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A comparison of friction and drum hoisting systems on an energy-input basis

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A COMPARISON OF FRICTION AND DRUM HOISTING SYSTEMS ON AN ENERGY-INPUT BASIS

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ABSTRACT

The purpose of this thesis is to provide a suitable basis for comparing the relative advantages of the friction and drum hoists under various conditions of operation.

Such comparisons are mainly and necessarily based upon physical characteristics of the mechanisms for lack of appropriate economic data. It is believed, however, that this inadequacy may be alleviated to some extent by substituting comparative theoretical energy requirements of the two hoisting systems under identical duty conditions over a practical range of mining situations involving various depths and daily productions.

This has been accomplished by adapting a computer to standard mine-hoist design techniques and utilizing basic data that are accepted by pertinent authorities.

The results are gratifying in that they do indicate areas of advantage for each of the hoisting systems within the span of operations considered.

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I. INTRODUCTION

Hoisting is an essential part of every deep mining operation. It is the principal means of access for men and materials and the only conveyance by which the mine products are brought out to the surface. Operational efficiency of the mine is directly dependent upon the hoisting system, and proper selection of the hoist design is extremely important.

Various hoisting systems have been applied to many mine conditions. However, only two general types have survived the tests of dependability and over-all economy: the drum hoist and the friction hoist. To date the preferred system has never been determined.

The drum hoist was the first type to be used in mining. Its popularity has persisted and is by far the most common form in the United States, England, South Africa, Canada, India, and most of the British Commonwealth countries. The system (Figure 1) consists of a drum, a headsheave, a rope, and a suitable conveyance. Rotation of the drum winds and unwinds the rope to raise or lower the conveyance. The drum may be cylindrical, conical, or some combination of the two, depending on the requirements of each particular mining condition. Cylindrical drums are the most frequently used, with the drum and headsheave diameters and grooves being compatible with rope diameter. The latter is selected to withstand the pull exerted, while the skips, or cages,

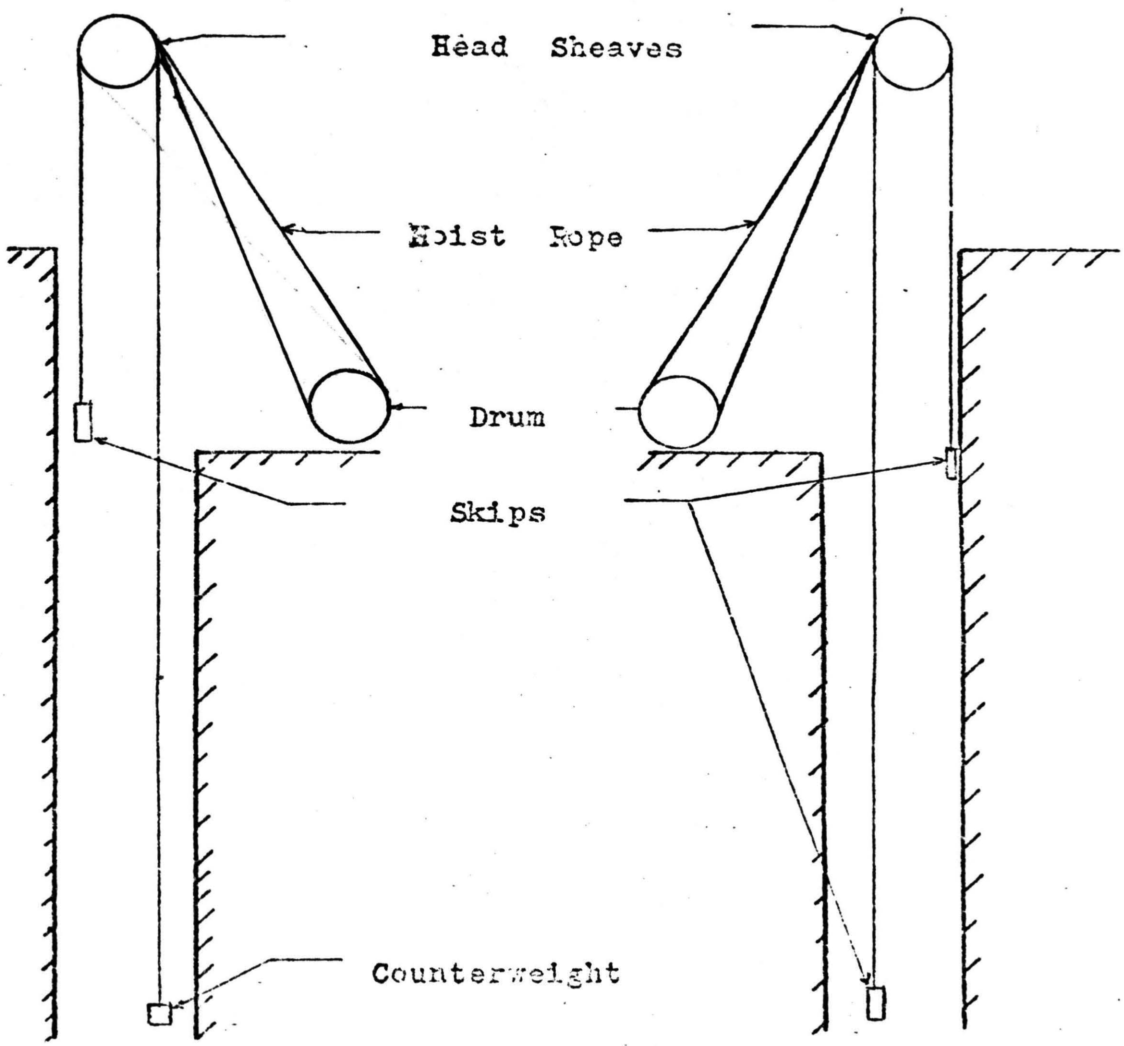

Figure No.1. Drum Hoists

are designed to meet the expected duty of the system. Hoisting may be unbalanced with the use of a single skip, or cage, or it may be partially balanced with two skips, or cages, being used to counterweigh each other. The same effect can be attained with a dead-weight on one side. For the balanced system two drums are often used.

The principle of friction hoisting was introduced by W. F. Koepe in 1877 at the Hannover Colliery near Westphalia, Germany. The unit had the outward appearance of a balanced drum hoist but differed in its drum arrangement. The rope was not wound on the drum, the drum imparting traction to the rope system by means of friction at the rope-drum contact. Gradually, this became known as the Koepe Hoisting System.

In later installations, the drum was eliminated with traction being imparted to the rope directly at a headsheave (see Figure 2). This offered the advantages of a lesser inertia of moving parts and greater compactness. Modern units are of this type but use two or more pairs of ropes for greater safety and efficiency. The remaining portions of this system are much the same as those of a drum hoist.

Because of its European origin, the friction hoist has remained extremely popular in Germany, Sweden, Holland, and Belgium. After World War II, the technique soon developed interest in other countries. In 1955, the first unit was installed in Canada, and later, others were installed at various locations in the United States.

