Braking Formulae for Emergency Braking without Electrical Braking

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SUMMARY

This report shows how equations were derived to be able to calculate the velocity/ distance characteristics obtained during the emergency braking of a winder without the use of dynamic braking.

Example calculations are also included in which the characteristics obtained during an overwind test are derived.

LIST OF SYMBOLS

C_1	=	mass of conveyance 1
M_2	=	mass of conveyance 2
M_1	=	load in conveyance 1
M_2	=	load in conveyance 2
l	=	total length of the wind
l_r	=	total length of the rope
m	=	mass per unit length of rope
X_o	=	distance of conveyance 1 from end of wind at the time of the trip
f	=	allowance for shaft friction
T_s	=	static torque
T_b	=	braking torque
T_d	=	decelerating torque
R	=	radius of drum
R_b	=	radius of brake path
B	=	braking effort
μ	=	coefficient of friction of brake lining
I_t	=	total inertia
I_d	=	inertia of drums
I_c	=	inertia of clutches
I_s	=	inertia of drum shaft

I_a	=	inertia of armatures referred to the drum shaft
I_g	=	inertia of gears
I_{sh}	=	inertia of both sheaves referred to the drum shaft
I_l	=	inertia due to net load, two conveyances and two ropes
α	=	angular acceleration of drum
a	=	linear acceleration of conveyance
F	=	braking force
V_o	=	velocity at time of trip
t_1	=	dynamic braking deactuating time delay
t_2	=	time after trip until brake shoe contact
t_3	=	time after trip until full braking force applied
S_1	=	distance at $t_a = t_1$ calculated from equations for $v \le t_a \le t_1$ by setting $t = t_1$
V_1	=	velocity at $t_a = t_1$ calculated from equations for $o \le ta \le t_1$ by setting $t = t_1$
S2	=	distance at $t_a = t_2$ calculated from equations for $t_1 \le t_a \le t_2$ by setting $t = t_2 - t_1$
V_2	=	velocity at $t_a = t_2$ calculated from equations for $t_1 \le t_a \le t_2$ by setting $t = t_2 - t_1$
S_3	=	distance at $t_a = t_3$ calculated from equations for $t_2 \le t_a \le t_3$ by setting $t = t_3 - t_2$
V_3	=	velocity at $t_a = t_3$ calculated from equations for $t_2 \le t_a \le t_3$ by setting $t = t_3 - t_2$
s	=	distance travelled after trip during time t_a
v	=	velocity at time t_a after trip

t_a	=	actual time after trip
t	=	time used in calculations

for $o \le t_a \le t_1 \quad t = t_a$
for $t_1 \le t_a \le t_2 \quad t = t_a - t_1$
for $t_2 \le t_a \le t_3 \quad t = t_a - t_2$
for $t_3 \le t_a$ $\quad t = t_a - t_3$

$n, \psi, \phi, \varepsilon_1, \varepsilon_2, \alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2, \beta_3$, - all calculated constants

SUMMARY OF BRAKING FORMULAE FOR EMERGENCY BRAKING WITHOUT DYNAMIC BRAKING

Total inertia $I_t = I_d + I_c + I_s + I_a + I_g + I_{sh} + 1$

$= \sum$ all individual inertias

$$n^2 = \frac{2.\ m.\ g.\ R^2}{I_t}$$

$$\gamma = \frac{\mu\ .\ R_h.\ R}{I_t}$$

$$\psi = [(1 - f)(C_1 + M_1 + Ml) - (1 + f)(C_2 + M_2) - 2.M.X_o]\ .\ \frac{g.\ R^2}{I_t}$$

Differential equation: $\dfrac{d^2s}{dt_2} - n^2.\ S = \psi.\ B + \phi$

Where B is the function of time

There are four distinct time periods to consider, each period giving a different value for and a different solution to the differential equations.

1

$\underline{O \le ta \le t}$

$$B = O$$

$$t = t_a$$

$$v = V_o$$

$$s = V_o . t$$

2

$\underline{t_1 \le t_a \le t_2}$

$$B = O$$

$$t = t_a - t_1$$

$$\alpha_1 = S_1 + \frac{\phi}{n^3}$$

$$B_1 = \frac{V_1}{n}$$

$$s = \alpha_1 . \cosh (n. t) + \beta_1 . \sinh (n. t) - \frac{\phi}{n^3.}$$

$$v = \alpha_1 . n \sinh (n. t) + \beta_1 . n . \cosh (n . t)$$

3

$\underline{t_2 \le t_a \le t_3}$

$$B = \frac{F . t}{t_3 - t_2}$$

$$t = t_a - t_2$$

$$\varepsilon_1 = \frac{\gamma . F}{t_3 - t_2}$$

$$\alpha_2 = S_2 + \frac{\phi}{n_2}$$

$$\beta_2 = \frac{1}{n} (V_2 + \frac{\varepsilon_1}{n^2})$$

$$s = \alpha_2 . \cosh (n. t) + \beta_2 . \sinh (n. t) - \frac{(\varepsilon_1, t + \phi)}{n^2}$$

$$v = \alpha_2 . n. \sinh (n. t) - \beta_2 . n. \cosh (n. t) \quad \frac{\varepsilon_1}{n^2}$$

4

$\underline{t_3 \le t_a}$

$$B = F$$

$$t = t_a - t_3$$

$$\varepsilon_2 = \gamma . B + \phi$$

$$\alpha_3 = S_3 + \frac{\varepsilon_2}{n^2}$$

$$\beta_3 = \frac{V_3}{n}$$

$$s = \alpha_3 . \cosh (n. t) + \beta_3 . \sinh (n. t) \frac{\varepsilon_2}{n^2}$$

$$v = \alpha_3 . n. \sinh (n. t.) - \beta_3 . n. \cosh (n. t.)$$

DERIVATION OF EQUATIONS

Description

The condition for which the equations were derived is illustrated in Figure 1. This figure also shows how the various distances are measured in relation to each other.

This derivation assumes that any dynamic braking is made inoperative and that only mechanical braking is used after the trip. The time required for the dynamic braking to trip out is catered for.

Figure 2 shows a typical velocity/distance curve obtained after the hoist has been tripped. The curve can be divided into four areas, each of which requires different treatment.

After the trip has occurred there may be a delay (t_1) before the dynamic braking cuts out and this results in the curve in area 1 where the velocity neither increases or de-creases by any appreciable amount.

After the dynamic braking has been removed there will be a period of time (t_1 to t_2) in which the brakes are not yet in contact with the drum. This is area 2 in Figure 2 and during this time the hoist will accelerate due to gravity.

From the moment the brakes have made contact with the drum their braking effort will start to increase as the brakes are brought more and more onto the drum. After a period (t_2 to t_3) the brakes will be fully applied and maximum braking torque will be available. During the initial application of the brakes the braking torque will be less than the static torque of the system and the conveyance will continue to accelerate. When the braking torque becomes sufficient to overcome the static torque the conveyance will start to decelerate. The application of the brakes takes place in area 3 of Figure 2.

After a time t_3 the brakes will be fully applied and the conveyance will be decelerated until it is brought to rest.

Differential equation

By referring to Figure 1 it can be seen that the static torque on the drum shaft due to the conveyances, load and rope is given by:

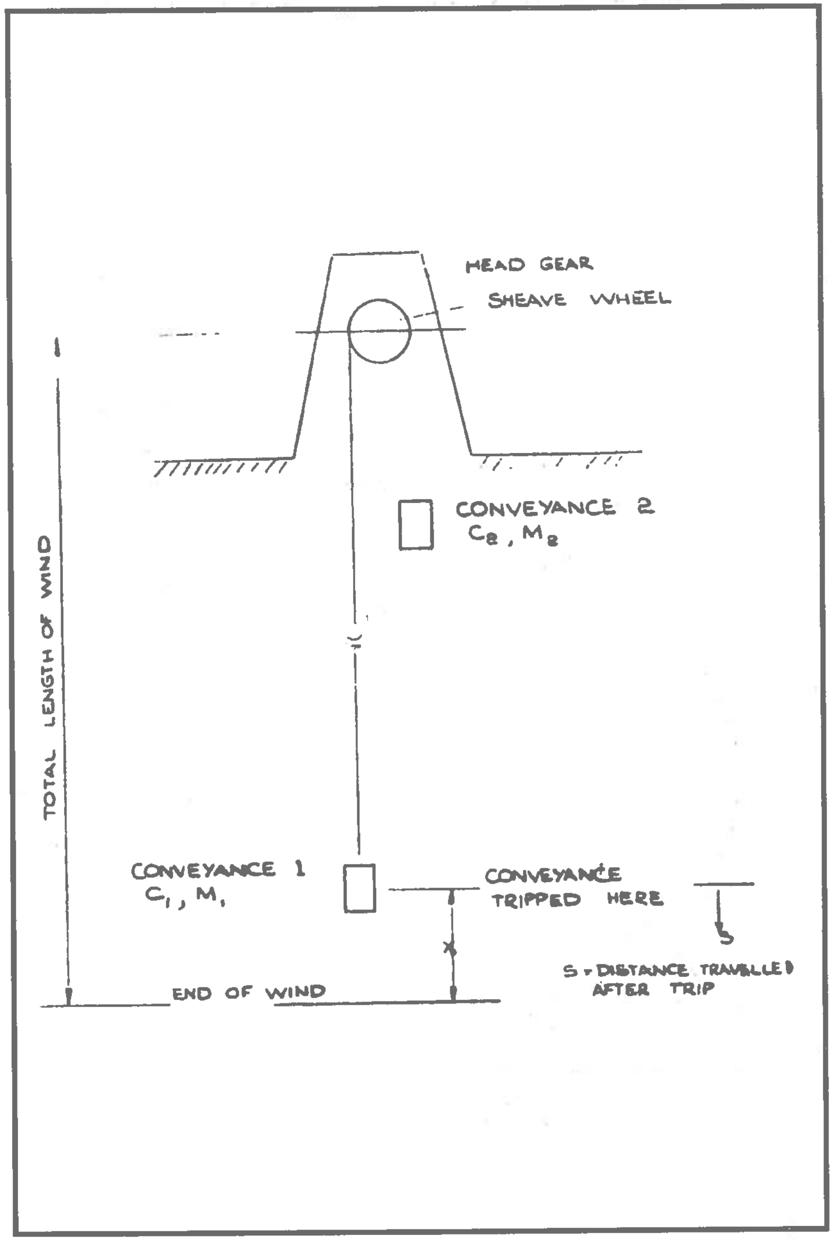

FIGURE 1
Relation of Distances

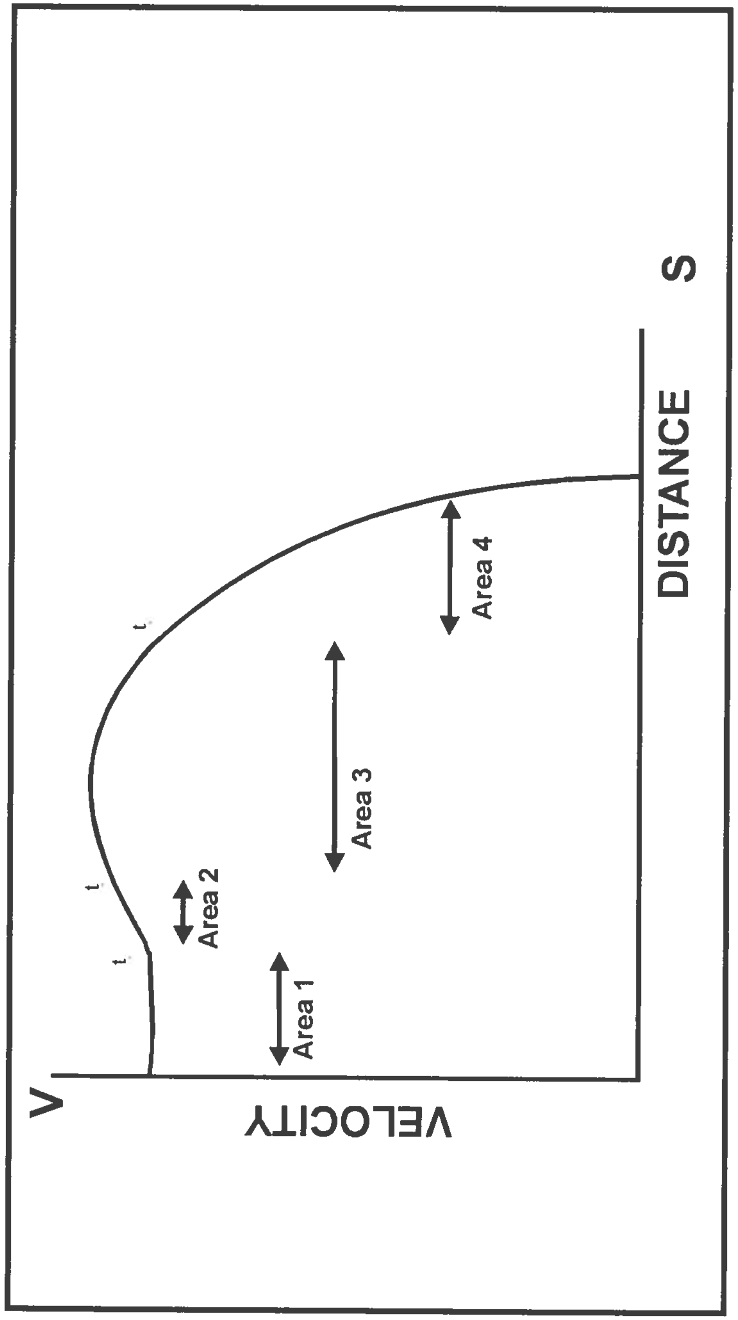

FIGURE 2
Typical Velocity/Distance curve

$$Ts = [(C_1 - C_2) + (M_1 - M_2) + m[l - 2(X_o - S)] - \frac{\text{friction}}{\text{allowance}}].\ g.\ R \quad (1)$$

The friction force is mainly due to the rollers in the shaft and windbag. If the friction force is expressed as a percentage of the total suspended weight of the load, conveyances and rope. This will give a static torque of:-

$$T_s = [\{(C_1 - C_2) + (M_1 - M_2) + m[l - 2(X_o - S)]\}$$

$$- [(C_1 + C_2) + (M_1 + M_2) + m.\ l]\ .\ f].\ g.\ R \quad (2)$$

$$T_s = [(1 - f)(C_1 + M_1 + M.\ l) - (1 + f)(C_2 + M_2) - 2.\ m.\ X_o + 2.\ m.\ s\ ]\ .\ g.\ R \quad (3)$$

the braking torque is given by:

$$T_b - B\ .\ \mu\ .\ R_b \quad (4)$$

Where B is dependant upon which area of the curve in Fig 2 the system is operating in. it is because B is different in each area of the curve that four separate sets of equations are needed to fully define the curve.

If the braking torque equals that static torque, the conveyance will continue to move with a constant velocity. Any difference between the braking torque and the static torque will be the torque available to decelerate the conveyance.

The decelerating torque is given by:

$$t_d = T_b - T_s \quad (5)$$

Having found the decelerating torque, the angular acceleration is given by:

$$\alpha = \frac{T_d}{I_t} = \frac{T_b - T_s}{I_t} \quad (6)$$

$$\alpha = \frac{T_s - T_b}{I_t} \qquad (7)$$

and the linear acceleration by

$$a = \alpha . R = (T_s - T_b) . \frac{R}{I_t} \qquad (8)$$

Substituting equations (3) and (4) into equation (8) we have:

$$a = \{[(1-f)(C_1 + M_1 + m.l) - (1 + f)(C_2 + M_2) - 2.m.X_o + 2.m.s] . g.R$$

$$-B.\mu.Rb) . \frac{R}{I_t} \qquad (9)$$

$$a = [](1 - f)(C_1 + M_1 = m.l) - (1 + f)(C_2 + M_2) - 2.m.X_o]. \frac{g.R^2}{I._t}$$

$$+ \frac{2.m.g.R^2.s}{It} \quad \frac{B.\mu.R_b.R}{It} \qquad (10)$$

Letting

$$n^2 = \frac{2.m.g.R^2}{It} \qquad (11)$$

$$\phi = [(1 - f)(C_1 = M_1 + m.l) - (1 + f)(C_2 + M_2) - 2.m.X_o] \frac{g.R^2}{It} \qquad (12)$$

$$\psi = - \frac{\mu.Rb.R}{I_t} \qquad (13)$$

we have:

$$a = \phi + n^2 . s + \psi . B$$

Now the acceleration $a = \frac{d^2s}{dt^2}$ and substituting in equation (14) and rearranging we have:

This is a second order differential equation whose general solution is:

$$s = \alpha . \cosh(n.t) + B . \sinh(n.t) + \text{particular integral} \qquad (16)$$

The particular integral is dependent upon the area in Fig 2 in which the system is operating.

Having obtained the specific solution to equation (16) the velocity is given by:

$$v = \frac{ds}{dt}$$

Specific Solutions

The specific solutions are derived for each area a follows:

1 <u>$O \leq t_a \leq t_1$</u>

During this period it is assumed that the dynamic braking present cancels out any accelerating torque due to gravity. This gives the following linear motion equations:

$$v = V_o \qquad (17)$$

$$s = V_o . t \qquad (18)$$

2 <u>$t_1 \leq t_a \leq t_2$</u>

During this period the braking torque B = O and the differential equation becomes:

$$\frac{d^2 s}{dt^2} - n^2 . s = \phi$$

(19)

The solution to equation (19) will commence from t = o where t is given by

$$t = t_a - t_1 \qquad (20)$$

For the particular integral we assume s = C

$$s = C, \quad \frac{ds}{dt} = O, \quad \frac{d2s}{dt} = O \qquad (21)$$

Substituting equations (21) in (19) we have

$$O - n^2 . C = \phi \qquad (22)$$

$$\therefore C = - \frac{\phi}{n^2} \qquad (23)$$

and the solution becomes

$$s = \alpha_1 . \cosh (n.t) + \beta_1 . \sinh (n. t) - \frac{\phi}{n^3} \qquad (24)$$

$$v = \alpha_1 . n . \sinh (n . t) + \beta_1 . n . \cosh (n . t) \qquad (25)$$

Now at t = O, ($t_a = t_1$) we have $s = S_1$ and $v = V_1$ where S_1 and V_1 can be found from equations (17) and (18) by lettering $t = t_1$

Equations (24) and (25)now become:

$$S_1 = \alpha_1 .1 + \beta_1 . O - \frac{\phi}{n^2} \qquad (26)$$

$$V_1 = \alpha_1 . n . O + \beta_1 . n . 1 \qquad (27)$$

giving

$$\alpha_1 = S_1 + \frac{\phi}{n^2} \qquad (28)$$

$$\beta_1 = \frac{V_1}{n} \qquad (29)$$

3 $t_2 \le t_a \le t_3$

During this period the braking torque is a function of time t. The variation of braking torque against time is shown in Figure 3.

where t is given by

$$t = t_a - t_2 \qquad (30)$$

The slope of the curve is given by

$$\text{Slope} = \frac{F}{t_3 - t_2} \qquad (31)$$

$$\therefore B = \frac{F. t}{(t_3 - t_2)} \qquad (32)$$

and the differential equation becomes

$$\frac{d^2s}{dt^2} - n^2 . s = \frac{\gamma. F}{t_3 - t_2} . t + \phi \qquad (33)$$

and letting

$$\varepsilon_1 = \frac{\gamma . F}{t_3 - t_2} \qquad (34)$$

we have

$$\frac{d^2s}{dt^2} - n^2 . s = \varepsilon_1 . t + \phi \qquad (35)$$

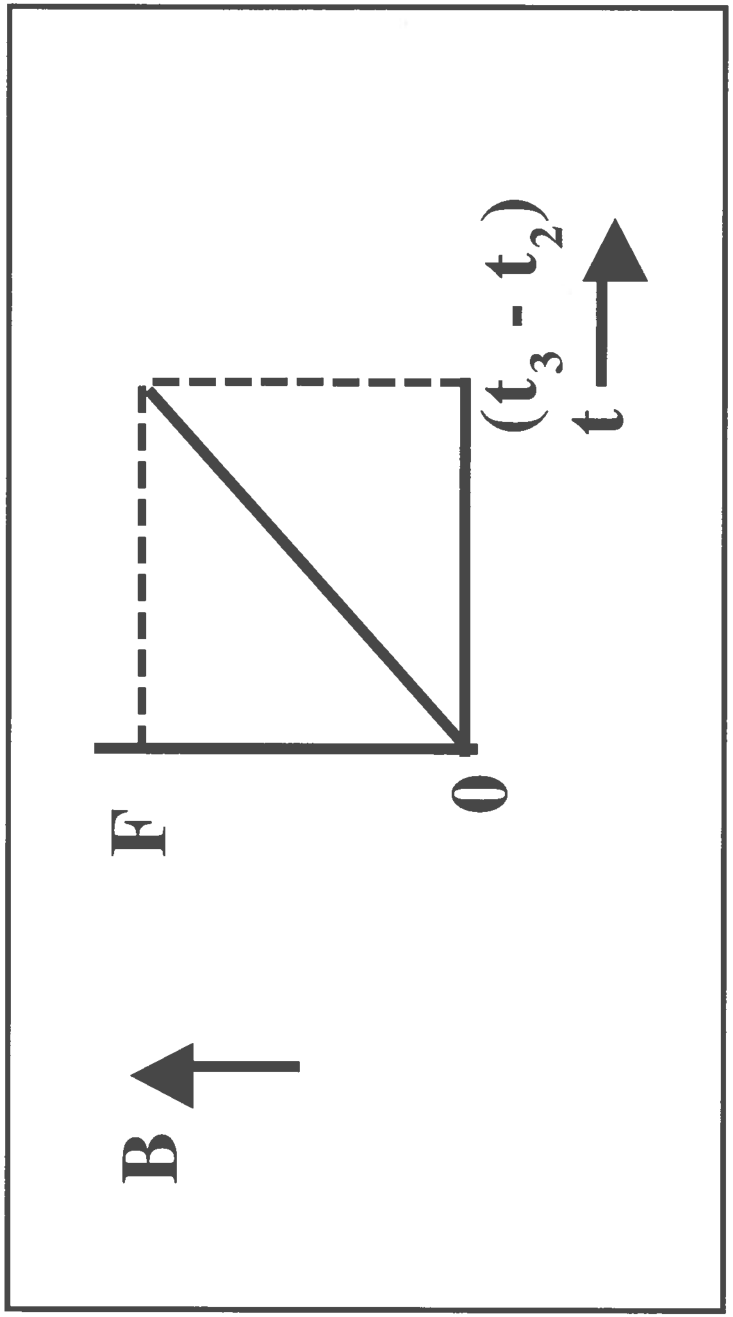

FIGURE 3
Braking Torque vs Time

For the particular integral we assume $s = C_t + 0$

$$s = C_t + D, \quad \frac{ds}{dt} = C, \quad \frac{d^2s}{dt^2} = 0 \tag{36}$$

Substituting equations (36) into (35) we have:

$$v - n^2 (c.\, t + 0) = \varepsilon_1 .\, t + \phi \tag{37}$$

$$- n^2 .\, c.\, t + n^2 .\, 0 = \varepsilon_1 \;.\, t_1 + \phi \tag{38}$$

giving

$$C = - \frac{\varepsilon_1}{n^2} \tag{39}$$

$$D = - \frac{\phi}{n^2} \tag{40}$$

The solutions are then:

$$s = \alpha_2 .\, \cosh (n .\, t) - \beta_2 .\, \sinh (n .\, t) - \frac{(\varepsilon_1 .\, t + \phi)}{n^2} \tag{41}$$

$$v = \alpha_2 .\, n.\, \sinh (n .\, t) - \beta_2 .\, n.\, \cosh (n \;\, t) \quad \frac{\varepsilon_1}{n_2} \tag{42}$$

Now at $t = 0$, $(t_a = t_2)$ we have $s = S_2$ and $v = V_2$, where S_2 and V_2 can be found from equations (24) and (25) by letting $t = t_2 - t_1$. Equations (41) and (42) then become:

$$S_2 = \alpha_2 .\, 1 + \beta_2 .\, 0 \; - \frac{\varepsilon_1 \;.\, 0 + \phi}{n^2} \tag{43}$$

$$V_2 = \alpha_2 .\, n .\, 0 = \beta_2 .\, n .\, 1 - \frac{\varepsilon_1}{n^2} \tag{44}$$

giving

$$\alpha_2 = S_2 + \frac{\phi}{n^2} \qquad (45)$$

$$\beta_2 = \frac{1}{n}\left(V_2 + \frac{\varepsilon 1}{n^2}\right)$$

4 $\underline{t_3 \leq t_a}$

During this period the braking torque B = F the differential equation becomes

$$\frac{d^2s}{dt^2} - n^2 . s = \gamma . B + \phi \qquad (47)$$

and letting $\varepsilon_2 = \gamma . B + \phi$ (48)

we have

$$\frac{d^2s}{dt2} - n^2 . s = \varepsilon_2 \qquad (49)$$

In the solution to equation (49) t is given by
$t = t_a - t_3$ (50)

For the particular integral we assume

$$s = C, \frac{ds}{dt} = O, = \frac{d^2s}{dt^2} \qquad (51)$$

Substitution equation (50) into equations (51) we have:
$0 - n^2 . C = \varepsilon_2$ (52)

hence

$$C = - \frac{\varepsilon_2}{n^2} \qquad (53)$$

The solutions are then

$$s = \alpha_3 . \cosh (n . t) + \beta_3 . \sinh (n. t) - \frac{\varepsilon_2}{n^2} \qquad (54)$$

$$v = \alpha_3 . n . \sinh (n. t) + \beta_3 . n. \cosh (n . t) \qquad (55)$$

Now at t = 0 ($t_a = t_3$) we have $s = S_3$, and $v = V_3$ where S_3 and V_3 can be calculated from equations (41) and (42) by letting $t = t_3 - t_2$

Equations (54) and (55) now become:

$$S_3 = \alpha_3 . 1 + \beta_3 . 0 - \frac{\varepsilon_2}{n^2} \qquad (56)$$

$$V_3 = \alpha_3 . n. 0 + \beta_3 . n . 1 \qquad (57)$$

giving

$$a_3 = S_3 + \frac{\varepsilon_2}{n^2} \qquad (58)$$

$$\beta_3 = \frac{V_3}{n} \qquad (59)$$

Using the above solutions the complete velocity/distance curve is defined.

OBTAINING THE REQUIRED DATA AND APPROXIMATIONS

Most of the data required (for example mass of conveyance) should be readily available from the winder permit or reports from overwind tests or G.E.C. reports or the winder manual.

However, some items of data (for example inertia of the armature) may not be readily available and some difficulty may be experienced in obtaining it. It is the intention of this section to provide guidance on obtaining this data and failing this various approximations which can be used.

Shaft Friction

The torque required for over-coming friction and windage depends on the condition of the shaft, conveyances, guides and sheaves as well as upon the winder speed. In practice this value of friction has been found to be from 5 % up to 25 or 30%.

As a rough guide for direct-coupled winders running at moderate speeds, the friction may be taken as being equal to an extra load of 5 to $7\frac{1}{2}$ percent of the total suspended weight including pay load, conveyances and ropes; and for geared winders from $7\frac{1}{2}$ to 10 percent.

The per unit value of friction used in the calculations will be given by

$$f =, \frac{\text{friction as a percentage}}{100} \qquad O \leq F \leq 1$$

If the example shown in appendix 2, a friction value of f = 0.1 was used.

Coefficient of friction of brake linings

The coefficient of friction can be found by consulting tables for the appropriate material as supplied by the manufacturer.

In information from the manufacturer is not available the following approximations may be used.

Material	Oak	Poplar	Elm	Willow	Bonded Asbestos	Impregnated Fibre
coefficient	0,30	0,35	0.36	0.46	0.3	0.5

For the winder considered in the example in Appendix 2 the brake linings were Feroda Ltd., type CR linings with a coefficient of friction of 0,53.

Inertias

If inertia figures are available from design data, manufacturers manuals or tests these should be used. However, if the information is not available the following approximations may be used.

a. Drums

The tables in appendix I give approximate values for the inertia and may be used with discretion.

b. Clutches, Drum Shafts:

For the clutches or drum shaft the moment of inertia can be calculated from:

$$1 = \frac{m.\ R^2}{4}$$

where m is the mass of the clutch or shaft
R is the radius of the clutch or shaft

c. Gears:

If the mass and pitch diameter of the gear is known the inertia may be considered to be due to 60 percent of the total weight concentrated at the pitch circle.

$$I = 0.6 \times m.\ k^2$$

m = mass of gear

k = pitch circle radius

d. Armatures:

If the mass of the armature and the radius is known the inertia is given approximately by

$I = m.(0.75 \times r)^2$

m = mass of armature

r = radius of armature

Having found the inertia of the armature it is necessary to refer this to the drum by multiplying by square of the gear ratio;

inertia of armature = $m.(0.75 \times r)^2 . (\text{gear ratio})^2$ (referred to drums)

e. Sheaves:

The tables given in Appendix 1 give approximate values of the inertia of sheaves.

f. Load, Conveyance, Ropes:

The inertia of the load, conveyance and ropes vary throughout the wind and is a difficult quantity to calculate accurately. However, the following formulae may be used to give a reasonably close value.

Loads:
Conveyances : mass of conveyance 1 + mass of conveyance 2

Loads : mass of load in conveyance 1 + mass of load in conveyance 2

rope : 2 x total length of one rope x mass per unit length

Total mass : sum of above mass = M

inertia $I = 0.74 . M. R^2$

R = radius of drum

For the winder given in the example in Appendix 2 all the inertia values were obtained from manufacturers data except the inertia of the armatures and load, conveyances and ropes which were calculated using the above approximations. The calculations are shown in Appendix 2.

Braking force

The braking force is the average force used to apply the brakes to the winder. Methods for estimating this will vary depending upon the type of brake configuration in use. As an example of how to calculate the braking force the reader should refer to the example in Appendix 2. This example is for a dead weight arrangement, although by using basic mechanical principles it should be possible to calculate the braking force for any system.

t_1, t_2, t_3

The dynamic braking deactuating time delay t_1 can be found for the curves produced during an overwind test. For the example in Appendix 2 this was found to be one second. The time after the trip until brake shoe contact t_2, and the time to full braking force is applied t_3 can be found by measuring the times at the winder.

DISCUSSIONS AND CONCLUSIONS

The equations derived are sufficient to characterise the velocity/distance curve obtained during emergency braking without dynamic braking.

It should be remembered that as the velocity passes through zero the brake holding power will be sufficient to maintain the conveyance in a state of equilibrium and that any negative velocities predicted by the equations will not exist.

While the equations provide a mathematical analysis of the braking characteristics they are in themselves a first step only. Future development would include the incorporating of control functions into the mathematical model, as well as dynamic braking and other system functions.

BIBLIOGRAPHY

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AN ENGINEERING DATA BOOK: by A J Munday and R A Farrar: The Macmillan Press Limited : 1979

Moment of Inertia Values for Cylindrical Drums having Cast Cheeks and Steel Plate Barrels (from Broughton)

For 1 drum only

Width M (ft)	Drum diameter M (ft)	1.83 (6)	2.13 (7)	2.44 (8)	2.74 (9)	3.05 (10)	3.35 (11)	3.66 (12)	3.96 (13)	4.27 (14)	4.57 (15)	4.88 (16)
0.9 (3)	Inertia kg.m².(R)²	2 411	4 158	5 553	11 395	16 660	20 507	29 420	41 583			
1 (3.5)	"	2 519	4 309	5 824	12 055	17 879	22 254	30 612	43 208	60 411		
1.22 (4)	"	2 763	4 715	6 095	12 444	19 098	23 893	32 102	44 834	62 646	89 397	
1.37 (4.5)	"	2 871	4 863	6 772	12 834	20 317	25 465	33 456	46 757	64 880	91 767	126 239
1.52 (5)	"	2 980	5 009	7 043	13 791	22 417	27 591	37 113	51 606	67 454	94 273	129 626
1.83 (6)	"	3 332	5 563	7 585	14 569	23 636	29 162	39 822	54 993	76 665	106 870	146 015
2.3 (7)	"		5 857	8 533	15 915	25 735	32 806	44 698	60 617	81 270	112 153	142 517
2.44 (8)	"			9 075	16 815	27 090	34 675	47 272	64 203	90 413	125 156	168 906
2.74 (9)	"				17 470	28 444	36 341	50 116	67 319	95 357	103 709	176 629
3.05 (10)	"					29 799	38 197	51 877	70 773	99 962	138 159	184 483
3.35 (11)	"						42 667	57 769	76 868	109 444	148 995	197 892
3.66 (12)	"	Drums 12 ft (3. 66 m) wide and fitted with a centre spider					49 439	64 610	88 855	126 646	175 543	231 619
3.96 (13)	"							67 183	91 970	130 845	181 774	239 205
4.27 (14)	"							69 486	95 492	135 450	180 419	245 842
4.57 (15)	"								98 878	140 868	193 016	251 531
4.88 (16)	"								102 400	145 067	198 841	260 877

The above inertia values were obtained from Broughton. The values are in kg. m². (GR²) i.e. the values in Broughton were converted from $\frac{lb \times ft^2}{g}$. R²) to kg . m² . (R²) by multiplying by

$$1.3545 \text{ i.e. } [kg.\ m^2 . (GR^2) - 1.3545 \ \frac{lb . ft^2}{g} \ (GR^2)]$$

The above values for I are for the drum only (not shaft, clutch etc.)

