SASTECH

The Dry Screening of Fine Coal

(BELTCON 8 CONFERENCE)

SYNOPSIS

The efficient dry screening of run of mine coal at 6 mm and cut points below is considered to be the most difficult of all screening duties. Normal practice is to perform wet screening with multiple deck vibrating screens which require extensive dewatering and fines recovery systems.

Sastech Engineering Services has developed and produced a revolutionary dry fine coal screening machine which base its screening technology on the simple fact that different sized materials displays different angles of repose.

This paper discuss part of the reasoning behind the development of a new dry screening technology as related to the SASOL screening process. It follows with a presentation of the development phases from pilot plant tests to producing a commercial machine. Finally the paper discuss some of the unique design features of the "Dry Screening Coal Separator" .

Dirk P Pieterse

SASTECH Engineering Services

Mechanical Engineering Department.

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The Dry Screening of Fine Coal

1. INTRODUCTION

The sorting of particles by sizing is an operation familiar to many industries, and in mined minerals processing and beneficiation production, the sizing of granular materials plays a dominant role.

One of the largest portions of capital outlay of a minerals processing plant is probably the establishment of the screening section, and backup infrastructure.

It is common practice to try and screen dry as far as possible, but at some point in the sizing process, this is not possible anymore, particularly at the sizes 5 mm to 6 mm and below, and the screening process has to be assisted by some other means. Normally this is done by adding water to the process (Wet screening) with very good results. As a rule of thumb for every ton of coal, 1 to 2 tons of water is required.

The wet screening process however requires quite a large infrastructure to recover the screened material from the water. If one now has to increase throughput, not only do you have to add more screens, but you also have to invest in upgrading or expansion of the infrastructure.

Constant economic pressure are forcing engineers to invest time and money in developing new technologies that are geared towards lower operating and production costs. In this case a new dry screening technology has been established with a high level of success.

This presentation will show why the need for a new technology was established and developed. Secondly it will discuss the phases of developing this technology, and finally some of the unique design features of the Dry Screen Coal Separator (DSCS)will be described.

1.1 WET SCREENING ! WHY DRY SCREENING ?

Considering a typical wet screening system, in this case the Sasol Secunda system, one will immediately recognize the benefits of dry screening. The Sasol system is purpose built to meet specific process requirements in the conversion of coal to gas.

The present Sasol screening system fulfills two main functions.

- The first and most important function is to supply a course coal fraction to the gasification plant. This fraction consists roughly of + 4 mm to 100 mm coal and is washed to eliminate fines hikers which cannot be tolerated in the Gasification process.
- The second function is to route the remaining - 4 mm coal fraction to the steam plant to generate steam used in the gasification process.

Considering a mass balance diagram of the system however, it is not a simple matter of separating a + 4 mm and - 4 mm fraction from a run of mine (ROM) feed as can bee seen from figure 1 which gives balance figures per 1000 t/hr feed.

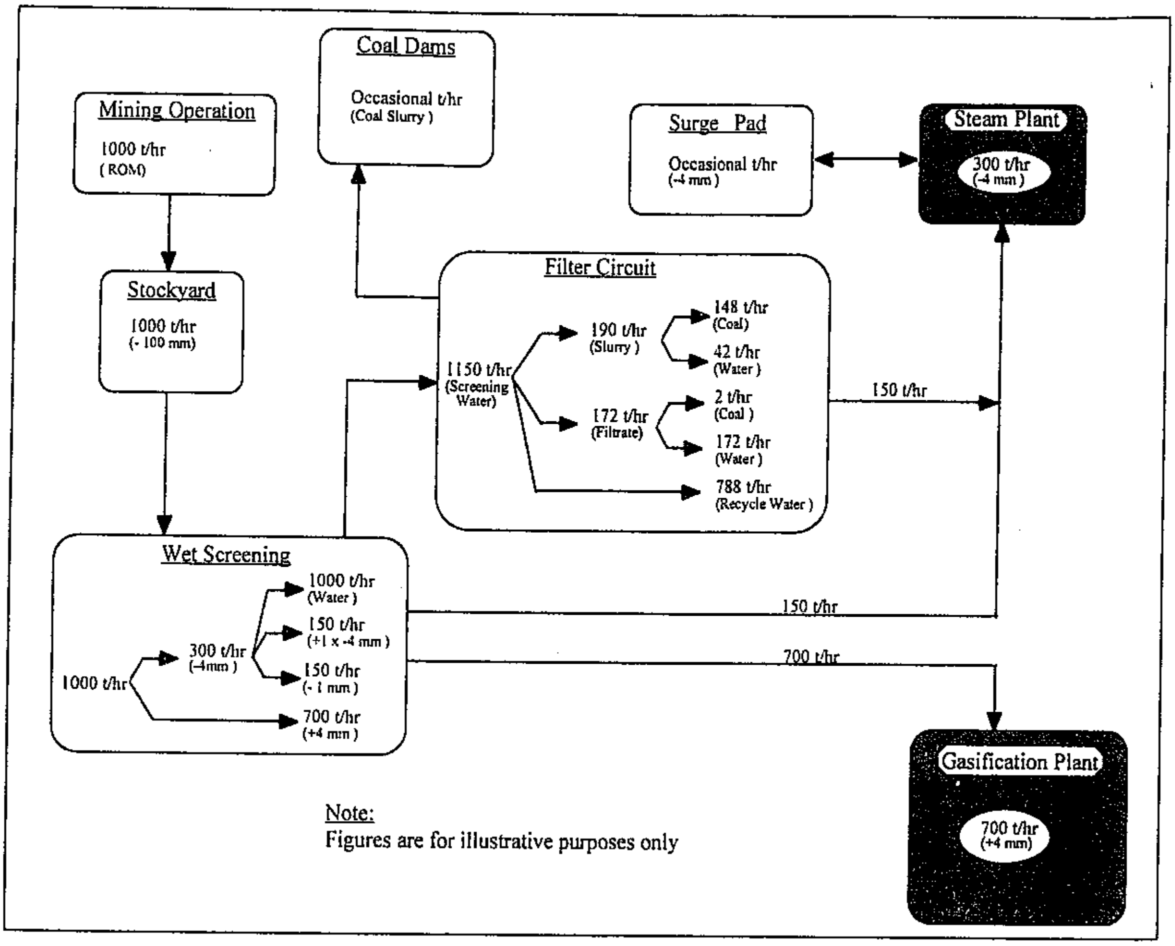


Figure 1 : Wet screening mass balance

From the above mass balance diagram we see that for every 1000 t/hr of coal supplied by the mining operation, 700 t/hr is gasification coal of + 4 mm to - 100 mm fraction, while the remaining 300 t/hr , - 4 mm material is used in firing the boilers for steam generation.

The separation of the main coal stream is performed by the primary and secondary vibrating wet screens in the first part of the screening process as shown in the plant mechanical flow diagrams following.

In order to perform wet screening, another 1000 t/hr of water (ton per ton) is added to the 1000 t/hr coal load (solids to water ratio of 1:1). After separating the + and - 4 mm fractions, this water has to be separated from whatever coal solids are in the water because both the water and the coal are valuable and expensive resources.

If the energy requirements to perform the total screening operation is considered, then it is found that to separate the ROM feed into a - 4 mm and a + 4 mm fraction requires 280 kW per 1000 t/hr feed. To recover the screening water, and the fines solids from the water requires a further 1460 kW per 1000t/hr feed.

Therefore it requires roughly 5 times as much energy to recover the water and coal from the slurry water, than to screen the ROM at 4 mm cut point.

The equipment used in this screening process is shown in the wet screening plant mechanical flow diagrams, figures 2,3 and 4 following.

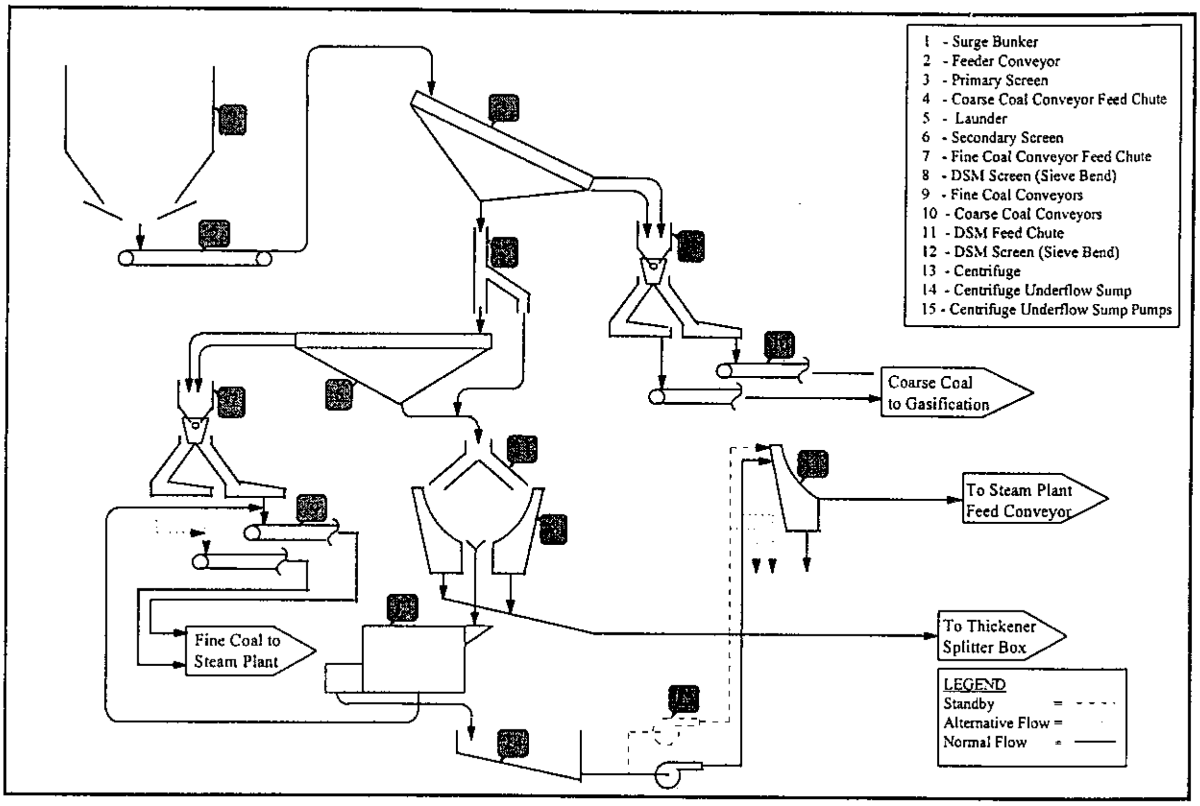


Figure 2 : Wet screening plant mechanical flow diagram (Sheet 1 of 3)

