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Belt Conveyors in Bulk Terminal Applications

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9, 10 & 11 September, 1985
Landdrost Hotel
Johannesburg

The S.A. Institute of Materials Handling
The S.A. Institution of Mechanical Engineers
The Materials Handling Research Group (University of the Witwatersrand)

BELT CONVEYORS IN BULK TERMINAL APPLICATIONS

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PAPER FOR : INTERNATIONAL MATERIALS HANDLING CONFERENCE
BELTCON 3 - 9TH TO 13TH SEPTEMBER 1985

1.0 SUMMARY :

1.1 Abstract :

1.1.1 This paper will discuss belt conveyors in Bulk Terminal applications.

1.1.2 A short history of conveyor development with emphasis on harbour applications is given.

1.1.3 Examples of belt conveyors in harbour applications are outlined.

1.1.4 Single and multi producty terminals will be discussed briefly.

1.1.5 Selection of belt conveyors in terminals with the help of simulation.

1.1.6 Methods and ways to handle duff and sized coal in the same terminal.

2.0 INTRODUCTION :

2.1 History :

The most important developments in the handling of bulk solids (i.e. iron ore and coal) at the beginning of the century were the famous Brown and Hulett machines (Ref.1). The first machine appeared in 1880. The credit for the design of the first mechanical unloader to take ore or coal from the hold of a ship and deliver it, either into trucks or on to stockpiles, without rehandling is due to A.E. Brown. Twenty years later G.H. Hulett put into operation an automatic unloader which bears his name. The early machines were all driven by steam engines. At a later stage electrical and hydraulic systems were tried and finally the machines were fully electrified (Figure 1).

Another pioneer in the development of material handling equipment was Mcmyller with the design of the car dumper. These machines provided a rapid and economical way to handle bulk in the Great Lakes Region and all over the world from 1855 to 1922 and beyond. In the United Kingdom bulk handling up to 1922 was generally by means of modified short-span-man-trolley equipment as described in a paper by F.G. Smith entitled "The Mechanical Handling of Iron Ore and Similar Bulk Material" read before the Cleveland Institution of Engineers on March 6, 1922. The author dealt mainly with loading/unloading on the Clyde at Middlesborough. The use of Huletts machines like the ones in the Great Lakes Region was not favoured in the United Kingdom as British Engineers rather preferred the use of transporters. The "Temperley" transporter was introduced in 1893 by Sir William Arrow of Glasgow. This type of equipment was tried with marked

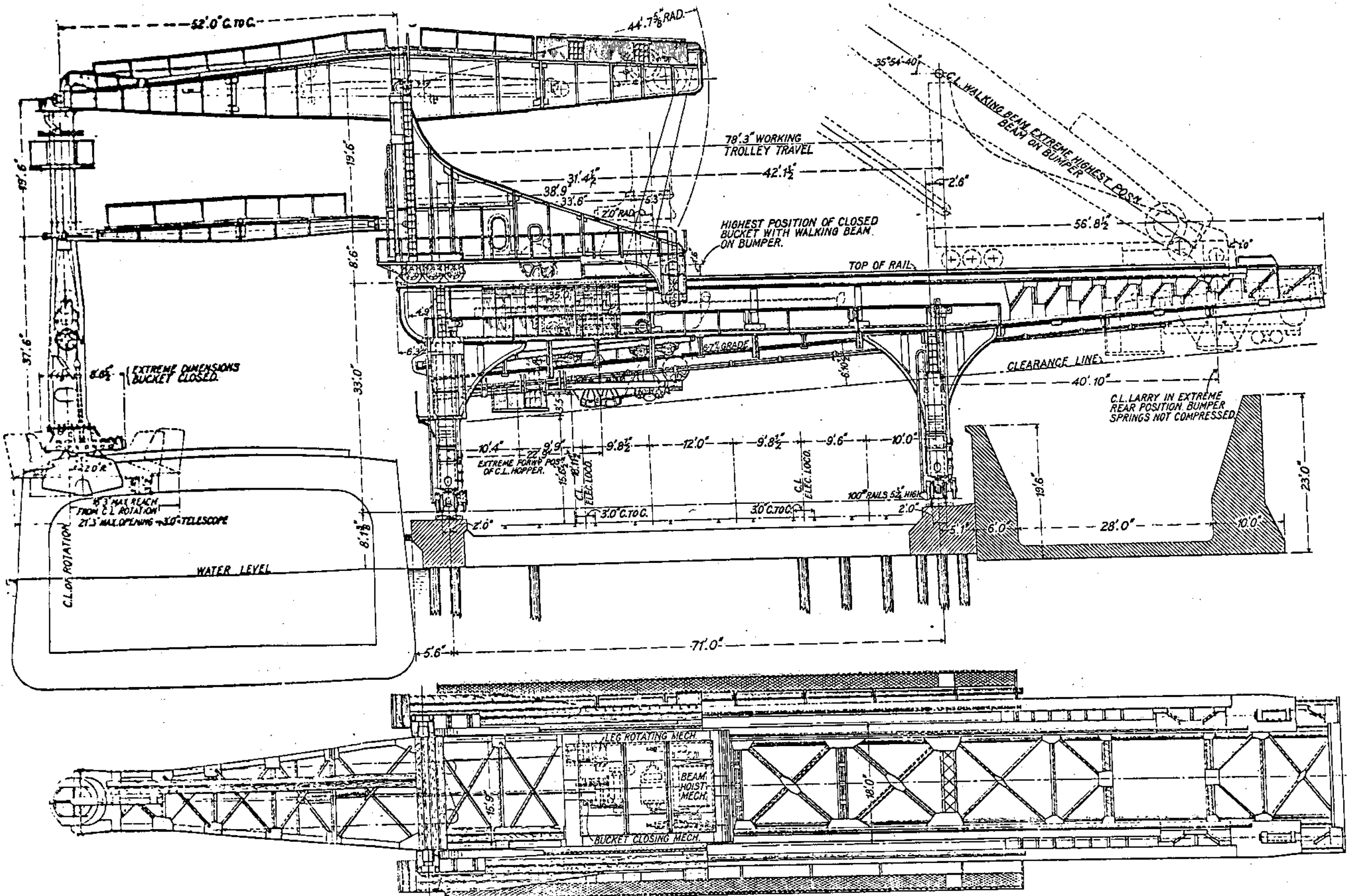


Figure 1

General Arrangement of Hulett Unloader at the Ore Dock of the Pennsylvania Company.

SOURCE: Ref 1

success by the British Admiralty. Since then, not only have these transporters been generally adopted, but they have been designed in a variety of forms; portable, radial, fixed, tower and bridge (Figure 2 and 3).

The first belt conveyors to be used in harbour applications were installed by the Mersey Docks and Harbour Board in 1868 to handle grain. The credit for the invention has been ascribed both to P.B. Graham Westmacott and to G.H. Lister (Ref. 2). Unlike many other areas of material handling, developments in the bulk conveyor field have come about very gradually. There have been no startling break throughs, instead design changes and developments have been built-up over a long period.

The first conveyors used cylindrical hardwood idlers and belts sliding in troughs (Figure 4.1).

From the 1860's to 1870's the grain industry used leather belts supported by iron bars or spreaders running over edge pulleys (Figure 4.2).

Another arrangement developed in 1875 was the spool shaped hard wood idler and wooden concentrator roll to be used at loading points (Figure 4.3). In about 1880 the Disphan idler was introduced (Figure 4.4).

The first troughing idlers employing three - equal length rolls, appeared in 1896 and were invented by Robins (Figure 4.5). These idlers were not an unqualified success. The original design utilised plain bored, cast iron, grease lubricated rolls. To ensure lubrication, separate grease cups were required for each individual roll and as can be imagined these idlers with grease cups were a sight to behold.

In the early days of the belt conveyor the ball bearing was not available in sufficient quantities and at a low enough price to allow its use in troughing idlers, with the consequence the plain bearing idler was largely used. Naturally, friction losses were a very important consideration on long conveyors and where large tonnages were being handled. For example, the use of ball bearing equipment instead of plain bearing decreases the power consumption by 66% depending upon the quality of the equipment and maintenance. The first designers tried other methods to reduce heavy friction losses by increasing the diameter of the roller to 150, 178 or even 200mm.

The first belts were constructed in the following categories; rubber belts, balata belts, stitched canvas belts, cotton belts or steel belts. The belts were specially made to the specifications of different belt conveyor manufacturers (i.e. Jeffrey Robins, Linkbelt, Sutcliffe, etc.). For example, in belts used by the Robins Conveyor Company, the flexibility of the central portion of the belt was increased by stripping off some of the plies of duck at varying distances from the edge and by substituting a thicker layer of rubber for the missing duck. For belts of this construction the designers claimed greater flexibility which would enable the belt to conform more readily to the troughing shape of the idlers and increase life due to the thicker layer of rubber at the place of maximum wear.

The belts used in the Mersey Docks were two plies of canvas with a facing of rubber as covers.

The turn of the century saw belt conveyors being more and more accepted by industry.

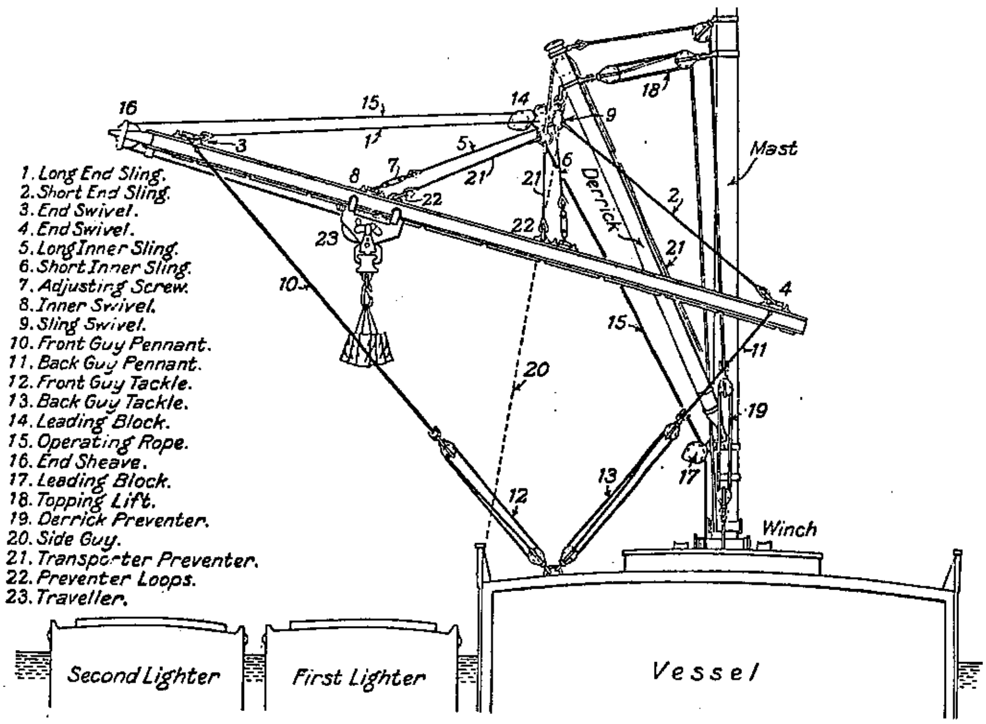
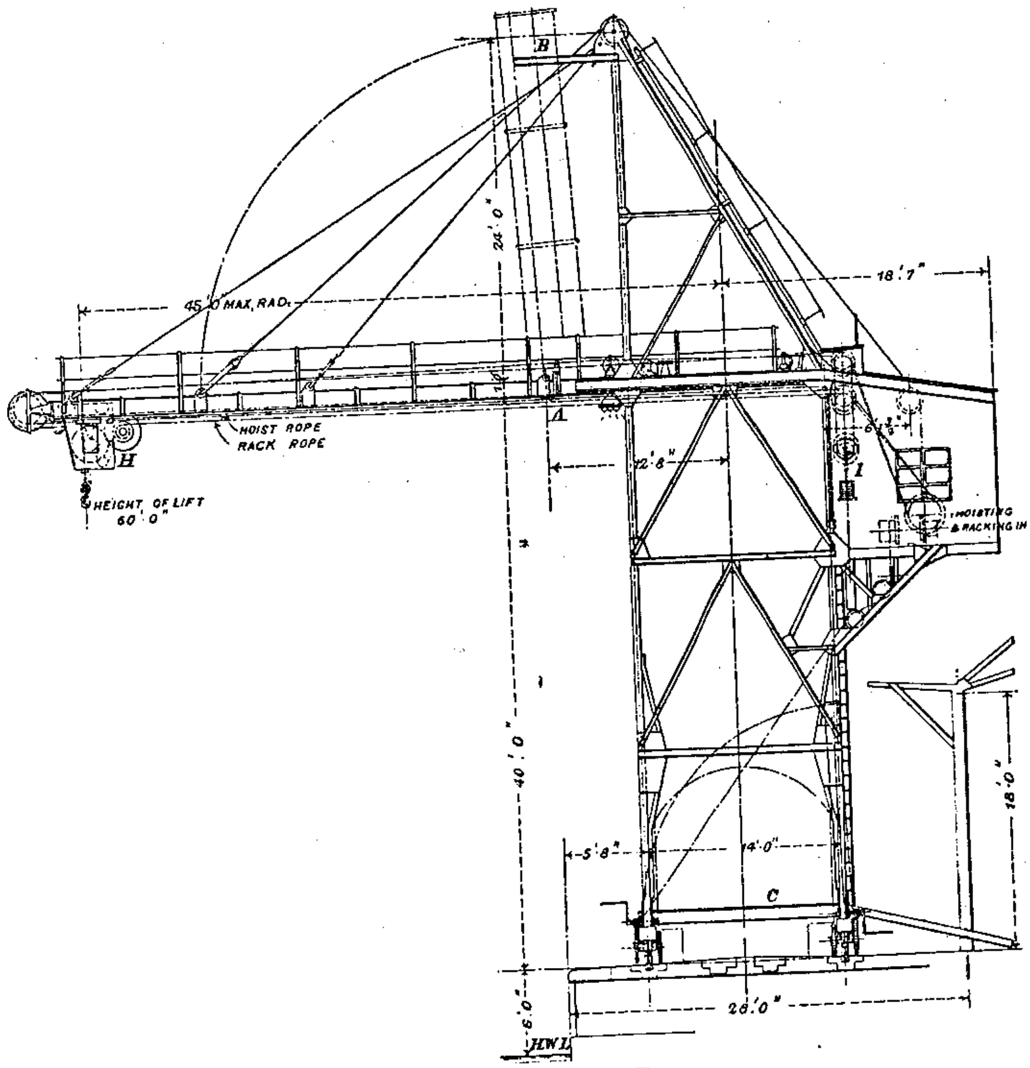


Figure 2 PORTABLE TRANSPORTER. SOURCE: Ref. 1



"Barry" Single-beam Transporter.

Figure 3

SOURCE: Ref. 1

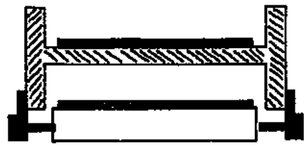


FIG. 4

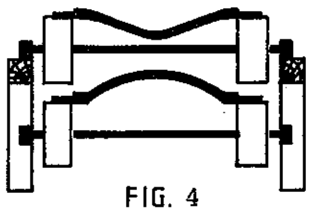


FIG. 4

FIG. 4

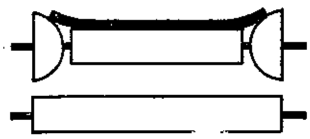


FIG. 4

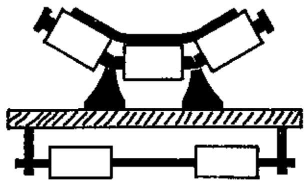


FIG. 4

The First Idlers

Figure 4

SOURCE: Robins

During 1902 the first conveyors were installed in South Africa and duly reported upon by the Commissioner of Mines in the Transvaal Chamber of Mines thirteenth report for the year 1902 as follows :

> "During the past year machine drills have been employed to a large extent, for stoping, and belt conveyors have for the first time, I believe in this country, been used where the angle of the reef is insufficient to permit the ore being readily shovelled down to the boxes, and where the stope itself is too narrow to allow trucks to be used. Belt conveyors have also been introduced for the transport of ore from the crusher station to the battery and at other places on the surface of the different mines". However, although primitive the first really conveyor belt to be installed in South Africa was a sorting belt consisting of six widths of ordinary 6 inches by 7/8 inches flat hoisting rope fastened together by clamps, the whole being heavily tarred and pitched. This belt was introduced by Sidney Farrar at Kleinfontein in 1894 (Ref. 5).

Prior to 1905 all belt conveyors were single pulley driven. In that year Richard Sutcliffe invented the coal face belt conveyor incorporating the first tandem drive (Ref. 2).

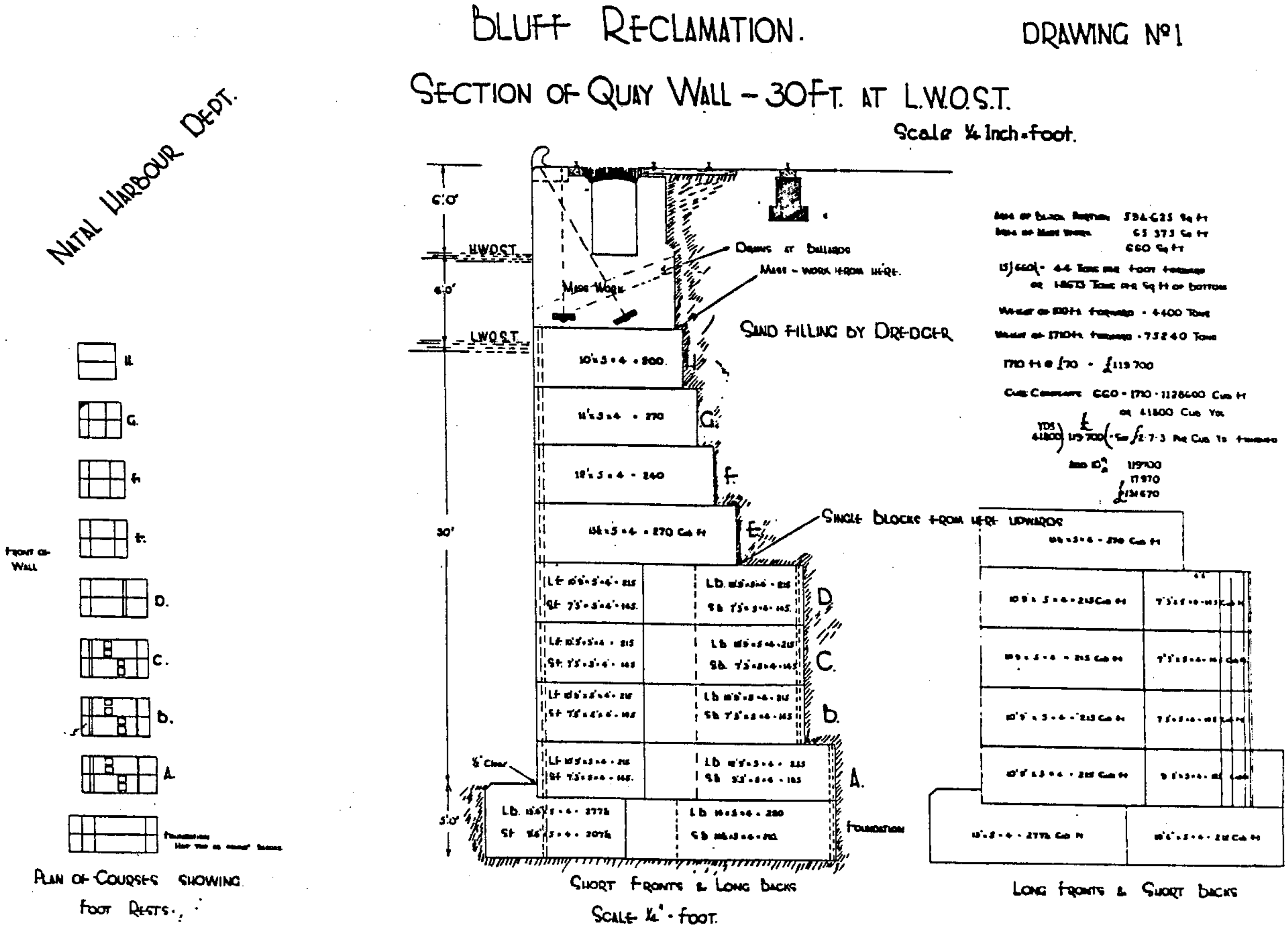
By the end of the first decade conveyors had been accepted as an economical method of handling a great variety of materials, either in bulk or in packages. During the discussions which followed the reading of W. Dixon and C.H. Baxter's paper on "Modern

Electrical Dock Equipment, with special reference to Electrically Operated Coal Hoists" (Ref. 4), Roger T. Smith stated that the belt conveyor possessed the following advantages over the hoist mechanism in the shipment of coal :

> "For the same capacity the initial cost of the conveyor is from a quarter to half the initial cost of the hoist.
>
> The load factor at which the machine works is 80 to 90 per cent because the maximum load is the same as the average load.
>
> There is a greatly reduced weight on the tower supporting the free end of the conveyor (which rises and falls) as compared with the weight of the hoist, thus lessening the cost of foundations of the jetty, if a jetty is necessary.
>
> There is a possible saving in land for sidings, because instead of all the sidings having to come end-on, as is necessary for the hoist they are much better arranged parallel to the quay; and
>
> There is an enormous reduction in the maximum demand on the power supply.
>
> The electrical machinery and control gear are of a more simple character for the conveyor than for the hoist.