NOTE:

The above values are low compared to those supplied by Vecor. This is due to the heavier construction used now.

For 1 drum (No Mechs) I. kg . m² . (R²) = 1.9 x I_B . kg . m² . (R²)

I_B = I from above table

Moment of Inertia
Values supplied by Vecor

Drum diameter M (ft)	Drum width M (ft)	Vecor I kg.m².(R^2) 2 Drum + Mech	Vecor I kg.m².(R^3) 2 Drums	Broughton I kg.m².(R^2) 2 Drums
2.438 (8)	1.067 (3.5)	23 680	21 312	11 648
2.75 (9)	1.22 (4)	44 760	40 284	24 888
3.96 (13)	1.98 (6.5)	244 130	219 717	116 758
4.27 (14)	1.22 (4)	268 600	241 740	125 292
4.92 (16)	1.32 (4.5)	490 500	441 450	252 478
4.92 (16)	1.64 (5.5)	515 000	463 500	278 214
5.5 (18)	1.83 (6)	881 600	793 440	NOT SUPPLIED IN TABLE
5.5 (18)	2 (6.5)	922 270	830 043	NOT SUPPLIED IN TABLE

NOTE:
The values supplied by Vecor are for 2 Drums + Mechs. Vecor informed the writer the mechanical parts, shaft, clutch etc., accounted for approximately 10% of the value.

COLUMN 1 Indicates kg. m^2 for 2 Drums + Mech
COLUMN 2 Indicates kg . m^2 for 2 drums

Diameters and Inertia Values for Sheave Wheels Supplied by B. Thomas and Pilliner Engineering

STANDARD DUTY

Sheave diameter (mm) (ft)	Moment of kg . m². (GR^2)
1 830 (6')	566
2 438 (8')	1 518
2 743 (9')	3 030
3 048 (10')	4 080
3 658 (12')	6 550
3 962 (13')	11 890
4 267 (14')	15 850
4 877 (16')	24 100
5 500 (18')	32 300

HEAVY DUTY

Sheave diameter (mm) (ft)	Moment of inertia kg . m². (R^2)
3 048 (10')	4 397
3 658 (12')	7 130
4 267 (14')	17 100
4 877 (16')	25 700
5 500 (18')	35 000
5 790 (19')	40 000
6 100 (20')	44 000

APPENDIX 2

Example: Buffelsfontein Gold Mine Pioneer Shaft 5 + 6 Winder Left Hand Lilly Lower Limits.

It was decided to test the derived formulae by calculating speed/distance curves and comparing these with the curves measured by Gencor Group Winder Department on 5 November 1985.

Most of the information required was readily available from the winder permit, test results and manufacturers data.

Other information was calculated as follows:

Distance from end of wind at trip

At the time of the trip the position of the conveyance is illustrated in Figure 4.

By adding the three distances illustrated in Fig 4 the total distance from the end of wind can be found.

Inertias

All the inertia values were obtained from manufacturers data except the following which were calculated as shown.

Armatures

From engineering drawings it was found that the mass of the armature = 8 845 kg and the radius = 0.45m and from the maintenance manual the gear ratio was found to be 8.204:1.

We therefore have:

Inertia of one armature	=	mass x (0.75 x radius)^2
	=	8 845 x (0.75 x 0.45)^2
	=	1 023 kg/. m^2 . (GR^2)
Inertia of two armatures	=	2 x 1 023
	=	2 046 kg. m^2 . (GR^2)

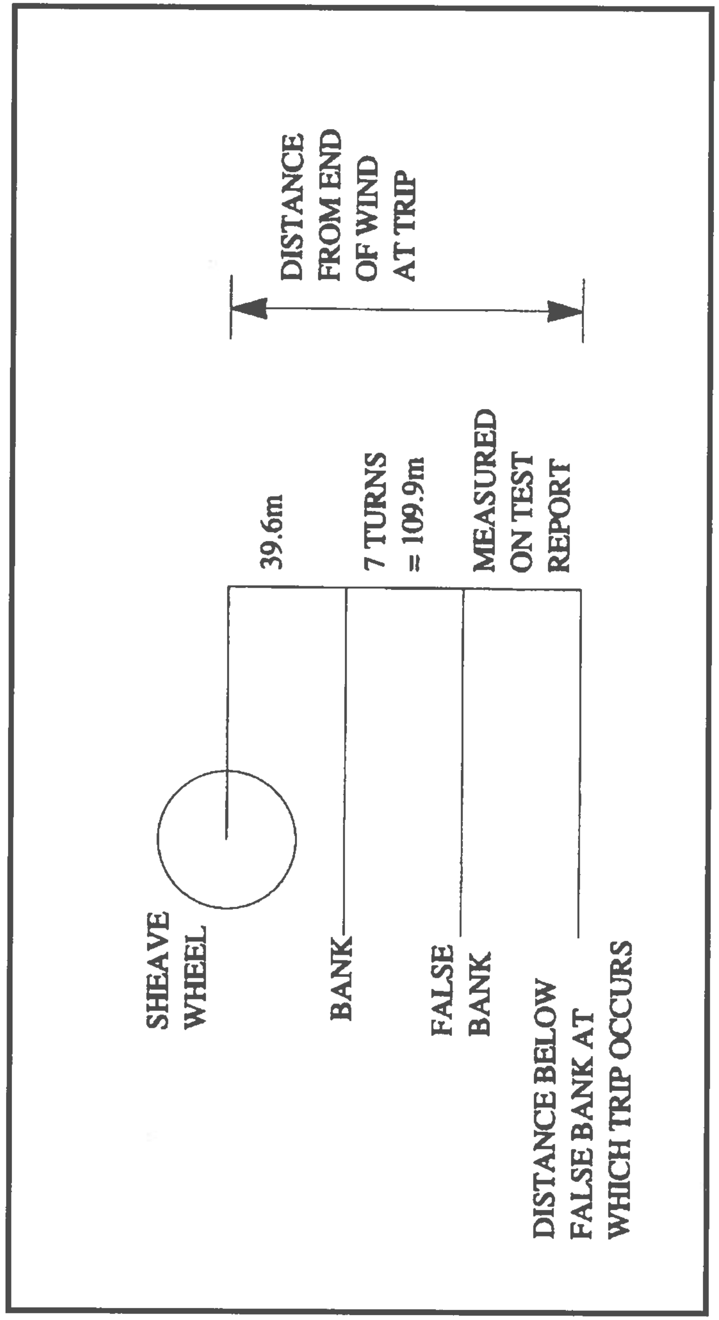

FIGURE 4
Position of conveyane at time of trip

Total inertia referred to drum = inertia of armature x (gear ratio)^2
= 2 046 x $(8.204)^2$
= 137 707 kg . m^2, (GR^2)

Gears

From the manufacturers data the inertia of the gear wheel is 31 153 kg . m^2. (GR^2) and the inertia of each pinion is 54 kg . m^2 . (GR^2). The gear ratio is 8. 204:1.

Inertia of two pinions = 2 x 54
= 108 kg . m^2. (GR^2)

Inertia of pinions referred to drum = inertia x (gear ratio)^2
= 108 x 8 2042
= 7 269 kg . m^2 . (GR^2)

Total inertia of gears = inertia of gear wheel + inertia of pinions referred to drum
= 31 153 + 7 269
= 38 422 kg . m^2 . (GR^2)

Sheaves

From the maintenance manual the inertia of each sheave is 7 450 kg . m ^{2}. (GR2) and the sheave diameter is 5.48m and the diameter of the drum is 4.88m . Therefore we have :

Inertia of 2 sheaves = 2 x 7 450
= 14 900 kg. m^2 . (GR^2)

Total inertia referred to drums

$$= \text{inertia of sheaves } \left(\frac{\text{sheave diameter}}{\text{drum diameter}}\right)^2$$

$$= 14\ 900 \text{ x } \left(\frac{5.48}{4.88}\right)^2$$

$$= 18\ 789 \text{ kg. m}^2 \text{ . (GR}^2\text{)}$$

Load Conveyances, Ropes:

The approximate inertia of the load, conveyances and drums is as follows:

From the winder permit the mass of the skip and attachments is 7 565 kg and the net load during the tests was 3 855 kg. The total length of the rope is 1 950 m and the mass per unit length is 10.4 kg/m

This gives:

Mass of two conveyances	= 2 x 7 565	= 15 130
Net load	= 3 855	= 3 855
Mass of two ropes	= 2 x 1 950 x 10.4	= 40 560
	TOTAL MASS	= 59 545 kg

The mean radius of the drum is 2.5m and this gives an inertia of:

inertia = 0.74 x Total mass x (mean radius)^2
= 0.74 x 59 545 x 25^2
= 275 396 kg. m^2. (GR^2)

Braking Force:

The braking arrangement for the winder is shown in Figure 5. From this we can obtain the following information.

The volume of the mass = 0.9 x 0.49 x 0.68
= 0.3 m^3

Taking the density of mild steel as 7 850 kg/m^3 this gives:

mass of weight = density x volume
= 7 850 x 0.3
= 2 355 kg

The force due to this mass = g x mass
= 9.81 x 2 358
= 23 103 N
= 23.1 kN

The mechanical advantage of the lever arm = $\frac{2.38}{0.28}$

= 8.5

The mechanical advantage of the bellcrank = $\frac{1.63}{0.41}$

= 3.98

force = 23.1 x 8.5 x 3.98
= 782 kN

This is the braking force for one set of brakes, therefore the total braking force is equal to twice this.

Total braking force = 2 x 782
= 1 564 kN

Braking Times

The deactuating time delay was measured from the overwind test and found to be 1s.

In order to establish the time until brake shoe contact and the time until full braking force is applied the braking times turn for turn were measured at the winder and the curves obtained are shown in Figure 6. The brake times were measured from the average of the two curves for the right hand and left hand brakes.