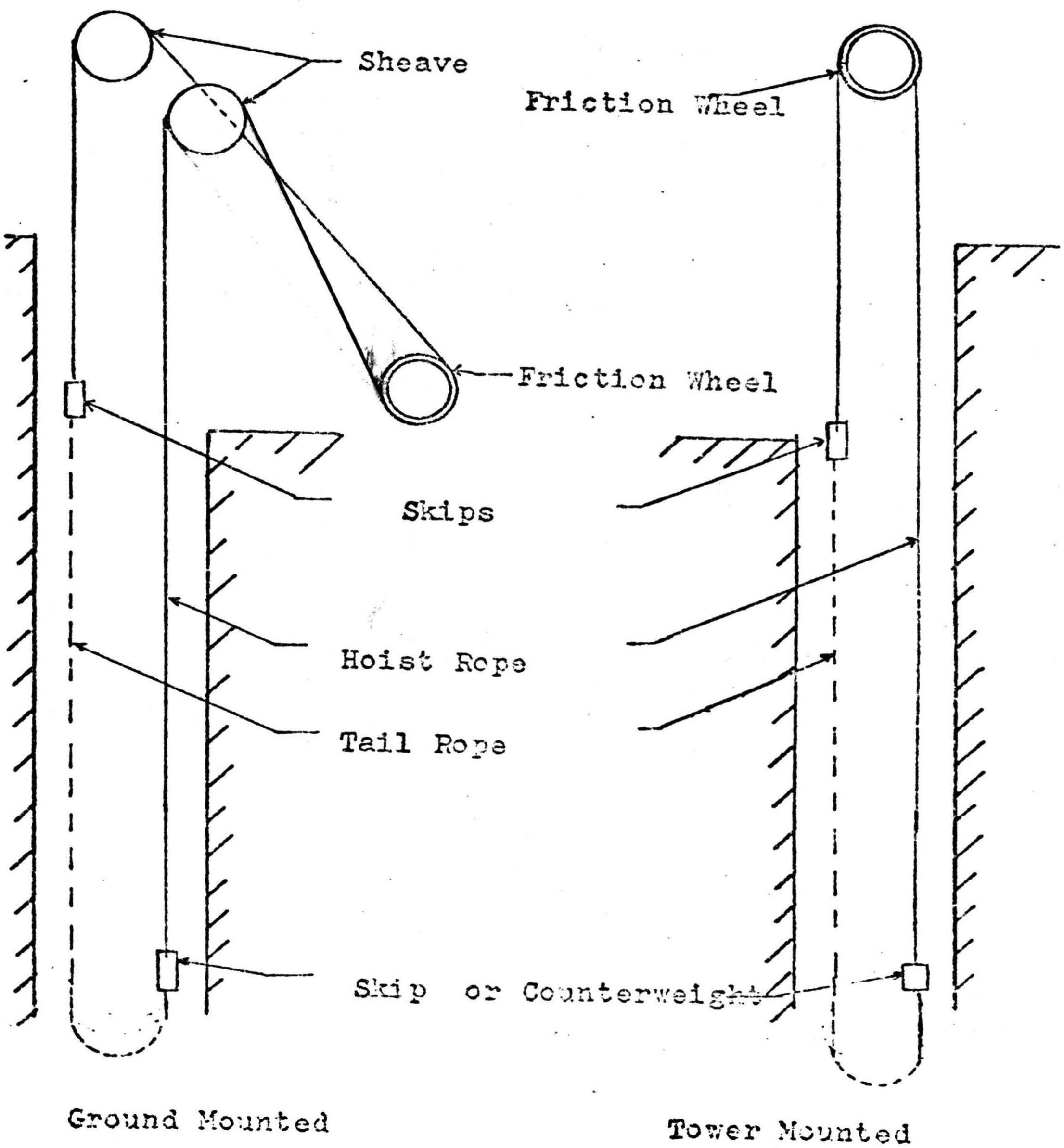

Figure No.2. Friction Hoists

Introduction of the friction hoist evoked controversies regarding its physical and economical advantages as compared to those of drum hoists. Extensive comparisons between the existing installations have been published, but due to the unique character of each mining operation exact, duplication of hoisting requirements is rarely achieved. Therefore, the analyses did not represent matching conditions. By careful selection of appropriate existing systems, major advantages can be demonstrated for either hoist.

In order to properly evaluate each system under similar mining conditions, a standard method for comparison would be required. No appropriate standard appears to exist at present. It was the purpose of this study, therefore, to investigate the essential required data and develop a method by which realistic comparisons could be made for the mining conditions most frequently encountered.

The author wishes to express his appreciation to Professor R. F. Bruzweski of the Mining and Petroleum Engineering Department, of the University of Missouri at Rolla, for his guidance and suggestions throughout the investigation.

II. THE STATUS OF PRESENT SYSTEMS-COMPARISONS

The various reports in the literature that compare friction and drum hoists have been confined to physical characteristics, capital and installation costs, etc., but operating costs apparently have never been evaluated adequately. For example, one of the first comparisons of hoisting systems, which resulted in considerable discussion, was published by Behr (1). Comparing the hoisting systems for deep mines, he stated that

> "The Koepe or Whitting systems (which uses sheaves instead of drums, thus driving the ropes by friction), though having, in most executed examples, with drums of insufficient diameter, a comparatively small Moment of Inertia, are not well adapted for great depths in a single lift, because they cannot employ taper ropes. The tail rope which they require is also objectionable in most cases."

In reviewing the comparison, Whitmore (2) wrote that

> "If Mr. Behr could be induced to extend his work a little further so as to draw a comparison between the advantages of the various systems by stating the sizes of steam cylinders required to wind the same load in the same time, the paper would give an excellent idea concerning the merits of each system; whereas the paper finishing as it did, and dealing with a subject in which there were so many points that must be considered

separately and all collectively, it was impossible to draw any inference as to the mechanical advantages and efficiency of any of the plants mentioned over any other."

It is surprising to note that no attempt was subsequently made by other investigators to follow this line of thought. However, many authorities have attempted to set some form of guideline for evaluating the systems. In some instances, a few problems were solved to demonstrate the difference in horsepower requirements, but the variables used for calculations were not identical for the two hoists. Therefore, no positive conclusion can be drawn. For example, Huelsome and Moore (3) stated that

"A complete analysis requires the study of
(a) First cost of electrical drive, electrical operating costs, power consumption and demand;
(b) First cost of mechanical equipment, operating advantages and disadvantages, and operating costs;
(c) Installation costs for mechanical and electrical equipment."

They bolstered their argument with four problems to show the economics of the systems. A paper by Landau and Malmow (4), in which they analyzed the problems solved by Huelsome and Moore, stated that

"The weight of the skip is larger for the friction drive hoist. In this

> case this weight could be smaller, if for some reason this would be preferable. It is to be noted that the skip weight has an extremely small influence on the size and cost of friction drive hoisting plants, whereas the skip and rope size directly influence the cost of the drum hoist."

Landau and Malmow solved a few representative examples to illustrate the points raised by them. However, no conclusions were drawn with absolute certainty. Essentially, the comparison was based on physical characteristics rather than power consumption.

The emphasis on physical characteristics for the selection of hoists is further exemplified in a more recent paper by Gronseth and Hardie (5), in which they stated that

> "All hoist builders have certain parameters in mind within which one hoist should be more economical than another. We are reluctant to state this, however, because it may be taken for fact and applied to a specific case without study."

Regarding the Koepe system, they pointed out that

> "At depths of 3,500 to 4,000 ft, some operators have been experiencing problems with hoists and tail ropes on Koepe hoists. The stress on the pull ropes decreases as it passes over the wheel from loaded side to the empty skip (counterweight) side, causing premature failure in the strand ropes. Locked coil ropes are used for deeper shafts but, of course, the weight to strength ratio becomes a problem."

With respect to the effects of depth on drum hoisting, Osthof (6) wrote that

> "With greater depths and higher useful loads the disadvantages of drum winders increase, as there are heavy drums with big diameters and widths, which cause high axial loads on main shafts and bearings and other unfavorable effects of the diagonal rope-pull on the ropes and headgear pulleys. Furthermore, the necessary power increases uneconomically as compared with winding capacity when bigger and bigger drum winders are used."

On the other hand, McCulloch and Futers (7) stated that

> "The Koepe and Whitting systems have the great advantage that exact maximum depth of the mine need not be known at the time when a winding engine is being built since, within the limits of the strength, more rope can be added to suit the requirements. In the case of a drum hoist or flat rope reel, this cannot be done because the size of the drum or reel closely determines the quantity of rope that can be used."

Bar (8) commented, also, on the depth problem with respect to drum hoisting:

> "The large diameters and masses of the drums, the widths of which depend on the length and diameter of winding ropes, require high acceleration and braking forces, long shafts, large foundations and spacious engine houses. This in turn means high weights and prices. These disadvantages of the drum winders have led to the introduc-

tion of friction of Koepe pulley which
was first tried in Germany."