> The mechanical equipment is less complicated for the conveyor than for the hoist, and rope maintenance is eliminated".

The above statements were fully scrutinised by planners and harbour engineers and, reinforced by the results achieved at Port Talbot, Parkeston Quay, Middlesborough, Durban and Baltimore. The results changed the future layout of harbours dramatically. Since then belt conveyors have had no rivals.



SCALE

Figure 5

SOURCE: S.A.T.S

13-3-'37. TRACED FROM PLAN DRAWN IN 15-1-'04.

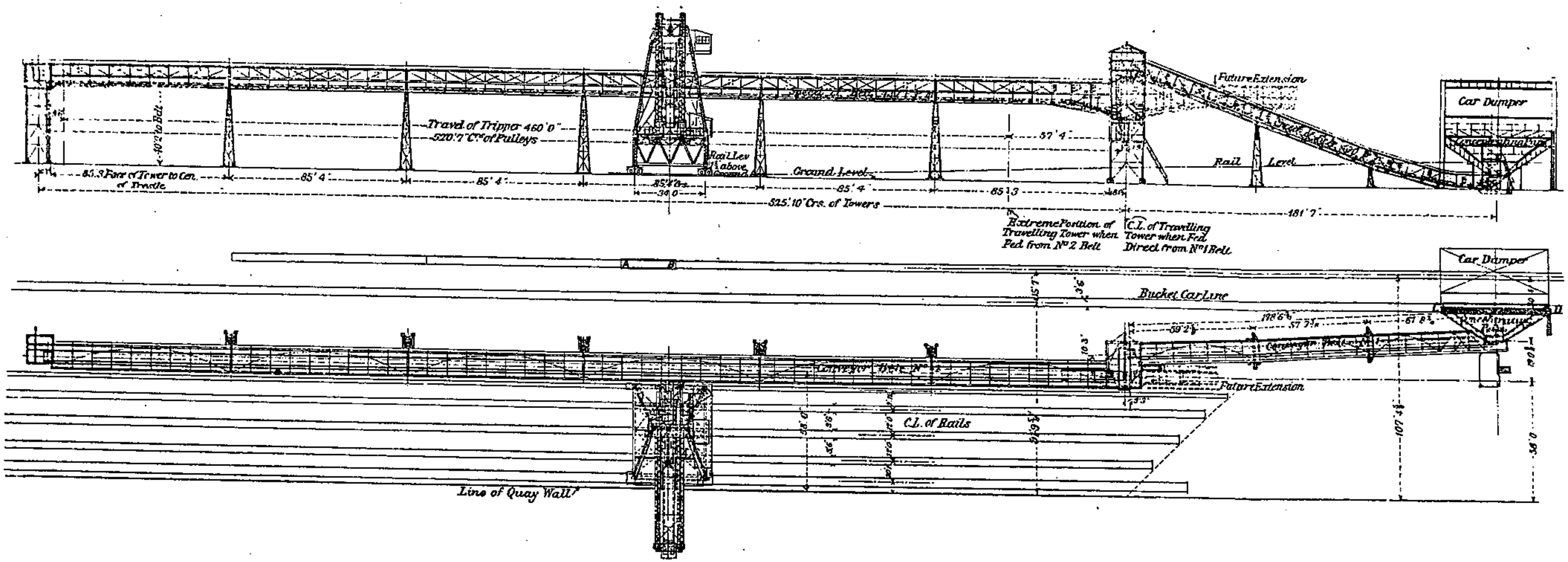
3.0 BELT CONVEYORS IN TERMINAL APPLICATIONS :

As mentioned earlier the first belt conveyor to be used in harbour applications was installed in 1868 to handle grain. Since then there has been a steady increase in utilisation of belt conveyors in different industries and in 1911 the merits and disadvantages of the belt conveyors were already fully established. Table 1, which is far from complete, gives some idea of the development of belt conveyors in harbour applications.

The first harbour installations with belt conveyors in South Africa were at the Durban Coal Appliance and the grain elevators of Durban and Cape Town.

The quay construction of Durban Bluff is traced back to 1904. Drawing no. 1 of the Bluff reclamation section of quay wall was drawn on 15-01-1904 and is an amazing record of history and engineering ingenuity (Figure 5).

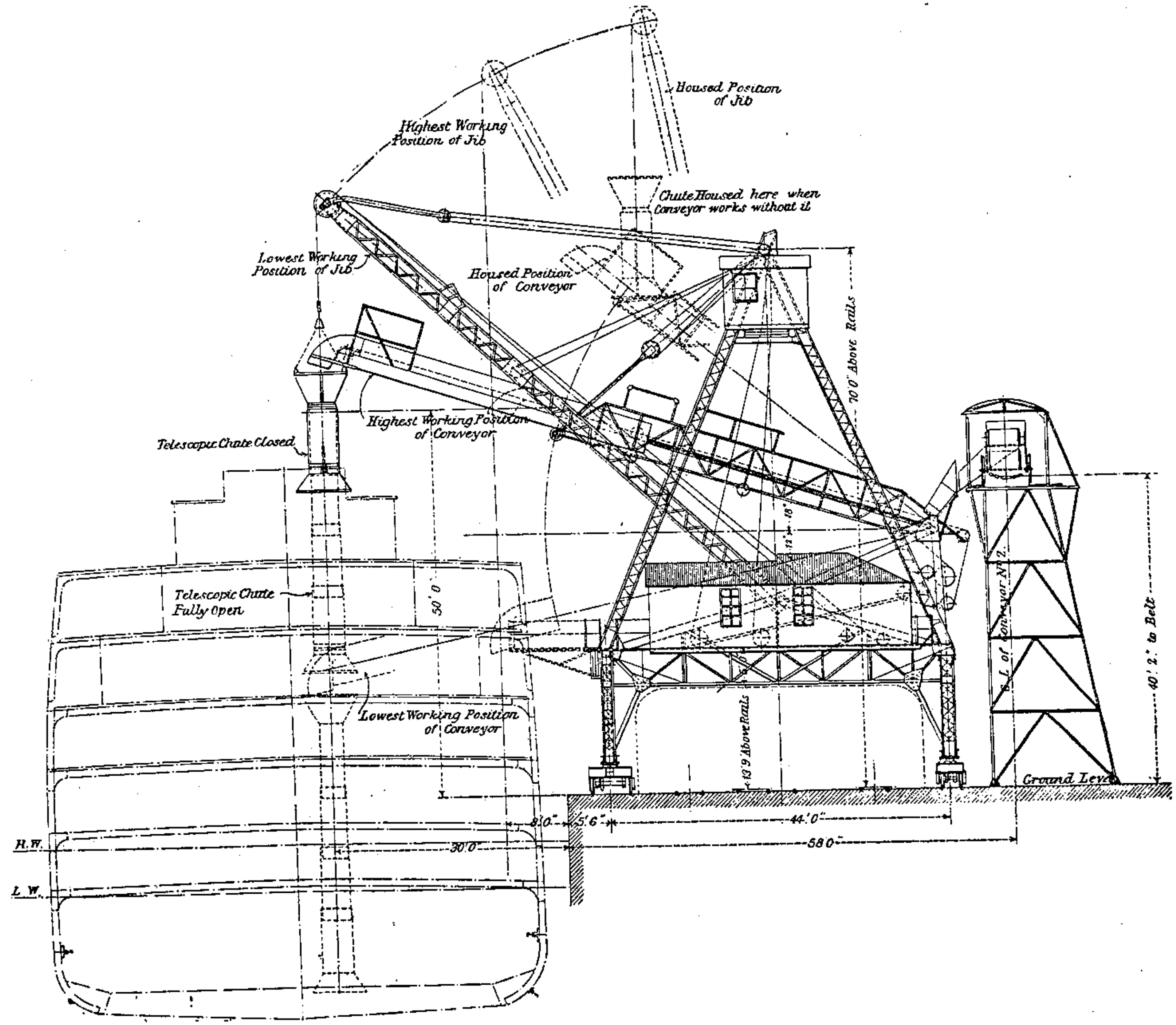
The first installation of a material handling system at the Bluff is traced back to 1914. Figure 6 depicts the first installation at the Bluff. This installation was completed in 1917 at a cost of nearly 50 000 pounds, excluding the cost of the foundations, and was erected by Roger T. Smith. The dumper was a McMyller machine designed to handle single 75 ton trucks (short tonnes) or two shor trucks in tandem. This machine is still in operation. Two conveyors were provided (C1 and C2). The conveyors were based on 1200 belt width, 20 degrees troughing and were able to load coal at any rate between 200 tonnes and 800 tonnes per hour. The speed of the belt when dealing with 200 tonnes per hour was 0,6m/second, and when dealing with 800 tonnes was 3,0m/second. For the first time a shiploader was used to load coal (Figure 7). This particular shiploader has only recently been scrapped.



ARRANGEMENT OF COAL-HANDLING PLANT AT DURBAN.

Figure 6

SOURCE: Ref 1



Travelling Tower supporting Telescopic Belt Conveyor.

Figure 7

SOURCE: Ref 1

The grain elevator system for South Africa was approved by the government in 1919 and W. Little-John Phillip was appointed as consulting engineer to report upon the location and design of different grain elevators. The two port elevators were located at Durban and Cape Town.

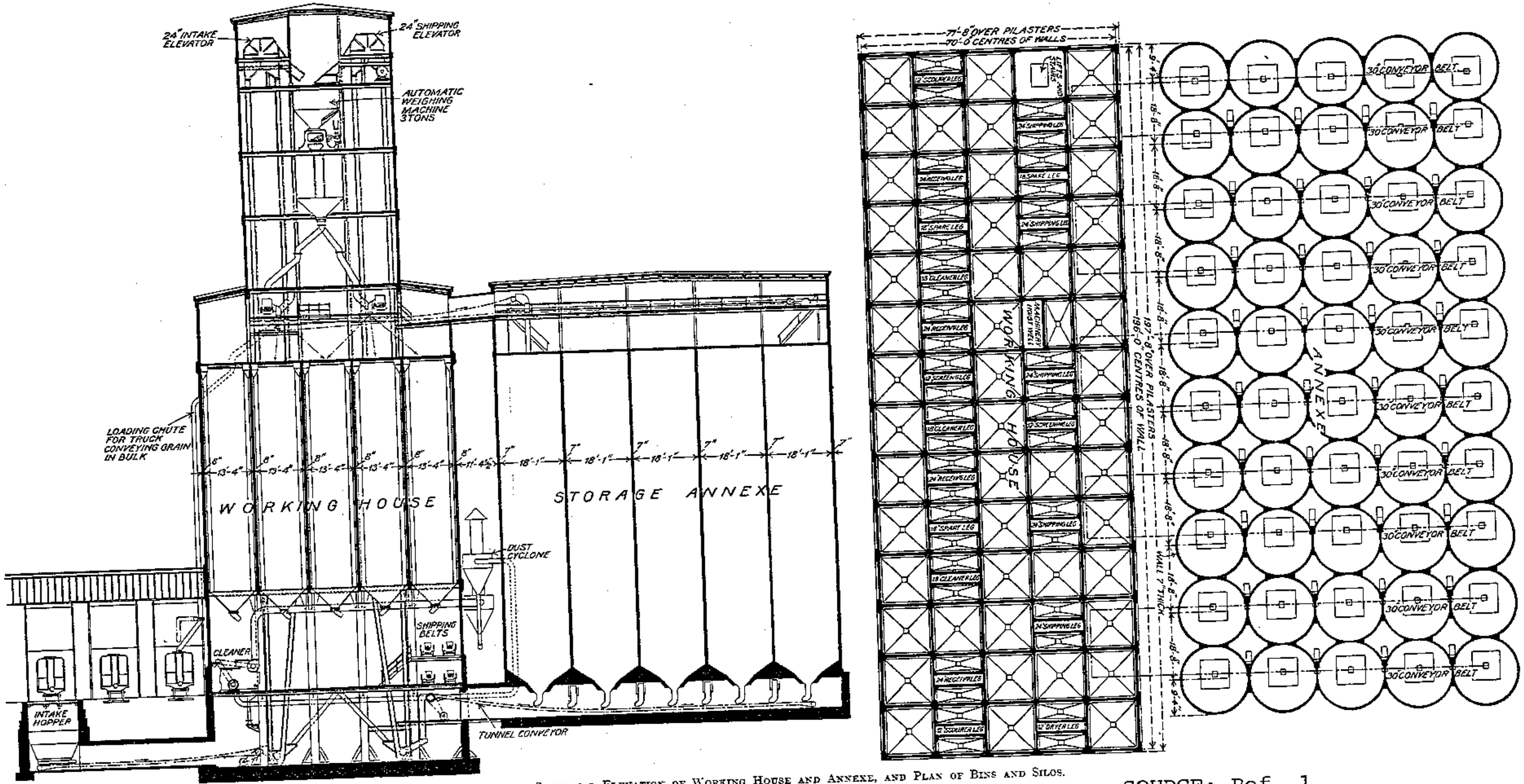
The Durban grain elevator (Figure 8) has a storage capacity of 42 000 tonnes and the Cape Town elevator (Figure 9) has a capacity of 30 000 tonnes.

Each of the port elevators consists essentially of a truck shed, working house, storage annexe and drive house. Galleries for weighing and improving the grain by cleaning, scouring and drying are also included. The main function of the port elevators is to receive grain from railway wagons, to handle and store grain, and to load it into ships as required.

The new generation of bulk handling facilities in South Africa started with the Port Elizabeth iron ore terminal in 1963 and the multi purpose Clean Bulk Terminal in Richards Bay in the early 70's. The beginning of the age of the super terminal in South Africa started with the construction of Saldanha Bay by Iscor in June of 1973.

In April 1976 Richards Bay Coal Terminal opened for traffic. Today with the Phase III Expansion Project complete it is the largest coal loading facility in the world.

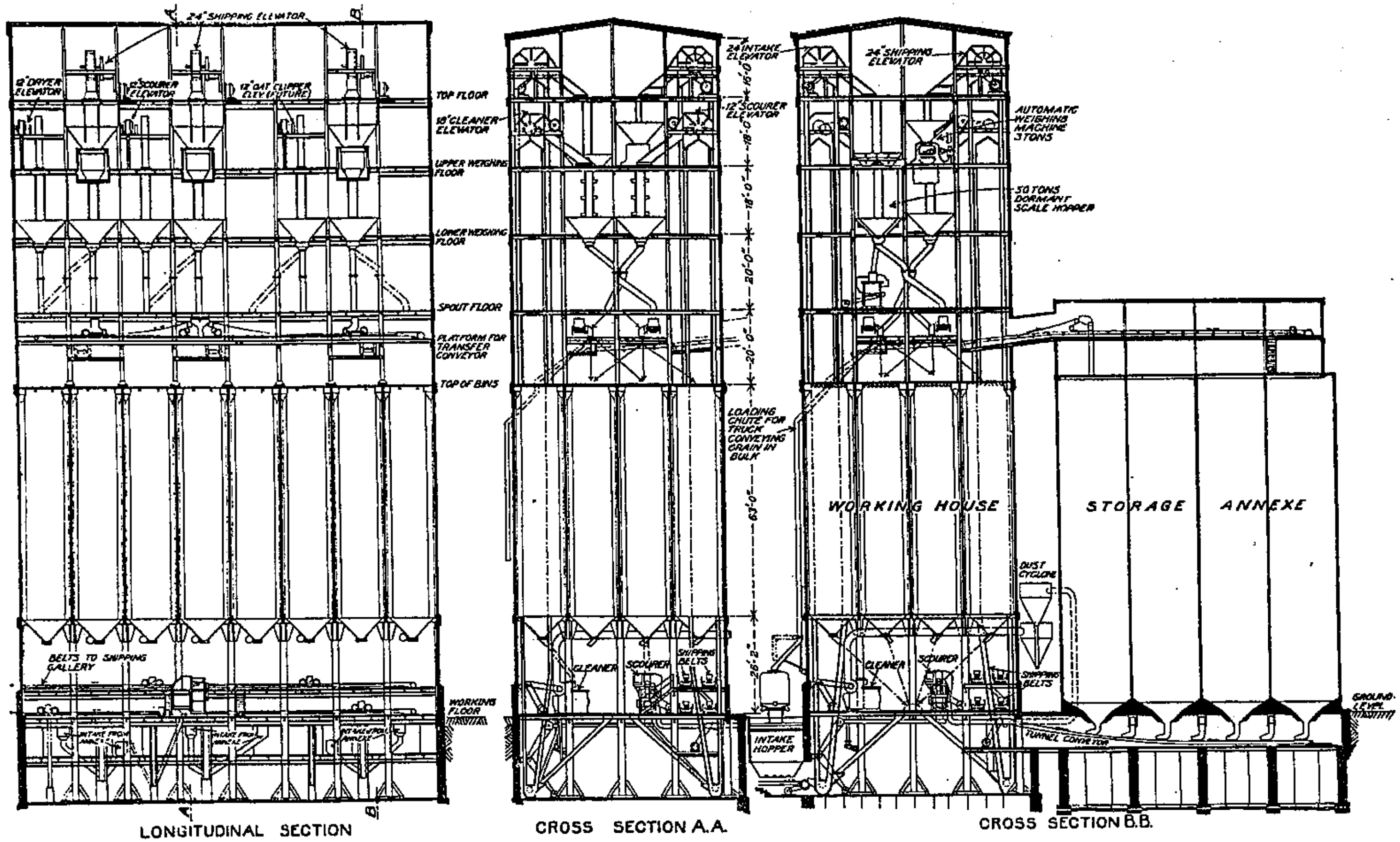
Table 2 shows loading/unloading facilities categorised by product and handling rate worldwide. No differentiation is made in the type of handling. From the table can be seen, as an example, that 51% of harbours handling coal have handling rates between 1000tph to 3000tph.