Because the cam position is relative to the false bank the distance of the tip from the false bank was converted into turns and this was used to find the brake times.

Input Data:

The following is a summary of all the necessary information required to calculate the speed/distance curves.

Mass of conveyance 1 = 7 565 kg
Mass of conveyance 2 = 7 565 kg

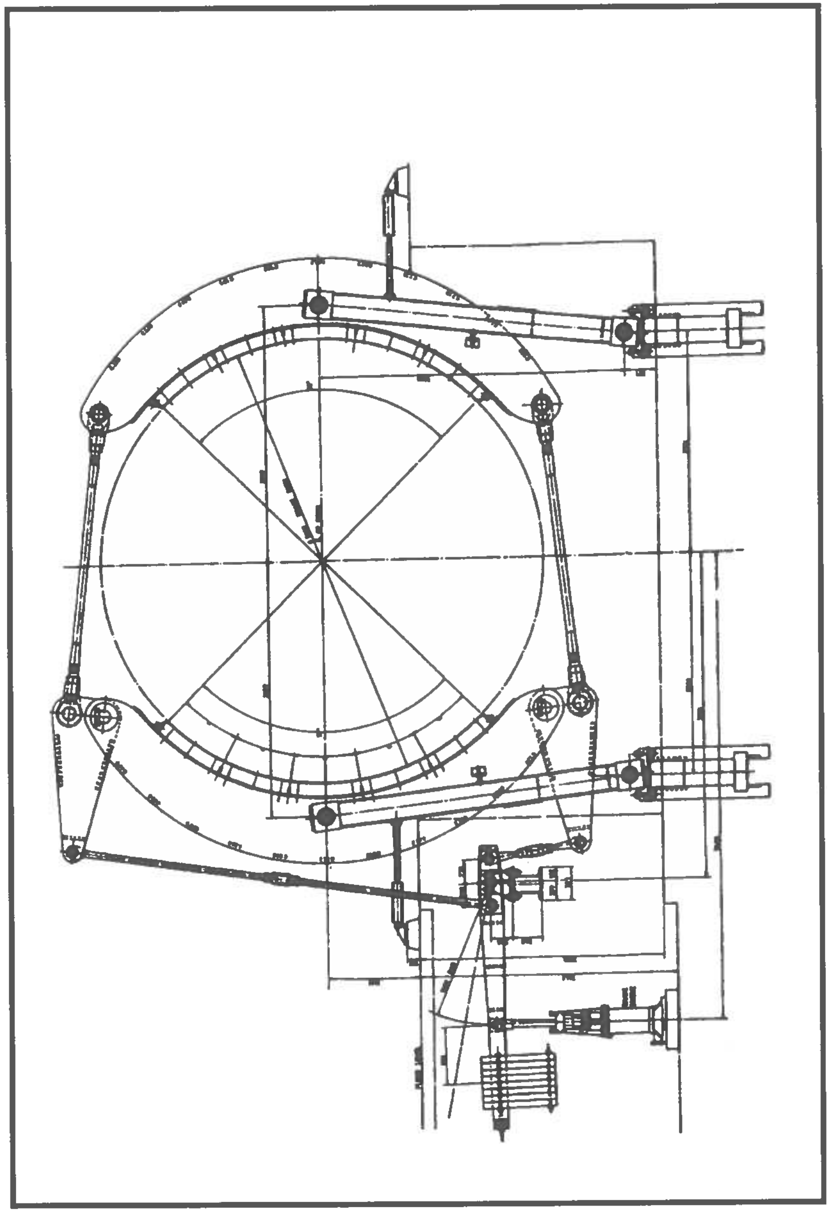

FIGURE 5
Arrangement of Brake Gear

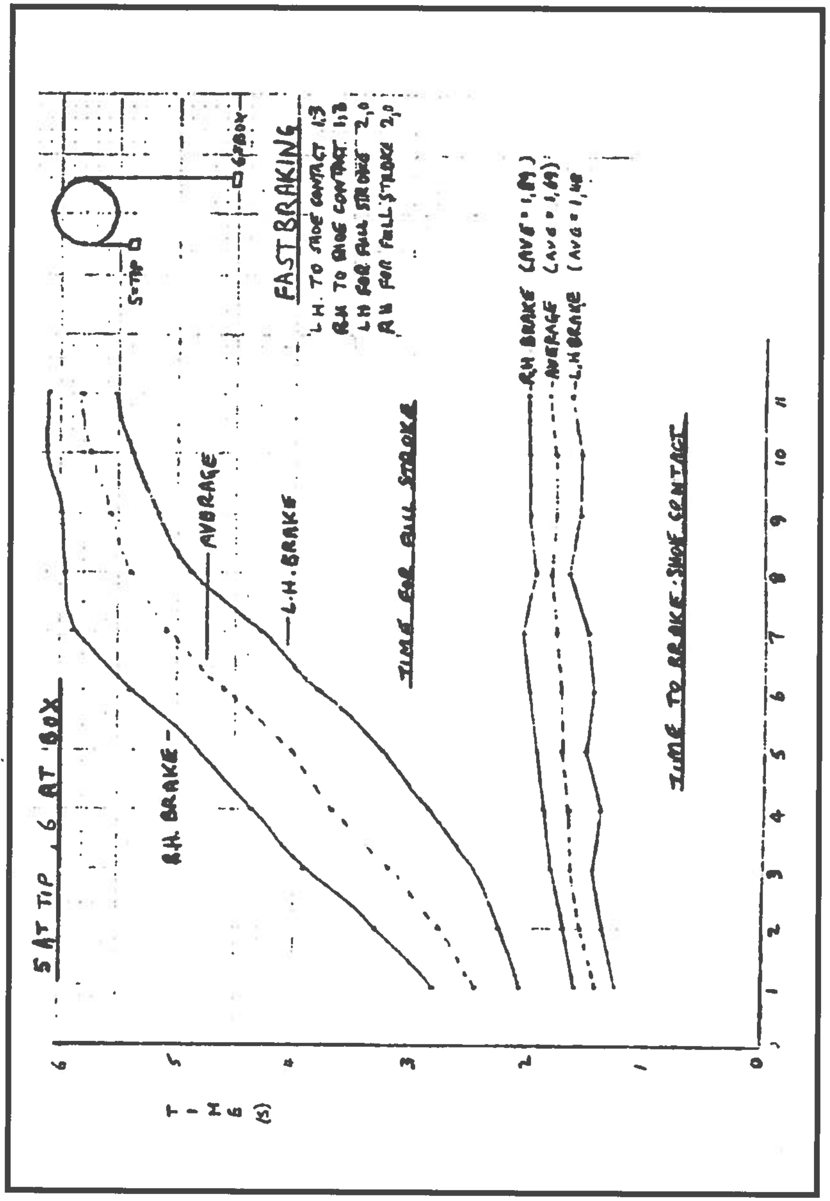

FIGURE 6
Brake times 5 and 6 Winder

Load in conveyance 1	=	3 855 kg
Load in conveyance 2	=	0 kg
Length of wind	=	1 588.3 m
Mass per unit length of rope	=	10.4 kg/m
Friction allowance	=	0.1
Radius of drum	=	2.44 m
Radius of brake path	=	2.6 m
Coefficient of friction of brake linings	=	0.53
Inertia of drums (including clutches + shaft)	=	474 075 kg . m^2 . (GR^2)
Inertia of armatures	=	137 707 kg . m^2 . (GR^2)
Inertia of gears	=	38 422 kg . m^2 . (GR^2)
Inertia of sheaves	=	18 789 kg . m^2 . (GR^2)
Inertia of load, ropes and conveyances	=	275 396 kg . m^2 . (GR^2)
Braking force	=	1 564 kN
Dynamic braking deactuating time delay	=	1 s

Trip velocity (m/s)	Distance of trip from end of wind (m)	Time after trip until brake shoe contact (s)	Time after trip until full braking (s)
15.0	269.5	1.63	5.3
8.2	200.5	1.63	3.35
3.8	167.5	1.43	2.3

Computer Program

Due to the large number of calculations involved a computer program was written. The machine used is a Hewlett Packard 85 and a listing of the program is shown in Appendix 3.

Results:

Using the computer program the curves for the 3 different trip speed were calculated and plotted against the experimental curves. The results are shown in Appendix 4.

All three sets of curves appearing in Appendix 4 are superimposed onto one graph in Figure 7.

Discussion:

As can be seen from Figure 7 the calculated curves and the experimental curves do in fact coincide.

This shows that the equations derived are correct and that applying the laws of physics to the problem of winder braking does give the correct answer.

Conclusion

The techniques outlined in this report are adequate for simulating emergency braking characteristics without the use of dynamic braking.