Another of the advantages brought forward in favor of the friction hoist was that it required no winding engine operator, which results in improved safety and more efficient operation. Kidd (9) stated that

"In Sweden, where there are fully automatic and push-button automatic winders are in use, one is told that no person there would care to ride in a cage driven by a man, in case the driver should make a mistake they feel safer in automatic winder, and shaft accidents are in fact almost unknown."

It may be said that a similar argument could be presented by people using shafts where the winders are operated by men. They may say that they feel more secure while riding in the cage driven by man. In any case, accidents in Germany and other countries using friction hoisting have been reported.

Broughton (10), while comparing the various hoisting systems, listed the following factors for and against the friction hoist:

"Objections to the Koepe system:

Periodic recapping of the rope is impossible,
It is not possible to lubricate the rope in service,
The use of balance (tail) rope is imperative
Detaching hooks cannot be fitted,
Damage on one side of the hoist endangers the other side of the hoist.

Advantages of the friction hoist:

Smaller than the conventional hoist,
Friction hoist can be easily adopted for changing level by changing ropes,
Lower peak power is required because of the tail rope,
Multi-rope systems can be used and this will reduce the pulley size by employing more ropes in parallel than in case of a drum hoist or single rope friction hoist. In this case, the factor of safety is also increased,
Automatic push-button controls eliminate delays and thus improve the efficiency and result in power savings."

In considering the problems associated with systems evaluation, Kidd (9) pointed out that

> "To obtain a true comparison one needs to take into account not only the cost of the winding engine itself with electric drive and control gear, but also headgear, a tower, winding engine house, foundations, decking gears and keps, shaft equipment and costs of the various landings and pitbottoms, and any difference in ventilating cost arising from the layout of shaft equipment."

Although there exists a very good understanding of the physical characteristics of the hoisting systems, consideration of these factors alone is not adequate to provide a realistic guide for the selection of the most appropriate hoisting system on a fair comparison basis. It is true that numerous advantages and disadvantages of physical characteristics have a profound effect upon the selection of a particular unit, but they should not be considered as the sole basis for final selection. The capital and operational costs also must be given prime consideration and resolved into unit production costs. Thus, any physical advantages may be related to unit costs, and rather than merely listing physical characteristic advantages as points in favor, their evaluation would be on a monetary basis.

III. REQUIREMENTS FOR DEVELOPMENT OF A SYSTEMS ANALYSIS

A extensive search was conducted for pertinent, basic cost data, but none was found. Data that were available were either antiquated, incomplete, or based upon different national economies. This may explain why a complete cost comparison had never been presented by others. Therefore, it was decided to investigate the feasibility of an evaluation based upon energy consumption per unit of production, which can be calculated.

A search of published data revealed that operating costs of mine hoists normally exceed two-thirds of the total production costs. Subtracting the charge for labor, repairs and maintenance, which may be nearly equal for both types of hoists, the resulting power cost would be the only significant variable. Furthermore, power costs could be expected to vary with the efficiencies of the prime mover and drive. Thus, the energy-input to the hoist itself could be considered as a true measure of the machine performance and an important factor for comparison. Because of operational restrictions on maximum speed and acceleration rates, the loads carried per cycle by each of the hoist types would not be same for any like-hoisting requirement. Therefore, the energy-input per unit of production should be considered in the evaluation, expressed as horsepower-seconds per ton of ore hoisted.

The problem, therefore, was to compare energy-inputs per unit of production for the drum and friction hoists under similar duty requirements, in order to provide a guide for their selection. This could be accomplished by applying standard design techniques to assumed identical conditions for both systems; and then, calculating the unit energy consumption by accepted procedures. For the purpose of obtaining a truly representative comparison, the following six hoist types were to be considered:

(1) A friction hoist with two skips and four pairs of ropes,

(2) A friction hoist with two skips and one pair of ropes,

(3) A friction hoist with one skip, a counterweight and four pairs of ropes,

(4) A friction hoist with one skip, a counterweight and one pair of ropes,

(5) A drum hoist with one skip and counterweight,

and (6) A drum hoist with two skips.

Because ore-raising costs by far outweigh those for man-riding and supplies handling, the study was to consider only ore hoisting. Hoist duty requirements were to range within the depth and tonnage limits normally encountered in the American mining industry. The horsepower-seconds per ton of ore hoisted would be calculated then for each hoist type for various depths and production-rate increments. The tabulated results and performances of the various hoist types, compared under identical conditions for each depth-production combination, should provide a significant guide for the selection of the most appropriate hoisting system.

Because the proposed data-derivations involved 1,920 individual hoist-design problems and a like number of energy calculations, completion of the study by conventional procedures would require many months of full-time effort. To reduce the magnitude of this undertaking, the necessary calculations would be conducted by computer, and with little additional effort, it would be possible to obtain root-mean-square horsepowers for further comparisons. The latter provides the average power rating required for a motor over all operating conditions.

IV. SELECTION OF DESIGN PARAMETERS

It was essential that basic design parameters be selected before appropriate design data could be assembled, prepared for computer application, the operation suitably programmed and processed, and the necessary results obtained. Appendix I provides a list of symbols used, and Appendix II outlines the expressions used for execution of the various mathematical operations. The basic information considered included the following ten factors:

(1) Depth of mine,

(2) Tons of ore to be raised per shift,

(3) Velocity and acceleration rates,

(4) Rope size, weight, and breaking stress,

(5) Drum size and weight,

(6) Weight and size of the friction wheel,

(7) Conveyance and counterweight used and their weights,

(8) Hoisting and rest time,

(9) Friction of the hoisting system,

and (10) Size of headsheave and its weight.

1. Depth of Mine

It was felt that the minimum depth of hoisting be fixed at 250 ft, because resulting minute energy-differences below this limit would be unsuitable for comparisons. The maximum depth was set at 5000 ft because few mines extend beyond this limit. The depth range, then, could be expected to provide adequate coverage of the great majority of present-day operations. Increments of 250 ft were selected to provide the maximum practical number of situations for comparison.

2. Tons of Ore to be Raised per Shift

Production limits were established between 250 and 4000 tons per 7-hour shift, in order to afford coverage that would be commensurate with that of industry. The 250-ton increments were chosen to provide adequate intermediate representation.

3. Velocity and Acceleration Rate

Hoisting speeds and accelerations for the various drum hoist situations were taken from a table compiled by a committee of rope manufacturers and recommended by the United States Bureau of Mines (11). These data were expanded (Table 1) as needed to better suit the conditions assumed. This would not alter the recommended values but could serve to adjust them to a more usable form.

For friction hoisting, hoisting speeds do not differ materially from those used for drum hoists. However, it is customary in friction hoisting to take hoisting speed as one half the maximum attainable velocity. With regard to accelerations, winding at high rates will cause slippage of the rope on the drive drum. The usual practice is to limit the acceleration rate to less than 3 fps^2. In some cases, lower values are preferable. It was decided for this investigation to use the acceleration rates from 2.5 to 3 fps^2. In each hoisting situation the highest possible acceleration rate, within the prescribed

Table 1.

Drum Hoisting Recommendations by the

United States Bureau of Mines (11)

A. Recommended Speeds:

Length of Rope, ft	Maximum Speed fpm	Factor of Safety
500 or less	1200	8
500 to 1000	1600	7
500 to 1500	2000	6
1500 to 2000	2000	6
1000 to 2500	2250	5
2500 to 3000	2500	5
3000 to 3500	2750	4
3500 to 4000	3000	4
4000 to 4500	3250	4
4500 to 5000	3500	4

B. Permissible Accelerations for Recommended Hoisting Speeds:

Speed, fpm	Acceleration, fps^2
500 or less	4.16
750	4.16
1000	5.55
1250	5.95
1500	6.25
2000	8.33
2500 to 3500	8.33

limitations, determined by computer would be used in calculating the unit energy input. When the required value was less than 2.5 fps^2, the situation would be rejected as being unpractical.

