IMHC

INTERNATIONAL MATERIALS HANDLING CONFERENCE

BELTCON 4

Degradation of Sized Coal at Transfer Points

C M Ramos
P J Goodwin

7 & 8 September 1987
Sandton Holiday Inn
Sandton

The S.A. Institute of Materials Handling
The S.A. Institution of Mechanical Engineers

1.0 SUMMARY :

This paper will discuss some tests and proposed solutions to reduce the degradation associated with the handling of sized coal. No final answers are presented. The study of coal degradation is still in it's infancy, however, the work done up until now gives an idea on assessment of the expected behaviour and detrimental effects on the coal if proper detailed design is not followed.

This presentation briefly outlines previous work done in South Africa and overseas in the study of degradation as well as TMS research work.

Finally, test data from TMS work is applied to existing plants, the Bluff Coaling Appliance in Durban and the proposed new terminal to replace the Bluff Coaling Appliance. This comparison exercise is a demonstration of the method proposed to investigate degradation on different routes. The main emphasis is to show the improvement in degradation by using a systematic approach to design.

2.0 INTRODUCTION :

During the design and operations of various Coal Terminals, TMS recognised the lack of worldwide research into the degradation of sized coal. Research into the literature has indicated that some work was undertaken in South Africa, the United States of America, Britain, France, Germany, Russia, Italy and Sweden. However, the most complete study on chute degradation was undertaken by the Swedish Mining Association. This study took over three years to complete, and was mainly dedicated to the steel making industry. This project sampled large numbers of 2 000 to 20 000 tonnes lumpy ore and pellet shipments at different points in the transport chain from the mine to the various blast furnaces on the European Continent.

A summary of the main findings is presented here.

Informal discussions with exporters and mine engineers indicate that little scientific data was available and degradation levels mentioned to the authors was more guess work than based on scientific methods.

The consumers are demanding products prepared to stringent specifications and degradation levels. The stringent specifications on degradation have caused tests to be performed at loading/unloading terminals to determine acceptable levels of degradation incurred by handling. This is the reason for tests performed recently by some South African mining houses at the Bluff Coaling Appliance in Durban and terminal operators in Europe, i.e. Frans Swarttouw. As a matter of fact the European terminals usually test the coal in routes where they intend to handle it before committing themselves.

3.0 DEGRADATION :

Before we proceed it would be wise to define what degradation means in this presentation.

Degradation is simply the breaking of coal during transport and, by inference, the reducing of the mean size grain.

In this report two cases of degradation will be discussed :

The whole coal degradation and the undersize coal degradation.

On the whole, degradation is defined as the loss or gain of a given fraction to a smaller fraction through the range of final products expressed as a percentage of the whole. The method used is the standard method of drop shatter test for coal - ASTM D440-49 (re-approved 1980). For better understanding let us consider the following example :

Table 1 - Sample (45 - 75) :

Square Hole Screen (mm)		FREE FALL				
		Weight, %		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	23,5	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 (S1)	53,75 (S2)

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

Size Stability calculation is as follows :

Size Stability = (100 x S2/S1) = (100 x 50,48)/53,75 = 93,92%

Friability % = 100 - 93,92% = 6,08%

In the case of the undersize coal, degradation is defined as the reduction of particles below the bottom size of the product.

The foregoing definitions reflect the necessity for reducing degradation as far as possible, in order to retain as much of the original size fraction as possible.

The following paragraphs of this paper will show that accurate coal degradation assessment is a monumental task and still in it's infancy.

4.0 PREVIOUS WORK :

The literature and scientific data relating to coal degradation in South Africa goes back to 1930.

Most of the friability studies of South African coals, were carried out by members of the Fuel Research Institute (now the National Institute for Coal Research).

The first study on coal degradation was initiated by the Natal Coal Grading Committee in 1930. This study was to demonstrate that the coaling appliances at the Bluff caused an excessive amount of breakage, and to prove that the transporter systems were better than the shiploader. Although a great deal of work was carried out and some valuable information was obtained, the results were on the whole unsatisfactory, mainly due to the small size of the samples taken.

In May 1937, Messrs. J.C. Vogel and F.W. Quass (ref. 2), presented a paper dealing with the friability of South African coals. This paper dealt only with the impact friability of the coal. To express the average decrease in particle size, the authors used the method developed by Messrs. Yancy and Lane (ref. 3), which is the basis of the American drop shatter test for coal - ASTM D 440-49 (re-approved 1980).

The results of the shatter tests, carried out on coals from twenty five collieries, show a fairly close parallel between the proportions of large coal, nuts and smalls formed. The Witbank and Breyten coals were the hardest and differ little from each other. The Natal coals show a much greater variation among themselves compared with those in the Transvaal. In other words, the Natal coals show a smaller yield of large coal and a larger yield of nuts, smalls and dust.

In 1945, Drs. F.J. Tromp and L.A. Bushell produced a report on the breakage of South African coal during preparation, haulage and shipping (ref. 3). This report was undertaken after numerous complaints by consumers that the shipments of coal mainly used for bunkering of ships contained an excessive amount of fines. The report deals mainly with breakage occuring during transit from the collieries to the Bluff, breakage caused by the handling systems at the Bluff, and storage.

Results of tests to identify degradation during transit from the Collieries to the Bluff by rail wagon, show there is very little -20 or -12 material produced during transit, even with the soft coals. There is, however, a substantial decrease in the percentage of +100 lumps, most being reduced to +38 size. The highest percentage encountered in test products was Burnside coal with a 5,3% decrease in 12mm size. The average percentage of decrease in other coals was between 1,1 to 2,1%.

The screen analysis of coals before and after loading at the Bluff Coaling Appliance, using two sets of tests, were examined to determine degradation. The first test was to put 5 tonnes of coal through the belt plant and drop it 11,3m from the telescopic belt into an empty truck. The other test was to examine two sets of samples : One after a drop from a transporter into an empty truck from 1,8m (a minimum working height), and the other a drop of 10,7m. (This value was assumed to represent the average working height in practice).

The comparison of the bin and stockpile methods shows that the coal suffers less relative breakage in the bin than on the stockpile (See Table 4).

The coal intended for the bins was conveyed from the tippler via the wharf conveyors to the bins. The drop from the belt conveyor feeding the bins varied from 1,5 to 9,0m.

The coal intended for the stockpile was tipped into skips and dropped by the stockpile crane onto the different compartments. The drop was between 0 to 7,5m depending on the operator. (7,5m Was assumed to be usual practice).

The loading from stockpile to the transporters was more complicated than for the bins. Usually a grab would pick up the coal, and its jaws on closing would exert a crushing effect on the coal. The grab would empty its charge into a funnel suspended above the skip. The drop from the grab to the skip was 6,7m.

Another method was to use a front end loader and drop the coal directly into the skips.

TABLE 3

SCREEN ANALYSIS OF COALS BEFORE AND AFTER LOADING AT THE BLUFF

Colliery			Durban Navigation					Natal Navigation (Northfield)					Burnside					Vryheid Coronation				
Loading System			Belt		Transporter			Belt		Transporter			Belt		Transporter			Belt		Transporter		
			Before	After	Before	After 1,8m Drop	After 10,6m Drop	Before	After	Before	After 1,8m Drop	After 10,6m Drop	Before	After	Before	After 1,8m Drop	After 10,6m Drop	Before	After	Before	After 1,8m Drop	After 10,6m Drop
Screen	On	100mm %	39,5	23,5	28,0	18,0	11,4	44,9	13,6	31,1	18,9	15,3	26,6	9,4	30,3	11,7	9,4	17,3	15,0	10,4	6,7	3,8
Analysis	On	38 mm %	88,7	66,4	75,0	60,7	52,2	81,8	48,5	76,1	64,3	45,4	67,2	34,5	68,9	53,5	41,7	55,0	43,5	60,6	47,5	31,7
	On	20 mm %	95,2	81,1	94,9	87,4	77,7	92,7	67,6	93,3	81,6	64,1	86,0	58,9	87,0	77,1	62,9	82,6	62,7	89,0	79,6	61,1
	On	12 mm %	97,2	87,6	96,9	91,4	85,5	95,1	76,5	96,7	88,9	72,6	91,1	73,0	92,3	83,4	74,6	88,2	72,7	92,7	86,1	72,0
	Through	12 mm %	2,8	12,4	3,2	8,6	14,5	5,0	23,6	3,3	13,1	27,4	8,9	27,1	7,8	16,6	25,4	11,6	27,2	7,2	13,9	28,0
Decrease in 20mm Size %			-	15	-	8	18	-	27	-	13	31	-	31	-	11	26	-	24	-	11	31
Decrease in 12mm Size %			-	10	-	6	12	-	20	-	10	25	-	20	-	10	18	-	18	-	7	22