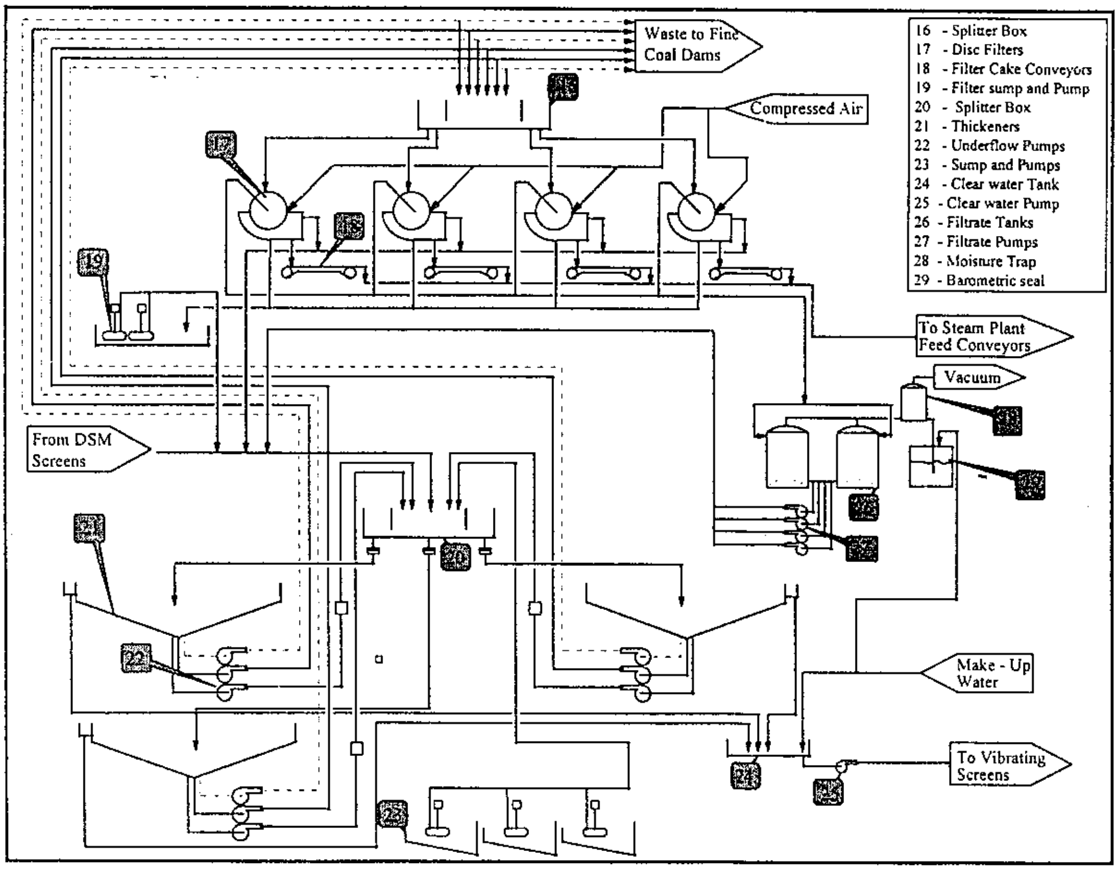


Figure 3 : Wet screening plant mechanical flow diagram (Sheet 2 of 3)

From Figure 2, and referring back to the mass balance diagram it is clear that the material that are used economically, comes off the primary and secondary vibrating screen right at the beginning of the screening process. The downstream equipment which includes the DSM (sieve bend) screens and centrifuges primarily removes the + 1 mm to - 4 mm from the secondary screen underflow which is the screening water.

Figure 3 shows the equipment required to now separate the solids from the water used in the wet screening process. Still this is not the full picture since a complete auxiliary infrastructure consisting of flocculant dosing, compressors , vacuum pumps and cooling water systems are required as shown in Figure 4.

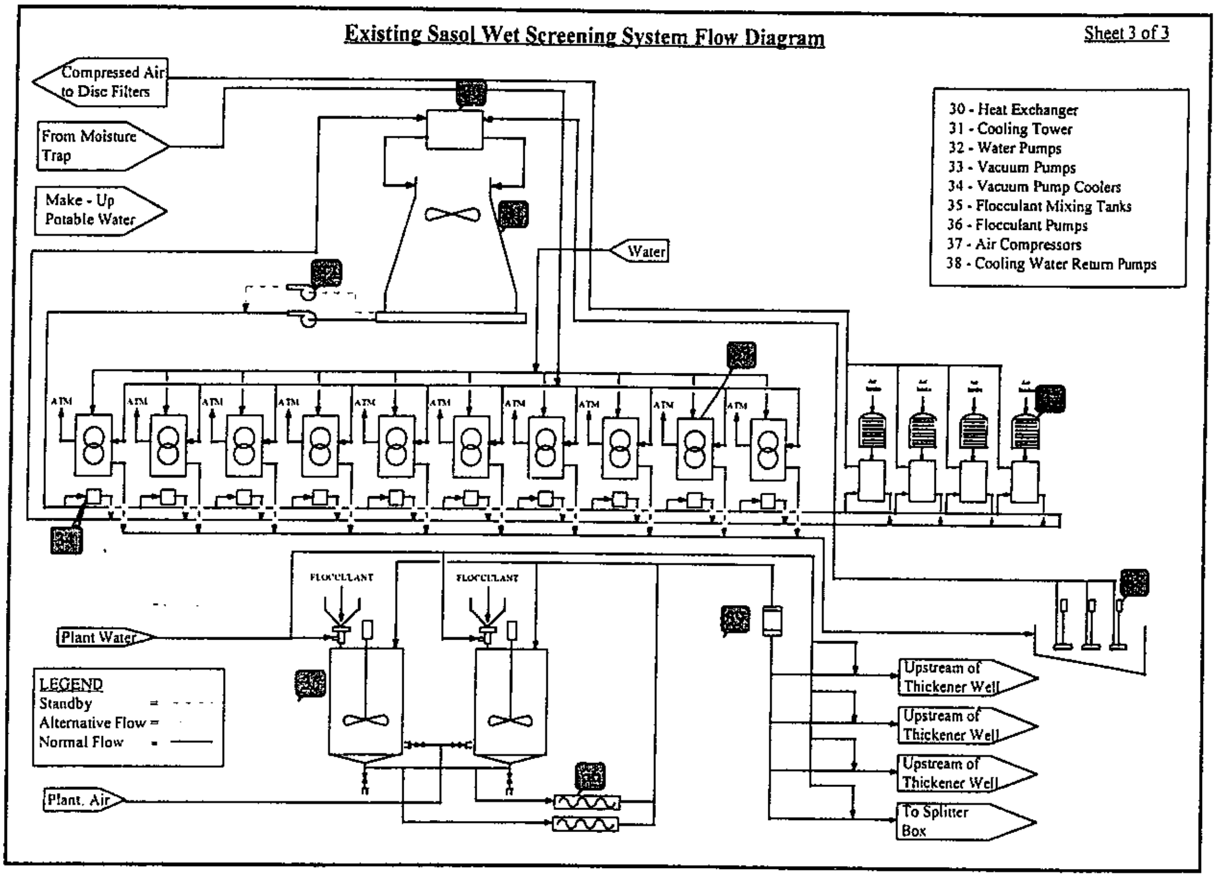


Figure 4 : Wet screening plant mechanical flow diagram (Sheet 3 of 3)

The advantages that a dry screening system would achieve on replacing the wet screening system described can be summarized as follows.

- Up to 70 % reduction in plant capital costs
- Up to 80 % reduction in operating and maintenance costs
- The further reduction in hidden costs like
    - No expenditure on providing coal evaporation dams
    - No production problems in supplying steam plant coal with too high a moisture content.(This often happens when the -1mm fraction in the ROM is very high)

The ideal mass balance diagram for a dry screening system in this particular situation would be something like the one shown in Figure 5.

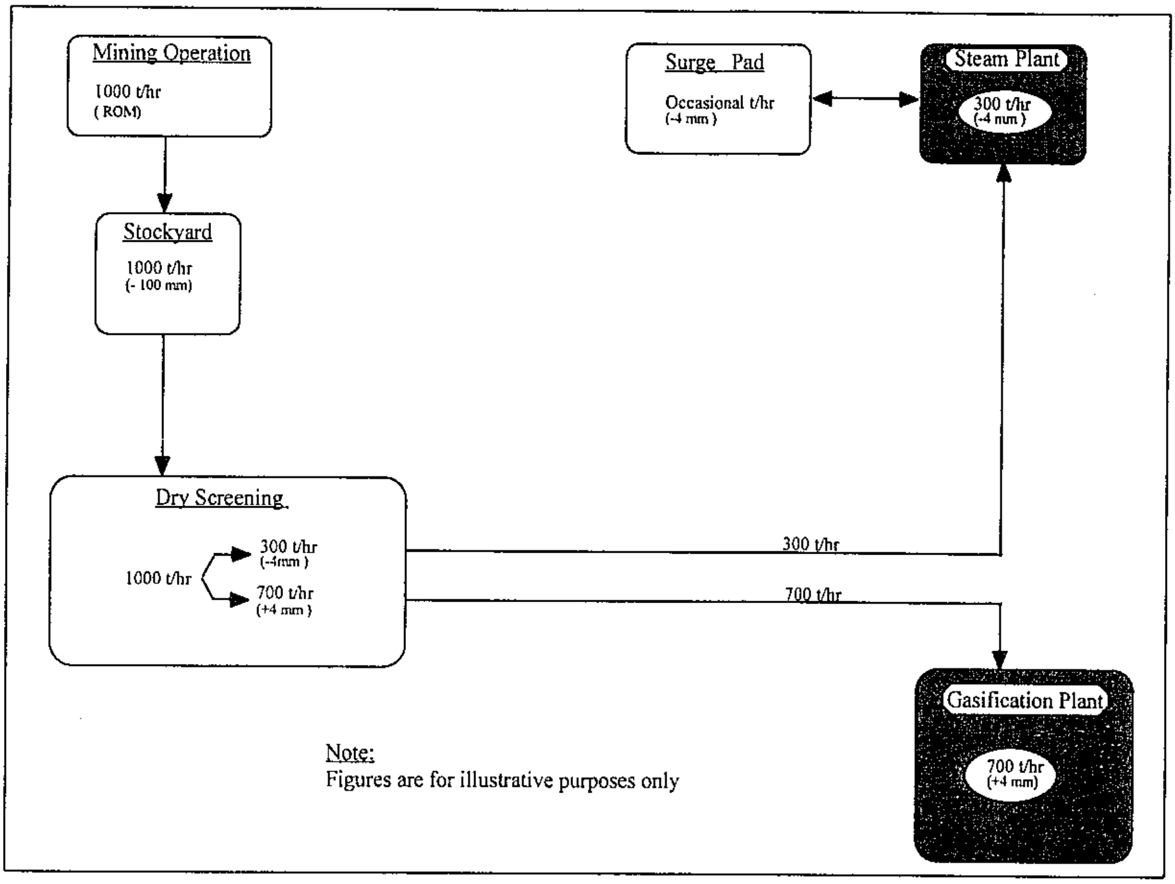


Figure 5 : Ideal dry screening mass balance diagram

The associated plant required to accomplish perfect dry screening is shown in Figure 6

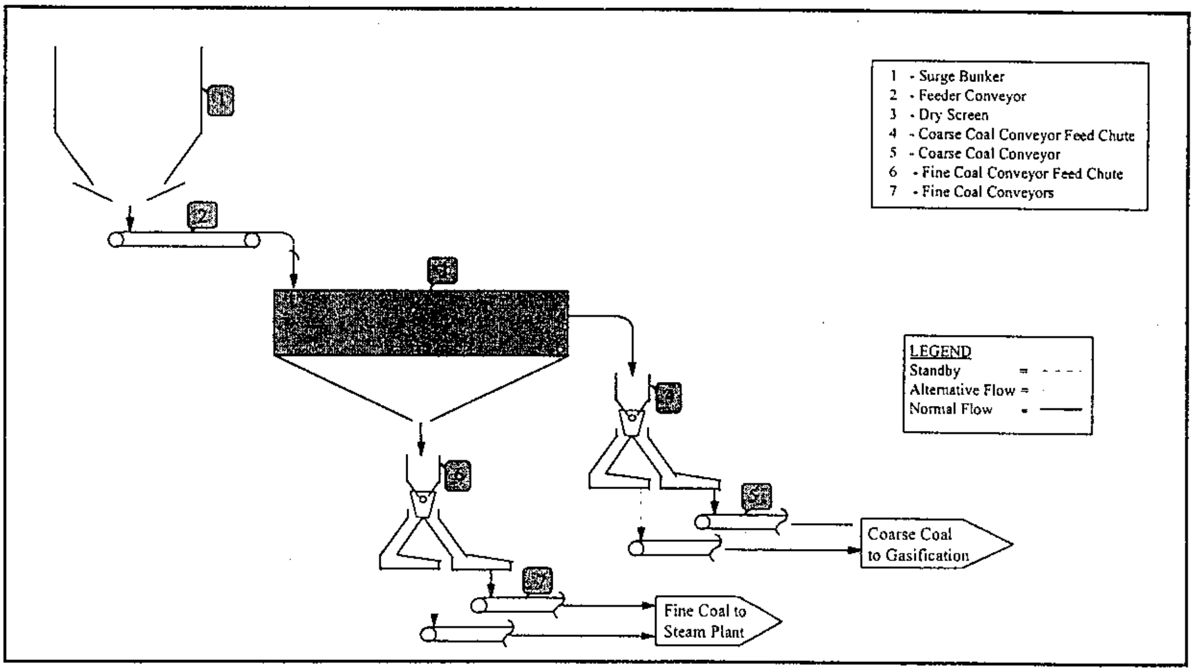


Figure 6 : Ideal dry screening plant mechanical flow diagram

The scenario sketched in figures 5 and 6 could only be possible with perfect dry screening. To be practical, it would be very difficult, if not impossible to screen completely dry, since the system efficiency would have to be 100 %.