4. Rope Size, Weight, and Breaking Stress

Rope size is governed by the required production and hoisting distance. It is chosen so that its tensile strength just exceeds the sum of its own weight and the load exerted by the conveyance, all attachments, ore being hoisted and acceleration, plus allowances for a suitable factor of safety. The computer could perform the necessary iterations for selecting the minimum usable rope-diameter for each condition, using manufacturers rope data as shown in Table 2 (12). It was necessary to convert this information into equations (Eq. 12 and 13, Appendix II) to facilitate programming. Any hoisting depth and production combination requiring a rope diameter in excess of 3.5 in. was discarded as being more suitable to multi-stage hoisting and not pertinent to this study.

A constant safety factor of 4.0 was selected for all hoisting systems for ease of computation. Although it could be argued that this value is slightly inadequate for certain conditions, and that it should be a little lower for others, the factor is generally acceptable for hoisting ore.

5. Drum Size and Weight

Cylindrical drum dimensions are governed by rope size

Table 2.

Rope Diameter, Weight, and Breaking Load for 6 x 37 Classification Hoisting Rope with Fiber Core Supplied by the United States Steel Corporation (12)

Rope Diameter, in.	Breaking Load, tons (Plow Steel)	Rope Weight, lb.
0.25	2.25	0.10
0.3125	3.50	0.16
0.375	5.02	0.22
0.4375	6.80	0.30
0.50	6.85	0.39
0.5625	11.20	0.49
0.625	13.70	0.61
0.75	19.60	0.87
0.875	26.60	1.19
1.0	34.60	1.55
1.125	43.50	1.96
1.25	53.50	2.42
1.375	64.50	2.93
1.50	76.40	3.49
1.625	89.30	4.09
1.75	103.00	4.75
1.875	118.00	5.45
2.0	134.00	6.20

and hoisting depth. Their diameters are usually fixed at about 90 times the rope thickness (9). The face width should be sufficient to accommodate, in a single layer, all of the rope to be wound, plus 3 safety wraps. These guides were followed throughout the investigation.

Drum weight and its moment of inertia were more difficult to obtain for lack of factual data. Many of the sizes required for this study have not been manufactured, and those that were in existence varied with manufacturers. Therefore, some means of estimating drum inertia had to be devised.

Bright (13) suggested that an acceptable drum weight approximation could be made by allowing 200 psf of drum face, from which the moment of inertia could be calculated when using a radius of gyration that is 3 in. less than that of the drum. In comparing these results to actual weights and inertias of presently manufactured drums, it was found that estimates were consistently too high and the error originated in the initial unit-weight assumption. The latter was recalculated from available drum data and found to be 160 psf of drum face. All hoisting drum weights and inertias used in this study were approximated on that basis.

6. Weight and Size of Friction Wheel

The friction wheel diameter was established at 90 times the rope size, the same ratio as used for the drum hoist. This was in keeping with accepted practices, and it maintained a fair comparison between the two basic hoisting systems. Effective weights could not be obtained directly from currently manufactured wheels for the same reason mentioned in discussing drums. Therefore, they were approximated by an equation (Eq. 97, Appendix II) derived from Table 3 from data published by Price (15). The relationship produced values that were reasonably accurate when compared to all available data.

7. Conveyance and Counterweight used and Their Weights

Because this investigation was concerned only with hoisting of ore, the conveyance considered in all cases was a skip. Its weight was taken to equal one-half the payload being hoisted. Although this assumption might not be in accord with all existing installations, it would be a fair average. According to standard practice, the counterweight equaled the weight of the conveyance plus one-half the pay load.

8. Hoisting and Rest Time

Hoisting time was arbitrarily fixed at 7 hours per shift, merely to establish a limit on the production period. Rest time, the interval required for loading and unloading the conveyance, was assumed to be 12 sec. for similar reasons. Neither hoisting system would gain any advantages by these decisions.

9. Friction of the Hoisting System

Friction for each of the hoisting systems was assumed as 10% of the sum of the positive and negative static moments, i.e., 10% of the up-load (TMUL), plus up-rope (TMUR), plus

Table 3.

Inertia of Friction Wheels Supplied by M/S British Ropes Limited, Doncaster, Durham, England (15)

Diameter of Friction Wheel, ft	Brake Path, ft	Inertia, psf	
		2 Ropes	4 Ropes
9.0	11.0	15,000	30,000
	8.0	10,000	17,000
10.0	12.0	22,000	35,000
	9.0	14,000	23,000
11.0	13.0	28,000	43,000
	10.0	20,000	30,000
12.0	14.0	35,000	46,000
	11.0	26,500	37,000
13.0	15.5	44,000	58,000
	12.0	32,000	46,000
14.0	16.5	56,000	75,000
	13.0	40,000	60,000
16.0	18.5	100,000	136,000
	15.0	71,000	107,000
17.5	20.0	128,000	175,000
	16.0	96,000	135,000
18.0	21.0	156,000	200,000
	17.0	102,000	155,000

down-skip or counterweight (TMDL). The ratio would be as accurate as any that is presently used.

10. Size of Headsheave and Its Weight

The headsheave diameter in each case was taken as being equal to that of the drum in accordance with standard practices. Its effective weight at rope center was determined from a relationship (Eq. 32, Appendix II), which was derived from Figure 140 presented by Staley (14). Because truly representative weights could not be obtained by this means for headsheaves having diameters less than 3.75 ft, a constant weight value of 300 lb was assigned for diameters to 2.75 ft and 375 lb for diameters to 3.75. The estimates should provide a more realistic basis for the shallow depth hoisting computations.

V. COMPUTATION PROCEDURE

Basic data were appropriately inserted into a computer program, representing each hoist type, and processed in a normal manner to provide the following data:

Ore per trip (OTR),

Rope diameter (RD),

Acceleration time (AT),

Peak horsepower (PHP),

Horsepower-second per ton (HPT),

and Root-mean-square horsepower (RMSHP).

The above mentioned were determined for each practical hoisting situation, e.g., incremental shift-production rates and depths for each hoist type. The complete programs and the related outputs are given in Appendices III through VI. The computer results were tabulated and plotted on graphs (Figures 3 through 7) for greater ease in the final analyses. Tables 4 through 6 give representative comparative data. The appended programs may be easily adjusted to obtain data for various other hoisting situations by merely substituting the desired inputs.

Appendix II gives the list of expressions used for the solutions of the various hoisting conditions considered.

VI. RESULTS OF THE STUDY

From Figures 3 through 8 the data indicate that all of the hoist types considered require fewer horsepower seconds per ton of ore hoisted at the higher daily production levels. This phenomenon is most obvious with the friction winders (Figures 3 and 4). Another point of interest is that the required energy inputs per unit output are not directly proportional to the hoisting depth. As shown in Figure 7, the energy requirements for drum hoists increases in less than direct proportion to the depth during the lower 2000 to 4000 ft, after which the ratio is reversed, i.e., the energy input curves attain a slope of less than 45^{o}. Friction hoists, on the other hand, display two such flexures, one at about 1000 ft and the other near 4000 ft.

The balanced 2-skip friction hoists (Figure 7 and Tables 4 through 6) appear to be impractical at hoisting depths less than 4500 ft, evidently due to excessive TU/TL ratios caused by rope slippage on the drive wheel. Although these ratios may be reduced by adding weights to the skips, this would increase the required energy inputs and, thereby, eliminate a standard basis for comparison. For this reason, only data derived from its practical operating range are computed and compared.

Drum hoists and the friction hoist with one pair of ropes and a counterweight require larger rope diameters,

Table 4.

Representative PHP & RMSHP of the Various Hoisting Systems

Compared for - Depth 250 ft

Type of Hoist	250 ton		2000 ton		4000 ton	
	PHP	RMSHP	PHP	RMSHP	PHP	RMSHP
Drum with Counter Weight	65.9	50.0	485.9	385.9	878.8	764.3
Drum in Balance	53.3	29.0	310.2	198.8	605.0	393.8
Friction with Counter Weight & 4 Ropes	529.8	327.5	564.4	315.9	822.4	535.7
Friction with Counter Weight and 1 Rope	361.4	218.5	461.6	283.6	774.3	523.0
Friction with 4 Ropes in Balance	-	-	-	-	-	-
Friction with 1 Rope in Balance	-	-	-	-	-	-

Table 5.