TABLE 4
SCREEN ANALYSIS OF COALS BEFORE AND AFTER STORAGE AT THE BLUFF

Colliery		Durban Navigation				Natal Navigation (Northfield)				Burnside				Vryneid Coronation			
Storage System		Bin		Storage		Bin		Storage		Bin		Storage		Bin		Storage	
		Before Stor.	After Stor.	Before Stor.	After Stor.	Before Stor.	After Stor.	Before Stor.	After Stor.	Before Stor.	After Stor.	Before Stor.	After Stor.	Before Stor.	After Stor.	Before Stor.	After Stor.
Screen	On 100mm %	39,5	12,9	28,0	13,2	44,9	10,8	31,1	8,7	26,6	7,3	30,3	8,8	17,3	7,7	10,4	3,0
Analysis	On 38 mm %	88,7	54,6	78,0	51,2	81,8	52,4	76,1	43,9	67,2	29,8	68,9	37,9	55,0	33,3	60,5	29,3
	On 20 mm %	95,2	73,8	94,9	76,9	92,7	71,8	93,3	64,6	86,0	50,6	87,0	60,1	82,6	58,2	99,0	58,6
	On 12 mm %	97,2	82,5	96,9	84,8	95,1	80,4	96,7	73,9	91,1	63,5	92,3	72,5	88,2	71,6	92,7	70,1
	Through 12 mm %	2,8	17,5	3,2	15,1	5,0	19,5	3,3	26,1	8,9	36,5	7,8	27,4	11,6	28,5	7,2	29,9
Decrease in 20mm size %		-	22	-	19	-	23	-	31	-	41	-	31	-	30	-	34
Decrease in 12mm size %		-	15	-	13	-	15	-	24	-	30	-	22	-	19	-	24

In 1946, Mr. C.C. le Grange published an article on the grindability of duff coals (ref. 4). His tests, using the ASTM ball mill method, once again confirmed that the Natal coals were generally the softest, and that the Ermelo-Breyton Transvaal coals were generally the hardest, with Witbank and Vereeniging coals occupying an intermediate position.

In May 1951, C.E. Bird presented a paper on the friability and weathering characteristics of South African coals (ref. 5). The main feature of the paper was the presentation of test results of friability of coal by using "Tumbler" tests as described in ASTM 1942 (D441-37T). This method was later replaced by the Standard ASTM (D441-45) in September 1945. This test covers the determination of the relative friability of a particular size of coal. It affords a means of measuring the friability of coal to break into smaller pieces when subjected to repeated handling at the Mine or subsequently, by the distributor or the consumer. The test, in essence, is useful for ascertaining the similarity of coals in respect to friability rather than for determining values within narrow limits in order to emphasize their dissimilarity.

When coal is exposed to the weather, it not only tends to alter chemically, but also to disintegrate. This is termed "slacking". Another interesting aspect of this study was the weathering and slacking of various coals sampled. Table 6 gives an indication of the effects of slacking during one year. Although South African coals seldom have moisture contents exceeding 8%, it is important to be aware of the increase of friability due to slacking.

Table 5 :

Coal Area - Mine	Coal Seam	Sample Number	Air - Dried Moisture	Initial Friability	Increase in Friability - Slacking *				
					After 14 Days	After 1 Month	After 3 Months	After 6 Months	After 1 Year
Witbank									
Springbok	No. 2	S75	1,0	17,5	2,5	6	7	10	10,5
New Douglas	No. 2	S14	1,9	18	5	7	11,5	12,5	13
Waterpan Washed	No. 2	S55	2,3	18	7	10	11,5	12,5	13
Phoenix Washed	No. 2	S105	2,1	18,5	5,5	6,5	8,5	9,5	13
Van Dyksdrift	No. 2	S74	1,7	16,5	4,5	7	8,5	12	13,5
New Albion	No. 2	S73	1,4	16	4,5	8	11	13	14
Clydesdale Washed	No. 2	S8	2,0	14,5	2,5	4,5	8,5	10,5	14,5
Greenside Washed	No. 2	S9	2,5	16	2	3,5	7	10	14,5
Landau	No. 2	S7	1,9	21	5	8	12	13,5	14,5
Navigation Unwashed	No. 2	S140	1,7	20	4	6,5	8	10	14,5
Tweefontein Washed	No. 2	S57	2,8	13,5	2,5	4,5	12,5	13,5	15,5
Greenside Unwashed	No. 2	S141	1,5	22,5	3	5	10	14	18
Tweefontein Unwashed	No. 2	S104	2,1	21	8,5	10	13	14	18
Waterpan Unwashed	No. 2	S106	2,1	22	1,5	4	6,5	11	18,5
Wolvekrans	No. 2	S15	2,1	21	4,5	7	15	17,5	19
Phoenix Unwashed	No. 2	S233	2,7	22,5	5,0	8,0	12	23,5	28,5
Honingkrans	No. 2	S16	3,4	23	12,5	19	28,5	33	39,5
T. and D.B.	1 & 2	S56	2,3	17,5	6	13	16	17	19,5
Clydesdale	No. 1	S44	1,9	21	2	5	8	9	14,5
Coronation	No. 1	S45	2,5	18	4	6,5	11,5	13	15,5
Uitkyk	No. 1	S43	3,4	18	8	13,5	21	23	30
Klippoortjie	No. 4	S151	2,9	23,5	10,5	17	23	29,5	41
South Witbank Washed	No. 4	S143	3,4	21	8	14,5	25	30	42
W.C.C.M. Washed	No. 4	S153	2,8	24	17	25	27,5	33	44
W.C.C.M. Unwashed	No. 4	S235	3,1	24,5	11,5	19,5	34,5	41,5	48,5
South Witbank Unwashed	No. 4	S234	3,3	23	11,5	17	31	41	50
Alpha Unwashed	No. 4	S152	3,9	22	30	31,5	36	44,5	56
Navigation Unwashed	No. 5	S342	1,9	19,5	5,5	8,5	10,5	19	20,5
Kendal	No. 5	S341	3,2	17,5	7	14	23,5	32	36,5

In 1953 in a further attempt to clarify the position, the Natal Coal Owners Association commissioned the Fuel Research Institute, once again, to undertake a fresh investigation into the breakage of export coal during handling.

Dr. P.J. van der Walt and Mr. J.M. van der Merwe produced a confidential report on breakage of Natal export coal during handling at the Bluff (ref. 6). The report studied the overall breakage occurring at the Bluff; the results proved the breakage to be excessive and further investigation was to be undertaken.

In a sense, the report did not shed more light on the degradation aspect already discussed by previous researchers.

After 1953, other reports on the coal degradation at the Bluff were commissioned. Due to the confidentiality involved they are not available for general information and are not mentioned here.

Most of the South African research has been dedicated to point out the levels of degradation, but few have attempted to solve the problem of degradation encountered practically. One exception was the development of the Langlaagte Chute (fig. 1). This chute design permits the finer portions of the feed to drop onto the belt first, followed by the coarser fractions. This particular chute was initially designed for the gold industry and successfully adapted to the coal industry.