—Sectional Elevation of Working House and Annexe, and Plan of Bins and Silos.

SOURCE: Ref. 1

Figure 8



SECTIONAL ELEVATIONS OF ELEVATOR AT CAPETOWN.

Figure 9

SOURCE: Ref. 1

TABLE 1

Name of Terminal	Product Type	Belt Width	Belt Speed	Belt Length	Capacity Tonnes/ Hour	Troughing Idlers	Return Idlers	Belt Type	Motor Used KW	Year	Annual Through-put	Publica-tion
Clyde Trustees Elevator at Meadowside	Grain	550 400 750 700	2,54 2,54 2,54 2,54	29 14 74 42	250 250 250 250			6 ply 4 ply		1915		Ref.
The Baltimore and Ohio Rail Road Company at Curtis Bay - USA	Coal	1500 1500 1500	2,54 1,27 1,91	213 213 213	2500					1917	12	Ref.
Granary at Sydney Australia	Grain Maize	900			1210					1921		Ref.1
Terminal Elevator at Durban	Grain Maize	750	3,56		250			Canvas	45	1921		
Terminal Elevator at Cape Town	Grain Maize	750	3,56		250			Canvas	45	1921		Ref.1
Elevator at Manchester Ship Canal	Grain	600 750	4,06 4,06	156 156	200 200			Canvas				Ref.1
Elevator at King George Dock, Hull	Grain	650	2,79		150			Canvas 6 ply				Ref.1
Thunder Bay Terminal - USA	Lignite	2000 1200	3,8	1071 1994	3630 3630	35			1 x 447 1 x 150	1978	2,7	Ref.
Kembla Coal Terminal - Australia	Coal	2200 1600 2200	4,5 5,37 4,4		6000 5700 9600	35				1981	15	Ref.
Dalrymple Bay Coal Terminal Australia	Coal	1800 1600 1600 1600 1600 1600 1600 2500 2500 2500 2000 2000 2500	3,28 4,93 4,93 4,93 4,93 4,93 4,93 4 4 716	35 650 750 1400 1300 1300 1300 270 240 29 3700 320 80	3600 3600 3600 3600 3600 3600 3600 8000 8000 3300 6600 6600 6875	35 35 35 35 35 35 35 35 35 35 35 35 35	Flat Flat Flat Flat Flat Flat Flat Flat Flat Flat Flat Flat Flat	Fabric Fabric Fabric Fabric Fabric Fabric Fabric Fabric Fabric Steel Steel Fabric Fabric	45 2 x 375 2 x 375 2 x 375 2 x 375 2 x 375 2 x 375 2 x 300 2 x 560 1 x 260 4 x 750 2 x 260 1 x 350	1985		Ref.7
Kooragang Island Coal Loader - Australia	Coal	2000 2200 2500 1400 3200	5,0 5,0 5,0 4,5 1,5		6600 8000 10500 2500 6600						15	Ref.16
Port Talbot U.K	Coal	1050		63	700					1910/14		Ref.1
Parkeston Quay UK	Coal	750		128	250					1910/14		Ref.1

Name of Terminal	Product Type	Belt Width	Belt Speed	Belt Length	Capacity Tonnes/ Hour	Troughing Idlers	Return Idlers	Belt Type	Motor Used KW	Year	Annual Through-put	Publica-tion
Middlesbrough UK	Coal	1050		94						1910/14		Ref.1
Durban Bluff South Africa	Coal	1200 1200	3 3	70 160	800 800	20° 20°	Flat Flat	Canvas 10 Ply Canvas	45 45	1917 1917	2	Ref.4
Haldia Port India	Coal	1400 1200	3,3 2,7		2000 1100	35° 20°		Nylon Cotton		1979	2,10 Future 3	Ref.9
Mormugao Harbour India	Iron Ore	1200	3,5		2500 4000	35°				1959	10	Ref.10
Eastern Harbour Dunkirk, France	Coal/ Iron				4500 1500					1982	6,1	Ref.11
Western Harbour Dunkirk, France	Coal/ Iron				4000 1700					1982	3,5	Ref.11
Westshore Terminal	Coal/	1830 2440 2130	5,1 5,1 5,1	9000 7000	6500					1982	22	Ref.12
Cape Lambert Australia	Iron Ore				6000							Ref. 13
Dampier Australia	Iron Ore				7500							Ref. 13
Port Holland Australia	Iron Ore				1000							Ref.13
Port Latta Australia	Iron Ore				5000							Ref.13
Yampi Point Australia	Iron Ore				3000							Ref.13
Bowen Australia	Coal				6600						15	Ref.13
Gladstone Auckland Barney Clinton Australia Hay Point Australia	Coal Coal				 1600 1100 4000 10000						 5 8 10 20	Ref.13 Ref.13
Newcastle - Carrington - PWCS Loader - Koorangang	Coal/				 2x1000 3x2500 10500					1981	28 15	Ref.13/14
Mauritius Bulk Sugar Terminal	Sugar	1200			1440					1980		Ref.17

Name of Terminal	Product Type	Belt Width	Belt Speed	Belt Length	Capacity Tonnes/ Hour	Troughing Idlers	Return Idlers	Belt Type	Motor Used KW	Year	Annual Through-put	Publica-tion
Leith Coal Out-loading Port England	Coal/	1220 1330 1800	3,05 2,38 0,51		1500 1500 1500					1977		Ref.18
Hadera Israel	Coal	1500 1200	3,3		3000 4000					1983		Ref. 19
Batangas Coal Terminal Phillipines	Coal	1200									1,5	Ref. 20
Europoort West Germany	Iron Ore	1400	2,62		5100	30°	15°	ST1600 EP800/4	160/45	1970	18	Ref.21
Sept-Iles Canada	Iron Ore				7600 4000 4000					1971	32,5	Ref.22
Roberts Bank Canada	Coal	1800	4,57		4000					1971		Ref.23
Ore and Coal Terminal at Hunterston Ayrshire, Scotland	Iron Coal	1400 1600 1400 1600 1400 1600 1600 1400 1600 1400 1400 1400 1400	3 3 3 3 3 3 3 3,1 3,1 3 3 3,1 3,1	430 388 1212 1222 405 344 30 932 930 86 61 632 440	5000 8000 5000 8000 5000 8000 8000 5000 8000 5000 5000 5000 5000			Fabric Fabric S/cord S/cord Fabric Fabric Fabric Fabric S/cord Fabric Fabric Fabric S/cord	2x370 2x370 2x910 2x1155 2x370 2x445 1x185 2x605 3x1035 206 185 2x530 3x1155	1977	4 Iron 1 Coal	Ref.24
Matola Ore Terminal - Australia	Iron Ore/ Coal	900 900	2,54 3,35		3000 3000							Ref.25
Port of Tyne U.K.	Coal	1400	4,5		2800			4 ply		1985	4	Ref.26
Puerto Bolivar Columbia	Coal	2400			10000					1986		Ref.27
Saldanha Bay S.A.	Iron/ Ore	1659	4		8000					1973	18,5	
Richards Bay Coal Terminal	Coal	1800 2200 2500	5,3 5,9		6000 10000/ 12000					1976 1984	12 44	
Richards Bay Clean Bulk Terminal	Various	1350 1350	3,3 2		2500	35	Flat	Fabric		1979	18	

TABLE 2 - Loading/unloading facilities categorised by product and handling rate

Product	World Traffic 1983	Up to 1000		2000		3000		4000		5000		6000		7000		8000		Above	
		Ports	%	Ports	%	Ports	%	Ports	%	Ports	%	Ports	%	Ports	%	Ports	%	Ports	%
Iron Ore	270	16	10	58	38	35	22	11	7	6	4	11	7	2	1	6	4	8	7
Coal	201	11	20	12	22	5	9	9	16	4	7	5	9	3	5	4	7	2	5
Grain	199	111	58	59	31	15	8	5	2	1	1	-	-	-	-	-	-	-	-
Bauxite Alumina	42	44	62	21	30	2	3	3	4	-	-	-	-	-	-	1	1	-	-
Rock Phosphate	37	21	-	14	-	9	-	1	-	1	-	-	-	-	-	-	-	-	-

4.0 SINGLE AND MULTI TERMINALS (REF. 3) :

Bulk terminals can be split into those which handle a variety of different bulk materials, and those which handle similar materials from a mine or different mines i.e. single and multi-product terminals. Furthermore, the necessity to provide storage facilities in the terminal in order to optimise both rail and ocean transport to and from the terminal often necessitates complex systems allowing for the rapid changing from one conveying route to another.

As will be seen from the preceeding sections, the development of bulk terminals in South Africa has taken place over a period of sixty years, the most recent of which incorporate conveyor systems which are amongst the most modern and complex in the world. The differing characteristics of single and multi-product terminals will be considered further by way of examples.

4.1 Single Product Terminals :

Richards Bay Coal Terminal, with a current capacity of 44mtpa and ongoing planned expansions to 65mt, is the largest coal export terminal in the world. While it is designated a single product terminal insofar as the handling and storage characteristics of the various exporters coal is similar, it nevertheless has to cater for approximately sixty different grades of coal in separate stockpiles.

Coal is received 24 hours per day in 200 wagon trains at Richards Bay with either a single grade or multiple grades per train. The trains are split into 100 wagon rakes in the terminal. Tipplers with a maximum capacity of 6 000tph are selected for this duty, matched by stacking conveyor systems of a similar capacity.

Phases 1 and 2 of the terminal, initiated approximately ten years ago, utilised the system of bifurcating chutes to divert the stream from one stockpile area to another during grade changes. Phase 3 of the terminal now incorporates the more flexible moving head principle, allowing shorter times between re-routing within the terminal.

Due to the nature of the tipplers installed, the conveyor system to stockpile may be regarded as having a reasonably constant rate. The reclaim system utilising slewing bucket wheel reclaimers is subject to far wider fluctuations in capacity as the machine moves through the stockpile reclaiming at its maximum rate in the centre portion, with reduction in reclaim rate at the extreme edges. Furthermore, reclaim rate is affected by the size and capacity of the stockpile.

The reclaim conveyor system, therefore, has to cater for far greater changes in capacity than the stacking system. Shiploaders with a capacity of approximately 10 000tph are utilised necessitating a combination of at least two reclaimers per shiploader.

The large number of conveyors associated with a terminal of this magnitude necessitates a sophisticated control system to set up the chosen routes in the minimum time, in order that a high average throughput can be maintained.

High capacity systems such as these require careful analysis of all components including tipplers, stackers and reclaimers, in order to optimise the conveyor capacity, and computer simulation is invariably the only reliable tool to demonstrate the effectiveness of the chosen design and the response of the system as a whole.

4.2 Multi Product Terminals :

An example of a multi product terminal is the South African Transport Services Clean Bulk Terminal at Richards Bay (Figure 11). Designed originally to handle 21 different products, each with their own differing grades and a total combined import and export tonnage of 18mt per annum, this terminal ranks as one of the most complex in the world.

Conveyor systems in such a terminal have to cater not only for the ease of route selection and the fluctuating load condition outlined above, but also for the different flow characteristics and bulk densities of the many materials concerned. Furthermore, the necessity to reduce cross contamination between products dictates sophisticated transfer and belt conveyor clean up systems.

From the outset the terminal was designed incorporating the moving head principle to economise both on power consumption and conveyor belt cost and permit rapid changeover of conveyor routes. Due to the complexity and large number of conveyors, it would have been virtually impossible to use the rather old-fashioned bifurcating chute system. Bulk densities range from 250Kg/m^3 for wood chips, up to 3 000Kg/m^3 for rutile and zircon. Belt conveyor systems such as these, handling a wide variety of different products from vessel to terminal storage and/or train loading, and an even wider variety arriving at the terminal by train into intermediate storage and/or combined reclaim from storage into vessel, require a minimum response time in setting up or changing the route. The plant incorporates a central control system with computer backup to carry out these functions. It was recognised that the design of the system would have to cater for the material with the highest bulk

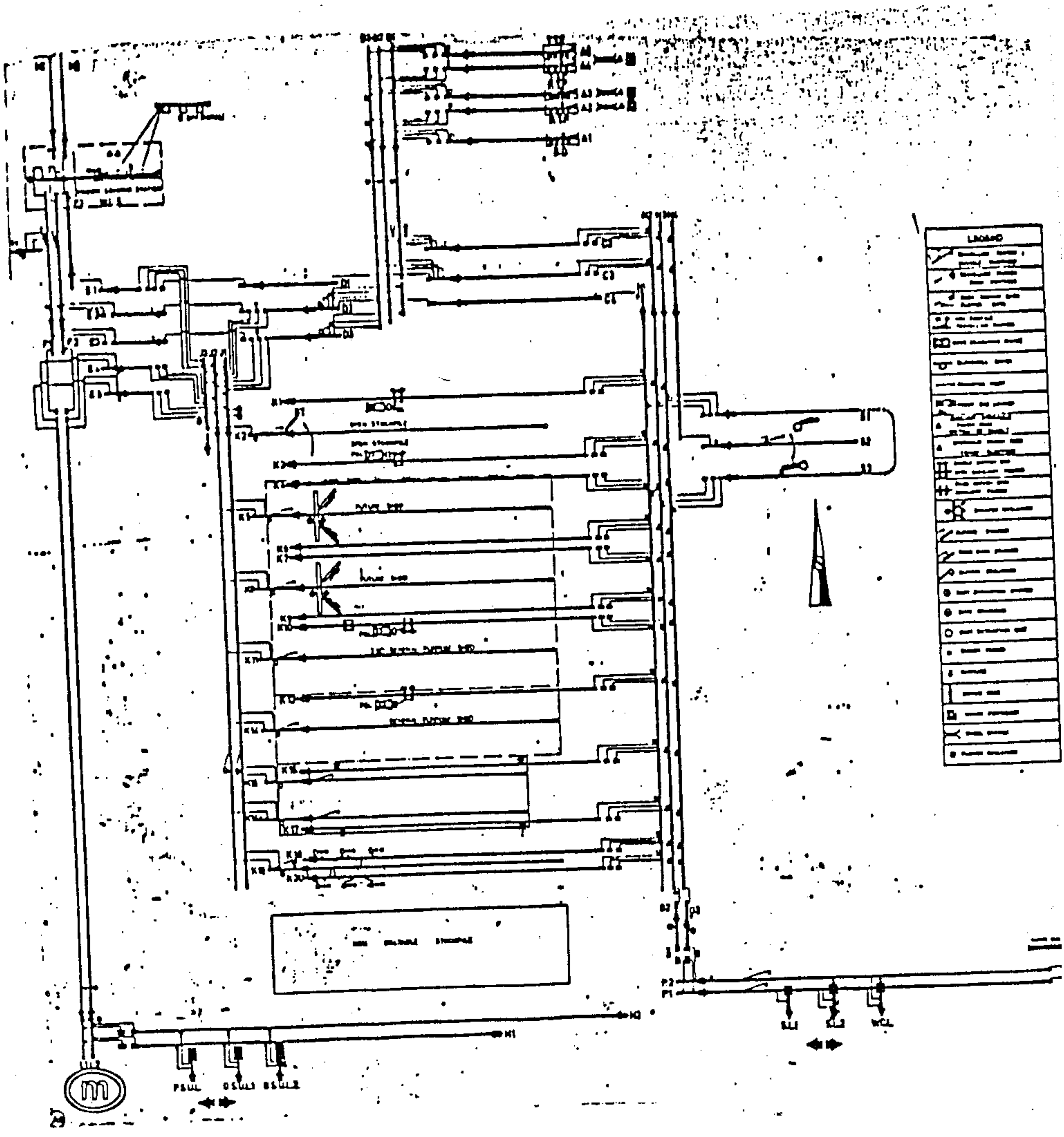


FIGURE 11

SOURCE: SATS.

density as far as power consumption was concerned, and that the conveyor speed and conveyor chute designs would have to take cognizance of the varying characteristics of all materials. In essence, the system becomes a volumetric system with sufficient reserve power to cater for the high density materials and relatively slow conveyor speeds of about 2m/second dictated by material characteristics.

From the above two examples, it will be seen that the specification of the conveyor duty is of primary importance in the design of a bulk terminal conveyor system. Thereafter designing of a sufficiently flexible system with minimum response times in setting up conveyor routes or changing them is vital to the efficiency of the Terminal as a whole.

Equipment such as stackers, reclaimers, shiploaders etc., in a modern bulk terminal are major items costing millions of Rands each. It is necessary therefore, to optimise the design of the terminal including the conveyor system to ensure that the initial capital investment is minimised without sacrificing flexibility.

During the life of a terminal of say, twenty to thirty years, market conditions will change, leading to changes in parcel sizes, storage requirements etc., all of which should be foreseen as far as possible in the original concept. The use of multi purpose machines, such as stacker/reclaimers, to achieve a relatively small cost saving when compared with single purpose machines, must be carefully considered to ensure that flexibility is not reduced to the level where minor changes in market would result in the terminal's inability to handle traffic efficiently.

Computer simulation is a valuable tool in this exercise provided it is borne in mind that the information given by the client relating to the intended terminal usage is more than likely to be the most inaccurate part of the simulation excercise. Seemingly tempting solutions such as stacker/reclaimers may in the long run prove to be too inflexible. A recent study carried out on behalf of the Independent Coal Producers Association for a proposed 20mtpa coal export terminal at Richards Bay is a good example of this philosophy (Figure 12).

The proposed terminal is required to handle 20mtpa in parcels averaging 30 000t from a large number of smaller mines in approximately 30 different grades. Coal will arrive at the terminal in 100 wagon trains, and be loaded into vessels ranging in size from 25 000t to 150 000t. Taking into account demurrage on rail traffic and ships, it was found to be more economical and efficient to design the terminal on the basis of dedicated stackers and reclaimers as opposed to the seemingly cheaper alternative of combined stacker/reclaimers.

The dedicated machines allow matching of the tipplers, conveyor system and the stackers themselves, all of which can operate according to the dictates of the arriving rail traffic with little or no interference from the reclaim system. Similarly it is possible to match the reclaim system including reclaimers, conveyors and shiploaders, to achieve optimum utilisation of the equipment.

The flexibility of the system allows rapid change to accommodate different incoming grades and allow shiploading at either 4 500tph utilising a single circuit or 9 000t utilising two reclaim circuits simultaneously.

Capital cost for the equipment and the conveyor system is somewhat higher than dedicated stacker/reclaimers would be. This is more than offset by the simplified overall plant layout and reduction in train handling time which leads directly to a simplification in the rail yard serving the terminal, not to mention operating simplicity.

