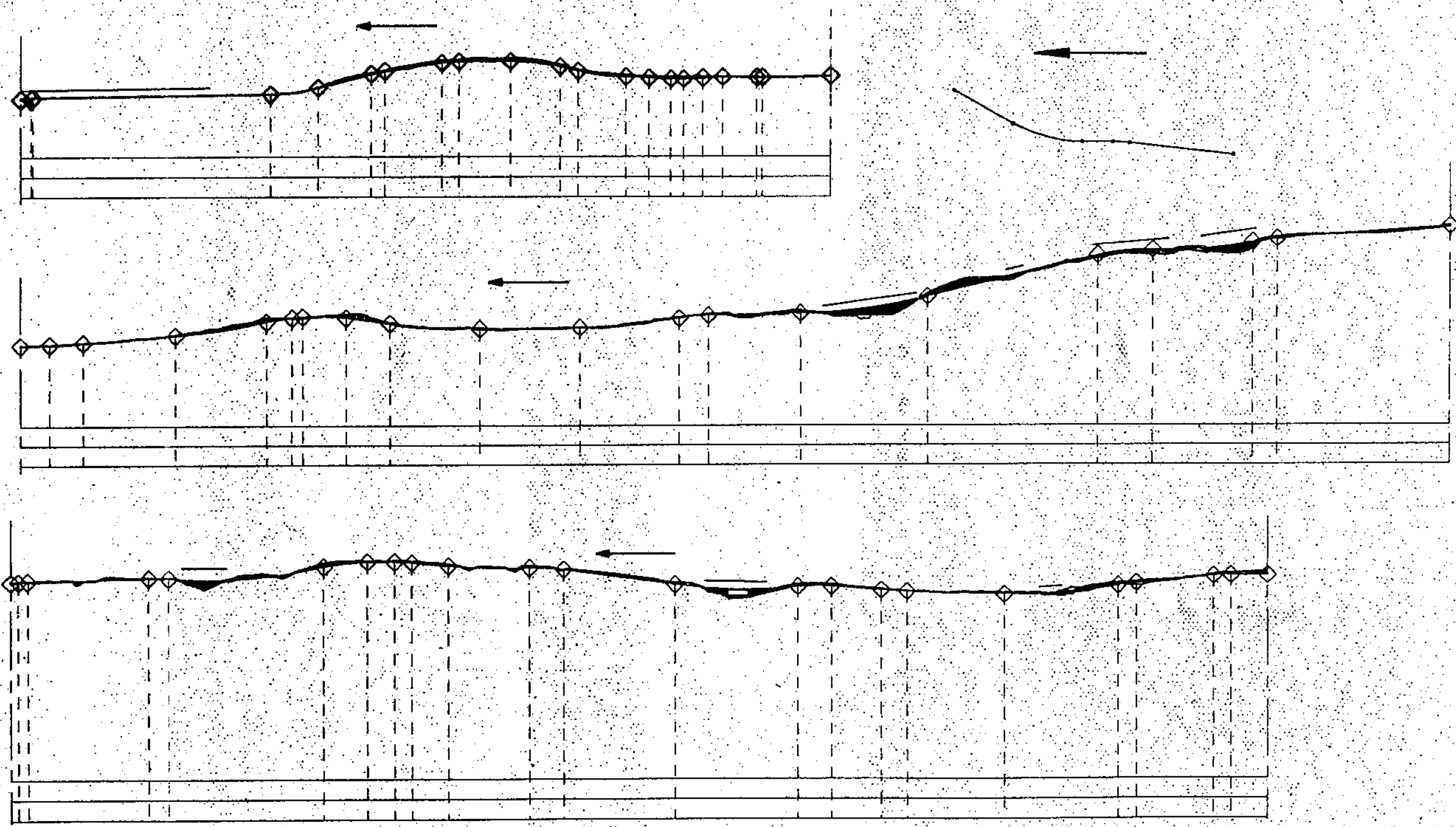
FV 32 T. Brüwer	Routing Union Oil	KRUPP



FV 32 T. Brüwer	Routing Union Oil	KRUPP



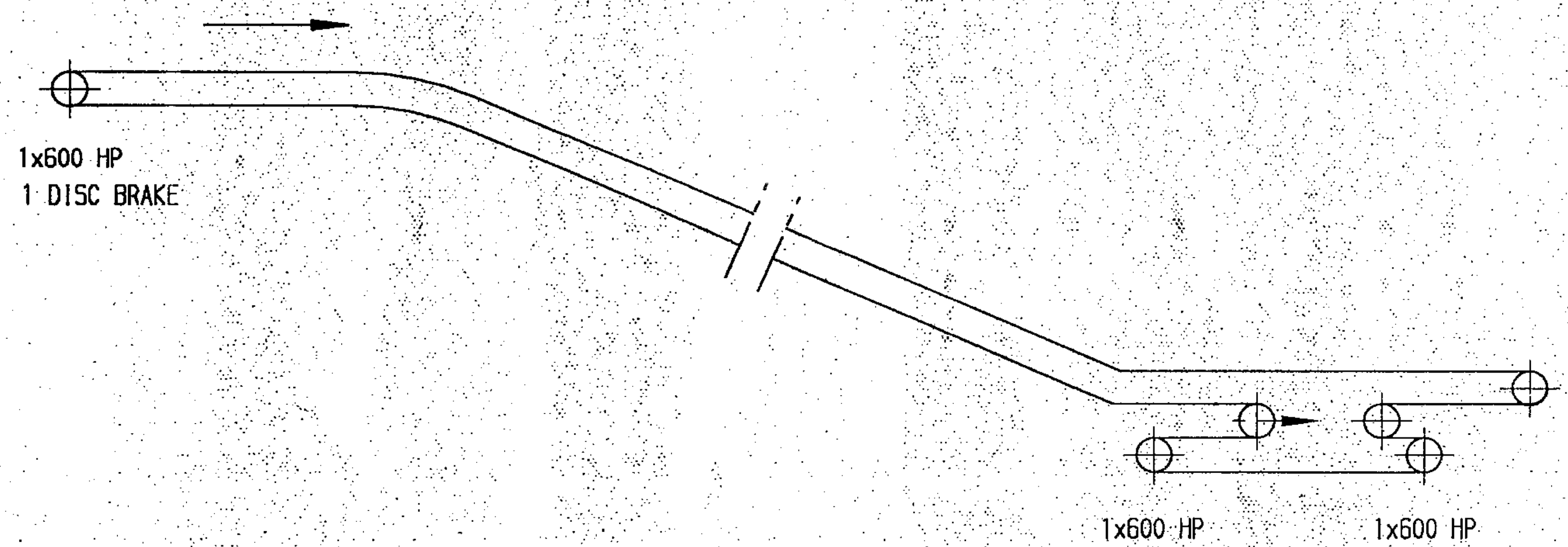
FV 32 T. Brüwer	Conveyor scheme Denis I	KRUPP



FV 32
T. Brüwer

Conveyor routing Denis I

KRUPP



FV 32 T. Brüwer	Conveyor scheme Union Oil	KRUPP

Technical Data - Belt Conveyor Union Oil

Total length	10.767 m	belt width	36" (914.4 mm)
Lift - 332 m	type	St 2250	
Capacity	700 t/h		
Material	coal	cover plate thickness	
Belt speed	4 m/s	carrying side	6 mm
		return side	6.5 mm
Carrying idler distance	2 m	installed power 2 + 1 x 600 HP (447.3 kW)	
Roll diameter	152.4 mm		
Troughing angle	35°	drive pulley diameter	1024 mm
Garland type idler		return pulley diameter	1024 mm
		take-up pulley diameter	824 mm
Return idler distance	6 m		
Roll diameter	152.4 mm	disc brake with 2 discs at the tail drive pulley	
Troughing angle	15°		
Garland type idler		coupling between motor and reducer VOITH DTP 487.	

FV 32
T. Brüwer

Belt Conveyor Union Oil

KRUPP

Technical Data – Belt Conveyor Denis I

Total length	8466 m	belt width	1000 mm
Lift – 338.5 m	type	St 1800	
Capacity	1000 t/h		
Material	coal	cover plate thickness	
Belt speed	4.5 m/s	carrying side	6 mm
		return side	5 mm
Carrying idler distance	2 m/1.5 m	installed power 2 + 1 x 350 kW	
Roll diameter	133 mm		
Troughing angle	35°	drive pulley diameter	1024 mm
Garland type idler		return pulley diameter	1024 mm
		take-up pulley diameter	820 mm
Return idler distance	6 m		
Roll diameter	133 mm	1 hydraulic disc brake at tail drive pulley	
Troughing angle	15°		
Garland type idler		frequency-controlled drive units	

FV 32 T. Brüwer	Belt Conveyor Denis I	KRUPP