Figure 2 : Langlaagte Chute

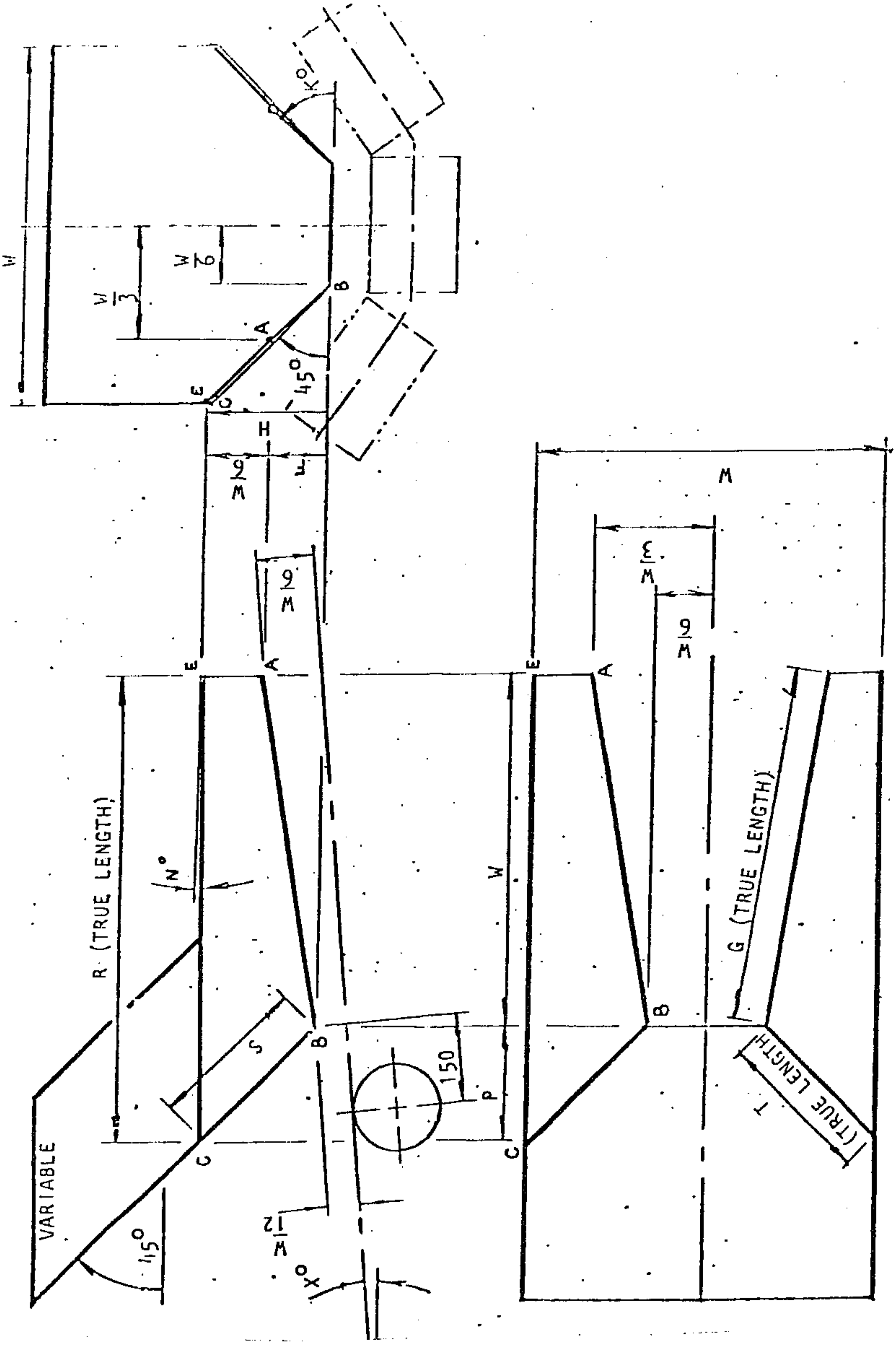
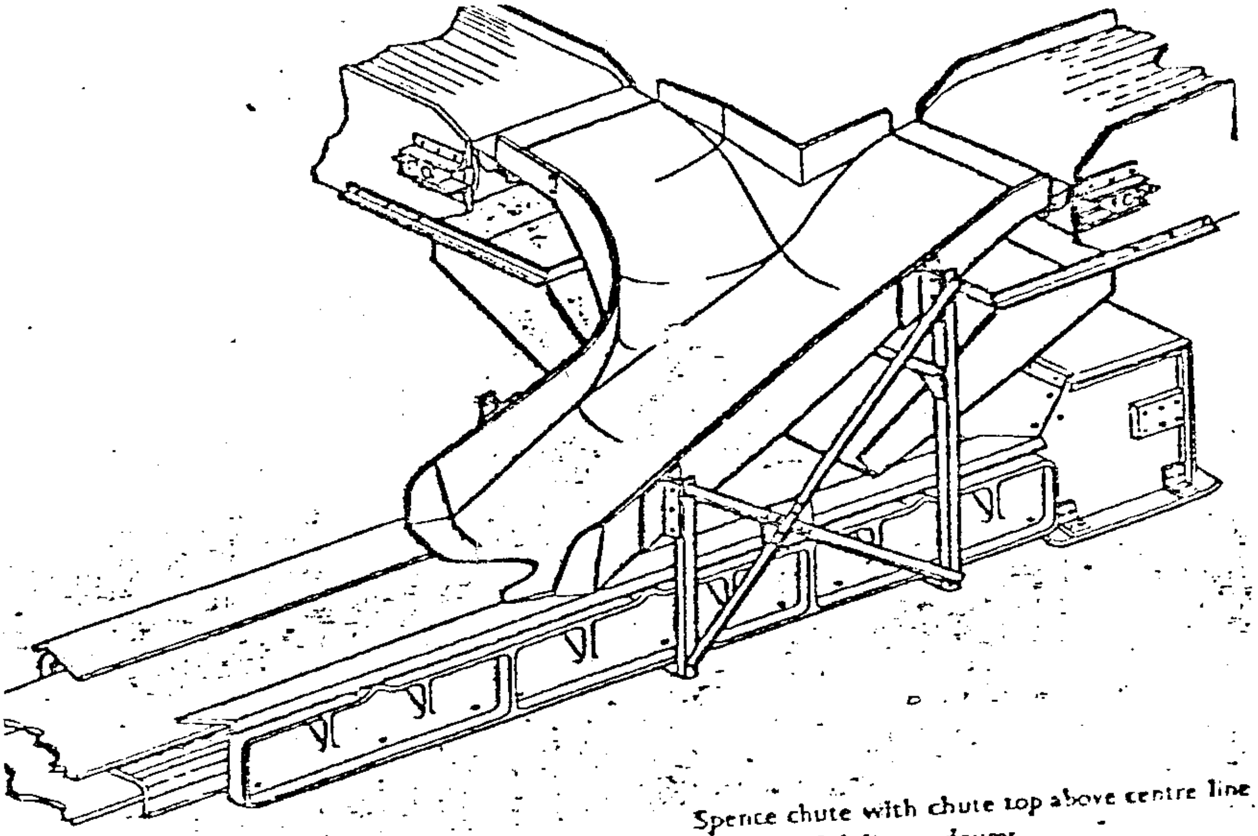


Figure 4 : Modified curved chute by J.V. Spence



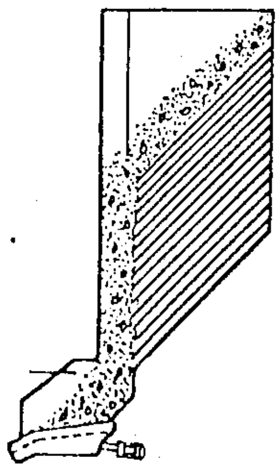
In the early 1950s, Mr. J.V. Spence (ref. 8) examined the problem of degradation at transfer points on National Coal Board underground conveyors. His work led to the development of two types of chutes. (Figures 2 and 3).

Although no tests were carried out on the chutes, they were successful in the sense that visual degradation was reduced and centralising of load achieved.

In 1964 the National Coal Board (ref. 9) again reported that the degradation of coal in silos and bins had been reduced from 44% to 2% by the use of spiral chutes. Unfortunately, as reported, the chutes were not a success as they were difficult to install and maintain in tall bins and, since they wore out rapidly, were not suitable for continuous plants.

This particular problem led to the development of the Kvapil type chimney discharge. Kvapil, in 1964 (ref. 10 and 11), proposed that a half chimney be inserted into the front wall of the bin above the discharge opening.

Figure 5 : Kvapil type Chimney discharge :



This type of design allows particles from the top layer in the bin to slide down into the chimney in a uniform manner. Test results from the National Coal Board indicated that for 38 x 75mm coal, the following values were observed :

Drawing from full bins :	Increase of -38mm fines % :
Center discharge	6 - 7
Chimney discharge	2

Because of the great technical details and economics involved, efforts were made by the Swedish Mining Association to appoint a research group (ref.12, 13 and 14) to investigate the degradation of lumpy materials in transport, and propose a suitable means for reducing the generation of unwanted fines.