Representative PHP & RMSHP of the Various Hoisting Systems

Compared for - Depth 2500 ft

Type of Hoist	250 ton		2000 ton		4000 ton	
	PHP	RMSHP	PHP	RMSHP	PHP	RMSHP
Drum with Counter Weight	1383.1	598.2	7129.7	3708.0	13065.2	7141.7
Drum in Balance	1382.9	496.7	5534.4	1856.3	9469.9	3151.8
Friction with Counter Weight and 4 Ropes	1549.0	941.3	3301.0	2277.8	6035.8	4392.3
Friction with Counter Weight and 1 Rope	922.1	537.2	3227.5	2244.3	7232.9	4759.6
Friction with 4 Ropes in Balance	-	-	-	-	-	-
Friction with 1 Rope in Balance	-	-	-	-	-	-

Table 6.

Representative PHP & RMSHP of the Various Hoisting Systems

Compared for - Depth 5000 ft

Type of Hoist	250 ton		2000 ton		4000 ton	
	PHP	RMSHP	PHP	RMSHP	PHP	RMSHP
Drum with Counter Weight	5769.7	2497.8	29952.2	14833.3	-	-
Drum in Balance	5641.4	2164.9	22460.8	8143.0	38921.8	13933.3
Friction with Counter Weight and 4 Ropes	2036.3	1199.6	7508.3	5076.9	14780.2	10130.3
Friction with Counter Weight and 1 Rope	1539.5	907.9	9295.4	5785.5	-	-
Friction with 4 Ropes in Balance	-	-	5075.4	3646.9	9278.3	7049.9
Friction with 1 Rope in Balance	-	-	5090.7	3802.9	11064.3	7568.4

i.e., above 3.5 in., than are normally available when production rates approach the maximum considered. Also, the required corresponding drum diameters, or above 28 ft become impractical due to excessive inertias.

A friction hoist with counterweight and one pair of ropes (Figure 3) requires its greatest horsepower-second input per ton of ore hoisted at extremely low rates of production. As the tonnage per shift increases, economy increases until about 1500 tons per shift are produced. At greater outputs, the unit-energy inputs are almost unrelated to the production. A strong point favoring this type of hoist is that it has the lowest peak horsepower in the intermediate and high production rates and depths (Tables 4, 5, and 6).

Figure 4 shows the characteristics of the friction hoist with four pairs of ropes and a counterweight. Its performance trends are much the same as those shown in Figure 3, with the exception that this particular winder is the least economical system at extremely low production levels. On the other hand, its economy at the highest outputs is exceeded only by the balanced drum hoist. Furthermore, its performance is not as limited by rope slippage and extreme diameters as are the other hoist types due to its multiple-rope arrangement. In addition, the multiple-rope type has the very desirable safety feature of each rope being able to sustain the total load when a safety factor of 4 is used. With this arrangement, a

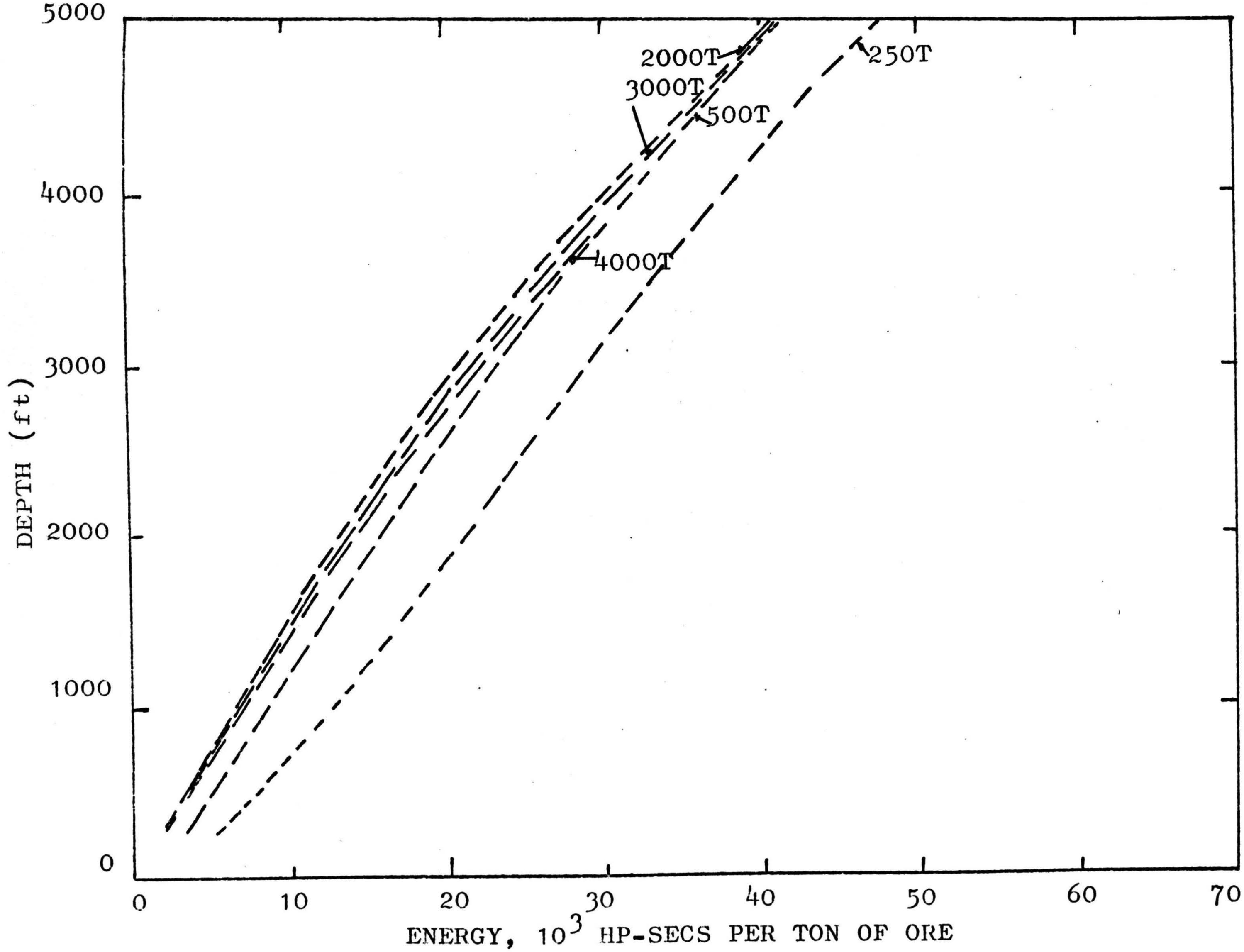

Figure 3. Energy Requirements Vs Depth for Friction Hoist (Counterweight with One Rope per Side)