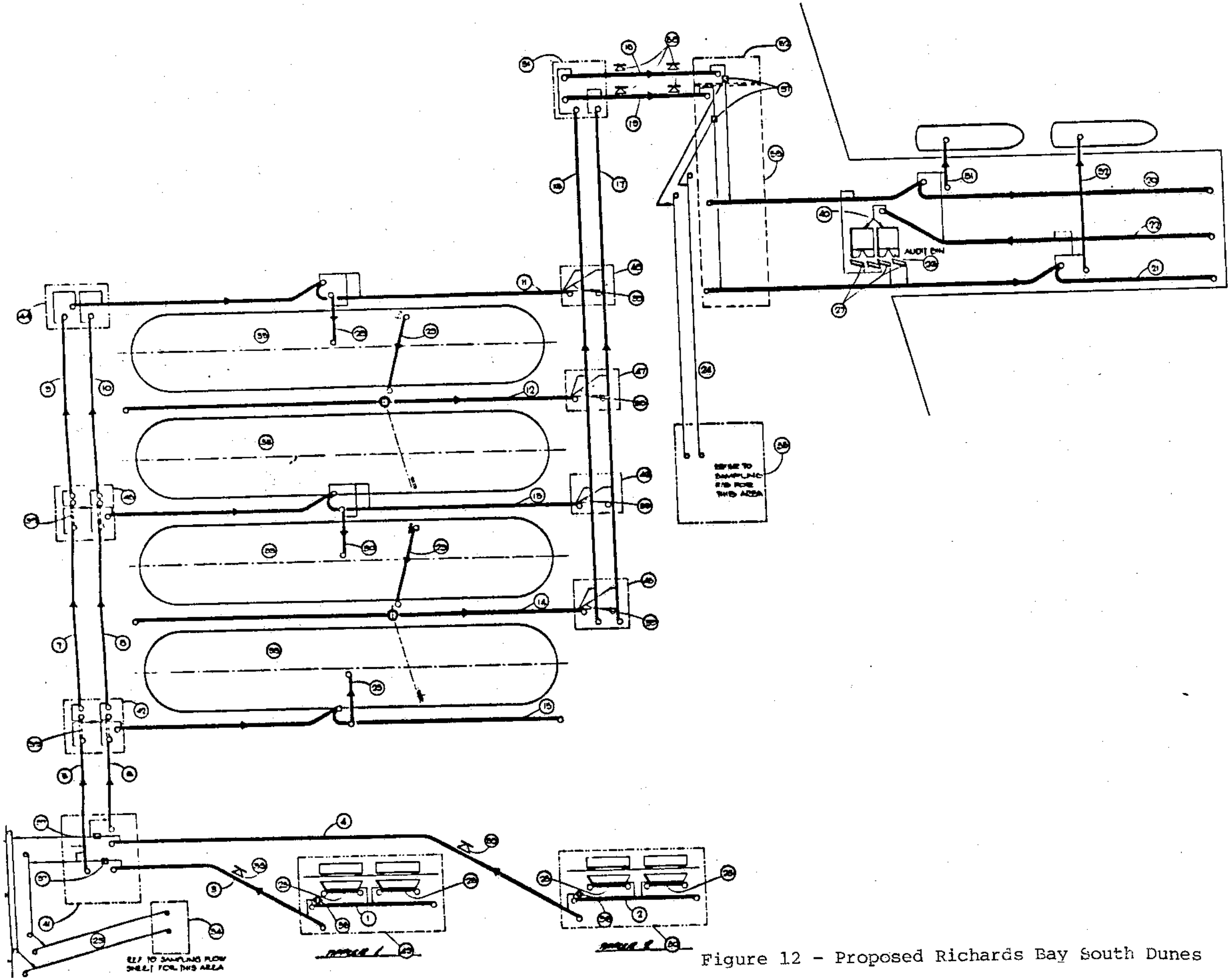


Figure 12 - Proposed Richards Bay South Dunes

A further example of a multi product terminal is the proposed Durban Coal Terminal soon to replace the old Durban Bluff Coaling Appliance (Figure 13).

Although this terminal will be handling coal exclusively, it is designed to handle both unsized coal eg. mixture and duff not sensitive to degradation as well as sized coal.

This latter type of coal is subject to degradation and it is necessary to handle it on slow speed conveyors and in specially designed chutework.

For this reason the terminal may be regarded as multi product since the flow characteristics of sized coal and duff are entirely different. The solution that has been developed is a two speed conveyor system operating at 1,25m/second for sized coal and 2,5m/second for unsized. A specially developed chute system with variable geometry will permit the free flow of sticky wet duff and in another setting control the flow of sized coal with minimum degradation.

Other interesting features of the terminal are :

- The necessity to soft load the coal into ship to limit degradation.

- The incorporation of a de-dusting facility to remove degradation fines immediately prior to ship loading.

- The provision of an automatic sampling system to provide the usual moisture, chemical composition and also the size analysis.

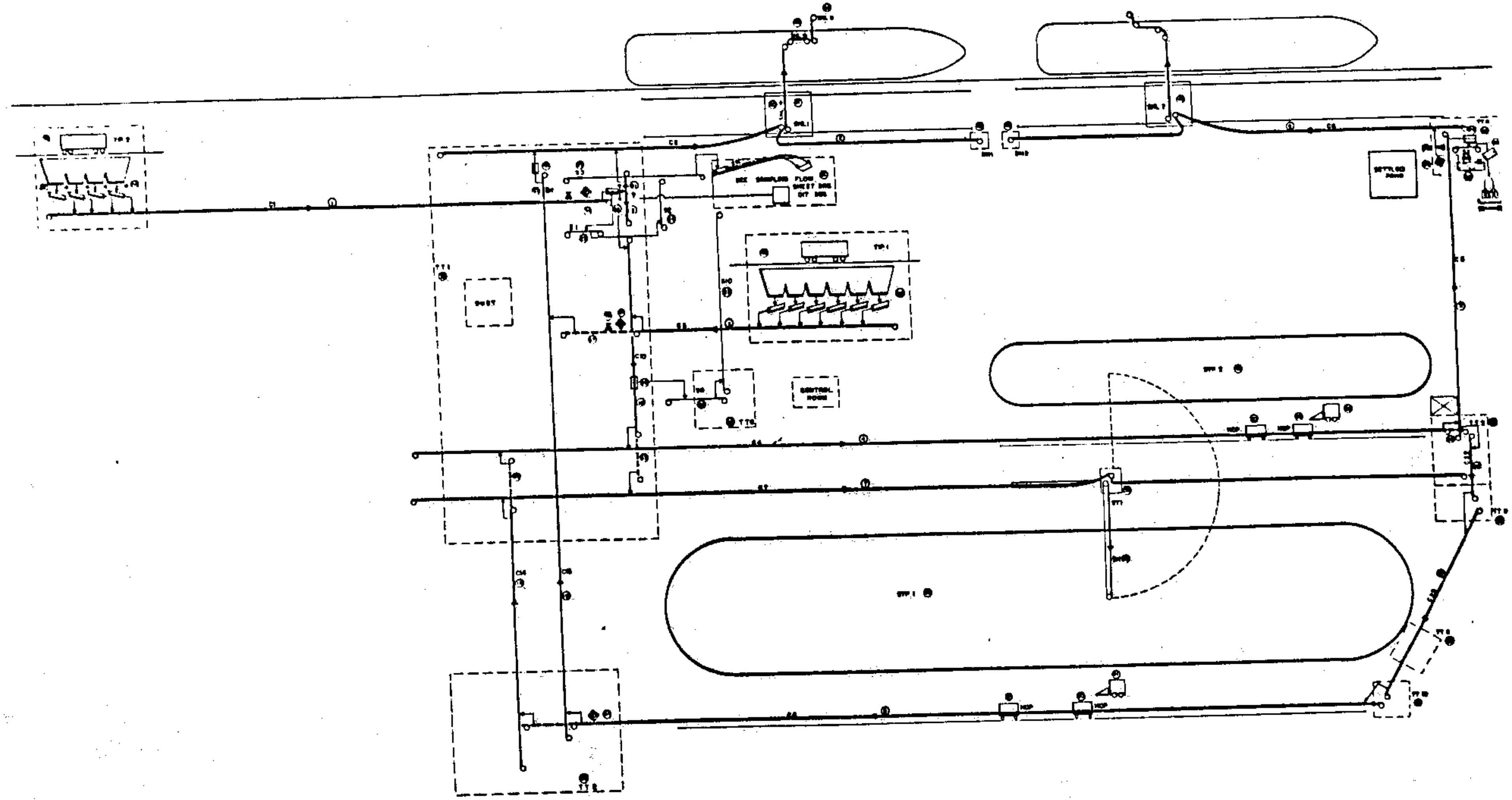


Figure 13 - Proposed Durban Coal Terminal

From the above examples it will be seen that the determination of the conveyor system layout and performance criteria assume great importance in Bulk Terminal design. The required flexibility to accommodate changing usage patterns, different products with different bulk densities and flow characteristics all contribute to the importance of sound engineering backed up by simulation studies if an efficient and economic terminal design is to be achieved. Once these basis parameters have been determined conveyor design may proceed along conventional lines.

5.0 SELECTION OF BELT CONVEYORS IN TERMINAL APPLICATIONS :

The selection of belt conveyors for harbour application is not a straightforward exercise and is the most important design consideration. Different combinations of belt speed, width and troughing angles can be chosen to meet the designed capacity requirement. The belt selection in the incoming and outgoing routes must be such as to satisfy train unloading, stockpiling, reclaiming and shiploading.

In the next paragraphs we are going to outline the main parameters which affect belt conveyor design.

The flow network of any terminal is usually sub-divided in zones. Each zone has its own characteristics. The main zones considered are :

- Tippler to stockpiles
- Tippler to ship
- Stockpile to ship
- Stockpile to stockpile

Before any selection can be made, the designer requires to know what products, grades, general characteristics, type of vessels and annual throughput will be handled by the projected terminal.

The first step is to assume a flow rate which can handle the annual throughput efficiently (experience has demonstrated that to be proficient a terminal requires single berth occupancy not greater than 68% - above this percentage inefficiency results with inherent heavy costs of demurrage). For instance, a client may have done a market research investigation and concluded that an "X" million coal terminal is required for the next five years with the possibility of increases to "2X" million. Using the Figure 15

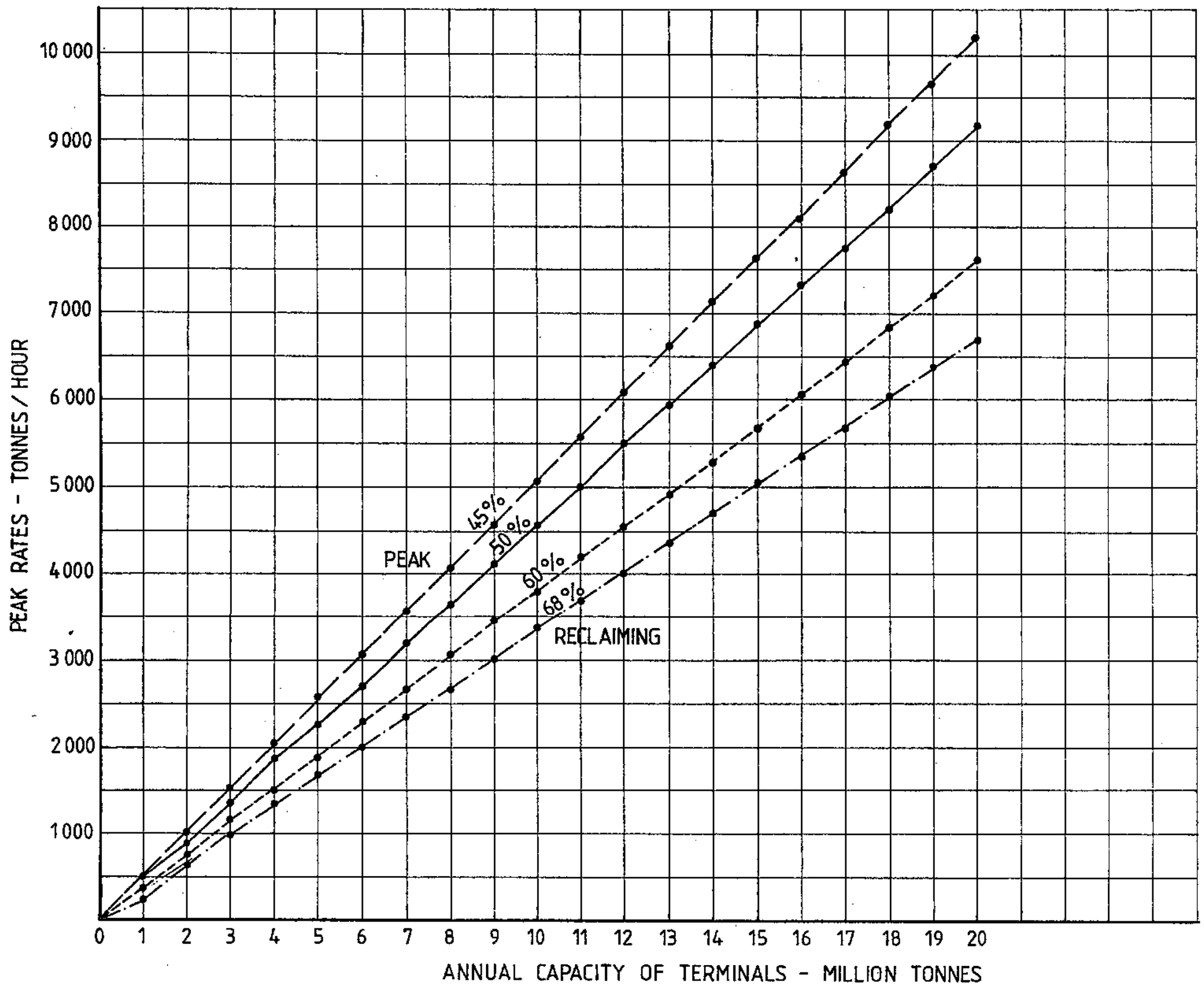


FIGURE 15: PEAK RATES VERSUS TERMINAL ANNUAL CAPACITY

NOTES:

- 35° TROUGHING IDLERS
- 25° SURCHARGE ANGLE
- 800 kg/m^3 BULK DENSITY
- CHANGING FROM 35° TROUGHING TO 20° REDUCE BY 24%
- CHANGING FROM 35° TROUGHING TO 45° INCREASE BY 9%

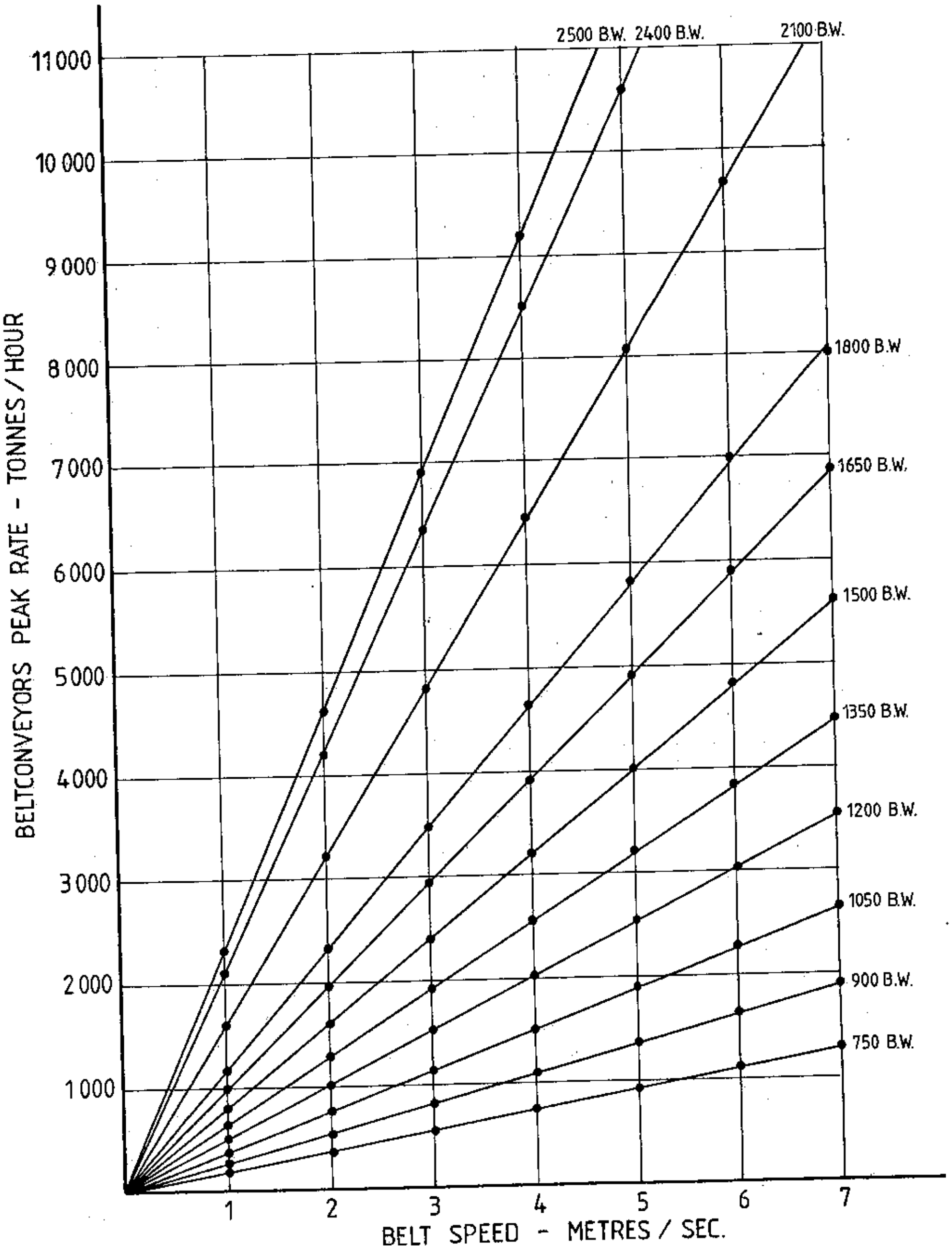


FIGURE 16: BELTCONVEYOR CAPACITY VERSUS SPEED

graph he would first select the peak rate and reclaiming required. Starting at 45% we would select the peak rate for all conveying systems from tippler to shiploader, and 68% would indicate the minimum reclaiming rate required. Having selected a flow rate the designer can then select a specific belt conveyor width and speed. If the terminal is to handle mixture/duff, coal friability will not be the major factor, and therefore can be handled at higher speeds. When handling sized coal for example, speeds above 1,25 metres are not recommended. Figure 16 gives the selection of belt width based on flow rates versus belt speed. After all factors affecting the capacity have been taken into account, the true occupancy and average rate will be in the region of 60-68%.

Present day trends appear to favour the conveyor width as narrow as possible with increased belt speed. This alternative is favoured on high capacity or long conveyors because of lower belt tensions. However, there are disadvantages and sometimes it is worth considering a wider belt at a lower speed. The decision to use narrow belts and high speeds or wider belts and lower speeds is a very tricky one, due to the fact that so many variables are involved, each one affecting cost, maintenance, life and reliability.

After selection of the belt conveyor, the next stage is to optimize by simulation the loading out either directly from incoming traffic or reclaiming from stockpiles into vessels of varying sizes (Ref. 28).

From stockpile to ship the main factors that will affect the conveyor capacity selection are the time spent waiting for tide at arrival or departure, berthing and deberthing, deballasting, net loading time, hatch shifting, cleaning conveyors for different types of products, repairs during loading, waiting for bulk due to blockages at stockpiles, type of reclaiming, draft checking and trimming. Another important factor is to decide what type of method will be used to allow the shiploader to move between hatches. Two methods are usually used by the industry, intermittent and continuous. With the intermittent mode the conveyor is stopped by sequence from the reclaimer or tippler. Continuous mode is the most frequent method used made possible by the use of a surge bin built between the shiploader and stockpiles. There are differences of opinion as to how much capacity these surge bins should have for initial design. There is support for consideration of a minimum of 10 to 15% of the peak capacity.