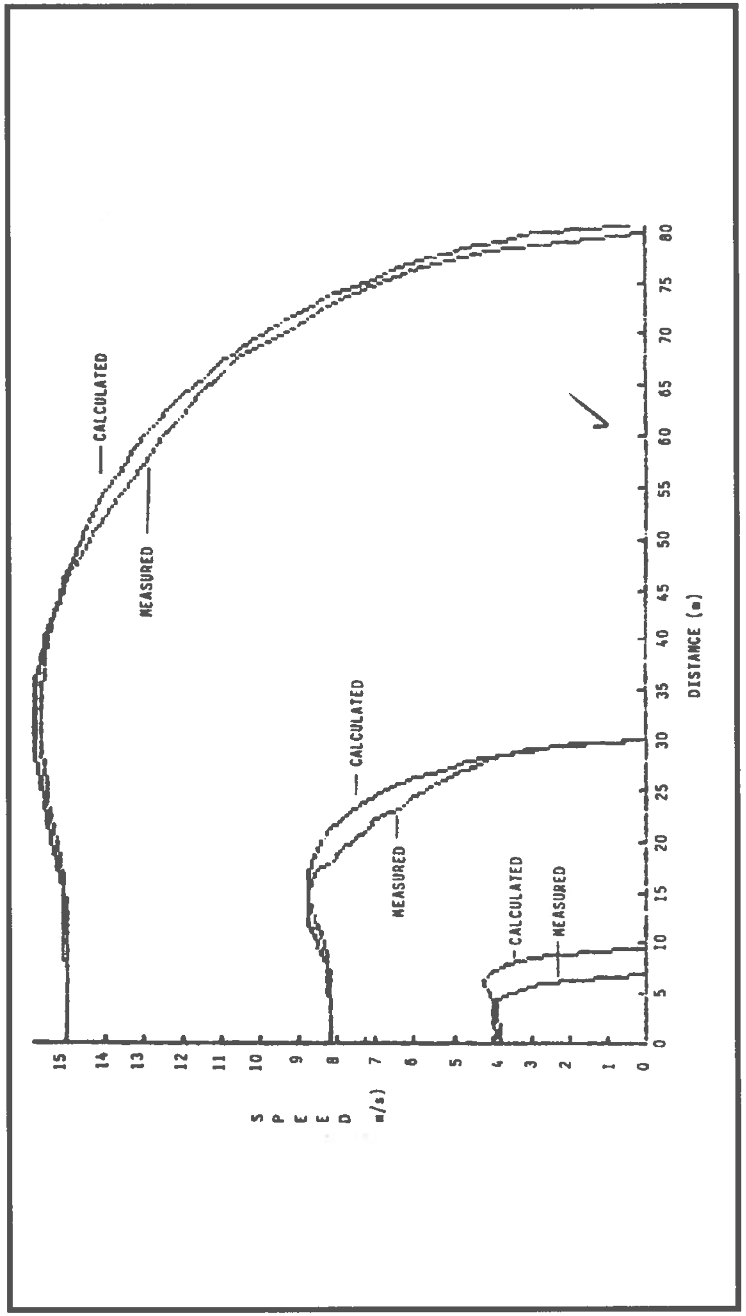

FIGURE 7
Measured vs Calculated Curves

APPENDIX 3

COMPUTER PROGRAM

Program Listing

```
5     CLEAR
6     DISP "EMERGENCY BRAKING
      CALCULATIONS"
7     DISP " ———————————
      ———————————"
8     DISP @ DISP "BY S.M. MCFADYEN
      " @ INPUT C1
1Ø    DISP "INPUT MASS OF
      CONVEYANCE 1" @ INPUT C1
2Ø    DISP "INPUT MASS OF
      CONVEYANCE 2 "
      @ INPUT C2
3Ø    DISP "INPUT MASS OF LOAD IN
      CONVEY 1 " @ INPUT M1
4Ø    DISP "INPUT LENGTH OF WIND"
      CONVEY2" @ INPUT M2
5Ø    DISP "INPUT LENGTH OF WIND"
      @ INPUT L
6Ø    DISP " INPUT MASS PER METRE OF
      ROPE " @ INPUT M
7Ø    DISP "INPUT DIST OF TRIP FOR
      M EOW" @ INPUT XØ
8Ø    DISP "INPUT FRICTION ALLOWANCE
      (0-1)" @ INPUT D1
9Ø    DISP " INPUT RADIUS OF DRUM"
      @ INPUT R
1ØØ   DISP " INPUT RADIUS OF BRAKE
      PATH" @ INPUT R1
11Ø   DISP "INPUT COEFF OF FRICT. FOR
      BRAKES" @ INPUT U
12Ø   DISP "INPUT INERTIA OF DRUMS"
      @ INPUT I1
13Ø   DISP " INPUT INERTIA OF CLUTCHES"
      @ INPUT I2
14Ø   DISP "INPUT INERTIA OF DRUM
      SHAFT" @ INPUT I3
2ØØ   DISP "INPUT DYNAMIC
      DEACTUATING
      TIME" @ INPUT T1
21Ø   DISP "INPUT TIME TILL
      BRAKE CONTACT" @
      INPUT T2
22Ø   DISP "INPUT TIME TO
      FULL BRAKE TORQUE"
      @ INPUT T3
23Ø   DISP " INPUT EXPER
      DATA FILE  NAME"
      @ INPUT P$
235   REM
24Ø   G=9.8Ø665 @ EM
      GRAVITY
3ØØ   REM
31Ø   REM EXPERIMENTAL
      DATA
32Ø   REM
34Ø   DIM X 1 (1ØØ). X 2 (1ØØ)
      Y2 (1ØØ)
35Ø   ASSIGN # 1 TO P$
36Ø   READ # 1; NØ
37Ø   FOR 1-1 TO NØ
38Ø   READ # 1; X1 (1). Y1 (1)
39Ø   NEXT 1
4ØØ   ASSIGN # 1 TO â
1ØØØ  REM
1Ø1Ø  REM CALCULATE
      CONSTANTS
1Ø2Ø  REM
1Ø3Ø  1Ø = I1 + I2 + I3 + I4 +
      I5 + I6 + I7
1Ø4Ø  N = SQR (2 M G R R/1Ø)
1Ø5Ø  Q1 =- U R1 R/1Ø
1Ø6Ø  Q2 = (1-D1) (C1 + M1 + M
```



```
15Ø   DISWP " INPUT INERTIA OFARMATURES"
      @ INPUT I4
16Ø   DISP "INPUT INERTIA OF GEARS"
      @ INPUT I5
17Ø   DISP "INPUT INERTIA OF SHEAVES"
      @ INPUT I6
18Ø   DISP "INPUT INERTIA OF LOAD.
      ROPE. ETC" @ INPUT I7
19Ø   DISP " INPUT BRAKING FORCE
      APPLIED" @ INPUT F1
2ØØØ REM
2Ø1Ø REMPLOT OUT CURVES
2Ø2Ø REM
21ØØ REM
211Ø REM FILL RRY X2.Y2
212Ø TO = Ø @ N1 = Ø
2125 IF TØ < = T1 THEN T = TØ
213Ø IF TØ < = T1 THEN GOSUB 3ØØØ
214Ø IF TØ < = T1 THEN 2ØØØ
2145 IF TØ < = T2 THEN T = TØ – T1
215Ø IF TØ < = T2 THEN GOSUB 4ØØØ
216Ø IF TØ < = T2 THEN 22ØØ
2164 IF TØ < T3 THEN  T = TØ – T2
2165 IF TØ < T3 THEN GOSUB 5ØØØ
2166 IF TØ < T3 THEN 22ØØ
2169 T = TØ – T3
217Ø GOSSUB 55ØØ
22ØØ IF V < 0 THEN 32ØØ
221Ø N1 = N1 + 1 @ X2(N1) = s @
     Y2(N1) = V
222Ø TØ = TØ + 1
223Ø GOTO 213 Ø
23ØØ REM
231Ø REM FIND MAXIMUM AND
232Ø REM MAXIMUM VALUES OF S
233Ø REM AND V
234Ø EM
235Ø Z1 = Ø @ Z2 = Ø Z3 = Ø @
     Z4 = Ø
236Ø FOR J = 1 TO NØ
237Ø IF X 1 (J) > Z3 THEN Z3 = X1 (J)
238Ø IF Y1 (J) > Z4 THEN Z4 = Y1 (J)
      L) – (1 + D1) ( C2 + M2) –
      2 M XO) GRR/1Ø
1Ø7Ø  REM
1Ø8Ø  REM CALCULATES S1.
      V1. S2. V2
1Ø9Ø  S3. V3
1Ø95  REM
11ØØ  T= T2- T1 @ GOSUB
      3ØØØ @ S1 = S @ V1 = V
112Ø  T = T2-T1 @ GOSUB
4ØØØ @ S2=S @ V2 = V
113Ø  T = T3 – T2 @ GOSUB
5ØØØ @ S3 S = @ V3 =V
15ØØ  REM
151Ø  REM DISP DATA
152Ø  REM
153Ø  GOSUB 6ØØØ
267Ø  NEXT 3
27ØØ  REM
271Ø  REM PLOT CALCULATED
      DATA
272Ø  REM
273Ø  MOVE X2 (1). Y2 (1)
274Ø  FOR J = 1 TO N1
275Ø  DRAW X2(J). Y2(J)
276Ø  NEXT J
28ØØ  REM
281Ø  REM COPY OUT GRAPH
282Ø  REM
283Ø  COPY
284Ø  PRINT @ PRINT @ PRINT
285Ø  PRINT "——————————
      ——————————."
286Ø  PRINT "——————————
      ——————————."
287Ø  REM
2871  REM GIVE MAXIMUM
      VALUES
2872  REM
2873  PRINT @ PRINT
2874  PRINT : VMAX="; Z4. :
      SMAX="; Z3
```

```
2390 NEXT J
2400 FOR J = 1 TO N1
2410 IF X 2(J) >Z3 THEN Z3 = X2 (J)
2420 IF Y2(J) > Z4 THEN Z4 = Y2 (J)
2430 NEXT J
2500 REM
2510 REM PLOT CURVES
2520 REM
2525 GCLEAR
2530 SCALE Z1. Z3. Z2. Z4
2540 XAXIS 0,5 @ YAXIS 0,1
2600 REM
2610 REM PLOT EXPERIMENTAL
2620 REM DATA
2630 REM
2640 MOVE X1(1). Y1(1)
2650 FOR J = 1 TO N0
2660 DRAW X 1 (J). Y1 (J)
5030 REM
5040 Q3 = Q1*F1/(T3-T2)
5070 A2 = S2 +Q2/(N*N)
5080 B2 = (V2+Q3/(N*N)/N
5090 H1 = (EXP (N*T) + EXP (-N*T) )/2
5100 H2 = (EXP (N*T) - EXP(-N*T) )/2
5110 S = A2*H1+B1*H2 - (Q3*T+Q2)/
5120 V =A2*N*H2+B2 NH1Q3/(N*N)
5130 RETURN
5500 REM
5510 REM SUBROUTINE FOR S AN DV
5520 REM FOR T3<T<&&&&
5530 REM
5540 Q5 = A1*F1+Q2
5570 A3 = S3 + Q5/(N*N)
5580 B3 = V3/N
5585 H1 = (EXP(N*t)+EXP(-N*T))/2
5586 H2 = (EXP(N*T)-EXP(-N*T))/2
5590 S=A3*H1+B3*H2 - Q5/(N*N)
5600 V = A3*N*H2+b3*N*H1
5610 RETURN
6000 REM
6010 REM PRINT OUT DATA
6020 REM
2875 PRINT @ PRINT
2876 PRINT : ————————"
2877 PRINT "——————————"
2900 REM
2910 REM END OF PROGRAM
2920 REM FOR 0<T<T1
2930 GOTO 9 999
3000 REM
3010 REM SUBROUTINE FOR S
     AND V
3020 REM FOR 0 <T<T1
3030 REM
3040 V = V0
3050 S = S = V0 T
3080 RETURN
4000 REM
4010 REM SUBROUTINE FOR S
     AND V
4020 REM FOR T1 <T<T2
4030 REM
4060 A1 = S1 + Q2/(N N)
4070 B1 = V1/N
4080 H1 = (EXP(N T) + EXP (-N
     T)/2
4090 h2 = exp(n t) - EXP)-N T)/
     2
4100 S = A1 H1 + B1 H1 - Q2/
     (N N)
4110 V = A1 N H2 + B1 N H1
4120 RETURN
5000 REM
5010 REM SUBROUTINE FOR S
     AND V
5020 REM FOR T2. T. T3
6290 PRINT "TIME DELAY=";
     T1
6300 PRINT "TIME AFTER
     TRIP UNTIL BRAKE"
6310 PRINT "SHOE
     CONTACT="; T2
6320 PRINT "TIME TO FULL
     BRAKING TORQUE"
```



```
6030 PRINT @ PRINT @ PRINT
6040 PRINT "——————————————"
6050 PRINT "——————————————."
6060 PRINT @ PRINT @ PRINT
6070 PRINT "MASS OF CONVEYANCE 1=".C1
6080 PRINT "MASS OF CONVEYANCE 2 =". C2
6090 PRINT "LOAD OF CONVEYANCE 1 =". M1
6100 PRINT "LOAD OF CONVEYANCE 2=".L
6110 PRINT "LENGTH OF WIND=". M2
6120 PRINT "MASS PER UNIT LENGTH OF ROPE=";M
6130 PRINT "DISTANCE OF TRIP FROM END OF"
6140 PRINT "WIND=". X0
6150 PRINT "FRICTION ALLOWANCE=;D1
6160 PRINT "RADIUS OF DRUM="R
6170 PRINT "RADIUS OF BRAKE PAT=".R1
6180 PRINT "COEFFICIENT OF FRICTION=";U
6190 PRINT "INERTIA OF DRUMS=";I1
6200 PRINT "INERTIA OF CLUTCHES=";I2
6210 PRINT "INERTIA OF DRUM SHAFT=";I3
6220 PRINT "INERTIA OF ARMATURES=";I4
6230 PRINT "INERTIA OF GEARS=".I5
6240 PRINT "INERTIA OF SHAVES=".I6
6250 PRINT "INERTIA OF LOAD. ROPES AND"
6260 PRNT "CONVEYANCES=";I7
6270 PRINT "BRAKING FORCE=";F1
6280 PRINT "DYNAMIC BRAKING DEACTUATING"
6330 PRINT "IS APPLIED=".
     T3
6340 PRINT "INITIAL
     VELOCITY="; V0
6350 PRINT @ PRINT @ PRINT
     (N*N)
6400 RETURN
9999 END
```