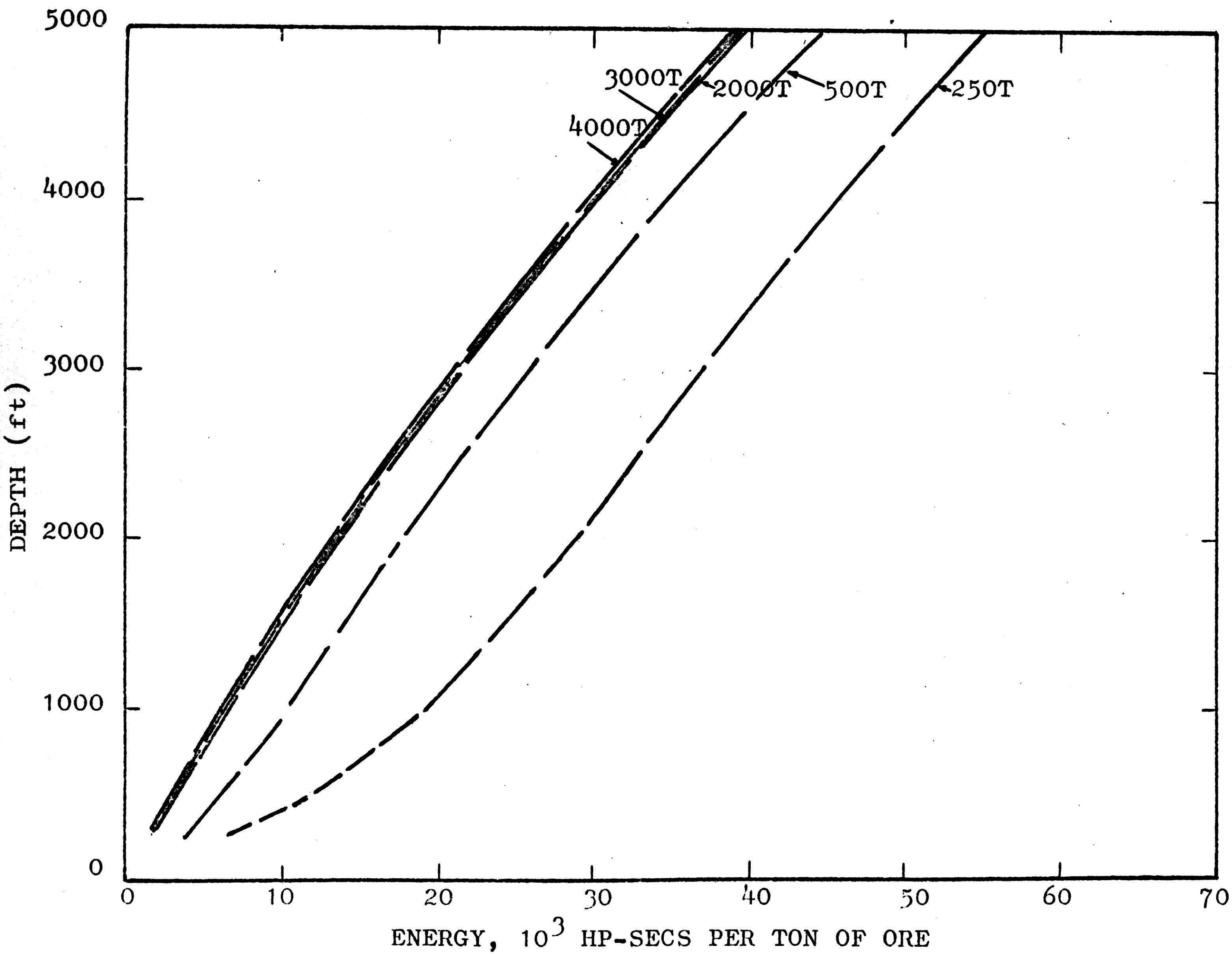

Figure 4. Energy Requirements Vs Depth for Friction Hoist
(Counterweight with Four Ropes per Side)

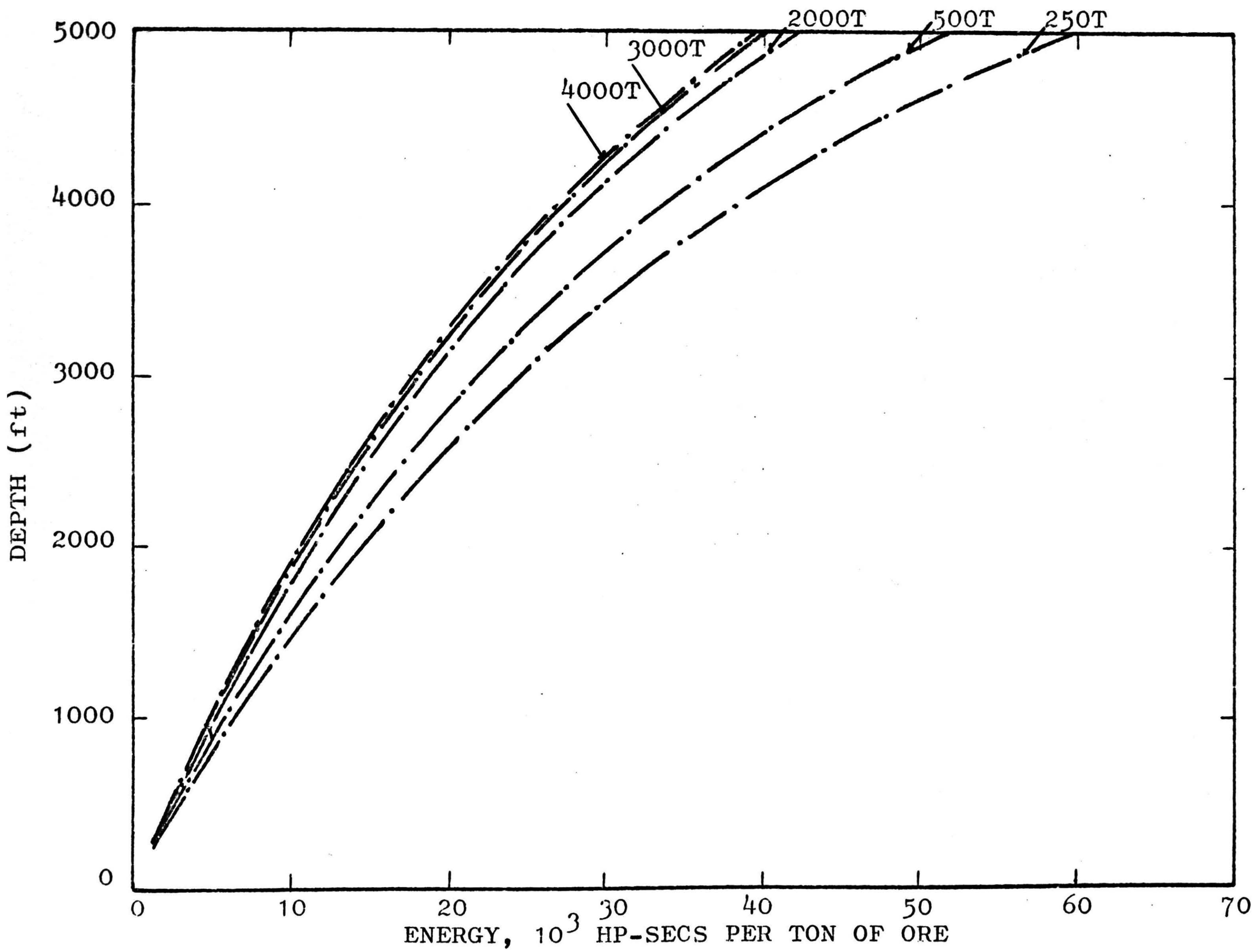

Figure 5. Energy Requirements Vs Depth Drum Hoist (Two Skips)