If in the case of the Sasol wet screening system, 70% of the -1 mm material could be removed dry before the ROM is put onto the wet screens, there would be no need to upgrade the existing wet section of the plant. Dry screening would also reduce operating and maintenance costs because the wet section would run at reduced loads. A further benefit would be the supply of dry fines to the steam plant which will eliminate the problems associated with high moisture content fines.

This then was the departure point for further investigations into a dry screening system because it was realized that most likely, no perfect (100% efficient) dry screening system exist, or could be developed.

The scope of the investigation is defined as :

- Develop a dry screening system that would screen efficiently at -6 mm
- Develop a system to compliment the existing wet screening operation rather than replacing it.

2. SASOL "Dry Screen Coal Separator" DEVELOPMENT

Dry screening is not a new concept as many screen suppliers would confirm. Many coal users and equipment suppliers are constantly searching for an efficient dry screening system because of the benefits that can be achieved with a dry system.

The reason that dry screening it is not commonly used for fine coal fractions below 6 mm could be that research and development is concentrating on optimizing existing wet screening technology to perform dry screening. The majority of existing dry screens will in fact perform more efficient with water spray or flood boxes.

In contrast, the DSCS system can only be used on dry coal, and will not operate at all under typical wet screening conditions.

In reviewing existing dry screening equipment, one will immediately recognize a common feature amongst all of them. This feature is that the material to be separated from the bulk of the feed, need to pass through an opening or aperture in the surface or deck of the machine.

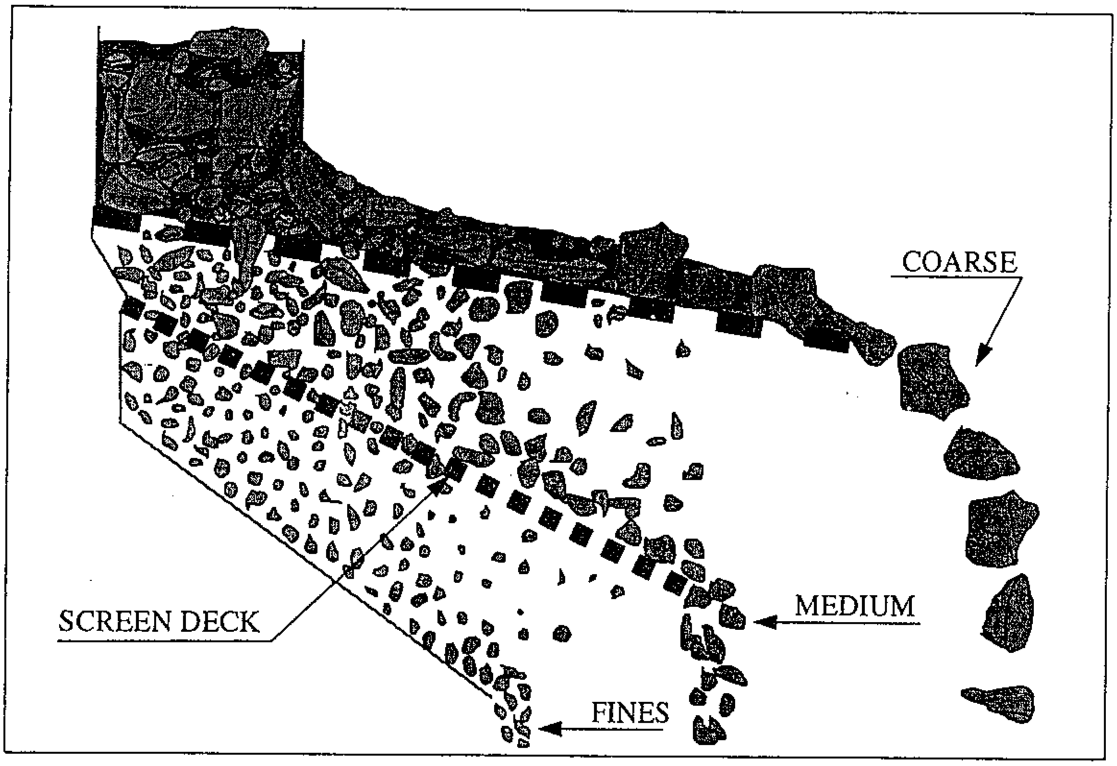


Figure 7 : Existing dry screening technology screening method

In all cases, the very feature that prevents successful dry screening is retained, and all efforts are put into optimization the size, shape, or movement of the opening.

When the future upgrading of the Sasol plants were investigated it was found that the most economical upgrading the Sasol plants, using wet screening technology would cost around R 120 mil. In addition the existing technology would result in increased operating and maintenance costs. Considering these costs there was no alternative but to look at cheaper screening solutions.

In evaluating alternatives that would meet the criteria of low capital investment, maintenance and operating cost, a number of sessions were called and by applying lateral thinking skills and value engineering techniques, the dry screening coal separator concept was developed.

2.1 THE BASIC "DSCS" PRINCIPLE

When the inherent natural properties of any granular material is considered, one of the properties that distinguish between different materials is it's angle of repose.

The angle of repose of coffee beans for instance is 25^0, whereas the angle of repose of bituminous run of mine coal is between 45^0 and 55^0.

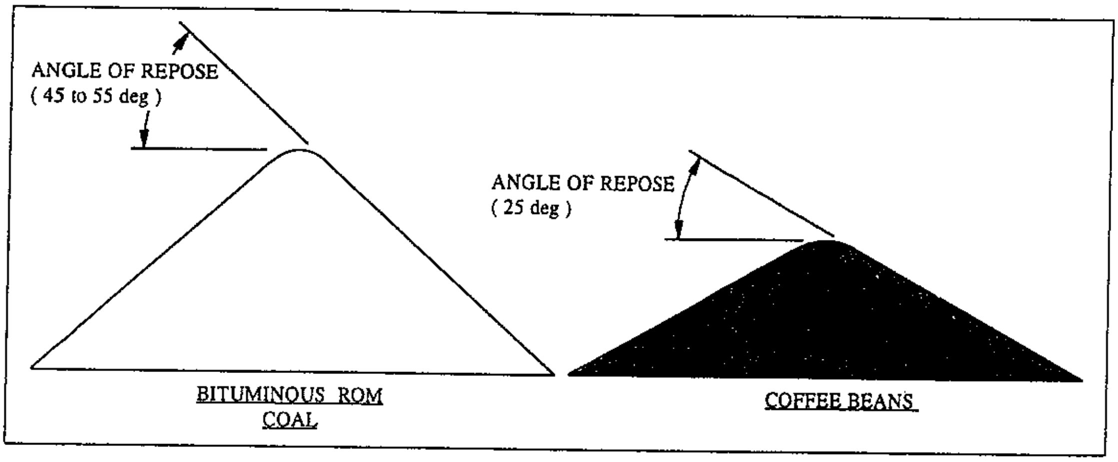


Figure 8 :Angles of repose of different materials

We further know that different sized particles of the same material has different angles of repose. The finer material would have a steeper angle of repose than the coarser material in the case of coal. At a cut point of 12 mm, the angle of repose of the -12 mm material is between 43^0 and 50^0, while the angle of repose for the +12 mm material is between 45^0 and 55^0.

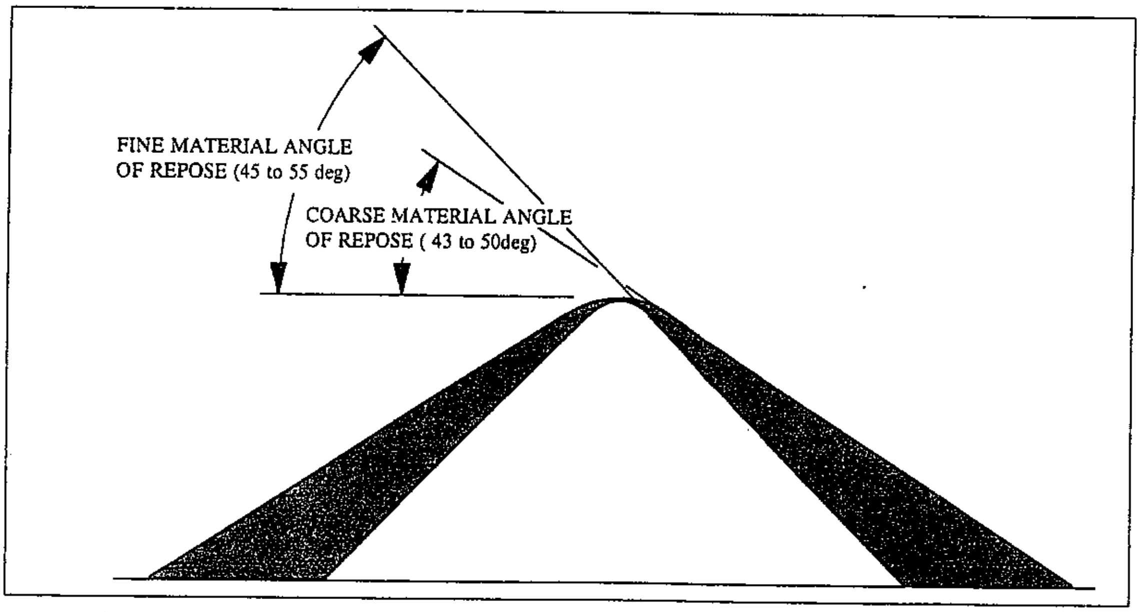


Figure 9 :Angles of repose of different particle size of the same materials

This difference in repose angle may not be significant enough to achieve any meaningful result when investigating a solution to dry screening, but it leads to a second material property which is considered in the design of chutes. This property is the chute design angle and as can be evaluated from table 1, these angles differ greatly between size fractions.

The Chute angle required to allow flow of a - 6 to + 0 mm size fraction (55^0) is 15^0 steeper than the chute angle for a - 16 to + 0 mm fraction (40^0), and 25^0 steeper for a - 50 to + 16 mm fraction (30^0).