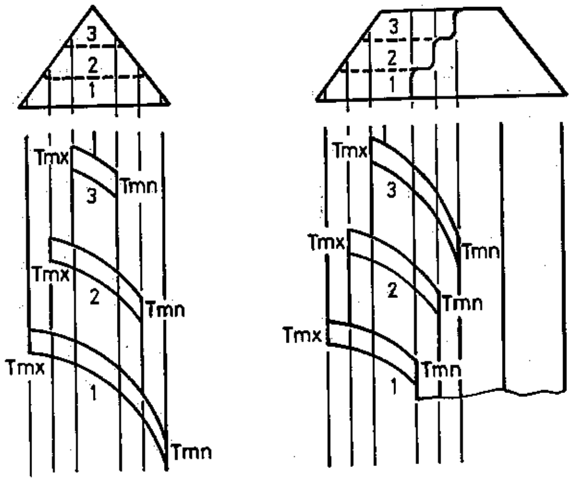
At this point, the type of reclaimer to be used must be decided; bucket wheel reclaimers with slewing booms, bridge type bucket wheel, drum type portal, front end loaders or under pile reclaiming methods. This decision is inherent or intrinsic to material physical or chemical quality, form of stockpile and flow rate variation. The designer has to decide how the stockpile is to be constructed, the area and subsequent reclamation. There are a variety of geometrical forms; conical heaps, circular prisms, crescent shaped prisms, semi-circular prisms and rectangular prisms which can be sited either undercover or in the open according to climatic, environmental or material considerations. It is always a difficult problem to decide precisely how much storage is required without the use of simulation models. From experience the storage requirements vary from 7% to 14% of annual throughput depending on ships, train arrivals and parcel sizes to be handled. Some authors (Ref. 29) suggest that 10% of the annual throughput or minimum ten vessels per year should be considered.

Linear Stockpile Systems are a common arrangement for coal and iron ore terminals. The stockpiles can be arranged in a variety of combinations, but are usually in line or parallel with each other.

For multipurpose terminals, the use of different types side by side is standard, of which Richards Bay Clean Bulk is an example. With high capacity terminals the use of a bucket wheel reclaimer equipped with a slewing boom is standard. Bridge and portal reclaimers are also used in terminal operations, where their use is not influenced by the nature of the product grades, width of stockpile and reclaiming rates.

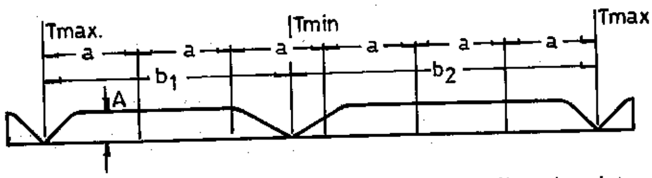
The standard cross sections of stockpiles are as shown in figure 17 (Ref. 30). Normally in the high capacity terminals the size of the stockpile does not permit a complete top-to-bottom layer to be removed. A number of cuts by the bucketwheel is required before the bottom layer of the dump is reached. Thus the flow of coal from the bucket reclaimers changes from layer to layer and can be higher than 1,5 times that of the average. This variation depends upon the theoretical wheel output and if a cell type wheel or cell-less type wheel is used. Although the control of the flow is achieved by belt weighers and other means these days, the reclaim conveyors are usually designed for peak capacity. For example, the present reclaimers at Richards Bay Coal Terminal operate from 3 500tph (average) to 6 000tph (peak) depending on the stockpile cross-section they are reclaiming.

From tippler to stockpile the main parameters affecting the belt conveyor design are the arrival of trains, type of trains, number of railway cars to be emptied, lagtime to prepare full cars and clear empties, availability of tippler due to breakdown, availability of railway feed, handling system, delay due to special constraints such as changing of route due to stockpile capacity, grade, breakdown, clearance of empties etc.



CONICAL STOCKPILE:
Reclaiming from one side on the left

TRAPEZOIDAL STOCKPILE:
Reclaiming from both sides (from the left is shown)



Material loading of the conveyor belt after leaving the bucket wheel reclaimer

a Measurement sections, using regular time intervals
b_1, b_2 Measurement sections between two reversal points of the slewing gear
Tmax Reversal point for maximum depth of cut
Tmin Reversal point for minimum depth of cut

Figure 17

Sourse: Ref. 30

Several variations in methods of stacking and stackers exist for bulk terminals. For example, the chevron method involves layering the stockpile along a fixed axis by means of a conveyor and stacker, the booms of which are usually adjustable in height to minimize segregation, degradation and dust problems due to height of freefall during the stacking operation. Where it is necessary to minimize variation in the quality of the reclaimed material, windrow or windrow/chevron layering methods are considered.

The control of flow from tippler to stacker usually is done by utilizing the tippler surge bunkers (designed with a minimum capacity of 1,5 of greatest railway car) and a variable belt feeder underneath to control the flow.

Having selected the most viable terminal design or concept the computer simulation will be utilized in a follow-up role to determine the effects of different usage patterns or market forces. This final step of the overall design process involves the utilisation of system models and stochastic techniques to measure and in turn evaluate the consequences of alternating system designs; thereby determining the costs and benefits of systems of differing physical concepts.

The system models use the fundamental theory of flow of electric currents in electrical networks Kirchoff' Law (Ref. 31) to check link flows and the out of kilter algorithm for the minimum network cost.

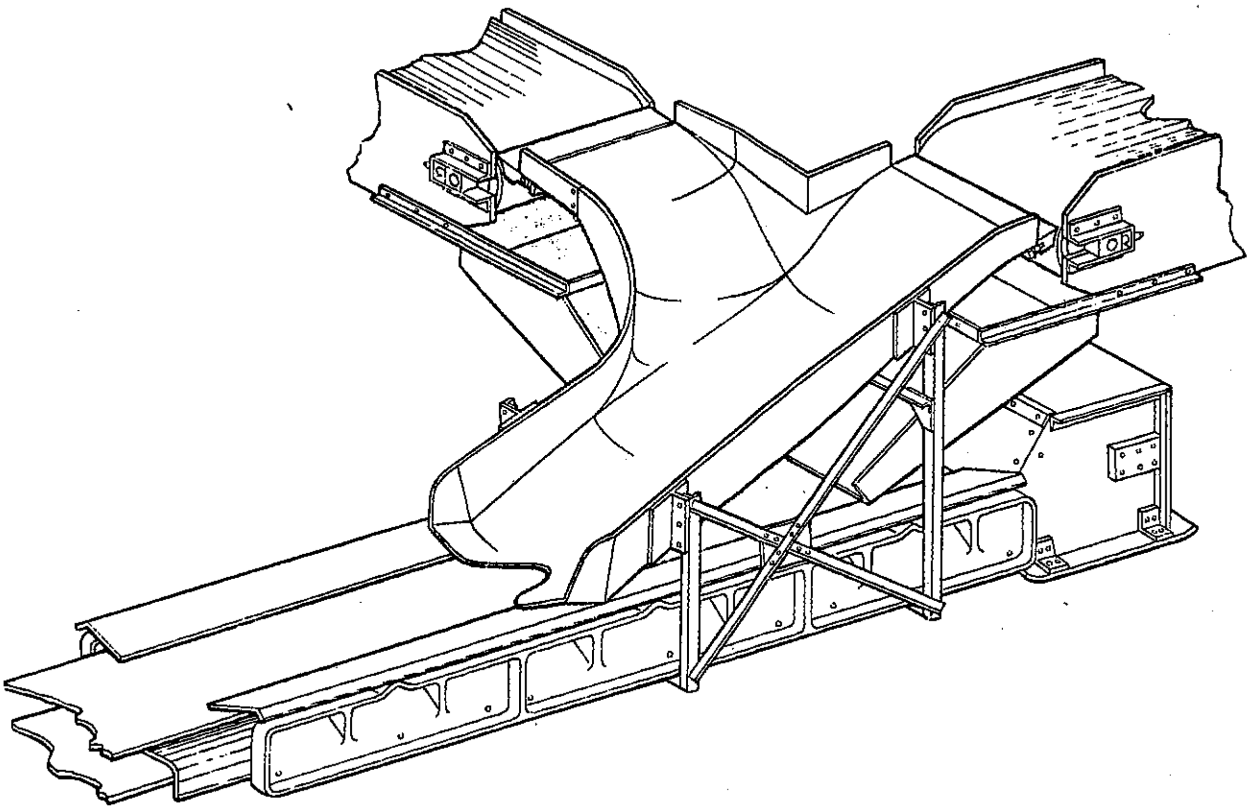
The stochastic models deal with time or space in accordance with probabilistic laws. Applications of Poisson, Montecarlo etc. stochastics processes are used to simulate different behaviours in time or space in the terminal.

6.0 METHODS TO REDUCE COAL DEGRADATION (REF 42.3) :

The first real attempt to study coal behaviour in chutes was initiated in 1945 by E.F. Wolf (35). The main concern in 1945 was to understand the flow characteristics of coal, the tendency of coal to drain somewhat faster along the vertical side than along the sloping side of chutes and to study blockages due to sudden collapse of coal columns or stoppages in bins. The earlier investigations were restricted to the determination of empirical relationships expressing flow rate in terms of the dimensional characteristics of the chutes.

In the early 50's experiments were carried out for the first time insofar as written records go, by J.V. Spence (Ref. 33) who examined degradation of coal at transfer points. This work was mainly related to underground conveyors (Figure 18). In practice, however, the chute was not a success because material was easily trapped between the pulley and wiper, thus damaging the belt. To prevent this happening a strip of flexible material about 50mm was fitted to the lip of the chute (Figure 19) to avoid damage to the belt. A switch was added to stop the conveyor if any obstruction did occur between the pulley and the chute edge.

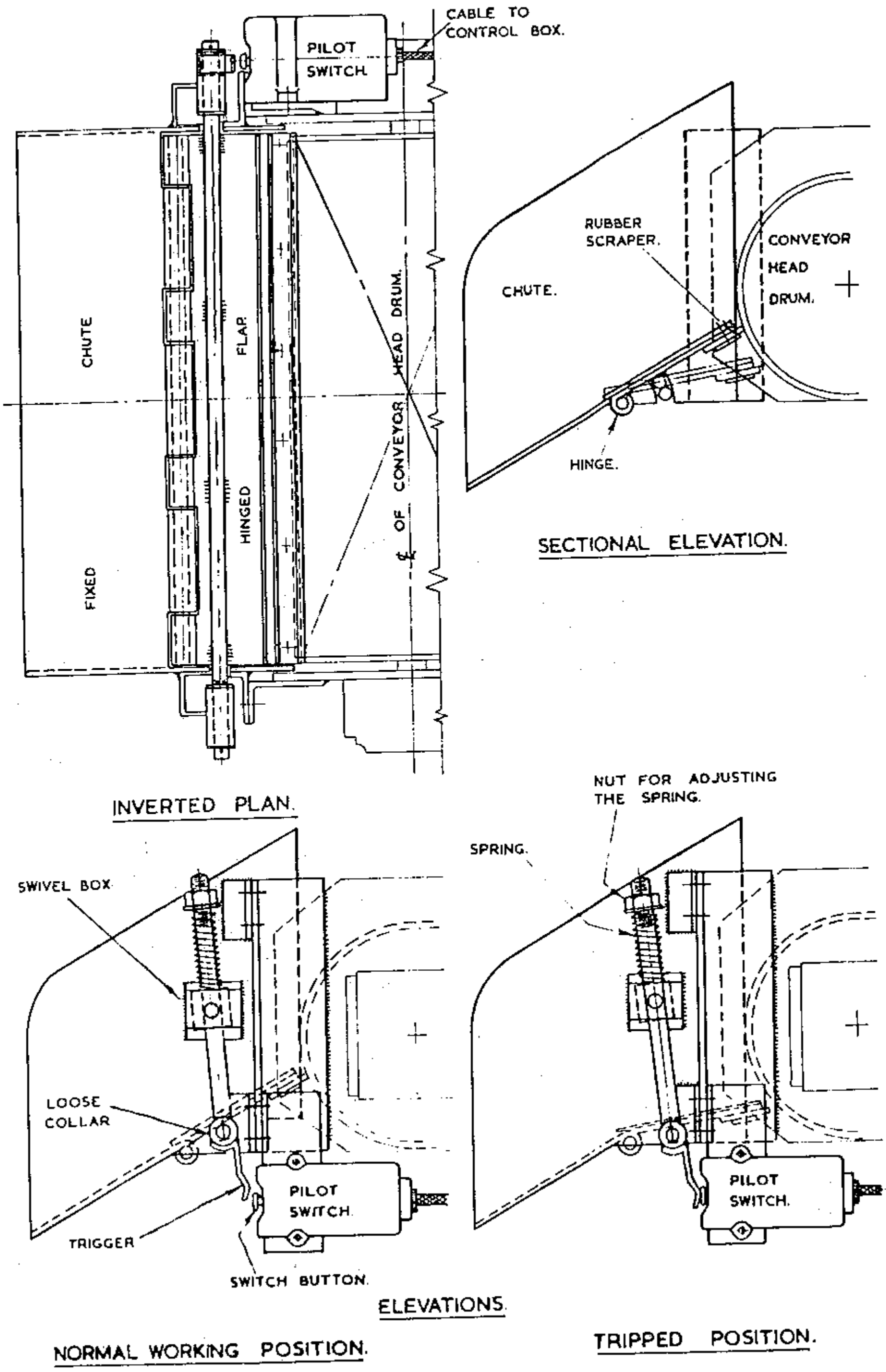
Dust tends to cling to the belt after passing the transfer or delivery point and is deposited at return idlers in contact with the dirty side of the belt and builds up on them; it then collects in heaps or becomes airborne along the conveyor (Figure 20). Since belt conveyors were designed engineers have used numerous methods to remove dust from the surface of the belt. Various methods, many of them involving comparatively simple and easily applied devices were developed (Ref. 34). The most common device used up to 1950 was the bar scraper held up against the belt by a counter balance weight or spring. Studies of fires underground after the explosion at NCB Easington Mine in 1951 changed the attitude of engineers in



Spence chute with chute top above centre line of delivery drums

Figure 18

SOURCE: Ref.33



Crossland hinged chute

Figure 19 SOURCE: Ref. 33

relation to transfer points. Studies of belt conveyor spillage frightened mine engineers. Weights of 300kg for top belt spillage, 600kg for bottom belt spillage and 850kg for transfer point were weighed over a single shift underground from thereon engineers were more concerned in avoiding dust spillage than degradation. The belt scraper inventors tried out, hundreds of devices, each one more complicated than the next, and each time the height of the transfer point was increased. The introduction of the automatic sampling further complicated matters.

Figures 21, 22, 23, 24, 25, 25A and 25B outlines some typical chute design.

With the proposed refurbishing of the Durban Coal Terminal, the authors realised the difficult task they had in trying to handle duff/mixture and sized coal of minus 90 to plus 25 from different collieries with different characteristics.

Test, instead of guesswork was decided upon. Some of you may recall J. Rosenthal's comments two years ago (Ref. 36) "Let us be honest - how often does the chute designer know the angle at which the material will slide but not bounce?".

In the transport from the mine washing plant to the user's facilities, sized coal or duff is usually exposed to rough handling which results in disintegration and generation of unwanted fines. Because of the economic problems involved, efforts must be made to find methods of preventing or reducing the degradation levels.

Choda and Willis (37) and Roberts (38) followed with a qualitative and experimental analysis study of the flow of granular materials through curved and straight chutes. Choda and Willis classified