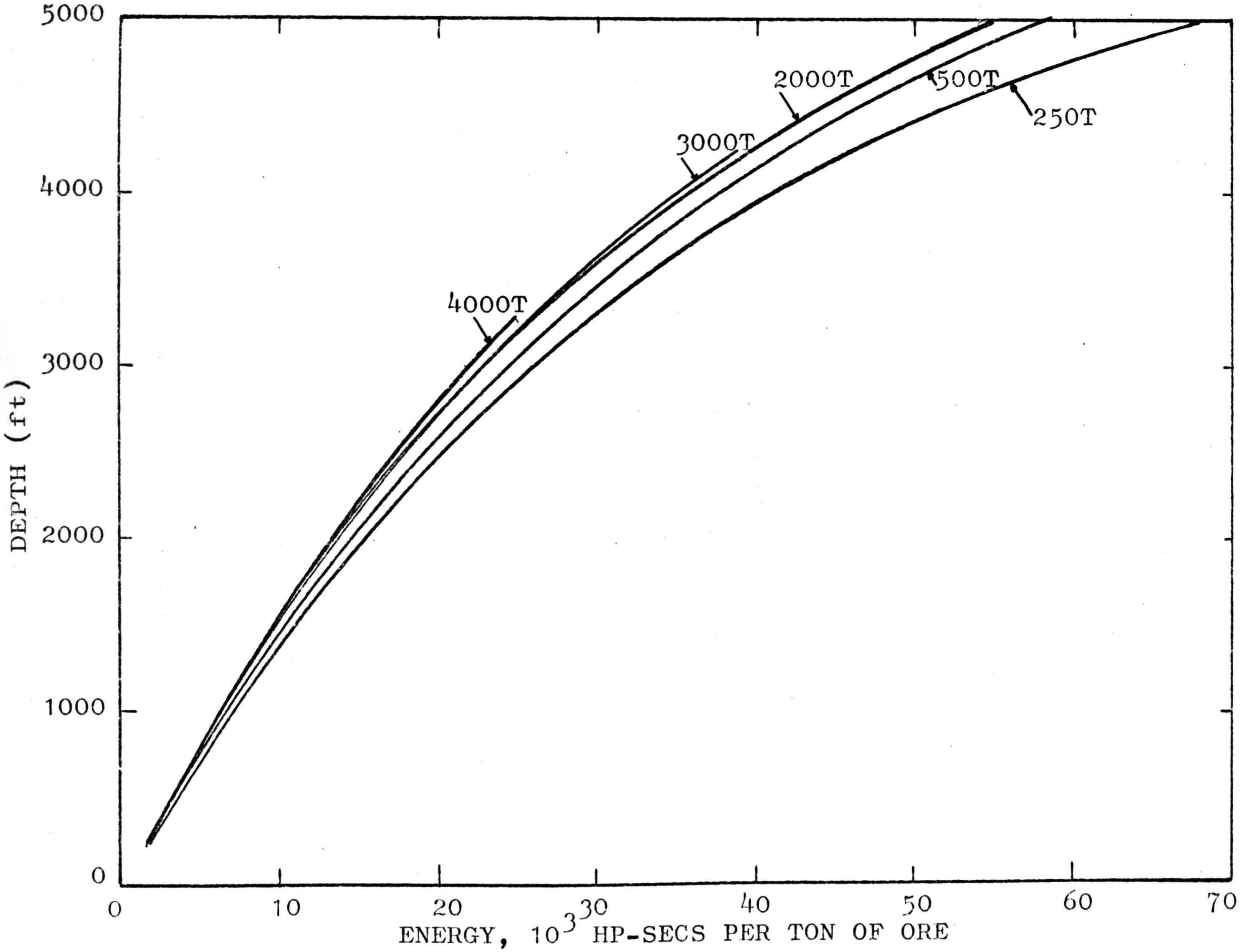

Figure 6. Energy Requirements Vs Depth for Drum Hoist (Counterweight)

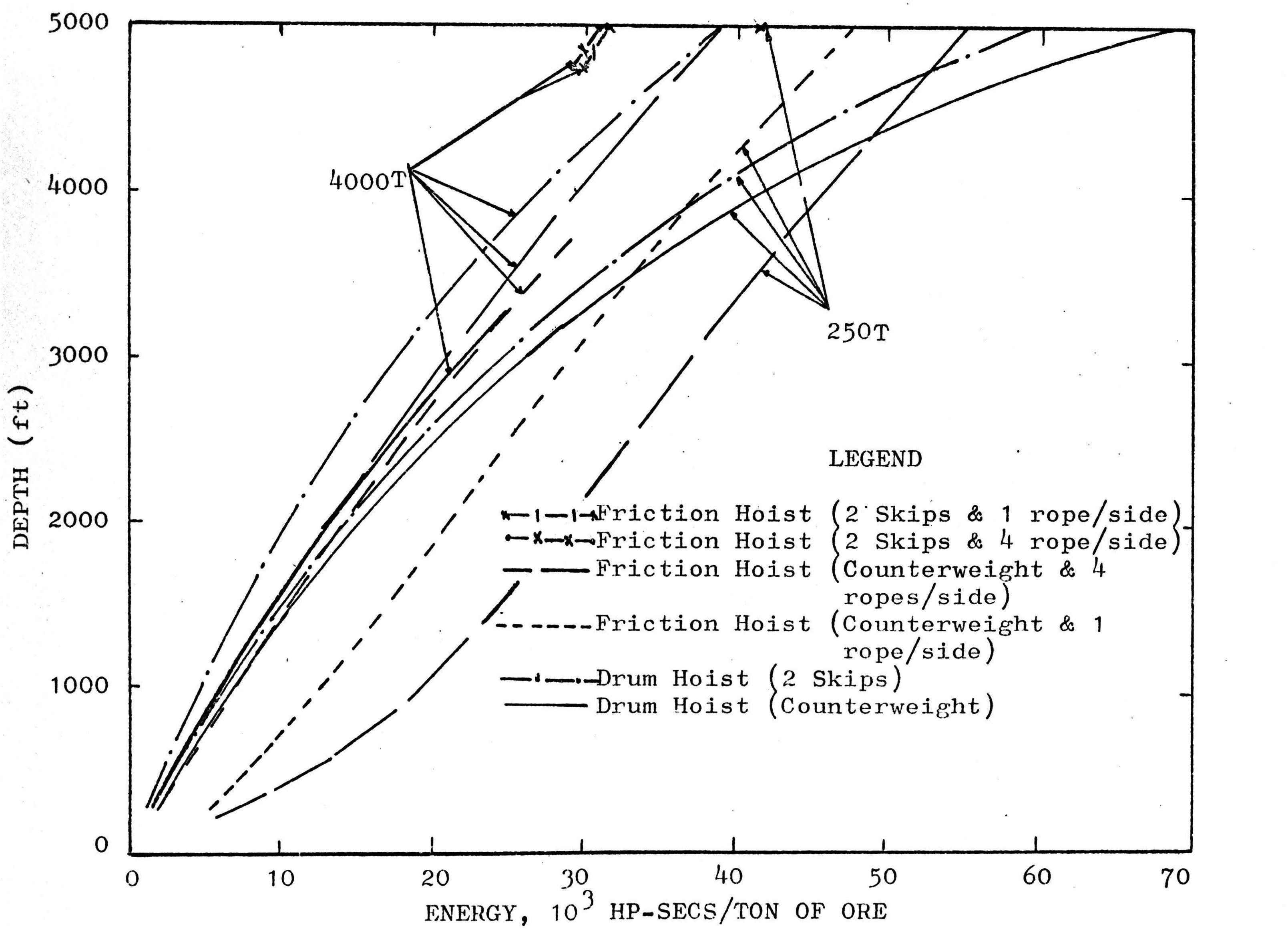

Figure 7. Comparison of Energy Requirements at Various Depths Between Drum and Friction Hoist (At 250 and 4000 Tons/7 hr.)

broken rope merely reduces the safety factor.

Drum hoists with two skips (Figure 5) and operating for less than about 4000 to 5000 ft of hoisting depth are more economical than any of the other types considered. In addition, this winder requires the most favorable peak and root-mean-square horsepower within the low to intermediate depth ranges (Tables 4, 5 and 6). However, its economic margin diminishes with the increased production.

Counterweighted drum hoists (Figure 6) are less economical and more limited in performance by rope size than its counterpart hoist with two skips. On the other hand, its energy requirements per unit of production are less in the low production and depth ranges than those of the counterweighted friction hoists. Its economic trends with respect to the depth and production are generally the same as those of the other hoists discussed.

In summation and with reference to Figure 7, it would appear that the balanced (2 skips) drum hoist is the most economical for all depths ranging below 4000 - 4500 ft. Also, this type of unit offers the most favorable peak and root-mean-square horsepower requirements within the intermediate to low depths and outputs. On the other hand, the friction hoists, particularly those with two skips, are the most economical and have the most favorable peak and root-mean-square horsepowers at depths greater than 4500 - 5000 ft. Counterweighted friction hoists have areas of optimum economic operation that fall roughly between these two.

Specific areas of optimum economic application are outlined in Figure 8 for each of the hoists considered. The depth zone of economic conversion between specific hoisting systems, or the area in which one type ceases and other commences to be most economical, is generally where the limits below which the balanced friction hoist becomes impractical due to rope slippage and above which the drum hoist requires excessive rope and drum diameters. It follows, then, that the drum and friction hoists each will have their specific areas of economical and practical application: balanced friction hoists for deep mines and balanced drum hoists for shallow depths. The favorable economy of the drum hoist may possibly be extended to greater depths through the development of multi-rope drum hoisting. The absence of a depth zone for the counterweighted drum hoist should be noted; apparently this particular winder never attains economic favorability.