LUMP SIZE (mm)	CHUTE ANGLE (deg)
- 150 to + 100	24^0
- 100 to + 50	27^0
- 50 to + 16	30^0
- 16 to + 0	40^0
- 6 to + 0	55^0 (Completely Dry)
- 6 to + 0	70^0 up to 7 % moisture in raw ROM
- 6 to + 0	90^0 above 7 % moisture in raw ROM

Table 1 :Chute angles of various coal sized fractions

If the material containing different particle sizes is discharged over a surface which is inclined at an angle greater than the chute angle of the finest material, then all the material should discharge as shown in figure 10A.

If the inclined surface angle is reduced, to an angle less than the required chute angle of the fine material, but greater than the chute angle of the coarse material, then theoretically the fine material would be retained while the coarse material would be discharged as in figure 10B.

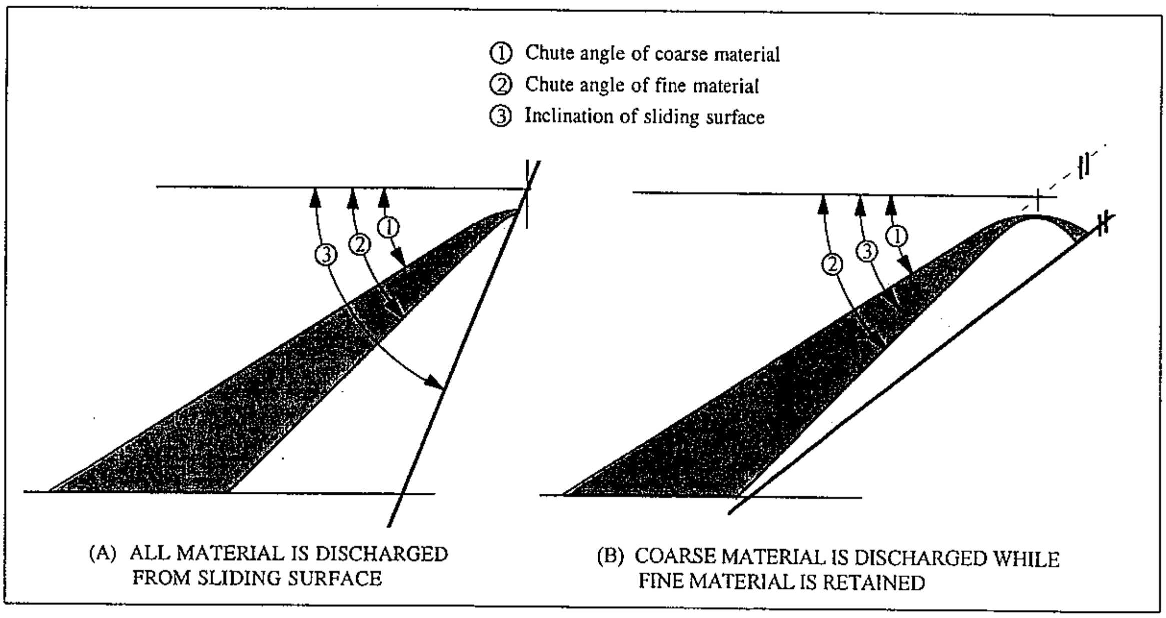


Figure 10 :Theoretical separation of sized fractions on a sliding plate

Now that a possible separation or screening concept has been established, the question of how to reclaim the fine material retained on the sliding surface still remains.

The solution is presented in the form of using a conveyor belt as the sliding surface. By using a conveyor, tilted at the angle of the sliding surface as in figure 10B, the fine material could be removed continuously in the direction of travel of the belt, while the coarse material is allowed to discharge across the belt as shown schematically in figure 11.

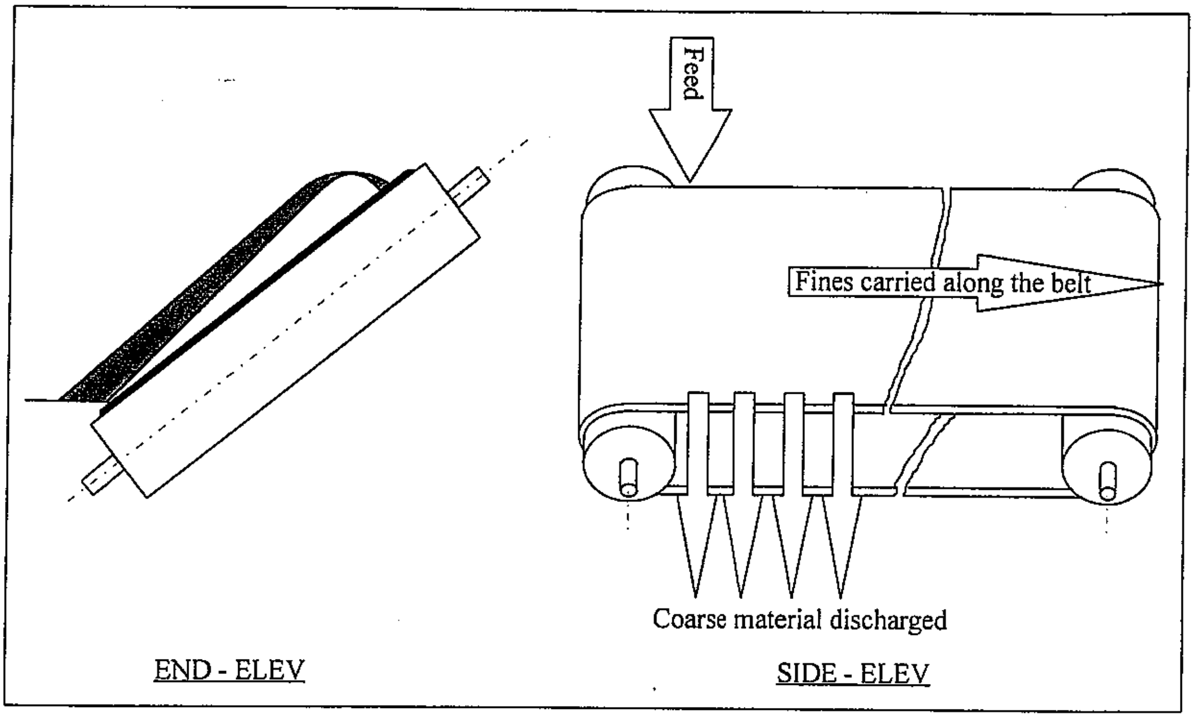


Figure 11 :Concept of Dry Screening using a Tilted Conveyor

2.2 DEVELOPMENT PHASES

In order to arrive at a commercially viable product, three basic phases were required. The fist phase is termed the Pilot Plant phase in which the concept was proved. The second phase were the Full Scale production phase in which process performance were verified, while the third phase was termed the Commercialization Phase in which the machine was developed into a commercially marketable product.

2.2.1 Pilot Plant Phase

To prove the concept of screening by using a tilted conveyor belt, and to evaluate it's potential , a pilot plant was built in co-operation with ISCOR Research and Development Division. This pilot plant machine consisted of a 4 meter long, by 450 mm wide conveyor belt.

The belt used in the pilot test was fitted with a grooved profile PVC top cover. This grooved profile is one of the design features of the machine. The size and shape of the groove, together with the belt speed and tilt angle determines the capacity of the machine and is related to the cut point at which the material is to be screened. The groove profile used for the pilot plant tests is shown in figure 12.

Belt speed was variable between 0.75 m/sec and 5.25 m/sec while the tilt angle of the belt was adjustable between 5^0 and 45^0 .

The material used for the pilot tests were run of mine coal from the Bosjespruit mine with a nominal top size of 100 mm, screened at 25 mm. Tests were carried out at moisture contents of 0%, 7% and 8.6% and at belt speeds of 2, 3 and 4 m/sec.

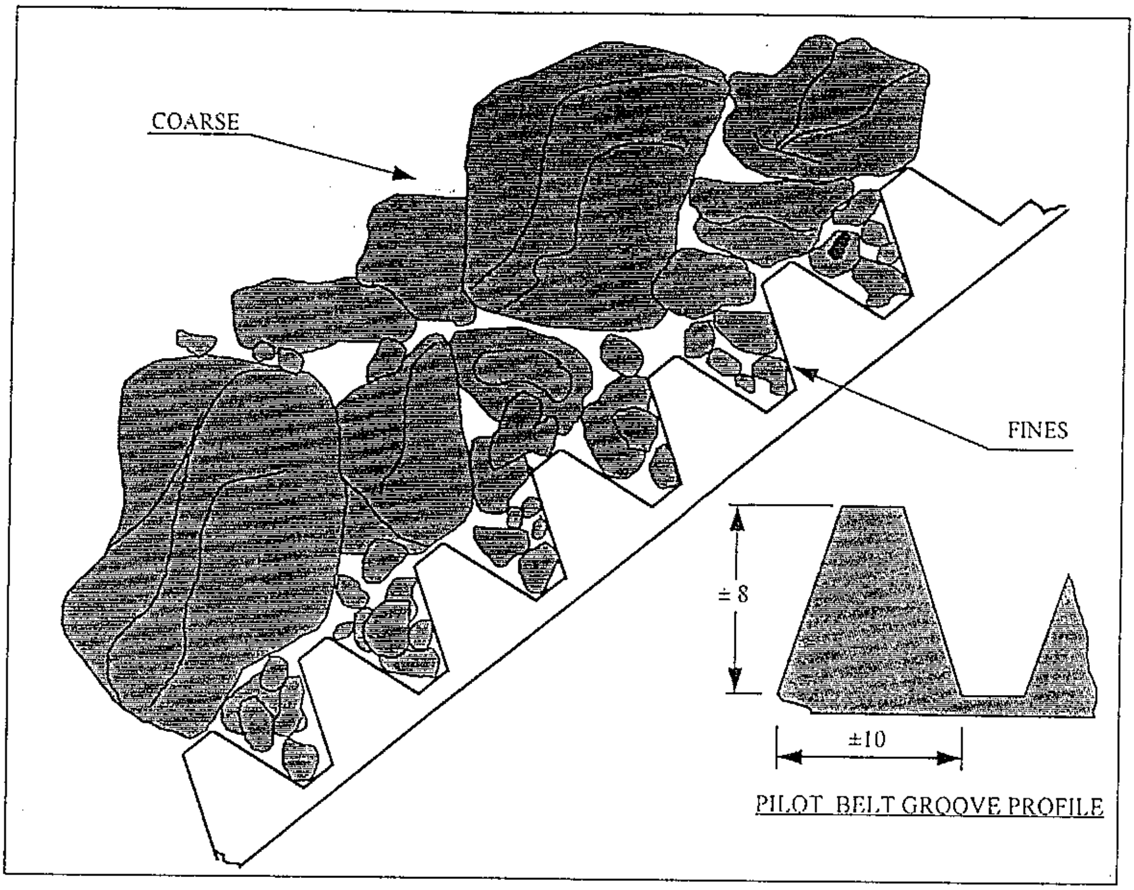


Figure 12 : Pilot belt groove profile

Figures 13 and 14 shows the test installation which comprised of the feed bin, vibrating feeder and tilted grooved conveyor belt.