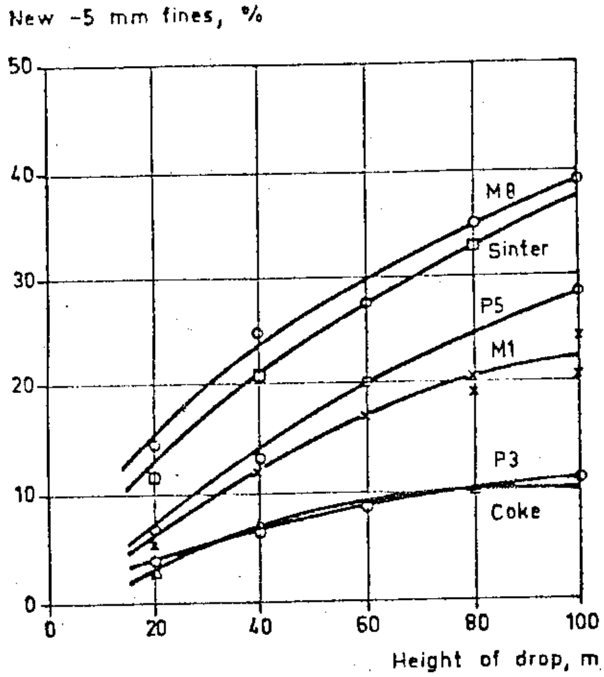
Although this study was mainly applied to the steel making industry (lumpy ore and pellets) the findings were, in principle, valid for the coal industry and, therefore, the relevant points are discussed here.

The test work mainly involved dropping and abrasion of different materials. Drop tests were carried out in a 20m high chute with inlet ports at different levels. The tumbler drum tests followed ISO Technical Commission 102, Iron Ore, (Fifth Draft Proposal), February 1970. This ISO test is slightly different from the one used in South Africa. The ISO test procedures indicate that the sample shall be put onto 1 x 0,5m rotary drum with two 50mm high lifters. The drum speed is 25rpm, and the rotation time 8 minutes. The formation of fines was measured by screen analysis before and after each test, the limit chosen was the 5mm fraction. Observations and results indicate that as the total drop increases, the size distribution gradually shifts. Large lumps are fractured and reduced in number, the medium sizes remain fairly stable, and the fines increase. The results suggest that a few large drops cause about the same disintegration as several small drops.

Figures 5 and 6 are based on the Swedish Mining Association report prepared by Messrs. B. Fagerberg and N. Sandberg (Ref.15).

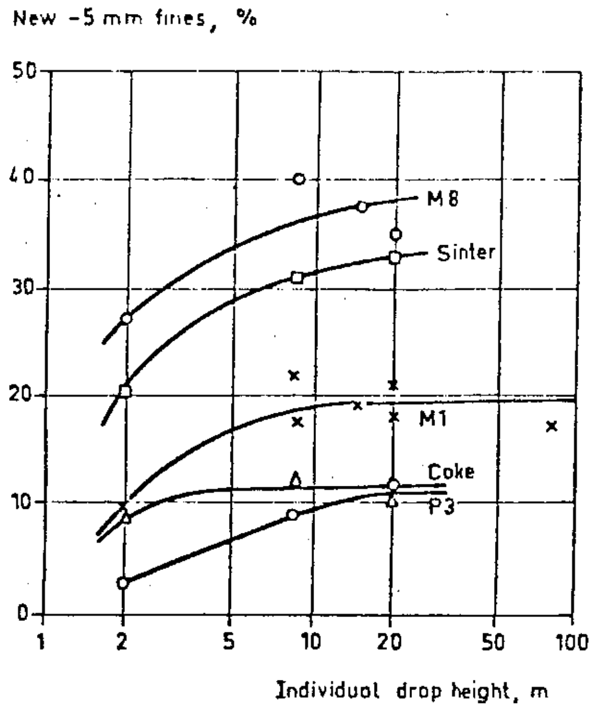
The particle speed after 20m of fall was calculated at 19,8m/second.

Figure 6 : Effect of total drop height on degradation in repeated 20m drops in a test chute



Material		Size, mm	TI, %
M8	Weak ore	10-100	~62
M1	Hard ore	10-100	~82
P5	Weak pellets	+5	~89
P3	Normal pellets	+5	~95
Sinter		10-100	~62
Coke		10-50	~92

Figure 7 : Effect of individual drop height on degradation at a total drop of 20m. Materials are the same as those in Figure 5



These two figures give a good idea of fines levels for different height drops.

The procedure in the tumbler test is slightly different and therefore difficult to compare. Previous tumbler test work in South Africa appears to indicate values for T1 in the range of 97 to 90%. These values are dependent on coal and particle size.

Usually T1 for small coal less than 38mm is in the region of 97 - 95%, and in the region of 95 - 90% for coal greater than 38mm. Accepting the above values as guidelines, the curves P3 and Coke can be used to express degradation from the figures.

The experiments of Messrs. Fagerberg and Sandberg also suggested that drops higher than 5m tend to show that impact stresses are greater than the strength of the material. The mechanical strength was measured by three methods, tumbler index, compression index and cold compression index. If the tests are correct, it shows that one should attempt to avoid impact speeds above 10m/sec, thus limiting the belt speed of belt conveyors handling coal.

Another item of research was to find out if the discharge through an empty bin was subject to greater degradation than through a full bin. The Swedish Research Group carried out a series of tests with bins filled to different levels. The bin level was kept constant by adding the same amount of ore as was drawn off. Discharge from filled bins was the least damaging method, indicating that 50% to 70% less fines were produced than through empty bins, and confirmed previous tests of the National Coal Board.

Following in the footsteps of the National Coal Board, the Swedish built a high tower provided with oblique rubber lined baffle plates spaced 1m apart in a zigzag pattern. The sloping baffles permit the material to slide down at a uniform and gentle rate. This type of tower reduced degradation as indicated in Table 6.

Table 6 :

Degradation of Pellets and Lump Ore at a total drop of 28m with and without a Baffle Plate Tower		
Material Stockpiling Method	5mm Fines %	Degradation %
Pellets, Test 1 :		
as received	2,0	
after stockpiling at 28m free drop	8,9	7,1
with tower	5,0	3,1
Pellets, Test 2 :		
As received	3,7	
After stockpiling at 28m free drop	8,4	4,9
with tower	4,1	0,4
Lump Ore, 10 - 50mm :		
as received	14,3	
after stockpiling at 28m free drop	18,9	5,4
with tower	15,7	1,6

Another item of study was the effect of loading ore by a boom stacker. The results show that by stacking onto a fixed 30m high prismatic pile, 4% degradation was measured, and stacking with a movable boom kept 2m above the pile, 1,5% was measured.

To finalise this section it is worthwhile as a point of curiosity to mention the use of transit shock recorders to assess coal breakage.

In 1962 the Scottish Divisional Production Directorate decided to investigate the behaviour of large coal at conveyor transfer points. The collection of large samples of coal and detailed size grading before and after using the industries standards, was investigated and considered by the Directorate to be time consuming and of limited accuracy. Dr. G.W. Bromfield and Mr. F.N. Brydom (ref. 16) were requested to assess and propose simpler methods. They decided to use shock recorders as a tool to measure impact shock suffered by large coal in the transfer chutes. The shock recorder concept was developed by the Enfield G.W. (E) for the Air Ministry for use on packaged guided weapon components to indicate if shock greater than the acceptable level is received by a package during transport.

The recorder had six indicators arranged to register when a shock in any one of the six directions (ie. each direction along three mutually perpendicular axes) exceeds a given value.

For the purpose of the tests the impact shock recorder was mounted in a 150mm cubical steel box "The Black Box". The direction of mounting was such that the six indicators monitored shocks along the normal axis to the face of the cube, and the weight of the box was arranged to be the same as the weight of an equivalent size piece of coal, plus/minus 5kg, so that the box transferred at the conveyor point will receive impact shocks of the same order as large coal transferred at the point.

Each indicator can be preset to operate at the shock levels 5, 10, 15, 20, 30, 40, 50, 75 and 100G.

Quite interesting is the effect of changes in the resilience of the impact surface at a drop of 0,5m as tested by the above authors. The impact speed from the free fall was calculated at 3,24m/second.

Table 7 :

Impact Surface	Steel Plate	PVC Conveyor Belt Rigidly Supported on Steel	75mm Bed of Small Coal on Steel	Unsupported PVC Conveyor Belt Under Tension	75mm Bed of Small Coal on Unsupported Conveyor Belt Under Tension
g Value	75	70	21	5	5

The results recorded by this instrument for individual passage over a conveyor chute consequently depend not only on the magnitude of the impact shock suffered by the box during transfer but also on the direction of the shock relative to the six faces of the instrument.

This type of instrument has not been used for a long time as it was not practical.