Figure 20. Showing heaps of material at Return Idler Location

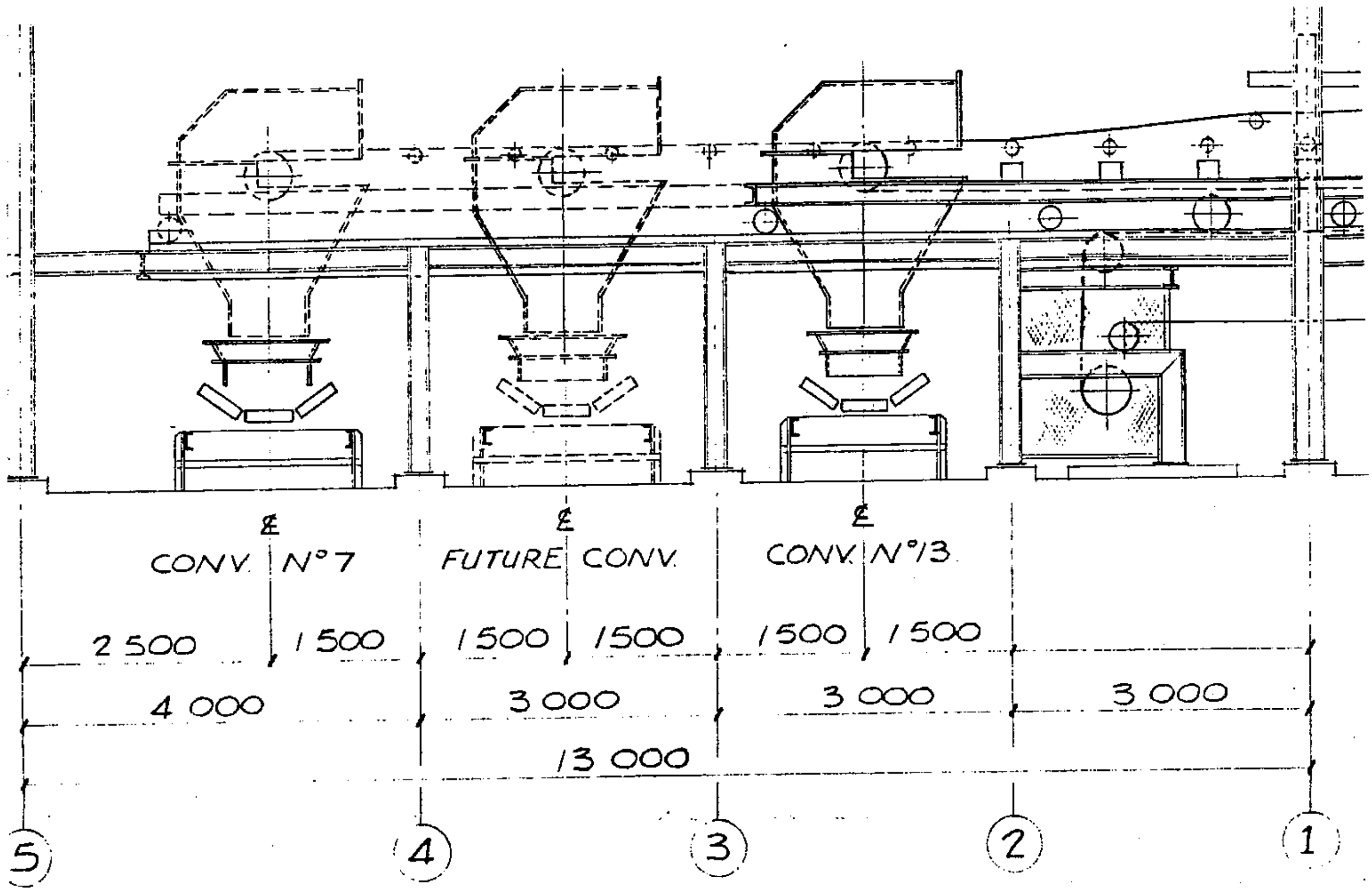


Figure 21 - Typical Moving Head Chute

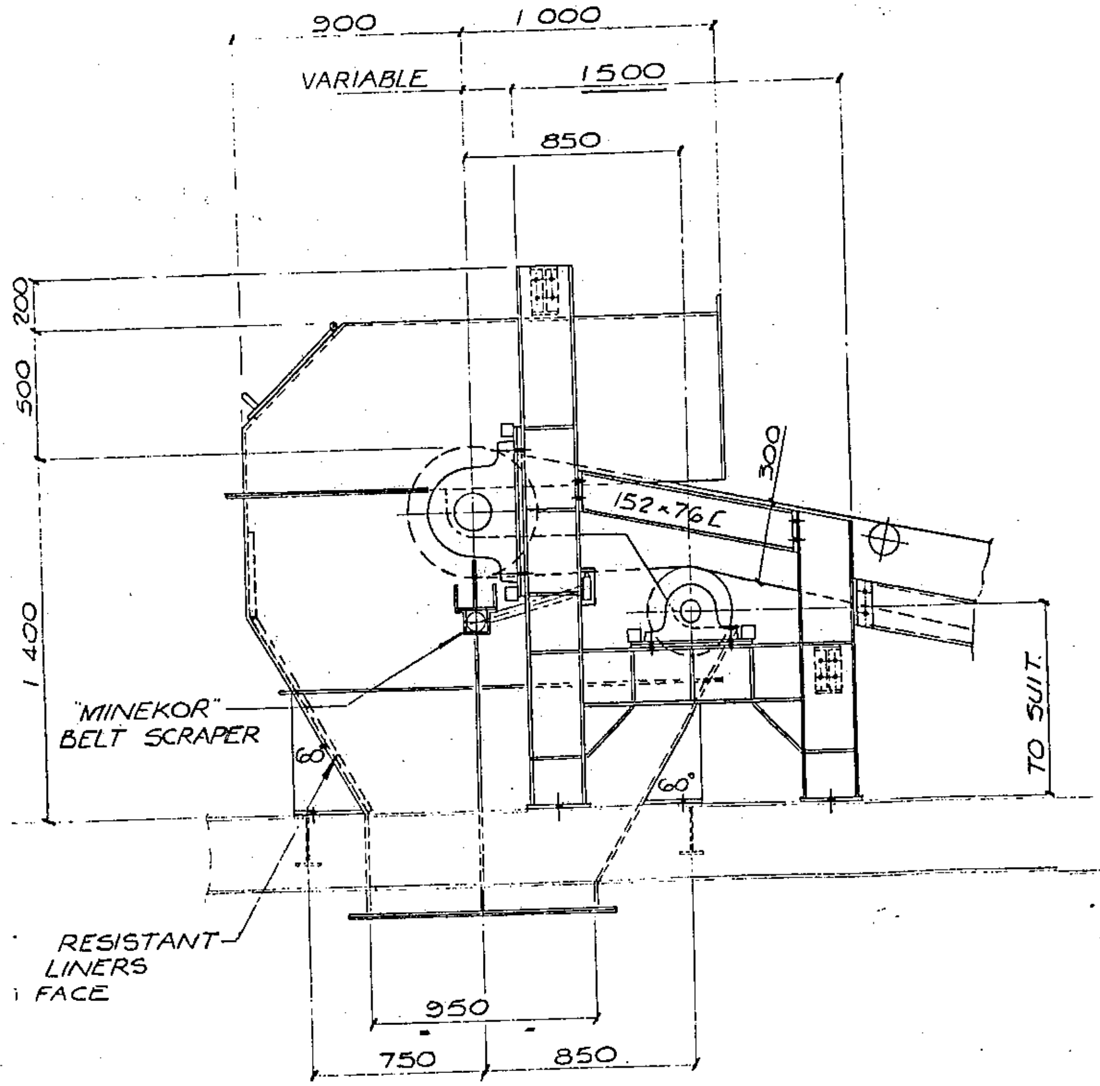


Figure 22 - Typical Head Chute. Spillage from Snub Pulley is collected

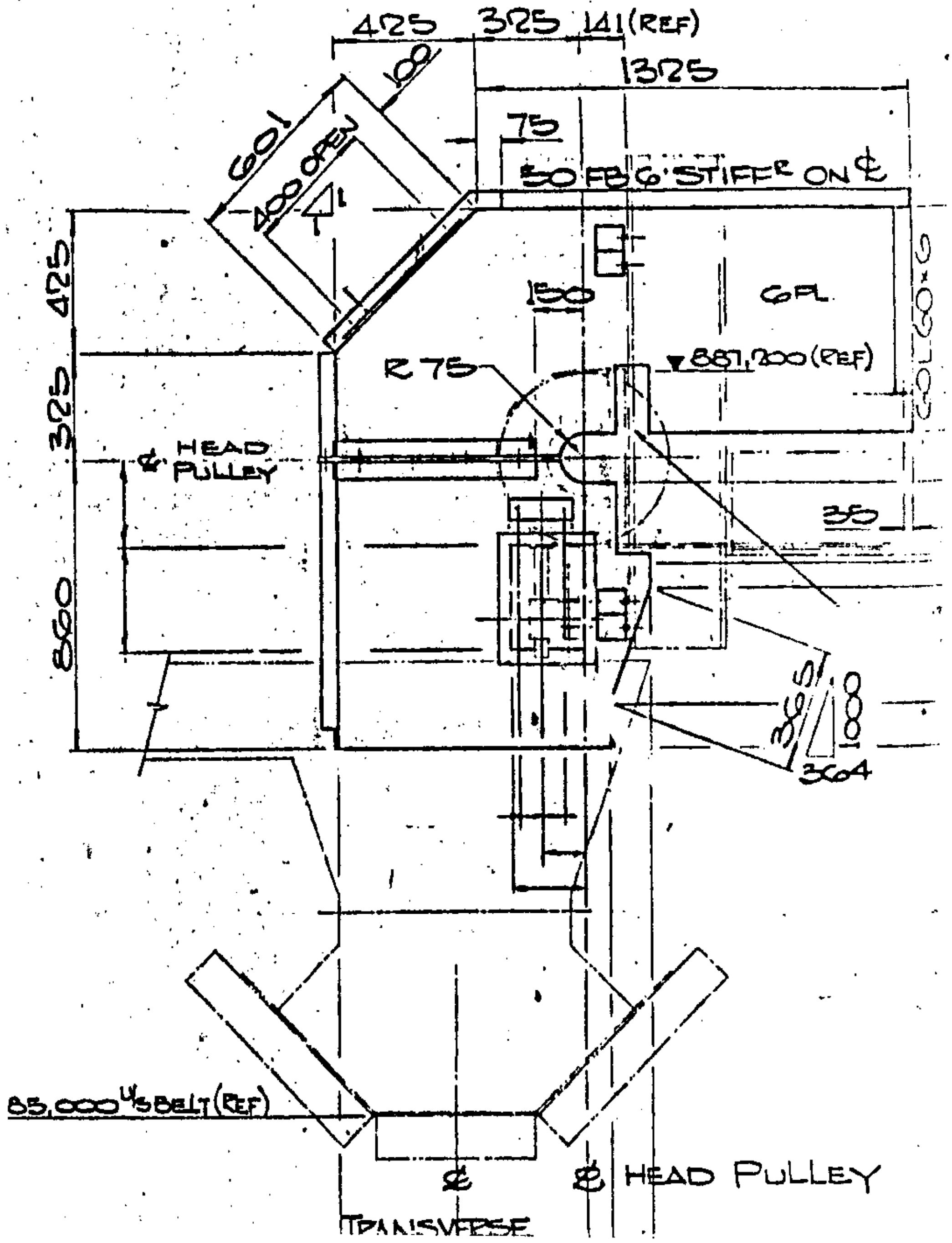


Figure 23 - Typical Head Chute. Spillage from Scrapers are Collected

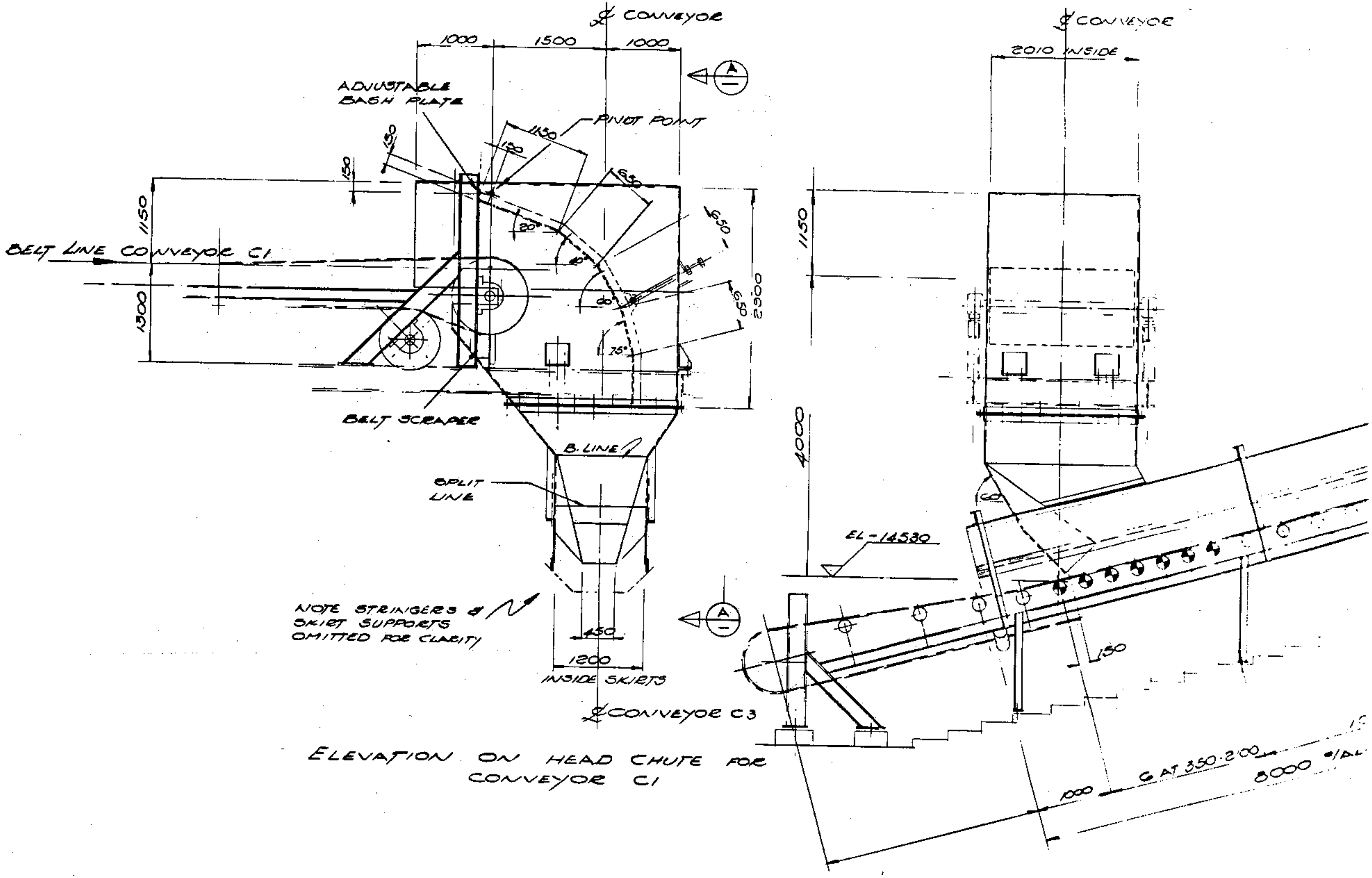


Figure 24 - Typical 90° Transfer for High Speed Belt Conveyor

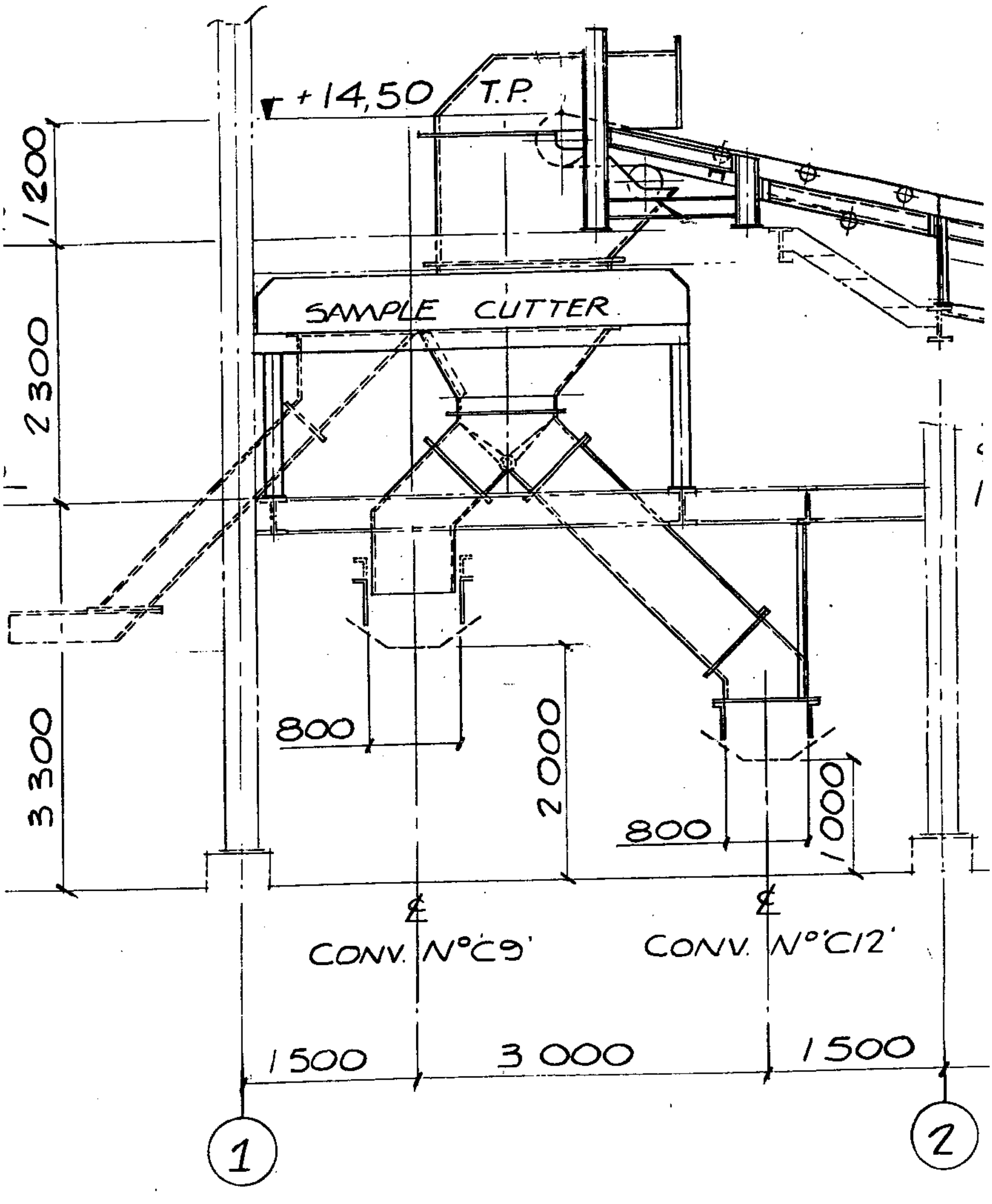


Figure 25 - Typical Chute with Sample Cutter

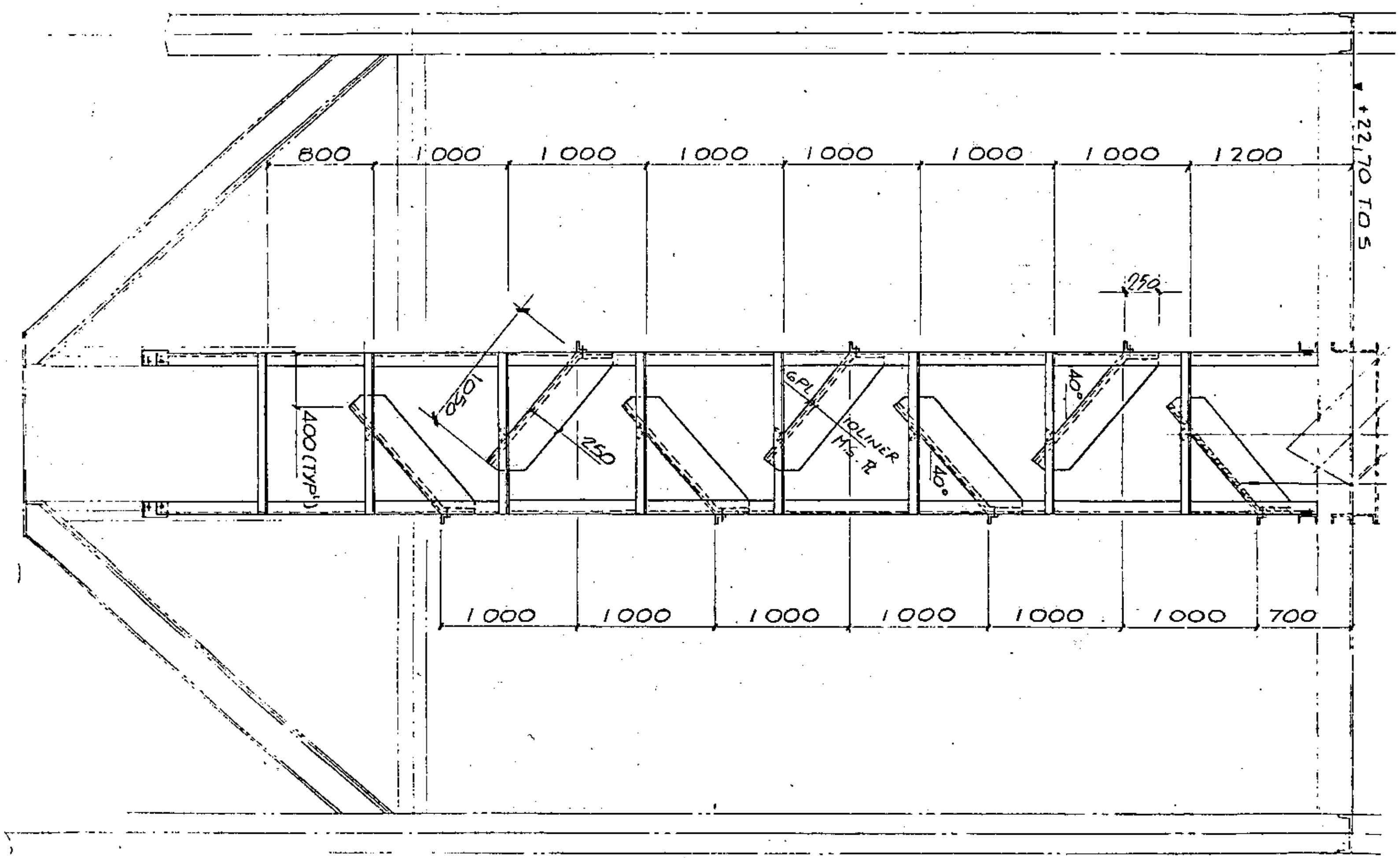


Figure 25A - Typical Ladder Arrangement Inside Bunker

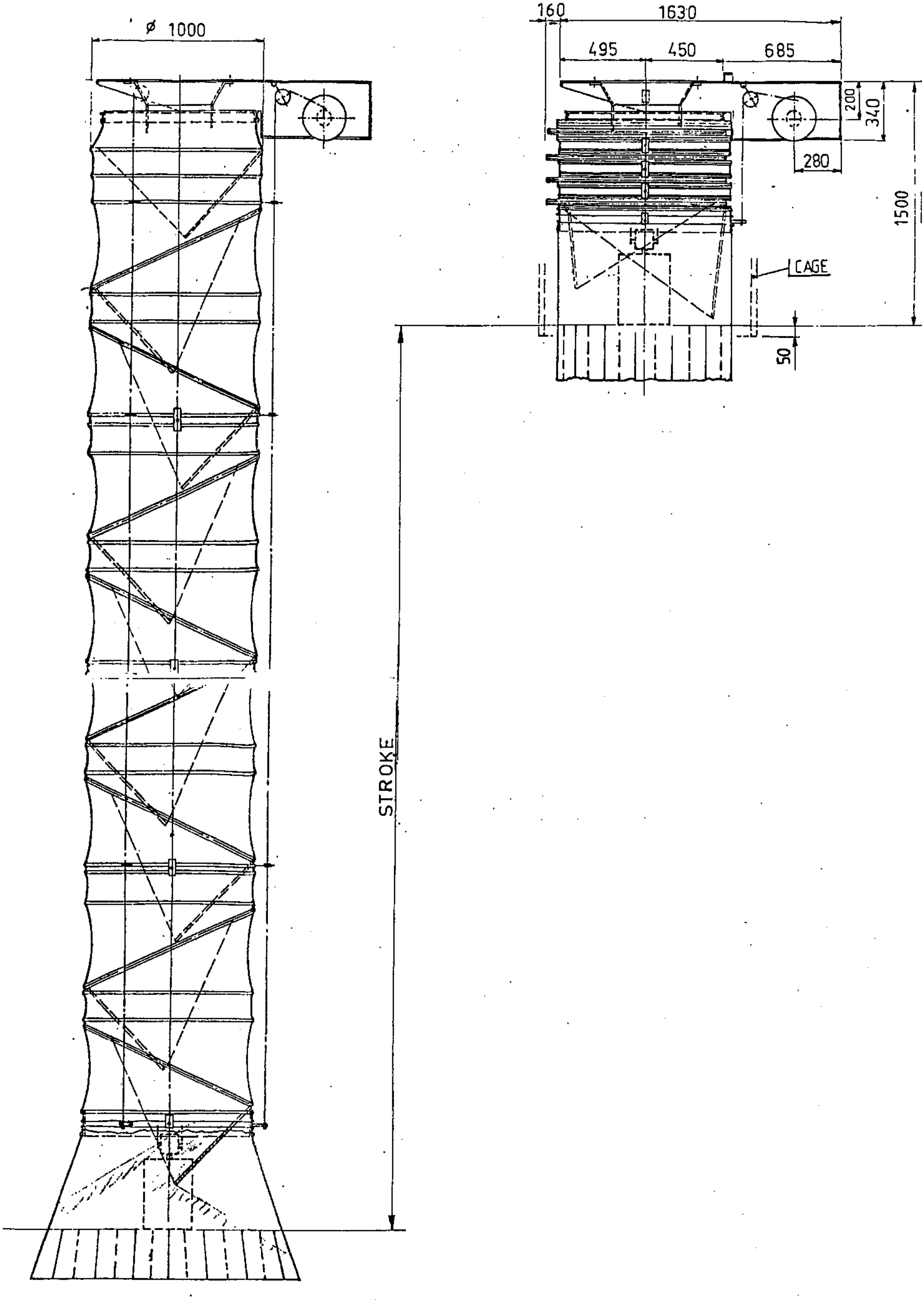


Figure 25B - Typical Telescopic Chute with Ladder Arrangement the flow of material either fast or slow. Fast flow is when the material makes partial contact with the walls of the chute. On the other hand slow flow is when the material makes contact with all four faces of the chute.

Part of the analytical approach presented and used in the design and development of the test chute is based on the work of Roberts (39,40), and we refer specifically to the design of the bottom section of the curved chute. As mentioned earlier, few studies have dealt with the behaviour of lump ore degradation. Fagerberg and Sandberg (42) report degradation findings on investigation of differents materials used in the iron making industry. Tumbler test equipment, drop shatter and gravity flows at LKAB Plants in Sweden were utilised to study average trends of degradation for oxiding ore, sinter and coke.

The main factors affecting any degradation at transfer points are the direction of transfer from loading to receiving, height and product type handled. There are two possible directions to load a belt conveyor :

- Loading in the direction of belt travel
- Loading transverse to the direction of belt travel

Loading in the direction of belt travel is the best type of loading and the one which any designer strives to achieve. The material flow is directed centrally onto the belt and the forward velocity of the material is close to the next belt velocity. Unfortunately, loading of belt conveyors in the direction of the belt travel is not the usual layout configuration. Loading transverse to the direction of the belt travel is the type of loading usually found in belt conveyor layouts. The proper design of any loading chute is difficult to achieve from the standpoint of desirable material velocity and central loading of the receiving belt.

It was decided to choose a belt conveyor layout with a ± 90° transfer for the test chute. This type of transfer presents the problems of turning the flow of material, difficulty in achieving the same speed as the receiving belt, central loading at all rates of material flow, considerable height requirements, hazards of belt cover wear, difficult chute work and, usual displacement transversely of the receiving belt on its supporting idlers.

Initially a transfer point at Rand London Siding in Paulpietersburg (Figure 26) was chosen for the tests. However, due to the lack of availability to perform later tests, the chute was transferred to Grinaker Penlee Dump in Glencoe, Northern Natal for continuation of the first programme (Figure 27).

Initial studies and site investigations showed that the most coal degradation is caused by impact when the material is dropped and transferred to another conveyor or stockpile, and to a lesser extent by compression and abrasion in gravity flows through chutes, bins and similar devices.

During any transfer there is usually a drop and at its end the potential energy is partly converted to crushing work, in other words large lumps are fractured and reduced in number, medium sizes remain fairly stable and the fines increase.

It is evident from test work that degradation can be prevented or reduced by suitable design of transfer points. The most important preventative measure is to reduce the height of transfer and avoid free fall.

When the flow leaves the head pulley the material is in free fall. Trajectory lumps are thrown while fluffy materials more sensitive to air resistance will spread vertically and laterally (Figure 28). At impact zone the flow usually strikes a

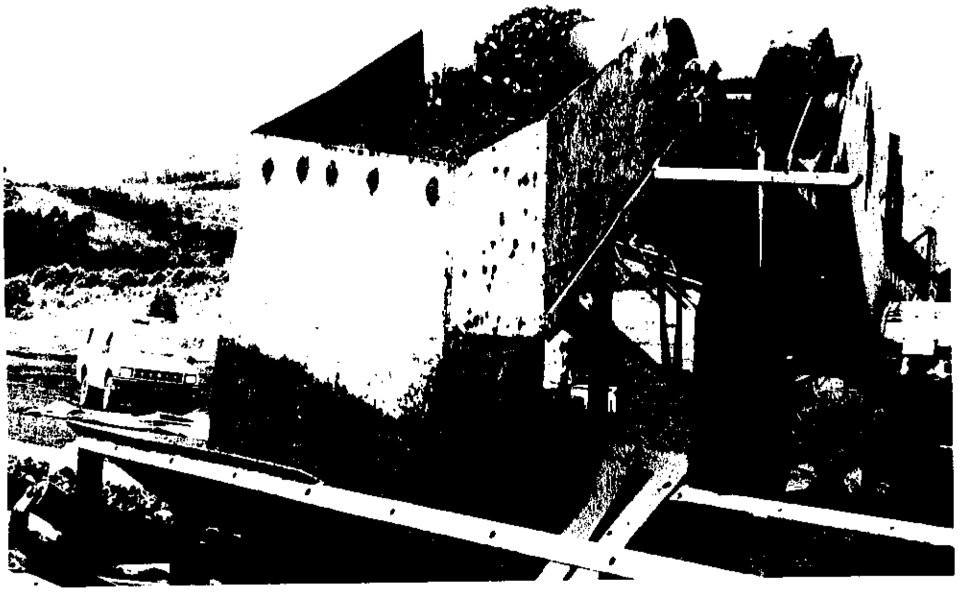


Figure 26 - Transfer Point at Paul Pietersburg

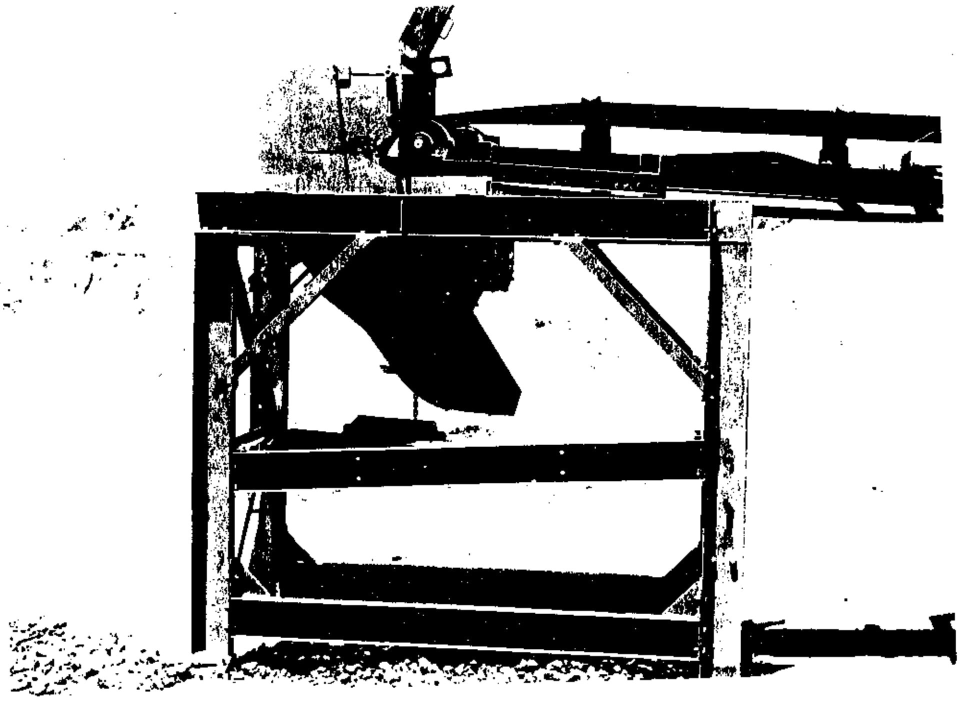


Figure 27 - Test Chute at Glencoe