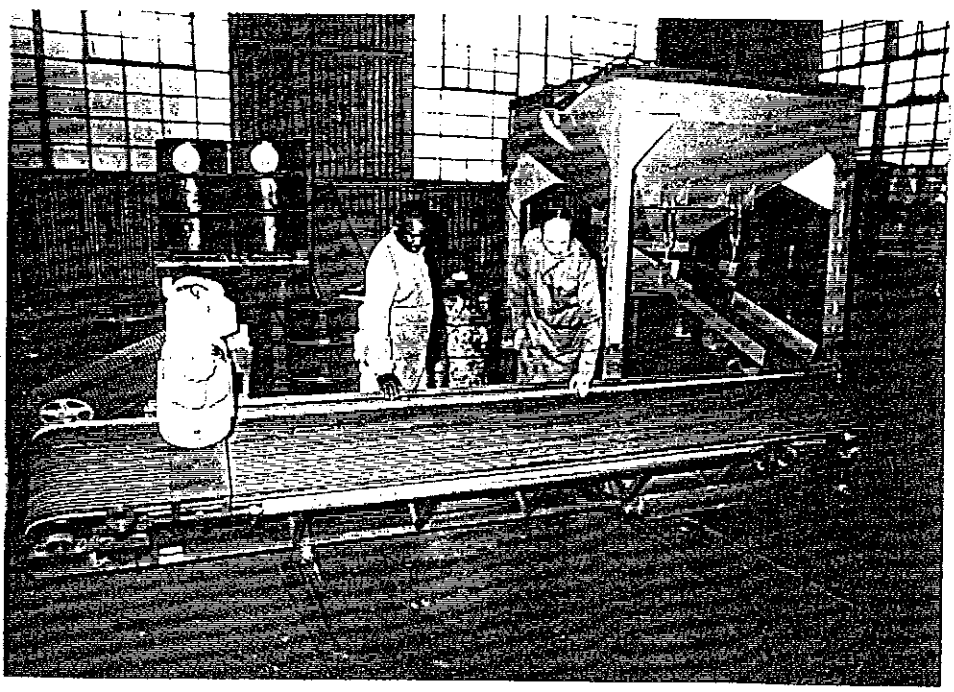


Figure 13 :Pilot plant test installation

Figure 14 :Pilot plant tilted conveyor screening belt

2.2.1.1 Test Results

Pilot plant tests showed that the best screening were obtained at a belt tilt angle of 33.5^0 and belt speed of 3 m/sec as shown in table 2.

	Test Number									
	1	2	3	4	5	6	7	8	9	10
Moisture (%)	7.4	7.4	7.4	7.4	8.6	8.6	8.6	8.6	0.0	0.0
Speed (m/sec)	3.0	3.5	3.0	2.0	3.0	2.0	3.0	4.0	3.0	3.0
Tilt Angle (deg)	33.5	33.5	39.5	39.5	39.5	39.5	33.5	33.5	33.5	39.5
Feed Rate (t/hr)	12.2	14	11.7	12.5	12.9	14.1	13.3	11.7	11.8	10.7
% Fines	29.7	25.9	18.9	21.4	16.4	21.3	28	21.5	30.5	24.2
% + 5 mm in Fines	4.5	3.9	1.0	1.8	1.4	2.0	8.1	4.3	4.4	1.5
Efficiency (-5 mm)	65.5	57.3	43.9	49.7	39.3	47.4	58.1	46	66.7	54.9

Table 1 :Results of pilot plant tests

From the results obtained we see that 66.7 % of the -5 mm fine material in the feed was removed. What is of more significance, although not shown in table 2, is that approximately 85 % of the -1 mm material in the feed was removed

Variations in moisture content had no influence on particles larger than 2 mm, and only caused a drop in grade efficiency of the finer particles.

Tests at different belt tilt angles showed that an increase in the tilt angle from 33.5^0 to 39.5^0 led to a reduction in cut size from approximately 3.5 mm to 2.0 mm. The percentage oversize in the undersize drops considerably, as does the grade efficiency.

Tests at different belt speeds showed that increased belt speed had a similar effect, but less dramatic as the increase in belt angle.

2.2.1.2 Pilot Test Conclusions

The conclusions which resulted from pilot plant tests clearly showed that the concept of using a tilted conveyor to separate coal fines in a dry state were feasible.

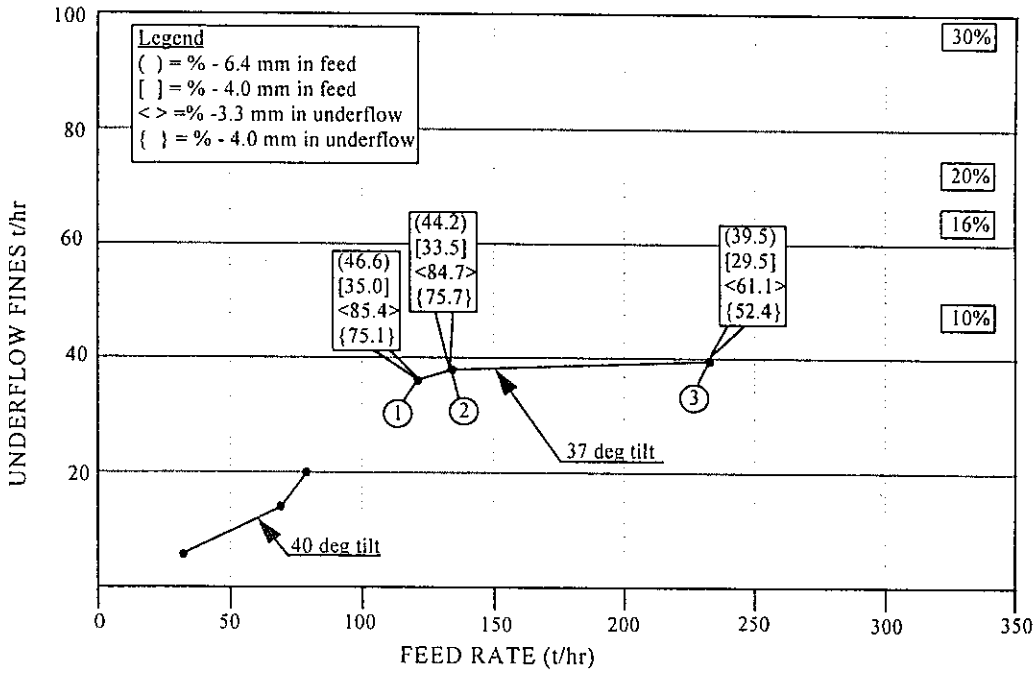
It was further demonstrated that in addition to achieving screening, changes in parameters like belt speed and tilt angles resulted in changes in cut point and efficiency which cannot be done with any other screening system without permanent modifications.

After the successful completion of the pilot plant phase, the next step was to implement a Full Scale Demonstration unit in a production environment.

2.3 FULL SCALE DEMONSTRATION PHASE.

A full scale machine with 2 meter wide belt and 12 meter pulley centers were manufactured and installed at Sasol Two in Secunda. This unit were fed with 200 t/hr ROM, prescreened at 25 mm.

Slightly different and better results were obtained with this unit as can be seen from figure 15 and the optimum operating point were found to be at a belt speed of 3 m/sec and 37^0 tilt angle. The capacity of fines removed remains constant at 40 t/hr, irrespective of the feed tonnage since it is determined by the belt speed and volume of the grooves.



Graph 1 :Test results of demonstration unit operating at 3 m/sec and 37^0 tilt

One of the surprises in the results shown is that a significant higher percentage of fines is removed and this trend was evident in different samples.

The first sample contained 46.6 %, -6.4 mm and 35 % -4 mm material. The underflow analysis shows that 75.1% of the -4.0 mm and 85.4% of the - 3.2 mm material in the feed is screened out to the underflow. This trend is also present in samples 2 and 3 and shows that there is a preference for finer material.

As far as the process of removing fines are concerned, the demonstration unit was a success and it provided the justification to continue with the development of the concept in order to increase the capacity of removing fines.

However major problems were encountered in the mechanical design of the machine. Since the belt is running at a tilt of between 35^0 and 45^0 the biggest problem encountered were in the tracking of the belt.

Initially the idea was to track with return idler, and head and tail pulley adjustment. These attempts however were fruitless and only worked for tilt angles up to approximately 28^0.

Attempts to vulcanize a guide strip to the top of the belt also failed and eventually the belt weight was reduce by reducing the width to 1.6 meters and the pulley center distance to 9 meters in order to perform the necessary process tests.

2.4 COMMERCIAL UNIT PHASE

Because of the unsuccessful attempts at tracking of the belt it was decided to embark on a search for a knowledgeable expert in the field of belt tracking. One of the requirements set was that this expert should have the necessary knowledge to integrate the belt design with the tracking design.

Rubber companies in South Africa showed little interest in doing tracking development especially in a situation where a one-off belt was required. It seemed also that rubber research capabilities were limited to conventional conveyor belts.

On the other hand local conveyor experts seemed to lack knowledge in the rubber field when it comes to unique designs such as the tracking of this belt.

This lead to a search in Europe in order to find suitable experts and although some overseas companies produce unbelievably unique belting systems, very few again were willing to combine the belt design with the mechanical design of the tracking mechanism.

After evaluating various overseas contacts it was decided to appoint the company, "HECKER & KROSCH" in Germany to assist in the development of the DSCS. Hecker & Krosch has been involved in the development of unique conveyor systems, involving both special belting and mechanical hardware and it was decided that they had the capability to combine the expertize of the different fields.

The design of the machine were jointly done by Sastech and a company, "E+PK" which operate with Hecker & Krosch in Germany. The design of the belt was done by "Tip Top - Dr Nordman" who specialises in rubber technology and the design of unique belting applications.

Fabrication and assembly of the machine was done by Hecker & Krosch and the assembled machine was bench tested in Germany before shipping to South Africa. This commercial machine is installed in the position of the demonstration unit at the Sasol Two plant. The complete installation is shown in figure 15.

Run of mine feed into the factory is discharged into a number of coal bunkers. One of these bunkers is fitted with an overflow, and this overflow is routed to the DSCS system. From the sketch in figure 15, coal from this bunker is fed over a 40 mm grizzly feeder on top of top of the DSCS feed hopper. The oversize (+40 mm) is routed back to the wet screening plant while the - 40 mm material remains in the bunker. A vibrating feeder feeds the - 40 mm coal over the tail end of the DSCS. The fine material collected on the belt is discharged at the head end of the DSCS. This fine material is then fed directly to the steam plant via the existing conveyor system. The coarse material from the DSCS is discharged onto a collector conveyor and this materail is also fed back to the main coal stream together with the + 40 mm material via a return belt.