5.0 TMS RESEARCH :

In 1984, TMS decided to test degradation levels at transfer points. The main objective was to test a chute developed, designed and manufactured to handle the complete range of products through a simple route (i.e. sensitive sized coal and duff mixture). After analysing the various types of chutes used in the industry, it became obvious that one of the best designs was the curved profile variable geometry chute initially developed by Professor Roberts of Newcastle University (14, 15 and 16) for the Grain Industry.

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

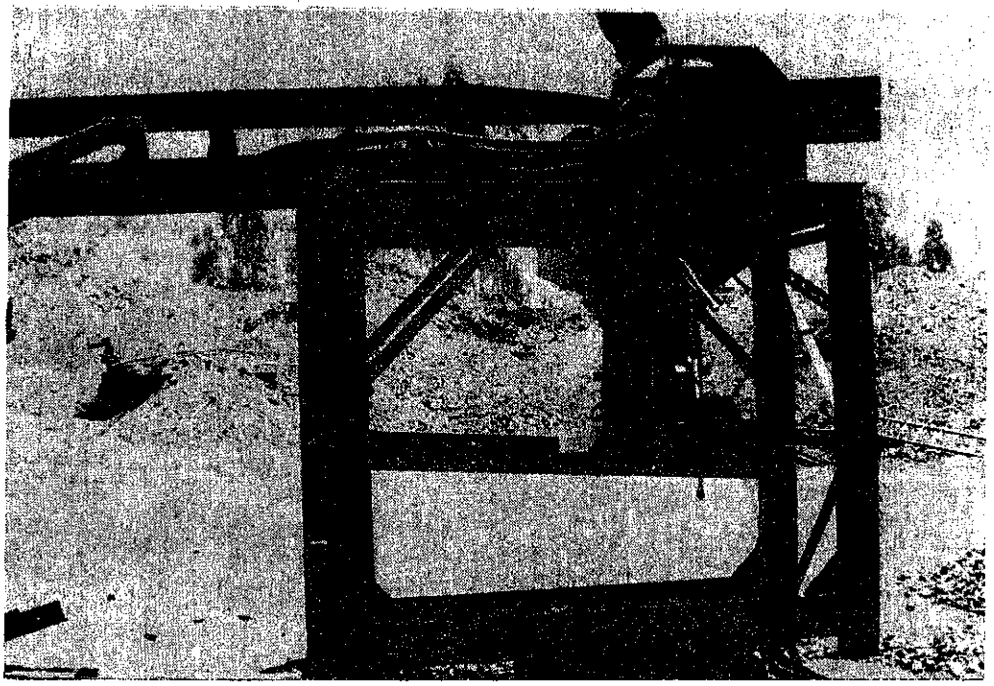
Loading in the direction of belt travel.

Loading transverse to the direction of belt travel.

Loading in the direction of belt travel is the most desirable type of loading which any designer strives to achieve. The material flow is directed centrally onto the next belt conveyor. 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.

TMS chose a belt conveyor layout with a plus/minus 90° transfer for testing their chute.

<u>Figure 8</u> : Test Chute



This type of transfer presents the problems of turning the flow of material, difficulty in achieving the same speed and the considerable height requirements, belt cover wear, difficult chute work, and usual displacement transversely of the receiving belt on its supporting idlers.

During conveying of materials, segregation in the cross section of the belt conveyor occurs each time the material goes over a set of idlers with lumps riding near the top of the material and fines at the 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, i.e. the relative velocity after impact is smaller than beforehand. The outside particles are in a 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 to be similar to the flow of fluids. The material on a belt conveyor consists 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 varies 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, or the turbulent flow in which the particles move in a disorderly manner occupying different relative positions in successive cross sections. Both types of flow occur in any belt conveyor system. The streamline flow is observed for material on belt. The turbulent flow is observed at any transfer point.

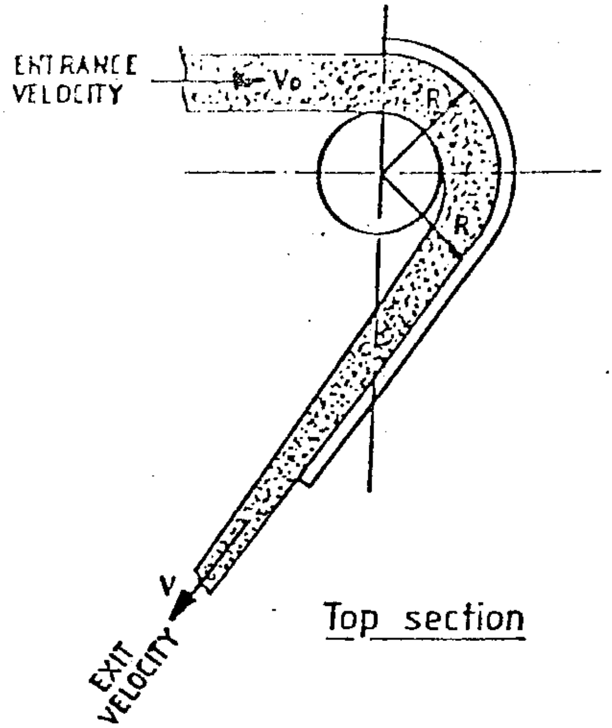
Any improvement in coal size degradation can only be achieved by avoiding impact, and controlling the speed and direction during transfer.

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.

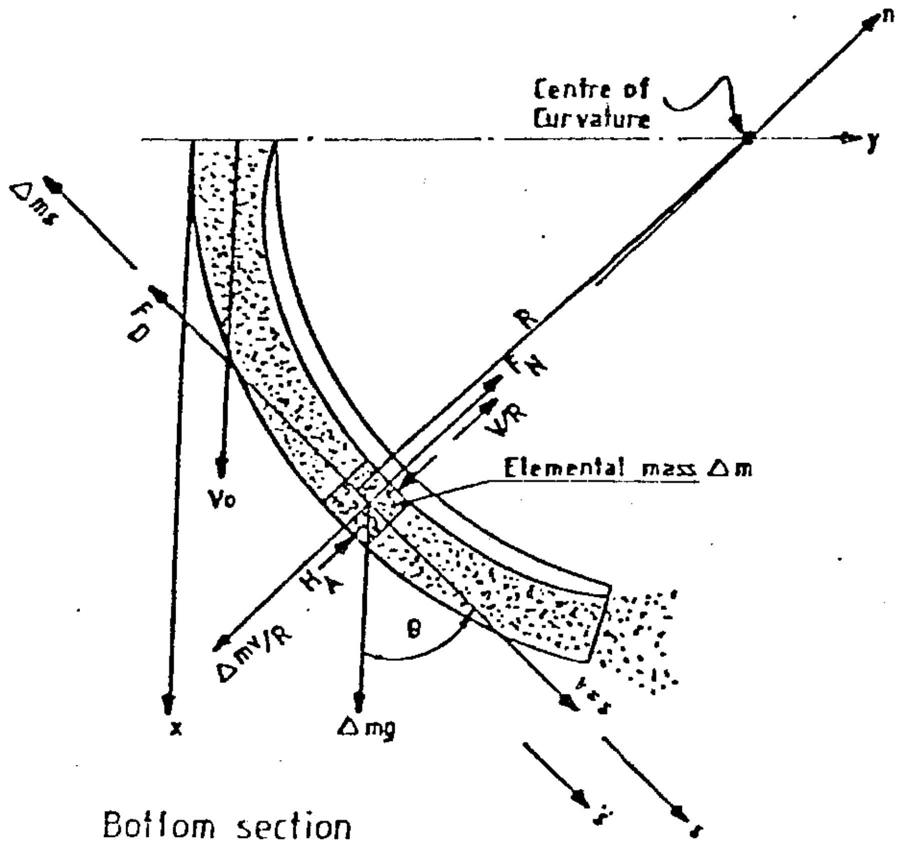
The test chute was built in three main components, top curve, bottom curve and skin structure. Both top and bottom chute components were radiusized fully and adjusted to allow the effect of various angles on coal flow during transfer to be studied.

The main feature of the test chute is a curved section in front of the head pulley. This curved section changes the flow in a controlled manner over 150°. From this point another curved chute section controls the flow until it is discharged onto the receiving belt conveyor.

Figure 9 : Diagramatic Indication of Flow



Top section



Bottom section

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 lumps rubbing against each other under pressure on the curved sliding plate, due to centrifugal forces. This top section is adjustable to regulate velocity of flow onto the next bottom section which is also adjustable and 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's dream of equating the existing speed with the speed of the collecting conveyor.