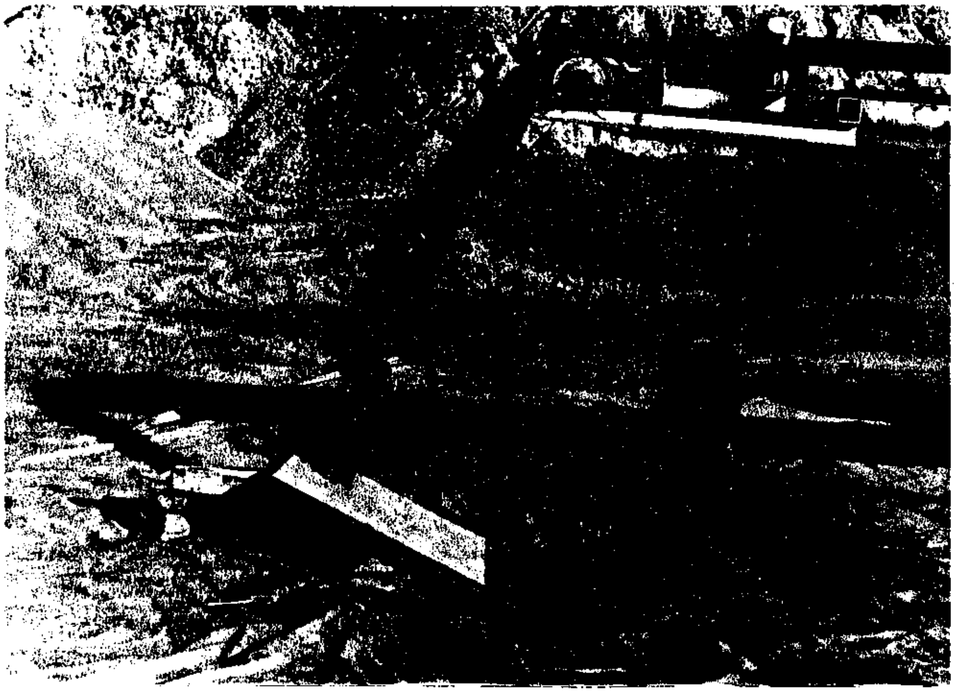


Figure 28 - Free Fall

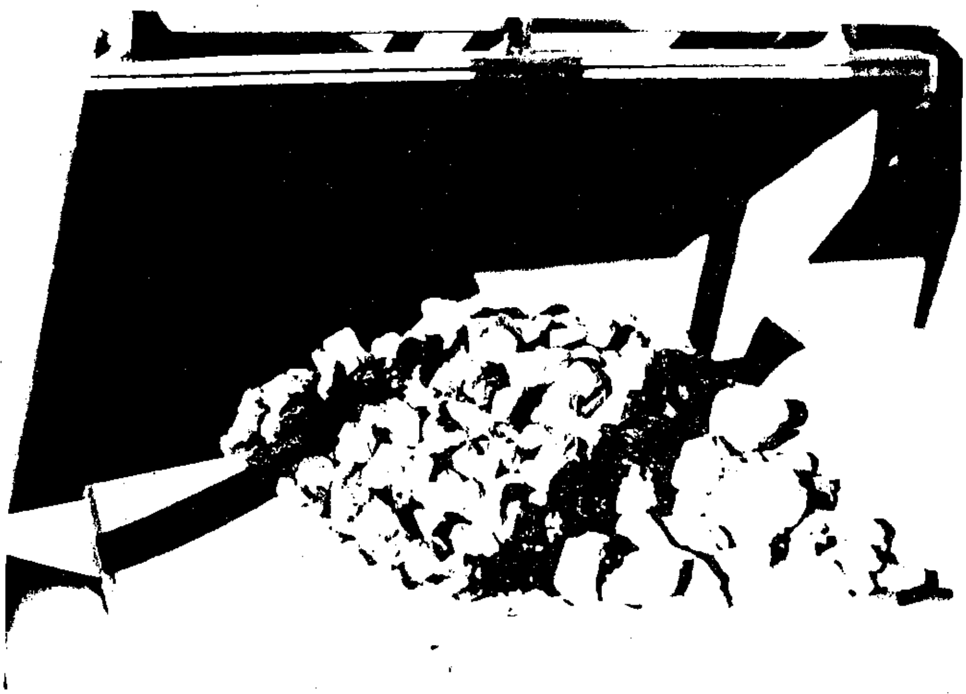


Figure 29 - Profile of Coal Flow Before Loading Head Pulley - Streamline Flow

chute plate. One of two situations will occur, direct central impact or oblique central impact. In any of the circumstances the flow will be disturbed, control will be lost due to change of direction and turbulence will result due to velocity differences, ricochetting and eratic bouncing of outside particles will take place.

During conveying of the materials segregation along the cross section of the belt conveyor occurs each time the material passes over a set of idlers with lumps riding near the top of the material and fines at bottom. At impact zone we have the phenomenon of the collision of two bodies where the shapes of the particles, their velocities and their elastic properties regulate their reactive forces. Analysis of high speed cine photographs and video recordings of the experiments show that there is a deviation from perfect elasticity in the centre of the flow, in other words the relative velocity after impact is smaller than before hand. The outside particles are in the state of perfect elasticity where there is no loss of energy in the system and the relative velocity after impact has the same magnitude as before impact.

The conveying of material can be postulated as the flow of fluids. The material in a belt conveyor consist of large numbers of individual particles moving in the general direction of flow, but some are not moving parallel to each other. The velocity of any particle is a vector quantity having magnitude and direction which vary from moment to moment.

Two distinct types of flow can occur. The streamline flow in which the particles move in an orderly manner and retain the same relative positions in successive cross sections (Figure 29) or the turbulent flow in which the particles move in a disorderly manner occupying different relative positions in successive cross sections

(Figure 31). Both types of flow occur in any belt conveyor system. The streamline flow is observed with material on the belt. The turbulent flow is observed in any transfer point.

Any improvement in coal sized degradation can only be achieved by avoiding free fall and controlling the speed and direction during transfer. Tests and calculations indicate that it is difficult to achieve a uniform continuous speed in a transfer due to the phenomenon of gravity and certain unknown reactive forces of friction.

The test chute was built with three main components, top curve, bottom curve and skin plate structure. Both top and bottom chute components were radiussed fully and made adjustable to allow the studying of coal flow during transfer.

The main features of the test chute are having a curved section in front of the head pulley. This curved section changes the flow in a controlled manner over 150°. After the material leaves the head pulley this type of design avoids free fall and impact. The coal is in streamline flow. The degradation in this situation is only based on the grinding effect of individual lump and fractions rubbing against each other under pressure in the curved sliding plate, due to centrifugal forces and not in erratic travel. This top section is adjustable to regulate velocity of flow into the next bottom section which is also based on a curved pattern. With proper design of radius and setting of the sections it is possible to control velocities and achieve the designer dream of equating the existing speed with the speed of the collecting conveyor.

The initial setting of the tests was intended to compare results in different grades of anthracite available at the siding between the old chute and the test chute. The old chute is depicted in

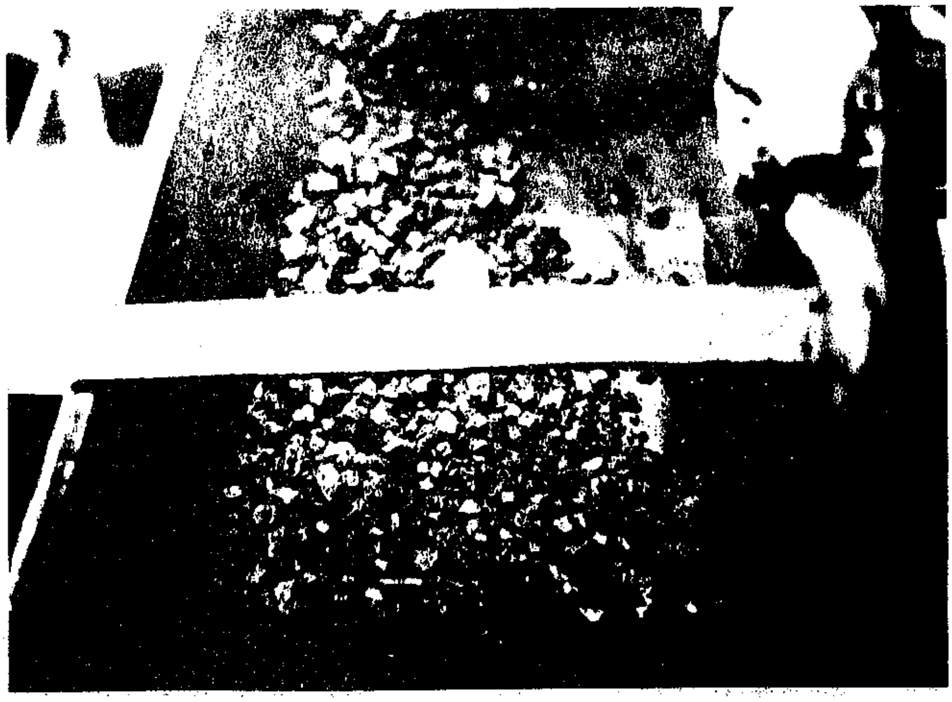


Figure 30 - Control Flow at Bottom curveD Section

Figure 31 - Fast Flow and Eratic

Figure 26. The coal/anthracite used at Paulpietersburg is very hard - (HGI43 Abr. 38mg FE/kg) and the following anthracite products were tested through the old chute 45 x 70 and 25 x 40. To determine the relative size stability and friability of sized coal, it was decided to use the standard method of drop shatter test for coal, the American National Standard ANSI/ASTM D440-49 (Reapproved 1980). The samples were screened and weighed before and after tests. Figure 32 indicates the suggested method of reporting.