Program Variables

As an aid to understanding the program the following is a list showing each program variables in alphabetical order and the actual variable it represents;

Program variable	Variable it represents	Program variable	Variable it represents
A1	α_1	Q1	γ
A2	α_2	Q2	ψ
A3	α_3	Q3	ε_1
B1	β_1	Q5	ε_2
B2	β_2	R	R
B3	β_3	R1	R_b
C1	C_1	S	s
C2	C_2	S1	S_1
D1	f	S2	S_2
F1	F	S3	S_3
F$	name of file containing experimental data	T	t
G	gravitational constant = 9.80665	TØ	t_a
H1	cosh (n.t)	T1	t_1
H2	sinh (n.t)	T2	t_2
I	program loop counter	T3	t_3
IØ	I_t	U	μ
I1	I_d	V	υ
I2	I_c	VØ	V_o
I3	I_s	V1	V_1
I4	I_a	V2	V_2
I5	I_g	V3	V_3
I6	I_{sh}	XØ	X_o
I7	I_ℓ	X1	array containing experimental distance values
J	program loop counter	X2	array containing calculated distance values
L	ℓ	Y1	array containing experimental velocity values
M	m	Y2	array containing calculated velocity values
M1	M_1	Z1	variable containing minimum distance value
M2	M_2	Z2	variable containing minimum velocity value
N	n $(=\sqrt{n^2})$	Z3	variable containing maximum distance value
NØ	number of data points in experimental data	Z4	variable containing maximum velocity value
N1	a program counter		

Data File

The experimental points need to be first placed in a data file so that the program can read them in. The format of the data file is as follows:

1st rec	:	< number of data points (n)
2nd rec	:	< dist (1) > , < vel (1) >
3rd rec	:	< dist (2) > , < vel (2) >
4th rec	:	< dist (3) > , < vel (3) >
5th rec	:	< dist (4) > , < vel (4) >
6th rec	:	< dist (5) > , < vel (5) >
7th rec	:	< dist (6) > , < vel (6) >
8th rec	:	< dist (7) > , < vel (7) >
nth rec	:	< dist (n – 1) > , < vel (n – 1)>
(n + 1) rec	:	< dist (n) >, < vel (n) >

A simple program for creating the data file is shown below:

```
1Ø   REM
2Ø   REM WRITE A DATA FILE FOR
3Ø   REM EXPERIMENTAL DATA FOR
4Ø   REM USE
     IN PROGRAM BRAKES
5Ø   REM
7Ø   CLEAR
8Ø   DISP
85   DISP "Note file must not exist"
9Ø   DISP "FILE NAM ETO SAVE DATA IN";
     @ INPUT F$
1ØØ  DISP
11Ø  DISP "IN RESPONSE TO PROMPT
     "??" INPUT
12Ø  DISP "THE NEXT DISTANCE AND
     VELOCITY"
13Ø  DISP "VALUES, THE VALUES MUST
     BE INPUT"
14Ø  DISP "IN CORRECT SEQUENCE
     AND NO"
15Ø  DISP "EDITTING FACILITIES EXIST"
16Ø  DISP "TO END ENTERING DATA
     INPUT Ø,Ø"
17Ø  DISP
26Ø  GOTO 195
3ØØ  CLEAR
31Ø  DISP "MAXIMUM
     NUMBER OF DATA
     POINTS
32Ø  DISP @ DISP
     "PROGRAM WILL
     AUTOMATICALLY SAVE"
33Ø  DISP "DATA"
34Ø  FOR I =I TO 1ØØØ @
     NEXT I
35Ø  GOTO 5ØØ
5ØØ  REM
51Ø  REM SAVE DATA
52Ø  REM
53Ø  CLEAR
54O  DISO "SAVING DATA"
542  NØ = NØ - 1
541  FOR I = 1 TO 5ØØ @
     NEXT I
545  R=NØ+1
546  CREATE F$.R.16
55Ø  ASSIGN # 1 TO F$
555  PRINT # 1, NO
```

```
180  DIM X (1ØØ). Y (1ØØ)
190  NØ = 1
195  IF NO>100 THE 300
200  DISP "?". @ INPUT X (NØ). Y (NØ)
210  IF X (NØ)=Ø THEN 240
220  NØ=NØ+1
230  GOTO 195
240  IF Y (NØ)=Ø THEN 5ØØ
250  NØ=NØ+1
560  FOR I = 1 TO NØ
570  PRINT # 1. X (1). Y(1)
580  NEXT I
590  ASSIGN # 1 TO 10*
600  CLEAR
610  DISP "END OF
     PROGRAM"
620  DISP @ DISP "BYE BYE"
630  END
```


RESULTS:

15m/s TRIP

MASS OF CONVEYANCE 1 = 7565
MASS OF CONVEYANCE 2 = 7565
LOAD IN CONVEYANCE 1 = 3955
LOAD IN CONVEYANCE 2 = Ø
LENGTH OF WIND = 1588.3
MASS PER UNIT LENGTH OF ROPE = 1Ø.4
DISTANCE OF TRIP FROM END OF WIND= 269.5
FRICTION ALLOWANCE = .1
RADIUS OF DRUM = 2.44
RADIUS OF BRAKE PATH = W.6
COEFFICIENT OF FRICTION = .53
INERTIA OF DRUMS = 474Ø75
INERTIA OF CLUTCHES = Ø
INERTIA OF DRUM SHAFT = Ø
INERTIA OF ARMATURES = 1377Ø7
INERTIA OF GEARS = 38422
INERTIA OF SHEAVES = 18789
INERTIA OF LOAD, ROPES AND CONVEYANCES = 27396
BRAKING FORCE = 1564ØØØ
DYNAMIC BRAKING
DEACTUATING
TIME DELAY =
TIME AFTER TRIP UNTIL BRAKE SHOE CONTACT = 1.63
TIME TO FULL BRAKING TORQUE
IS APPLIED = 5.3
INITIAL VELOCITY = 15

8.2 m/s TRIP

MASS OF CONVEYANCE 1 = 7565
MASS OF CONVEYANCE 2 = 7565
LOAD IN CONVEYANCE 1 = 3955
LOAD IN CONVEYANCE 2 = Ø
LENGTH OF WIND = 1588.3
MASS PER UNIT LENGTH OF ROPE = 1Ø.4
DISTANCE OF TRIP FROM END OF WIND = 2ØØ.5
FRICTION ALLOWANCE = .1
RADIUS OF DRUM = 2.44
RADIUS OF BRAKE PTH = 2.6
COEFFICIENT OF FRICTIN = .53
INERTIA OF DRUMS = 474Ø75
INERTIA OF CLUTCHES = Ø
INERTIA OF DRUM SHAFT = Ø
INERTIA OF ARMATURES = 1377Ø7
INERTIA OF GEARS = 38422
INERTIA OF SHEAVES = 18789
INERTIA OF LOAD, ROPES AND CONVEYANCES = 275396
BRAKING FORCE = 1564 ØØØ
DYNAMIC BRAKING
DEACTUATING
TIME DELAY = 1
TIME AFTER TRIP UNTIL BRAKE SHOE CONTACT = 1.63
TIME TO FULL BRAKING TORQUE
IS APPLIED = 3.35
INITIAL VELOCITY = 8.2