5.1 Particle Velocity Tests :

Initially a transfer point at Rand London Siding was chosen for tests. The belt conveyor was running at a constant speed of 1,2m/second during all experiments at Paulpietersburg. The drop height between belt conveyors was 2m.

Due to lack of availability the tests were transferred to Penlee Dump in Glencoe. The free fall of tests at Penlee Dump indicated that in a 2 450mm free fall the material hit the steel plate at a velocity of plus/minus 7,15m per second.

The flow through the design chute, depending on different combinations of the curved sections, achieve exit speeds as follows :

TOP SECTION :

Position 1 :

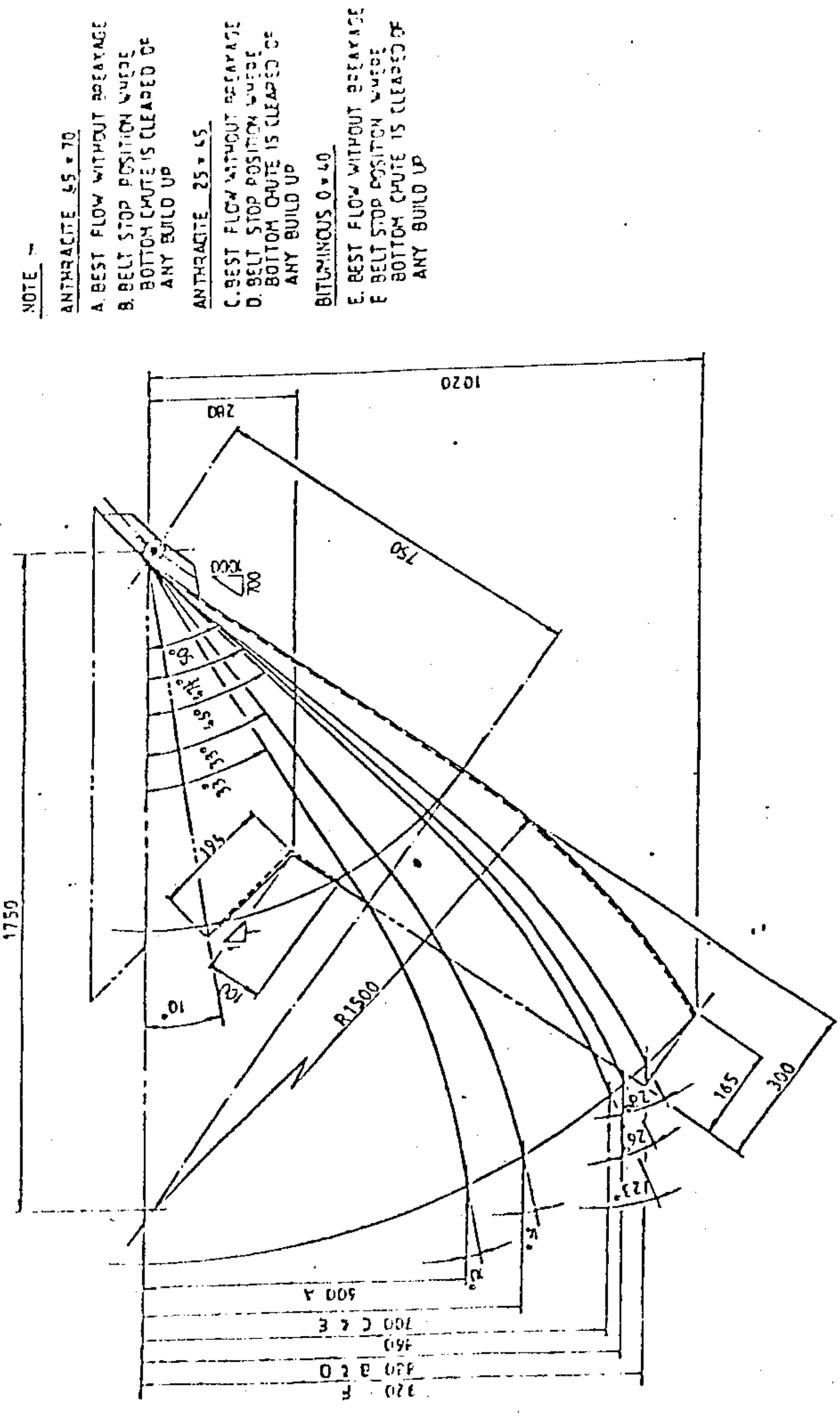
Curved section away from head pulley - 500m
Exit speed of 4 to 4,5m/second

Position 2 :

Curved section away from head pulley - 300m
Exit speed of 3,5 to 3,9m/second

BOTTOM SECTION :

Figure 11 :



Position 1 :

Curved section at 50°
Exit speed of 3 to 5m/second

Position 2 :

Curved section at 33°
Exit speed of 1,3 to 2m/second

The belt conveyor was running in all experiments at Glencoe at a constant speed of 1,63m/second. The material travel in the chute 2,6m.

6.0 DESCRIPTION OF TESTS AND COMPARISON OF DEGRADATION :

At Glencoe site 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. Two types of tests were conducted :

Free fall and through the test chute.

Over 70 screen analysis tests were executed on this site. The summary results indicate the following results :

Table 8 : Difference between free fall and test chute (test in Glencoe)

Sample	Size Friability		Improvement Times Free Fall Test	HGI
	Free Fall	Test Chute		
45 x 74 (Anthracite)	6,09	2,75	2,21	42
25 x 45 (Anthracite)	4,49	1,53	2,93	47
0 x 40 (Bituminous)	4,36	1,62	2,69	62

The percentage of degradation discussed on the above table is based on the analysis of all samples as per the American Standard mentioned previously. Another way to view degradation is to consider that below a certain sized particle, the increase of fines is the most important criteria to the exporter. In other words, the exporter will sign a contract where he stipulates coal size and percentage of undersize expected. This is usually done on higher grades and sizes of the coal market. It has been practice by some exporters to screen coal before loading onto the ship to avoid penalties and coal is re-screened by the purchaser at destination. The following table represents the degradation accounted for in the undersize critical particle range, based on the tests performed by TMS in Glencoe.

Table 9 : Undersize Particle Range Comparison

Description of Sample	Under Size Considered	Weight % Free Fall			Weight % Test Chute			Times Improve From Free Fall to Test Chute
		Before Test %	After Test %	% Diff.	Before Test %	After Test %	% Diff.	
45 x 75	-15	0,3	3,7	2,7	1,0	2,8	1,30	2,08
25 x 45	-15	3,0	6,3	3,30	6,2	7,5	1,30	2,54
0 x 40	-15	57,6	61,2	3,60	62,5	63,9	1,40	2,54

7.0 WORKING EXAMPLES :

After analysing the test work it became apparent that a relationship exists between particle size and particle velocity. Any meaningful chute design should take the following parameters into consideration :

Particle velocity, particle size and hardgrove index.

Different particle sizes showed different levels of degradation when speed was increased or decreased (1,3 to 4m/second).

This led to the conclusion that there is a straight line relationship between speed, particle size, and degradation. In other words higher speeds increase the impact forces and abrasion effects through the chute, lower speeds the opposite.

Although no tests have been made in this regard, it is firmly believed that a cut off point in this relationship exists when the impact stresses are greater than the strength of the coal particle, and that other parameters such as rank of coal will also play an important role.

The use of hardgrove index will help to correlate coals of the same rank from different collieries and allow the designer to use test data from previous tests to design chutes where tests are not available.