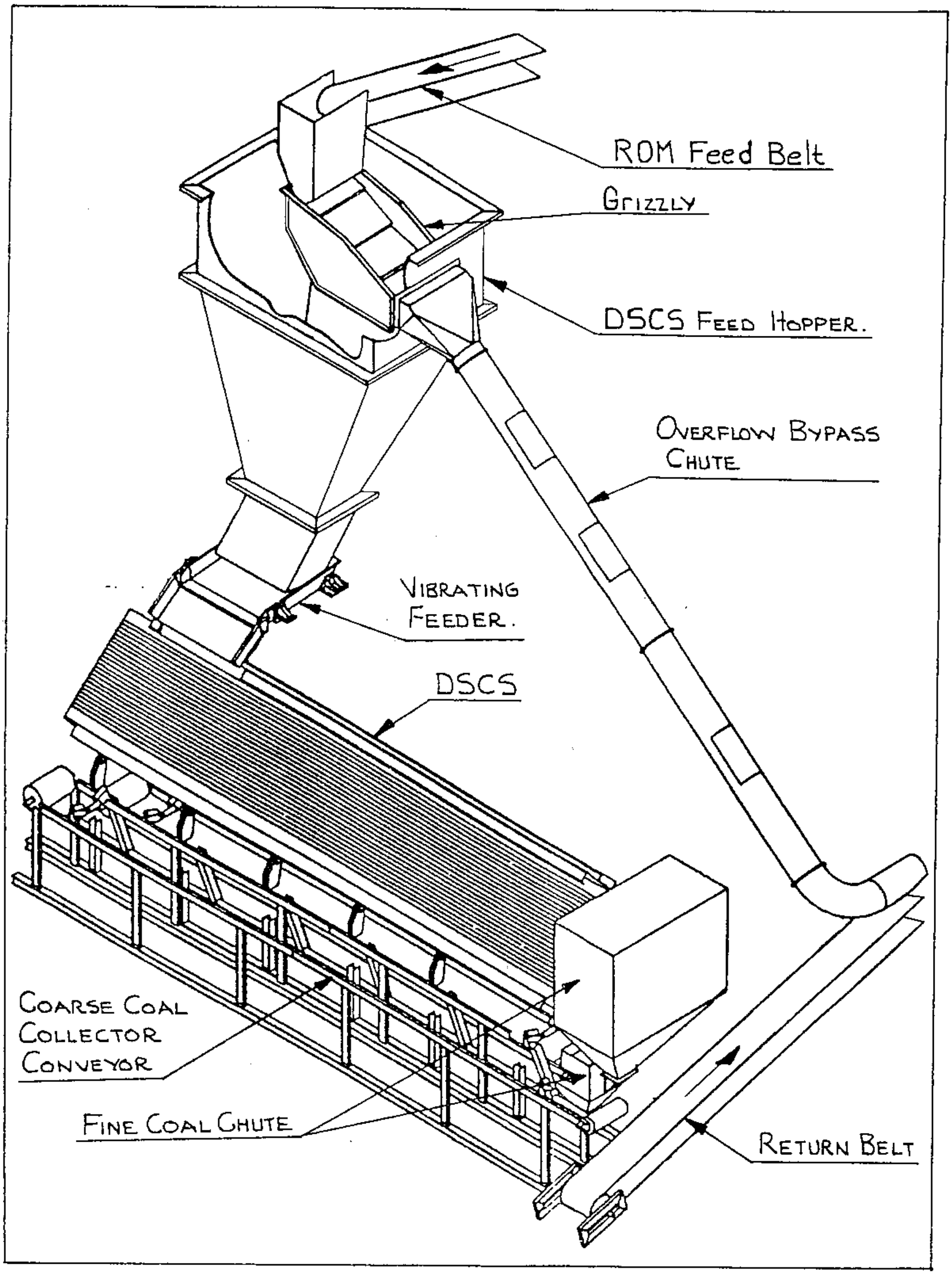


Figure 15 :Commercial unit installation (Sasol plant)

3. THE "DSCS" DESIGN FEATURES

The development of the "DSCS" screening technology has resulted in a number of patented design features of which approximately 34 is registered in South Africa and Europe. The process of screening or sizing of material using this technology however has already been patented in 1907 in France. This patent was found during a worldwide patent search, and the reason we believe that the concept has never made it further than a patent is that nobody has developed the tracking of the belt.

The following describes the "DSCS" features.

3.1 THE "DSCS" SCREENING BELT

As mentioned before, the "DSCS" belt is fabricated by "Tip-Top , Dr. Nordman" in Germany.

The basic belt is a 2,2 meter wide fabric conveyor belt as shown in figure 16. This belt is spliced endless at a length of 27 meter to provide a pulley centers length of 12 meters with 1.0 meter diameter pulleys.

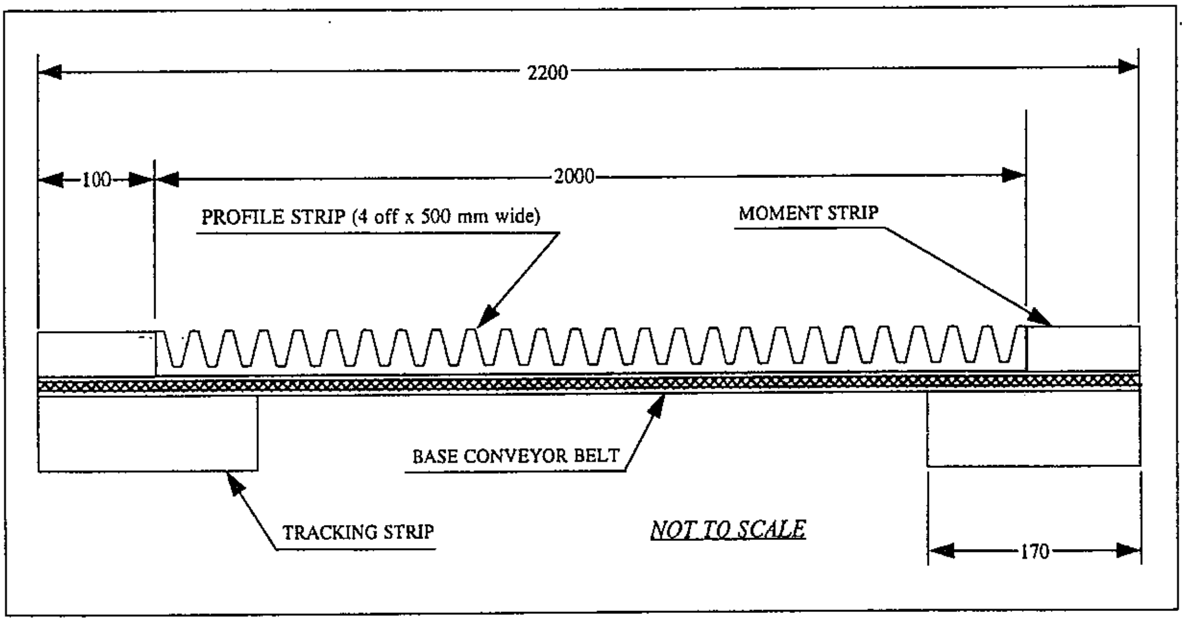


Figure 16 : DSCS belt cross section

The grooved profile strips are manufactured from 500 mm wide rubber strips on which the profiles are pressed. The tracking strips are provided with grooves as shown in figure 17 to enable bending around the drive and tail pulleys without distortion (See figure 18 photo) which normally causes internal heat build up in the rubber and eventually failure. The profile strips, tracking strips and moment strips are all glued (cold vulcanized) to the conveyor belt in separate operations.

The joint between tracking strip and belt is the most critical part of the belt since it has to withstand the full dynamic loading of the belt which weighs approximately 2000 kg and at speeds up to 4 m/sec. This joint is designed to withstand running the belt in a vertical position without any damage to the joint or tracking strip.

In order to allow for maximum deflection on the running surface of the tracking strip without shearing the joint, the tracking strip is chamfered towards the joint as shown in figure 17.

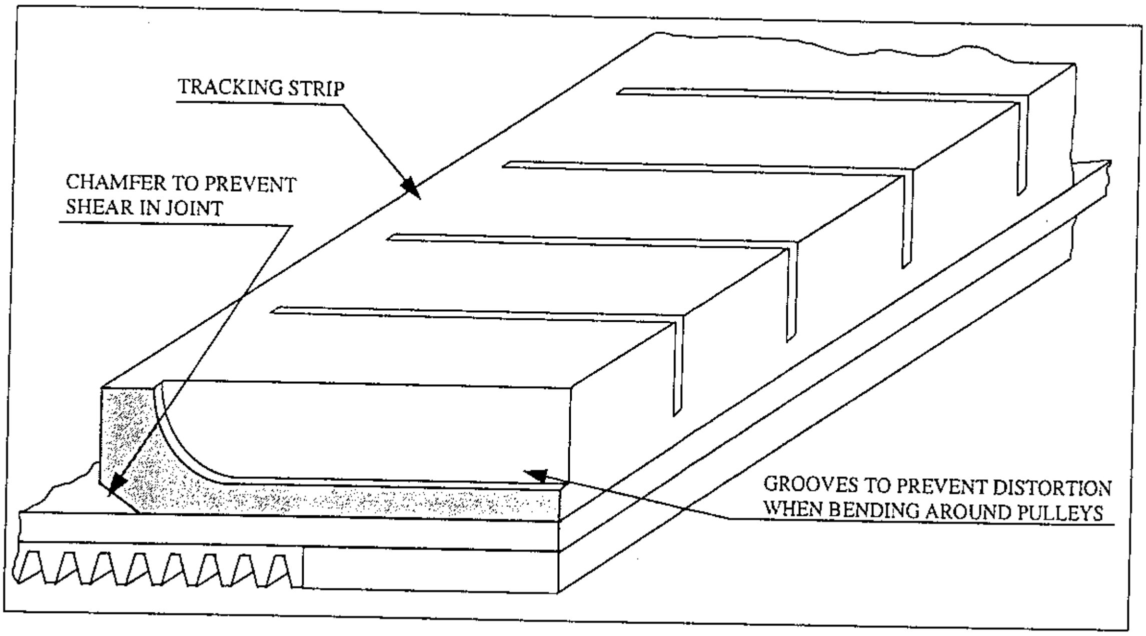


Figure 17 : Tracking strip details

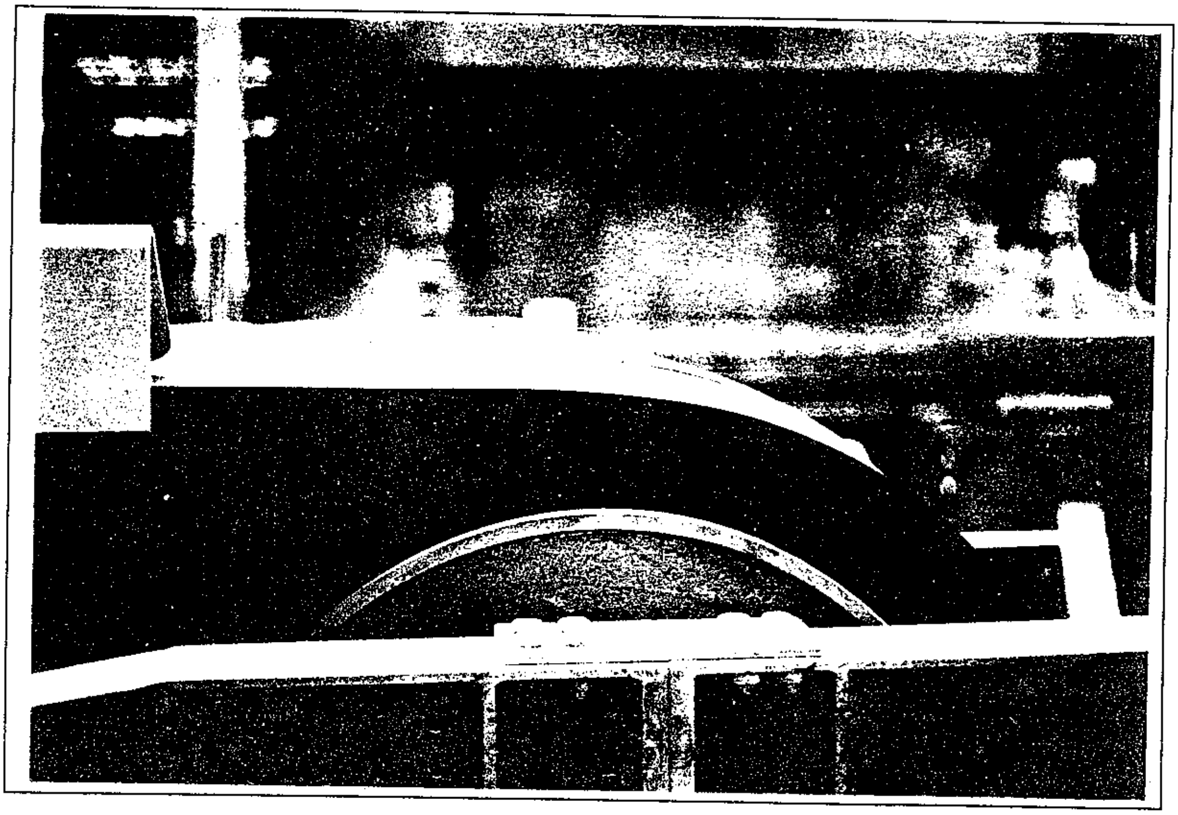


Figure 18 : Tracking strip deflection around pulleys

The belt design is such that if excessive wear is experienced on one side of the grooves, it can be turned around on the machine.