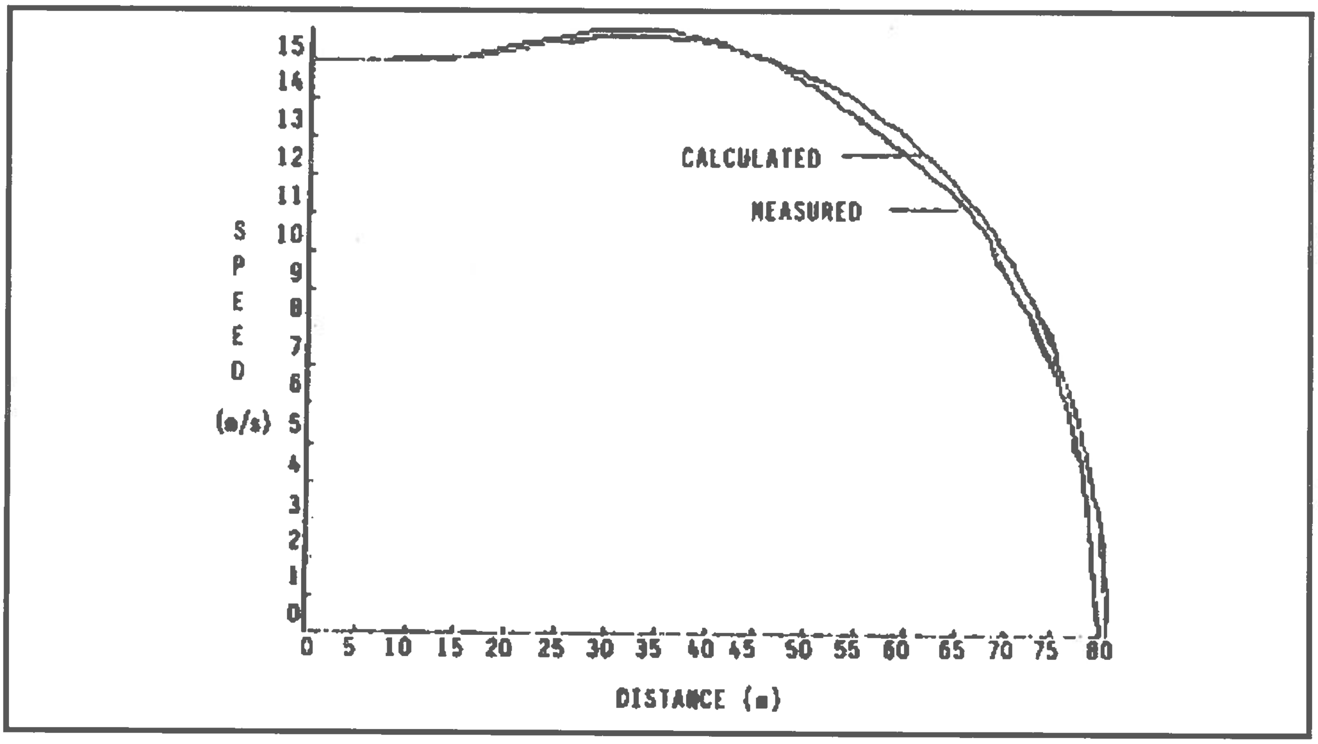

FIGURE 8
15 mn/s Trip

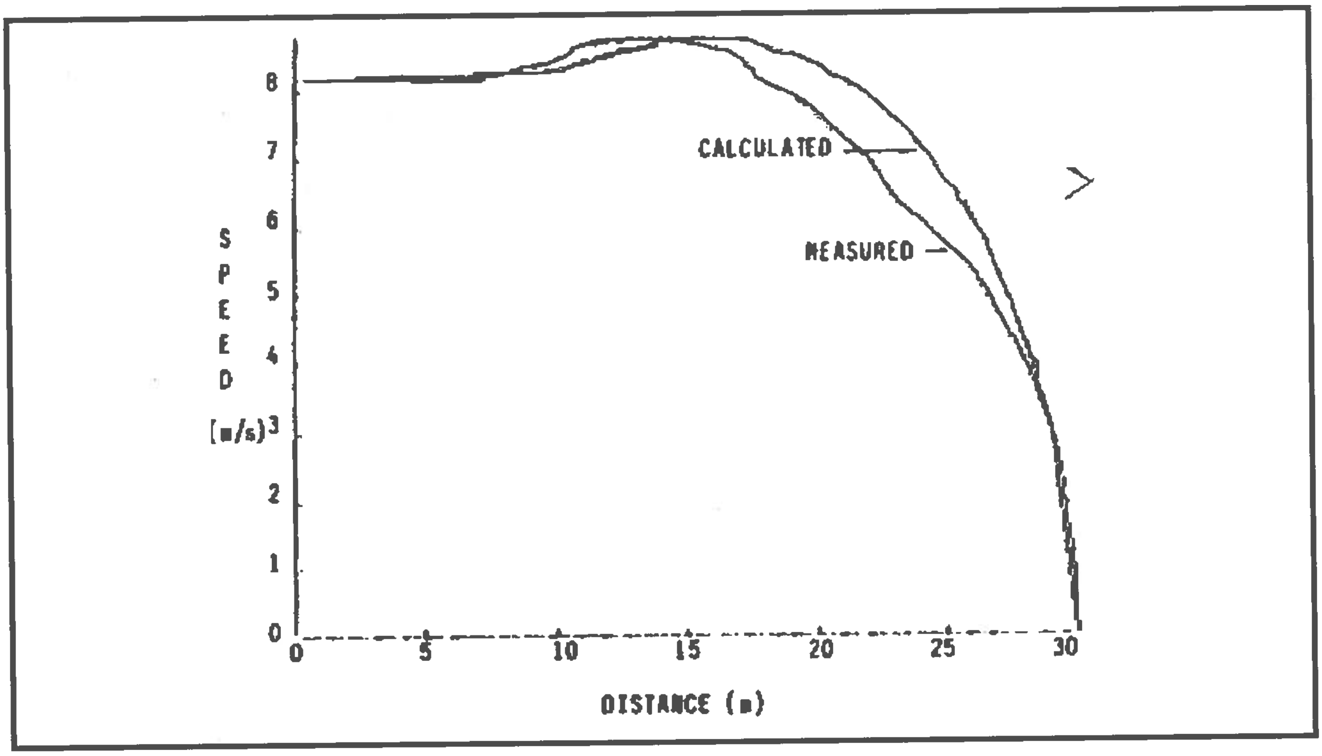

FIGURE 9
8.2 m/s Trip

3.8 M/S TRIP

MASS OF CONVEYANCE 1 = 7565
MASS OF CONVEYANE 2 = 7565
LOAD IN CONVEYACE 1 = 3855
LOAD IN CONVEYANCE 2 = Ø
LENGTH OF WIND = 1 588.3
MASS PER UNIT LENGTH OF ROPE = 1Ø.4
DISTANCE OF TRIP FROM END OF WIND = 167.5
FRICTION ALLOWANCE = .1
RADIUS OF DRUM = 2.44
RADIUS OF BRAKE PATH = 2.6
COEFFICIENT OF FRICTION = .53
INERTIA OF DRUMS = 474Ø75
INERTIA OF CLUTCHES = Ø
INERTIA OF DRUM SHAFT = Ø
INERTIA OF ARMATURES = 1377Ø7
INERTIA OF GEARS = 38422
INERTIA OF SHEAVES = 18789
INERTIA OF LOAD, ROPES AND
CONVEYANCES = 275396
BRAKING FORCE = 1564ØØØ
DYNAMIC BRAKING DEACTUATING
TIME DELAY = 1
TIME AFTER TRIP UNTIL BRAKE
SHOE CONTACT = 1.43
TIME TO FULL BRAKING TORQUE
IS APPLIED = 2.3
INITIAL VELOCITY = 3.8

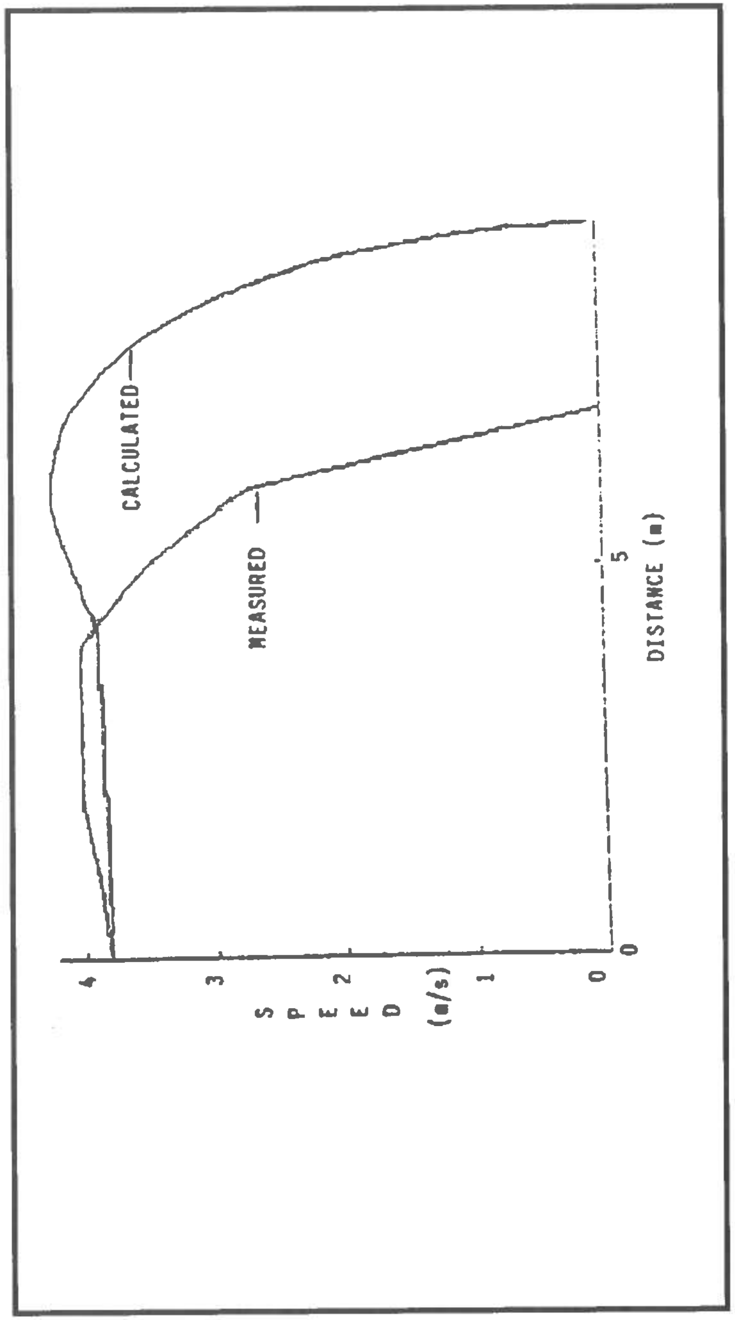

FIGURE 10
3.8 m/sec Trip

APPENDIX 5

RUN IN TESTS TO PROVE END-OF WIND PROTECTION

Observations	Recommendations/Action
1. Although the safety margin of not less than 40% was satisfied by all tests high average rates of deceleration were recorded. This condition is caused by the long brake delay after tripout.	1. It is recommended, (as was done in the previous report of 9.11.84) that a cage mounted decelerometer brake test should be carried out to obtain optimum brake settings for this winder.

Inspector's Remarks

Arrangements need to be made with the Head Office Winder Department to set a data for carrying out the decelerometer brake test.

BRAKE AND CONTROLLER SETTINGS AT COMMENCEMENT OF TEST

False landing position: Drum diameter 4.88 m
Full speed 16.2 m/s 3 200 ft/min
Turns above or below end of wind 7.0 T

Brake operation test	Left hand	Right hand
Brake engine stroke	270 mm	270 mm
Length of initial quick-drip (Emergency)	148 mm	130 mm
Full load torque position	Nil mm	Nil mm
Fast Braking time (90% stroke)	1.2 sec	1,3 sec
Slow braking time (90% stroke)	5,0 sec	5,9 sec
Conversion to fast braking (midshaft)	N/C m/s	N/C m/s
Conversion to fast braking (end-of-wind) (top)	N/C T	N/C T
(bottom)	N/C T	N/C T

Brake holding test against power: (tested with max. out of balance rope plus 1,5 x rated motor torque (geared winders).

2,5 x rated motor torque (direct coupled winders).

Left Hand 3 000 A movement Nil Right Hand 3000 A movement Nil

Trigger level (Escort braking system) LH m/S² rh m/S² (m/S²)

Overspeed protection: Type Lilly Duplex	**Left Hand**	**Right Hand**
Overspeed alarm contact float	0,0 mm	0,2 mm
Overspeed alrm contact gap with roller on top of cam	1,0 mm	0,5 mm
Minimum trip speed (with roller on top of cam) (top)	N/C m/s	N/C m/s
(bottom)	2,0m/s	1,3 m/s
Overspeed alarm contact gap at full speed	1,0 mm	0,3 mm
Deceleration cam position	Correct	Correct