Based on the above relationships two facilities are compared :-

Existing Durban Bluff

Proposed Scheme "C"

7.1 Existing Durban Bluff : (See Figure 13)

The existing scheme comprises two tipplers, one shiploader and two transporters. In general terms there are two routes available :

Tippler 2 to Shiploader

Tippler 1 to Transporters

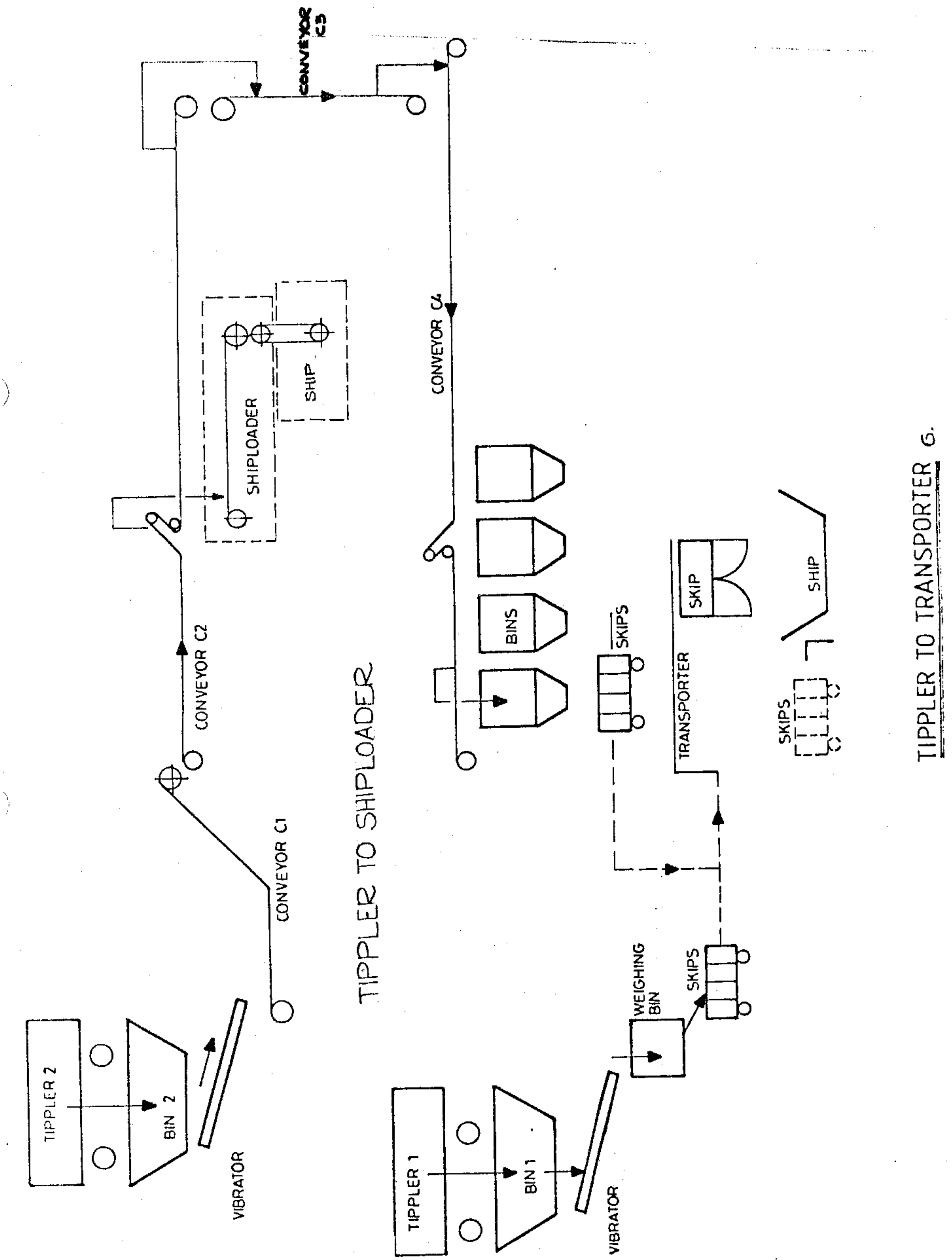
7.1.1 The route Tippler 2 to Shiploader comprises the following main parameters relevant to the calculation of degradation :

Tippler 2 discharges to a bin with an approximate capacity of 2 rail wagons. There is a drop of 2m before the coal starts to slide into the bottom plate.

From the bunker coal is loaded into conveyor C1 by means of two vibrators. The drop height from the screens to the belt is 1m.

Conveyor C1 takes the coal to wharf conveyor C2. The belt width is 1 200mm with a belt speed of 3m/second. The drop height from C1 to C2 is 2,5m.

Figure 13 : Existing Bluff Coaling Appliance Flow Sheet



From conveyor C2, the coal is loaded onto the shiploader belt. Two options exist, direct to ship, or to be screened. Initially the shiploader was provided with a lowerator and a spreader. At present, a cascade chute with a spreader is used. The belt width is 1 200mm with a belt speed of 3m/second. The drop height at different points are as follows :

From C2 to shiploader belt	6,0m
From shiploader to Lowerator	3,0m
From Lowerator to shiploader	2,5m
From shiploader to ship hold	2,0m
From screens to belt	11,0m

7.1.2 The route <u>tippler 1 to transporters</u> comprises the following main parameters :

Tippler 1 to bunker with an approximate capacity of two rail wagons. A drop height of 3,5m.

From Bunker coal is discharged to a weighing bin. A drop height of 1,5m.

From weighing bin to rail wagon a drop height of 2m.

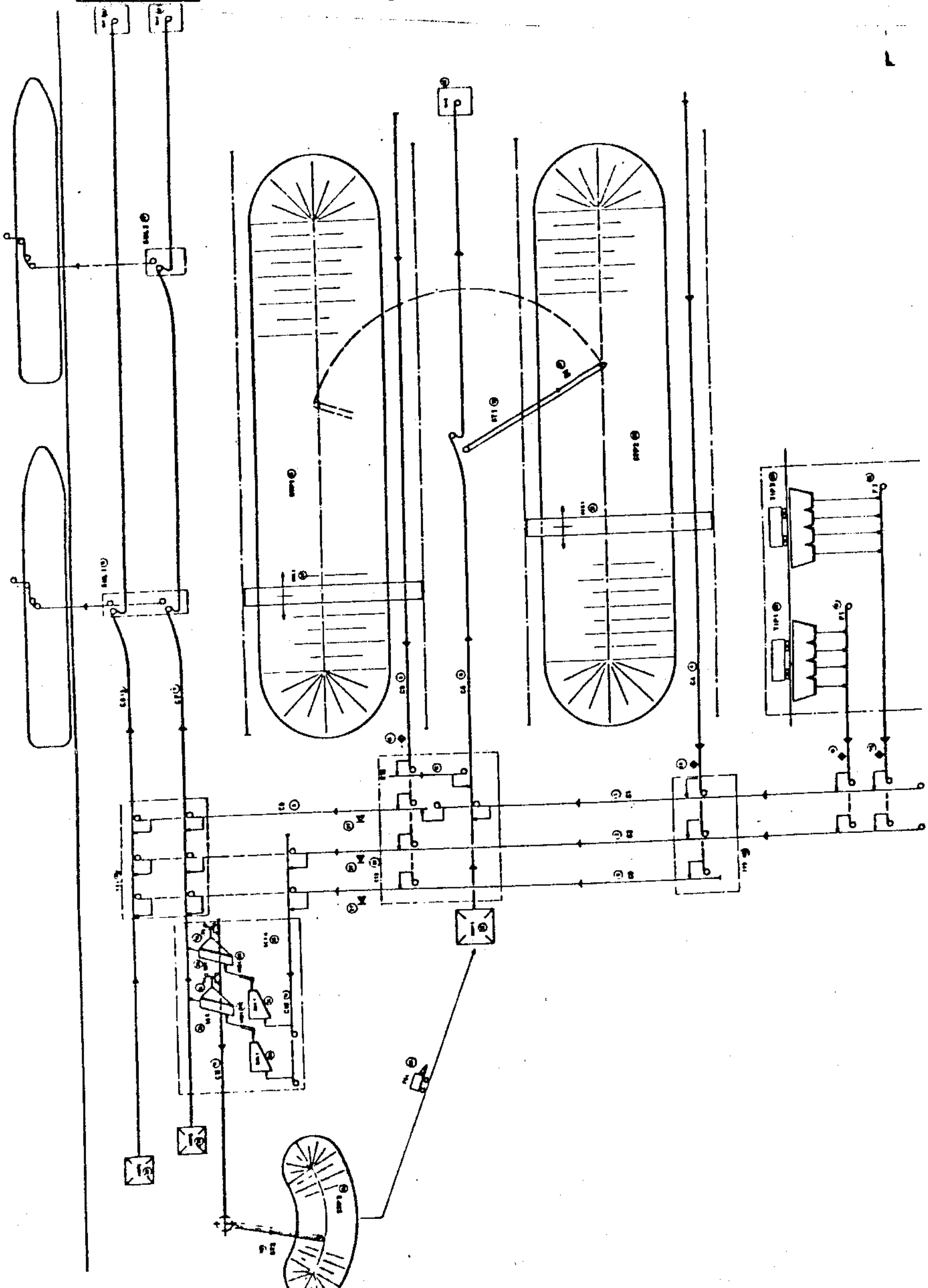
From transporter to ship's hold is 2m

7.2 <u>Proposed Scheme "C" :</u> (See Figure 14)

The proposed scheme comprises two new tipplers, stockpiles, screen and analysing facilities and two new shiploaders. There is a multiple selection of routes available in this proposal. For the sake of comparison, the following have been considered :

<u>Tipplers to Shiploaders</u>
<u>Tipplers to Stockpiles</u>
<u>Stockpiles to Shiploaders</u>
<u>Screen House to Shiploaders</u>

Figure 14 : Flow Sheet Proposed Scheme "C"



The proposed conveyor system has been designed with dual speeds of 1,25 and 2,5m/second to handle 500tph sized coal (45 x 75, 25 x 45), and 1 000tph Duff/Mixture (0 x 40). Respectively the conveyor belt width has been standardized at 1 200mm. The transfer chutes have been standardized at 2m heights, and when sampling cutters are used, 2,4m.