Should the groove profiles wear to such an extent that efficient screening is no longer possible, only the groove strips need to be replaced and not the complete belt.

3.2 THE "DSCS MACHINE

The DSCS machine is designed in modular form to allow for minimum spare parts inventory and easy maintenance.

Fitting of the endless belt is simplified by tilting the machine vertically and lowering the belt over the head and tail pulleys as shown in figures 19. This operation is normally done with the machine in the installed position without the need to remove the complete machine to a workshop.

After fitting the belt, the machine is tilted back to the horizontal position as shown in figure 20 to track and tension the belt.

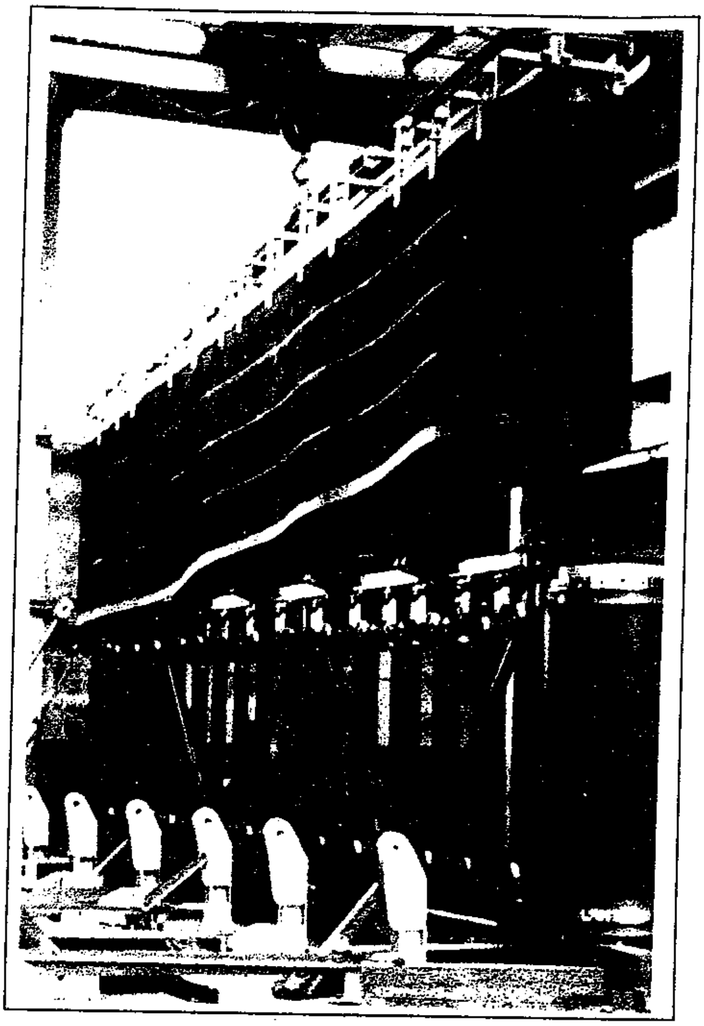


Figure 19 : Fitting the screening belt to the machine

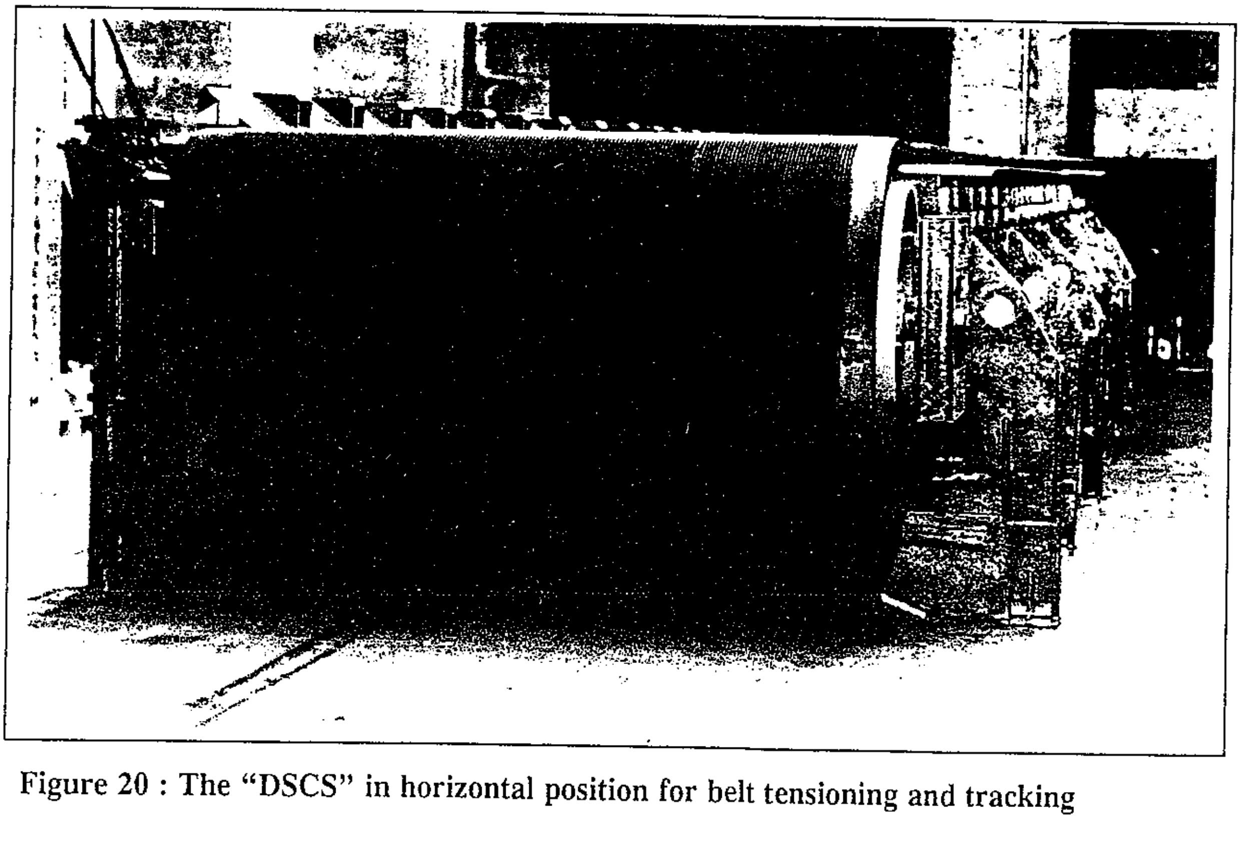


Figure 20 : The "DSCS" in horizontal position for belt tensioning and tracking

Each side of the tail pulley is fitted with a hydraulic load cell (figure 22) to enable equal tensions on both sides of the belt. Tensioning is performed by screw take-up on each side of head and tail pulleys and initial alignment is simply performed by dimensioning. Figure 21 shows the screw take-up arrangement and bearing housing.

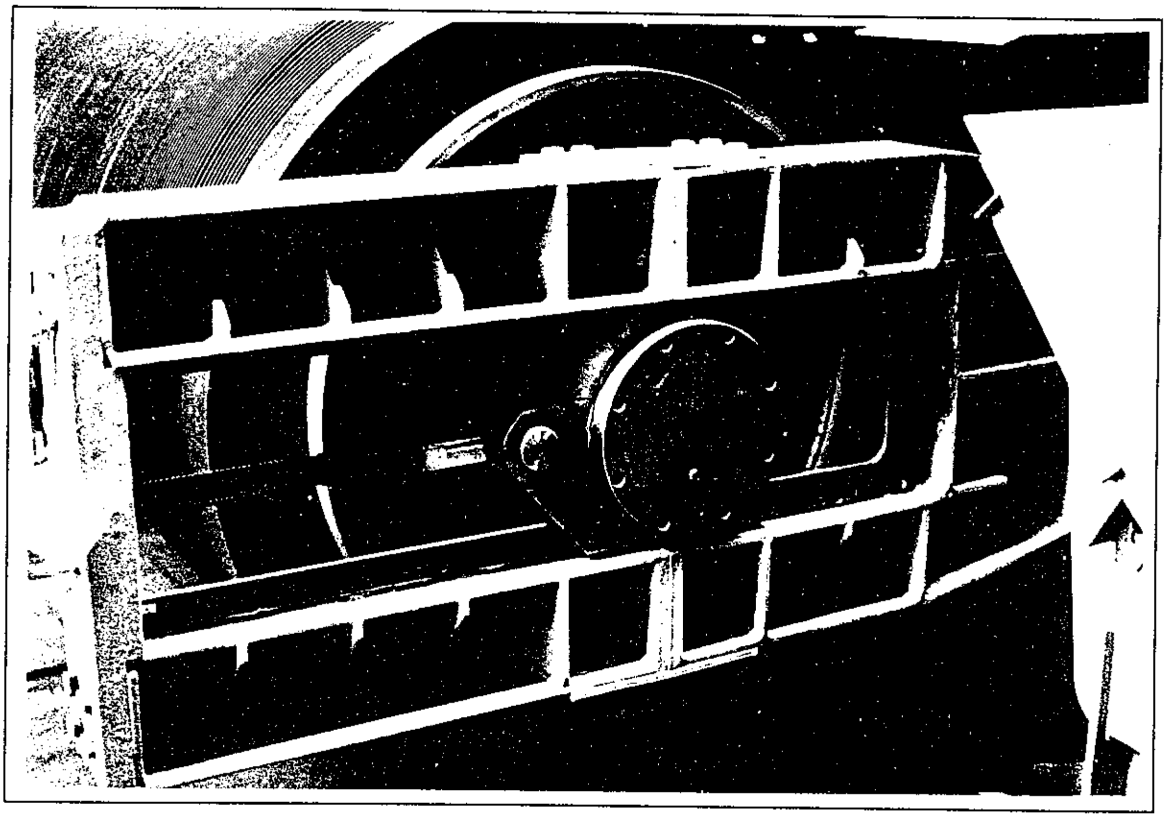


Figure 21 : Screw take-up and bearing housing

Figure 22 shows the two hydraulic tensioning gauges which allows direct readout of belt tension.