The following tests were executed at Penlee Dump :

Free fall and through the test chute. Two types of coal products were tested, anthracite and bituminous. The anthracite was tested in large nuts (45 x 75) and small nuts (25 x 45). The bituminous coal was tested in 0 x 40 and 0 x 6 size grades. Over 70 screen analysis tests were executed.

TABLE 1 General Form for Reporting Data and Calculations

Round-Hole Screens, in. (mm)		Weight, percent		Average of Screen Size Openings, in.	Product of Weight Percentage and of Screen Openings	
Retained on	Passing	Before Test	After Test		Before Test	After Test
8 (...)						
6 (...)	8 (...)	...	...	7.000	...	...
4 (100)	6 (...)	...	...	5.000	...	...
3 (75)	4 (100)	...	...	3.500	...	...
2 (50)	3 (75)	...	...	2.500	...	...
1½ (37.5)	2 (50)	...	...	1.750	...	...
1 (25.0)	1½ (37.5)	...	...	1.250	...	...
¾ (19.0)	1 (25.0)	...	...	0.875	...	...
½ (12.5)	¾ (19.0)	...	...	0.625	...	...
¼ (6.3)	½ (12.5)	...	...	0.375	...	...
⅛ (3.35)	¼ (6.3)	...	...	0.185	...	...
	⅛ (3.35)	...	...	0.060	...	...
Total passing ⅜ (9.5)		...	...	0.185	...	...
Total passing ¼ (6.3)		...	...	0.125	...	...
					Total, S	Total, s
Average size of coal before and after test (two drops), in.					...	...

Size stability, percent = $(100 \times s)/S$ = ...

(Friability, percent = 100 − size stability)

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TABLE 2 Form and Example for Reporting Data and Calculations for a Selected Single Size

Round-Hole Screens, in. (mm)		Weight Recorded, lb (kg)	Weight, percent (1)	Average of Screen Openings		Product of (1) × (3)
Retained on	Passing			Inches (2)	Factor (3)	
			SAMPLE			
4 (100)	6 (...)	50 (22.7)	100.0	5.000	1	100.00 = S
			DROPPED COAL			
4 (100)	6 (...)	24¼ (11.0)	48.5	5.000	1	48.500
3 (75)	4 (100)	7 (3.2)	15.0	3.500	0.7	10.500
2 (50)	3 (75)	6½ (2.9)	13.0	2.500	0.5	6.500
1½ (37.5)	2 (50)	3 (1.4)	6.0	1.750	0.35	2.100
1 (25.0)	1½ (37.5)	2½ (1.1)	5.0	1.250	0.25	1.250
¾ (19.0)	1 (25.0)	1½ (0.7)	3.0	0.875	0.175	0.525
½ (12.5)	¾ (19.0)	1½ (0.7)	3.0	0.625	0.125	0.375
	½ (12.5)	3¼ (1.5)	6.5	0.250	0.05	0.325
Total (Sum of products (1) × (3) for dropped coal)						70.075 = s

Size stability, percent = $(100 \times s)/S = (100 \times s)/100 = s = 70.1$

To be reported as: Size Stability, 70 percent

(Friability, percent = 100 − 70 = 30)

Figure 32 - Suggested Form of Reporting. SOURCE: ASTM D440

Summary of results are outlined in the following tables.

TABLE 3

Sample Size mm	AVERAGE SIZE		FREE FALL	
	Before mm	After mm	Size Stability %	Size Friability %
45 x 75 (Anthracite)	53,75	50,48	93,91	6,09
25 x 45 (Antracite)	29,66	28,33	95,51	4,48
0 x 40 (Bituminous)	13,76	13,19	95,64	4,36

TABLE 4

Sample Size mm	AVERAGE SIZE		TEST CHUTE	
	Before mm	After mm	Size Stability %	Size Friability %
45 x 75 (Anthracite)	53,49	52,12	97,43	2,57
25 x 45 (Antracite)	28,14	27,71	98,47	1,53
0 x 40 (Bituminous)	13,04	12,83	98,38	1,62

TABLE 5 - Difference between free fall and test chute

Sample	Size Friability % Difference
45 x 74 (Anthracite)	3,52
25 x 45 (Anthracite)	2,93
0 x 40 (Bituminous)	2,74

TABLE 6

Sample	Hard Groove Index
45 x 74 (Anthracite)	42
25 x 45 (Anthracite)	47
0 x 40 (Anthracite)	36

TABLE 7 - SAMPLE (45 - 75)

Square Hole Screen (mm)		Weight, %		FREE FALL		
				Average Screen Opening (mm)	Product of WT % And Screen Size	
Retained	Passing	Before Test	After Test		Before	After
70	80	9,7	9,4	75,0	7,27	7,05
60	70	17,8	16,4	65,0	11,57	10,06
50	60	38,3	28,7	55,0	21,06	15,78
40	50	23,6	26,6	45,0	10,62	11,97
25	40	9,2	13,1	32,5	2,99	4,25
20	25	0,7	1,5	22,5	0,15	0,33
15	20	0,4	1,3	17,5	0,07	0,22
	15	0,3	3,0	7,5	0,02	0,22
AVERAGE SIZE OF COAL BEFORE AND AFTER TEST					53,75	50,48

SIZE STABILITY : 93,91%
SIZE FRIABILITY: 6,09%

TABLE 8 - SAMPLE (25 - 45)

Square Hole Screen (mm)		Weight, %		FREE FALL		
				Average Screen Opening (mm)	Product of WT % And Screen Size	
Retained	Passing	Before Test	After Test		Before	After
40	50	11,8	9,8	45,0	5,31	4,41
25	40	54,4	51,2	32,5	17,68	16,64
20	25	21,2	21,9	22,5	4,77	4,92
15	20	9,6	10,8	17,5	1,68	1,89
	15	3,0	6,3	7,5	0,22	0,47
AVERAGE SIZE OF COAL BEFORE AND AFTER TEST					29,66	28,33

SIZE STABILITY : 95,51%
SIZE FRIABILITY: 4,49%

TABLE 9 - SAMPLE (0 - 40)

Square Hole Screen (mm) Retained	Square Hole Screen (mm) Passing	Weight, % Before Test	Weight, % After Test	FREE FALL Average Screen Opening (mm)	FREE FALL Product of WT % And Screen Size Before	FREE FALL Product of WT % And Screen Size After
40	50	0,7	0,5	45,0	0,31	0,22
25	40	8,6	7,9	32,5	2,79	2,56
20	25	11,1	10,1	22,5	2,49	2,27
15	20	22,0	20,3	17,5	3,85	3,55
	15	57,6	61,2	7,5	4,32	4,59
AVERAGE SIZE OF COAL BEFORE AND AFTER TEST					13,76	13,19

SIZE STABILITY : 95,51%
SIZE FRIABILITY: 4,49%

TABLE 10 SAMPLE (45 - 75)

Square Hole Screen (mm) Retained	Square Hole Screen (mm) Passing	Weight, % Before Test	Weight, % After Test	TEST CHUTE Average Screen Opening (mm)	TEST CHUTE Product of WT % And Screen Size Before	TEST CHUTE Product of WT % And Screen Size After
70	80	6,5	6,0	75,0	4,87	4,50
60	70	15,8	12,7	65,0	10,27	8,25
50	60	36,4	36,0	55,0	20,02	19,80
40	50	28,3	28,3	45,0	12,73	12,73
25	40	9,5	11,5	32,5	3,08	3,73
20	25	1,2	1,6	22,5	0,27	0,44
15	20	0,8	1,1	17,5	0,14	0,19
	15	1,5	2,8	7,5	0,11	0,21
AVERAGE SIZE OF COAL BEFORE AND AFTER TEST					51,49	49,85

SIZE STABILITY : 96,81%
SIZE FRIABILITY: 3,19%

TABLE 11 - SAMPLE (25 - 45)

Square Hole Screen (mm)		Weight, %		TEST CHUTE		
				Average Screen Opening (mm)	Product of WT % And Screen Size	
Retained	Passing	Before Test	After Test		Before	After
40	50	9,5	7,5	45,0	4,27	3,37
25	40	51,1	52,3	32,5	16,60	16,99
20	25	22,1	21,5	22,5	4,97	4,83
15	20	10,1	11,2	17,5	1,76	1,96
	15	7,2	7,5	7,5	0,54	0,56
AVERAGE SIZE OF COAL BEFORE AND AFTER TEST					28,14	27,71

SIZE STABILITY : 98,38%
SIZE FRIABILITY: 1,62%

TABLE 12 SAMPLE (0 - 40)

Square Hole Screen (mm)		Weight, %		TEST CHUTE		
				Average Screen Opening (mm)	Product of WT % And Screen Size	
Retained	Passing	Before Test	After Test		Before	After
25	40	8,8	8,6	32,5	2,86	2,79
20	25	9,7	9,0	22,5	2,18	2,02
15	20	19,0	18,5	17,5	3,32	3,23
	15	62,5	63,9	7,5	4,68	4,79
AVERAGE SIZE OF COAL BEFORE AND AFTER TEST					13,04	12,83

SIZE STABILITY : 98,38%
SIZE FRIABILITY: 1,62%

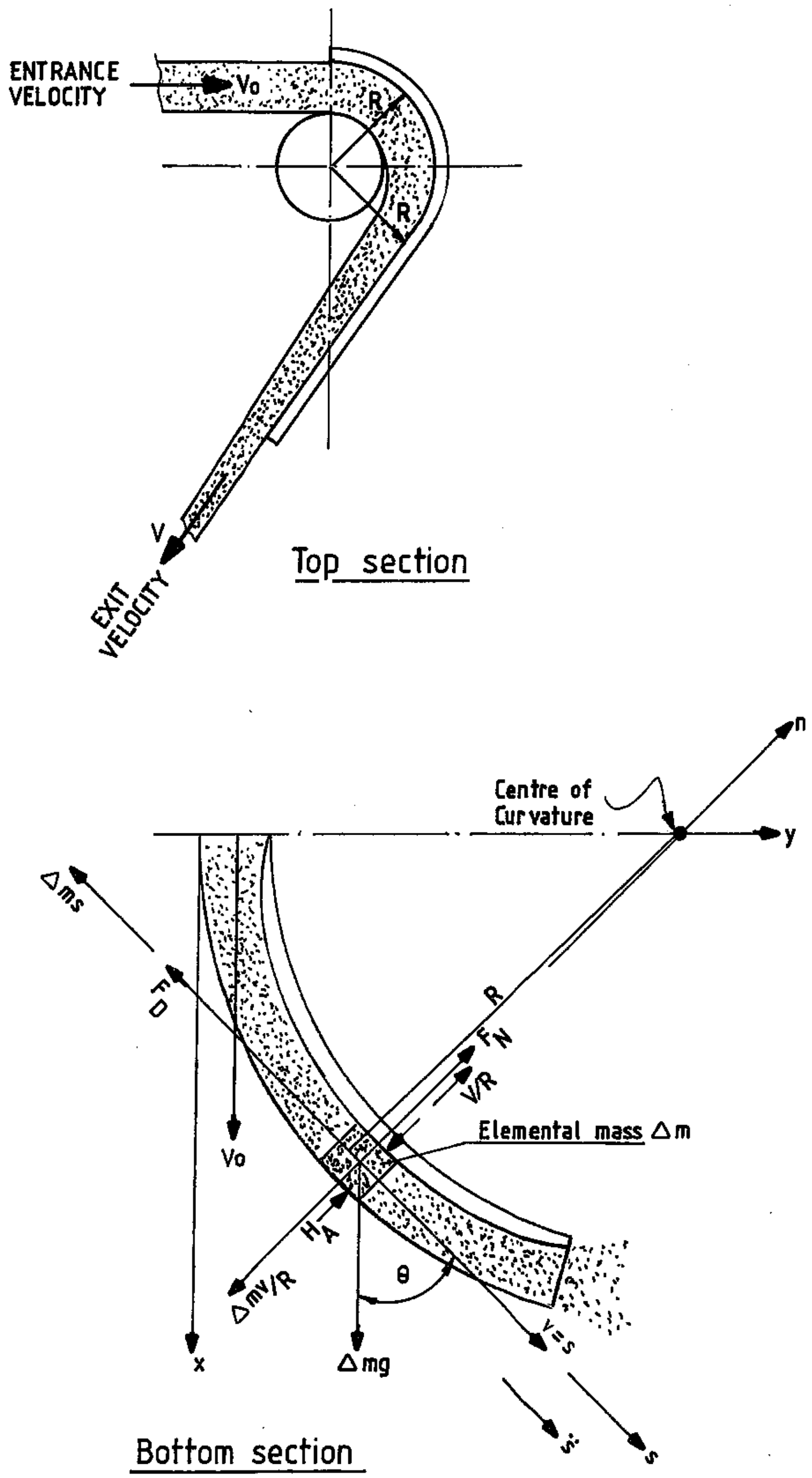
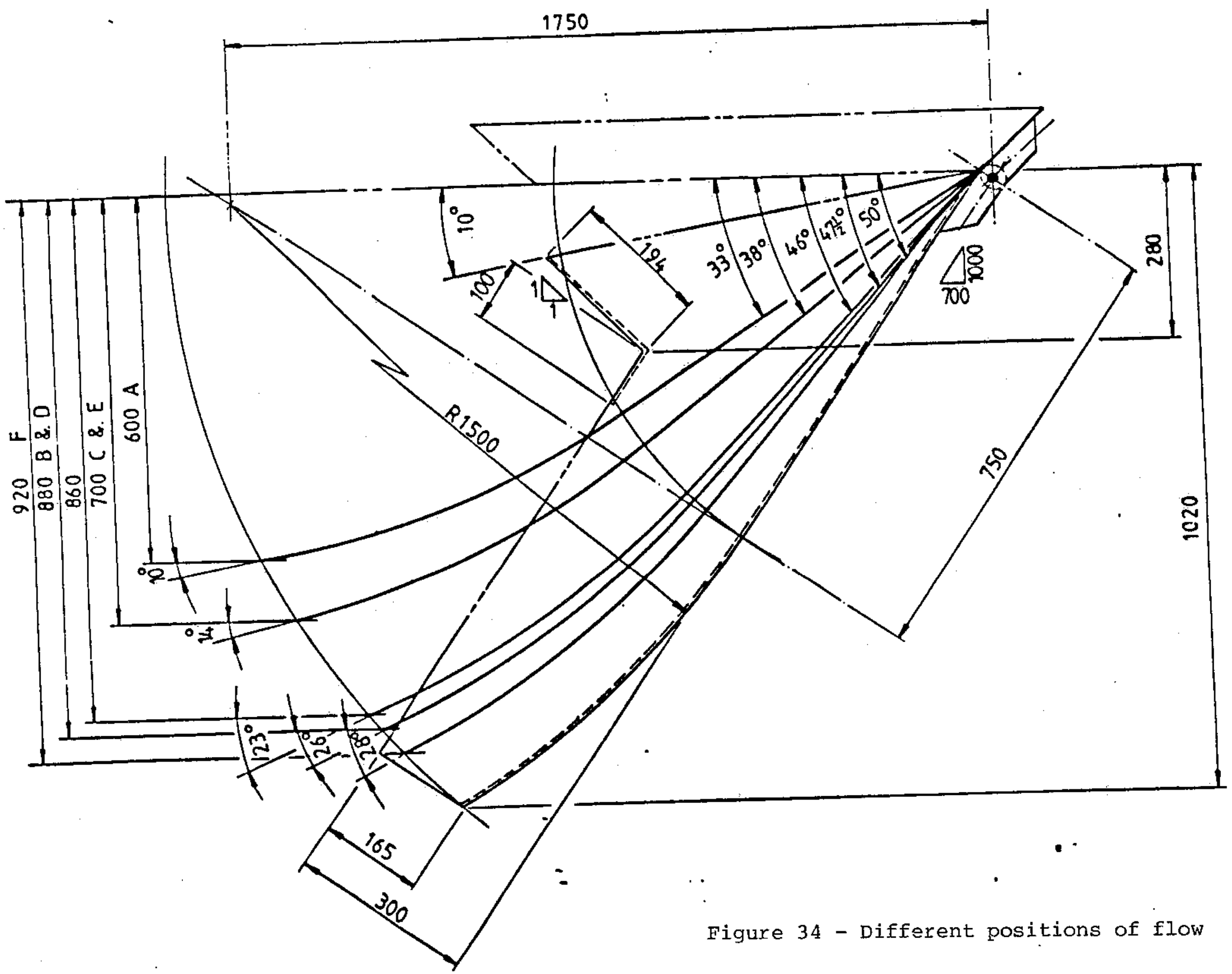


Figure 33 : DIAGRAMATIC INDICATION OF FLOW



NOTE :-

ANTHRACITE 45 × 70

A. BEST FLOW WITHOUT BREAKAGE

B. BELT STOP POSITION WHERE BOTTOM CHUTE IS CLEARED OF ANY BUILD UP

ANTHRACITE 25 × 45

C. BEST FLOW WITHOUT BREAKAGE

D. BELT STOP POSITION WHERE BOTTOM CHUTE IS CLEARED OF ANY BUILD UP

BITUMINOUS 0 × 40

E. BEST FLOW WITHOUT BREAKAGE

F. BELT STOP POSITION WHERE BOTTOM CHUTE IS CLEARED OF ANY BUILD UP

Figure 34 - Different positions of flow

Different positions of top and bottom sections were investigated. Figure 33 shows in diagram format the study of forces and velocities. The same co-ordinate system used by Roberts (Ref. 40) was applied.

Figure 34 shows different positions of bottom chute, tested on site for different coals.

The results indicated in Table 4 were based on the best flow positions as per Figure 34.

The total length of material travel in the chute surface is ± 2 600mm.

The speeds were measured using a stop watch. Average times of 10 measurements each were considered.

TOP SECTION :

Position 1 :

Away from head pulley - 500mm.
Exit speeds of 4 to 4,5m/second.

Position 2 :

Curved section close to head pulley - 300mm.
Exit speeds of 3,5 to 3,9m/second.

BOTTOM SECTION :

Position 1 :

Curved section at lower position.
Exit speeds of 3 to 5m/second.

Position 2 :

Curved section at top position.
Exit speeds of 1,3 to 2m/second.

Tests indicated that in a 2 150mm free fall the material hit the steel plate at ± 7,15m/second.

The belt conveyor was running in all experiments at a constant speed of 1,63m/second.

6.1 Conclusion :

It can be said that tests confirm that the main objectives in any design, to prevent degradation, will be to have a controlled flow. With the use of proper layouts i.e. radiussed curved sections and chute angles controlled flow is achieved.

The results summarised in Table 5 indicate size friability between free fall and test chute 3 to 4% depending on size.

Test chute indicates a reduction of 50% fines degradation for -15 top size for every transfer point. (Free fall versus test chute).

Turbulent flow in this type of product should be avoided.

Degradation during chute travel was based mainly on the grinding effect of the individual lumps, rubbing against each other under pressure in the sliding plate.

The chute flow theory by Roberts (40) is an acceptable basis for chute design.

Further investigations in other South African coal fields is required as well as the study of wearing rate of liners at curved sections.

In conclusion we would recommend continuing research in this field.

ACKNOWLEDGEMENTS :

The author's thank the Independent Coal Producers Associations (Pty) Limited (ICPA) for permission to publish data based upon various Techni economic studies carried out during the past years.

The authors are also grateful to the Planning Department of the South African Transport Services (SATS) for the support and data supplied for the various investigations carried out in their Terminals.

The authors express their thanks to the Management of Rand London and Grinaker Coal Spar for permission to use their facilities at Paulpietersburg Siding and Penlee Dump respectively.

Lastly, but by no means the least important to TMS and all our collegues involved in typing, gathering information and proof reading, we extend our warmest appreciation.

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