7.2.1 The route Tipplers to Shiploaders comprises the following main parameters relevant to the calculations of degradation :

Tipplers discharge to a bin with an approximate capacity of two rail wagons. There is a drop of 1m between tipplers and bins, after that the coal will slide on a steel floor which is adjustable for sized coal or duff/mixture.

From bins coal is discharged to conveyors C1 and C2 by belt feeders with a drop of 2m. It is not a free fall, the curved chute concept is used.

From conveyors C1 and C2 coal is discharged to conveyors C7 and C8 with a drop of 2,4m, of which 0,4m, due to sampler, is free fall. The rest is controlled by curved chutes.

8.0 MAIN CONCLUSIONS :

The degradation improvement achieved by the test chute in relation to the conventional type can be observed in the following tables 10 and 11. These tables depict comparison results for the Existing Bluff Coaling Appliance and the Proposed Scheme "C" to replace the Bluff in the future.

The tables express degradation by assuming a related increase for each transfer point. The values are relative, not absolute, and will vary for different coals and grades. As an example, the tests at Paulpietersburg showed that the 25 x 50 anthracite was very hard and would produce plus/minus 4 times less degradation than the same grade at Glencoe. Table 2 of this paper shows a variation in the degradation levels of 2,4 times between the softest and hardest coal test.

Table 10 : Comparison (Full Sample)

Description of Route	Estimated Degradation % Based on Product Analysis		
	45 x 75	25 x 45	0 x 40
Existing :			
Tippler 2 - Shiploader	39,30	28,97	28,13
Screens - Hold	19,43	14,32	-
Tippler 1 - transporter	24,85	18,31	17,85
Proposed Scheme "C" :			
Tipplers - Shiploaders	16,15	10,95	18,3
Tipplers - Stockpile	17,86	11,98	21,77
Stockile - Shiploader	17,42	11,18	13,72
Screens - Shiploaders	9,71	6,57	-

Table 11 : Comparison (-15 undersize)

Description of Route	Estimated Degradation % Based on Product Analysis		
	45 x 75	25 x 45	0 x 40
Existing :			
Tippler 2 - Shiploader	17,15	20,97	23,55
Screens - Hold	8,35	10,21	-
Tippler 1 - transporter	11,06	13,46	14,68
Proposed Scheme "C" :			
Tipplers - Shiploaders	7,42	8,34	12,01
Tipplers - Stockpile	8,12	9,04	13,71
Stockile - Shiploader	7,71	8,24	13,72
Screens - Shiploaders	4,41	4,94	

To summarise, let us view the data collected by the other South African researchers in this field, and compare it with the TMS results.

Table 12 and 13 show the overall friability and indicate that there is a certain degree of similarity in the results of the other researchers. The coals compared are no longer being mined however, but they are part of the same coal field.

Table 12 : Comparison of Degradation results on the Bluff (Existing - Fullsample)

Description of Route	Vogel and Quass	Tromp and Bushell	C.E. Bird	van der Walt and van der Merwe	TMS Existing
Mine Location	Dann-hauser	Vryheid Coro.	Cambrian		Glencoe
Tippler 2 - Shiploader	44,2	31			39,30
Tippler 1 - Transporter	22,86	24			24,85
Sample size	50 x 150	38 x 100	25 x 38	38 x 100	45 x 75

Table 13 : Comparison of Degradation of Results on the Bluff (Existing - Undersize)

Description of Route	Vogel and Quass	Tromp and Bushell	C.E. Bird	van der Walt and van der Merwe	TMS Existing
Mine Location	Dann-hauser	Vryheid Coro.	Cambrian		Glencoe
Tippler 2 - Shiploader	19,04	24			17,15
Tippler 1 - Transporter	6,12	18			11,06
Particle size Undersize	50 x 150 -25	38 x 100 -20	25 x 38	38 x 100	45 x 75 -15

Based on the results, we conclude that the existing chute design in the coal industry should be revised to the curved chute concept proposed by TMS.

Further tests should be carried out in other coal fields of South Africa to allow a complete scientific standard design procedure.

ACKNOWLEDGEMENTS :

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

The Authors are also grateful to the National Institute for Coal Research for the support and data supplied during the various investigations carried out in the past few years and the permission to publish data based on various research projects undertaken by Institute personnel.

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

REFERENCES :

1. Smith, Roger T.

2. Vogel, J.C and Quass, F.W "The Friability of South African Coal" Part 1 - Journal of the Chemical, Metallurgic and Mining Society of South Africa, March 1937.

3. Tromp, F.J and Bushell, L.A "The Breakage of South African Coal during Preparation, Handlage and Shipping", Fuel Research Institute Report No. 9 of 1945.

4. Bird, C.E : The Friability and Weathering Characteristics of South African Coals" - Journal of the Chemical, Metallurgical and Mining Society of South Africa, May 1951.

5. Van der Walt, P.J. and Van der Merwe, J.M "Breakage of Natal Export Coal during Handling at the Bluff", Fuel Research Institute - Technical Memorandum No 21 of 1953.

6. La Grange, C.C The Grindabilities of South African Duff Coals" - Journal of the Chemical, Metallurgical and Mining Society of South Africa, December 1946.

7. "Report of the Committee on Roadway Conveyors", National Coal Board, October 1964.

8. "Bunker Design to Reduce Coal Degradation". Unpublished report, National Coal Board, September 1964.

9. Kvapil, R "Bergmekanik" (Rock Mechanics) Compendium, Royal Institute of Technology, Stockholm 1966 - 1970.

10. Kvapil, R. "Probleme des Gravitations Flusses von Schüttgutern", Aufbereitung - Stechnik 5, 1964 pp.183 - 189.

11. Jarnuff, K. "Ekonomiska Aspekter Pa Mullbildning Under Transport" (Economic Aspects of Degradation in Transit). Unpublished report LKAB. MET 8/20, 1970.1973.

12. Fagerberg, B. Sandberg, N. and Osterborg, B. "Mullbildning vid Godshantering" (Degradation in Transit), Jernk Ann 154 Stockholm 1920 pp. 369 - 385.

13. Fagerberg, B. and Sandberg, N. "Degradation of Lump Ores in Transport". Proceedings of the second internation Symposium of transport and handling of minerals, volume 2 - Rotterdam, Netherlands, October 4 - 5, 1973.

14. Van Vuuren, M.C.J and Boshoff, H.P. "A Comprehensive Survey of Analysis of most Chemical and Physical Properties of Colliery Samples taken by the Fuel Research Institute during 1982", Fuel Research Institute, Bulletin No. 96.

15. Roberts, A.W : "An Investigation of the Gravity Flow of Non-Cohesive Granular Materials through Discharge Chutes".

16. Roberts, A.W : "The Dynamics of Granular Material Flow through Curved Chutes". Mechanical and Chemical Engineering Transactions Institution of Engineers, Vol. MC3 No. 2.

17. Roberts, A.W : "Short course on Bulk Solids Handling". University of the Witwatersrand of May 1983.

18. Yancy and Zane : "Comparison of methods for determining the Friability of Coal". U.S. Bureau of Mine Report of Investigations 3215 June 1933.

19. Broomfield, G.W and Brydon, F.N. : "The use of transit Shock Recorders to assess Coal Breakage". Colliery Guardian, April 5 1962. Vol. 204, No. 5268.

20. Ramos C.M. : "Report on Degradation" a TMS internal report, 1986

21. Goodwin P.J and C.M. Ramos : "Design of Belt Conveyors in Bulk Terminal Applications" ; Bulk Solids Handling Vol. 5 (1985) No. 5 and Vol. 6 (1986) No. 2.