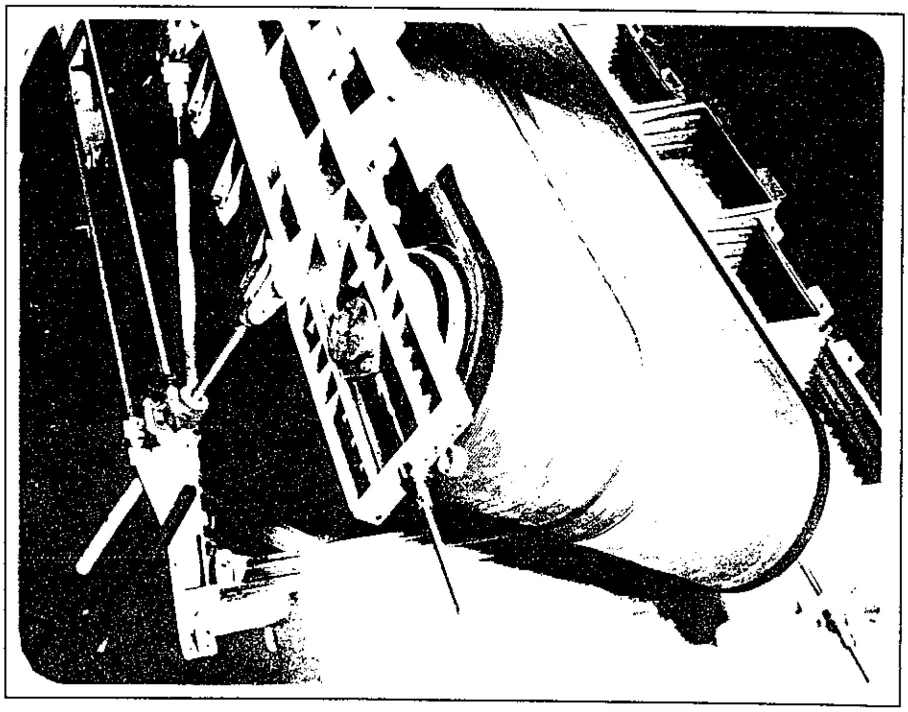


Figure 22 : Hydraulic belt tensioning measurement

As mentioned before, one of the unique design feature of the DSCS design is the method of tracking the belt. Tracking is done by 15 tracking assemblies which consist of tracking, moment and support rollers and idlers along the upper and lower side of the machine. Figure 23 shows the belt and tracking mechanism.

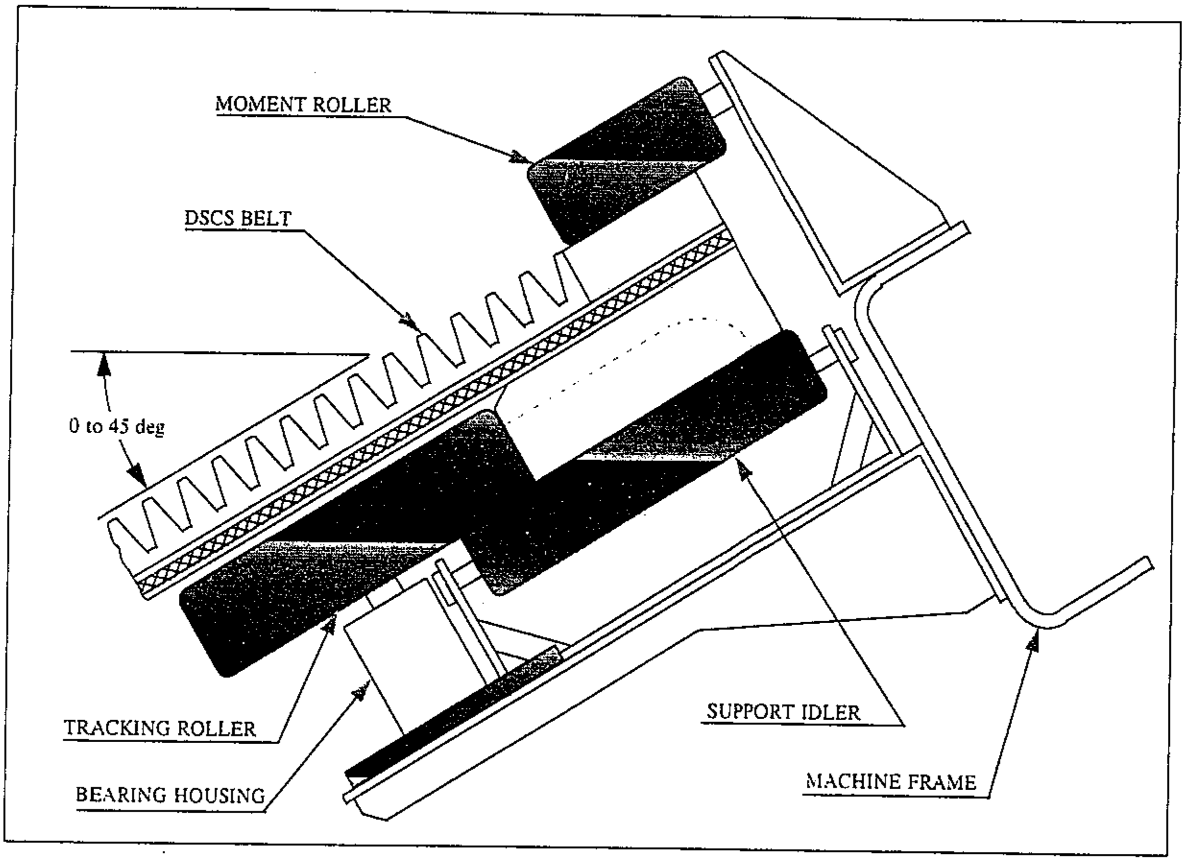


Figure 23 : Tracking arrangement

Adjusting tilt angle of the machine to screen at different cut points while in operation is done by motorized jacking screws mounted at the upper side of the machine as can be seen from figure 24. These Jacking screws also serve as supports for the machine.

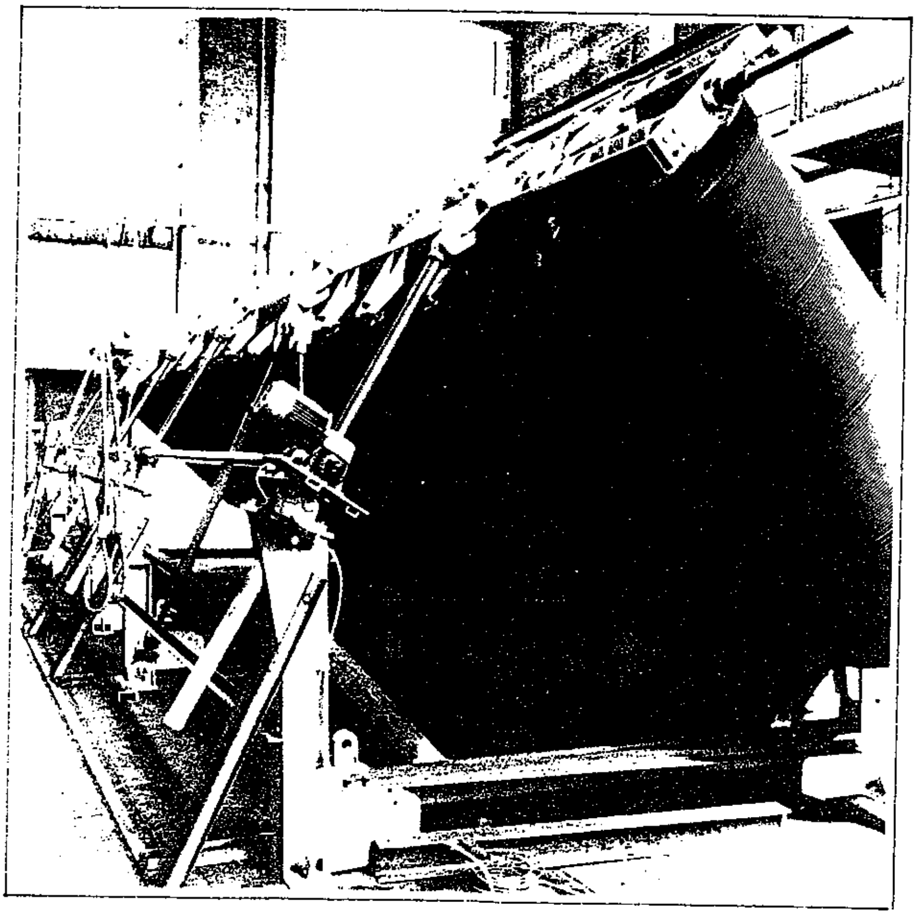


Figure 24 : Tilt angle adjustment by motorized jacking screws

Where a fixed cut point is required by the screening process, the jacking screws can be replaced by fixed supports. Even in this case the cut point can still be changed by extending or shortening the upper side supports.

The drive of the DSCS consists of a 37 kW shaft mounted gearbox, as shown in figure 25. Maintenance of the drive is normally done with the machine in the operating position. For replacement of the drive, the machine is lowered to the horizontal position to allow easy access and eliminate the need for access platforms at the working level.

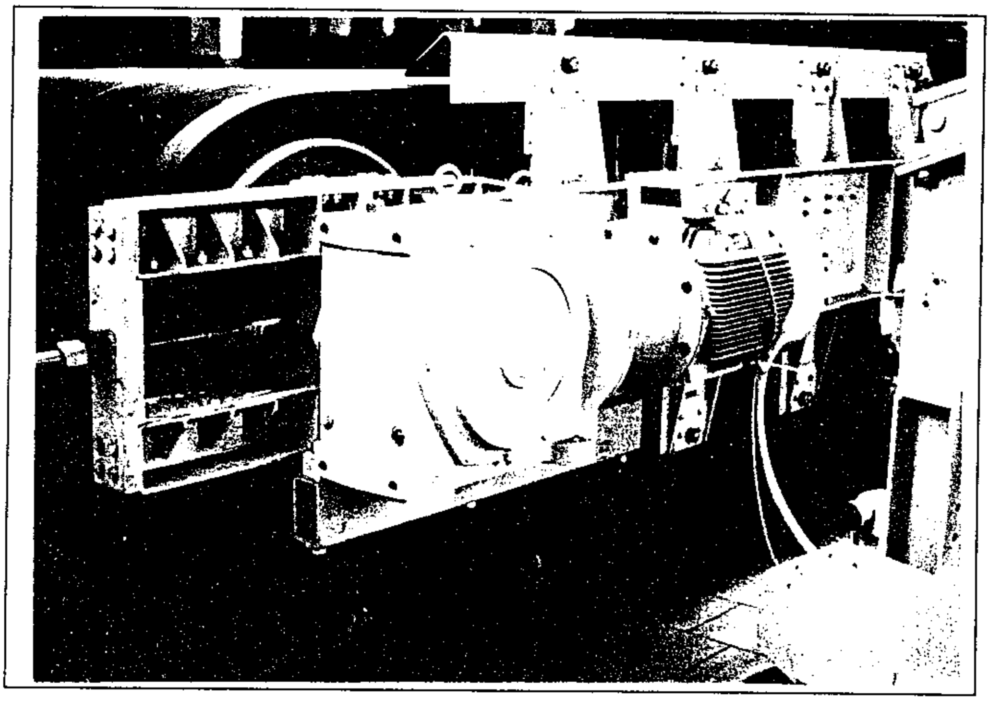


Figure 25 : Gearbox and motor arrangement

4. CONCLUSION

The successful development of the SASOL "Dry Screen Coal Separator" has opened a new screening technology and it is possible to screen dry coal down to size fractions below 6 mm.

The design of the DSCS machine allows the user to vary the cut point at which screening is done whilst the machine is running.

Because of the size of this machine, it would be difficult to retrofit it into an existing plant where space is a limitation. The machine lends itself ideally to being installed in parallel with existing conveyors, even overland conveyors due to the fact that no additional infrastructure other than electricity is required.

Apart from coal, this technology is equally applicable to any material that requires screening.

SASOL is continuously developing this screening technology ,including optimization to improve on the fines removal capacity of the belt and reducing the size of the machine.

Screening fines with moisture content above 8% does present a problem in as far as efficiency is concerned, and clogging of the grooves does take place. Development of a cleaning system for the grooves is currently being done. Because the machine is basically a conveyor we do not foresee difficulty in developing a cleaning system.

By no means is the DSCS considered as a replacement of existing screening technology, although it has definite advantages over any other technology. The DSCS is considered supplementary to existing screening systems. It can however be used as a stand alone system provided the amount of fine material in the feed does not exceed the capacity of the machine, as with any other screening system, and where only a fines cut is required. This machine does not require a prescreened feed material although it is preferred to supply a prescreened feed.