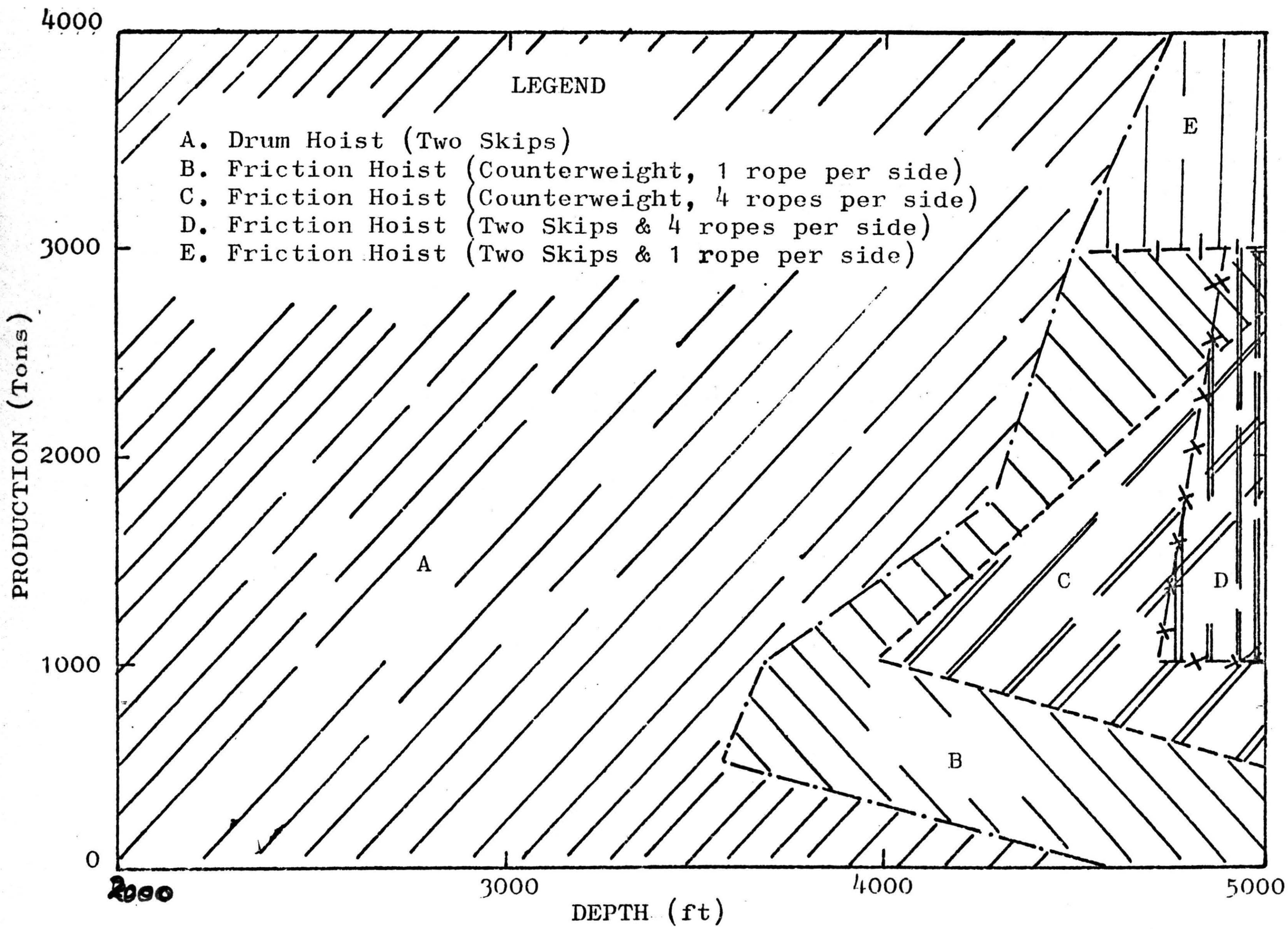

Figure 8. Optimum Economic Production & Depth for Hoisting Systems Compared on Energy Input Basis.

VII. CONCLUSIONS

The computer technique developed by this study permits various mine-hoist types to be compared on the theoretical basis of horsepower-second input per ton of ore hoisted. Because of the flexibility possible with the system, corresponding peak and root-mean-square horsepowers also can be determined with little additional effort. The data obtained from calculations provided the following conclusions:

1. Each of the hoist types considered, except the counterweighted drum hoist, has an area in which it is economically most favorable.
2. Balanced drum hoists are generally most favorable at less than 4500 ft of hoisting depth.
3. Balanced friction hoists are generally most favorable for greater than 4500-ft mines.
4. Counterweighted friction hoists are most favorable in an intermediate zone of hoisting depths and production levels.
5. All hoists are more economical at higher production rates.
6. The margin of economic advantage diminishes for the balanced drum hoist with increased production.
7. Drum hoists are limited in hoisting depth because of excessive rope and drum diameter requirements.
8. Balanced friction hoists are limited to use at greater depths due to rope slippage on the drive wheel.

The results presented are based upon theoretical values and may differ somewhat from those obtained under specific mining conditions. However, since energy input constitutes a large portion of the total hoisting costs, power costs necessarily must be given prime consideration in the selection of mine hoists.

VIII. RECOMMENDATIONS

Considerable additional research should be extended into areas of greater production rates (above 1000 tons per hour) and hoisting depths (above 10,000 ft) in order to provide comparative data pertaining to the very large and deep foreign mines. Such information could show the maximum limits to which drum hoists may be used, perhaps even with a multi-rope arrangement. Also, the economics of balanced friction hoists may be more appropriately portrayed for extreme hoisting depths.

A study of the economics of optimum acceleration and constant speed rates may result in a worthy contribution to the mining profession. Such an investigation may be conducted by utilizing the basic computer programs already developed.

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APPENDIX I

Table of Symbols

```
C        AL=ACCELERATION FOR DRUM HOIST
C        PR=PRODUCTION IN TONS
C        D=DEPTH OF WIND IN FEET
C        VL=IS LINEAR VELOCITY
C        RD=ROPE DIAMETER
C        G=ACCELERATION DUE TO GRAVITY
C        H=HOURS WORKED
C        FS=FACTOR OF SAFETY
C        RT=REST TIME IN SECONDS
C        AT=ACCELERATION TIME
C        CT=CONSTANT SPEED TIME
C        AD=ACCELERATION DISTANCE IN FEET
C        CD=CONSTANT SPEED DISTANCE IN FEET
C        TP=TIME PER ORE HOISTING TRIP
C        TN=NUMBER OF TRIPS PER DAY
C        OT=ORE PER TRIP
C        OTR=ORE PER TRIP +10%
C        SW=SKIP WEIGHT IN TONS
C        CW=WEIGHT OF THE COUNTERWEIGHT IN TONS
C        TDL=TOTAL DEAD LOAD BY LOAD
C        WR= WEIGHT OF ROPE IN POUNDS
C        TLR=LOAD DUE TO ROPE IN TONS
C        RN=NUMBER OF ROPE USED IN CASE OF FRICTION HOIST
C        RW=WEIGHT OF 4 ROPES USED FOR MULTI-ROPE HOISTING
C        VO=MAXIMUM VELOCITY
C        V=HOISTING VELOCITY FOR FRIV
C        V=HOISTING VELOCITY FOR FRICTION HOIST
C        A=MAXIMUM PERMISSIBLE ACCELERATION FOR FRICTION HOISTING
C        BST=BREAKING STRESS OF ROPE IN TONS
C        TU=TENSION ON LOADED SIDE
C        TL=TENSION ON EMPTY SIDE
C        TS=STATIC TENSION ON ROPE
C        TD=DYNAMIC TENSION ON ROPE
C        TAN=NUMBER OF ACTIVE TURNS OF HOISTING DRUM
C        V IS IN R.P.S
C        VR=VELOCITY IN R.P.S
C        P=PITCH IN INCHES
C        DD=DRUM DIAMETER IN FEET
C        FW=FACE WIDTH OF DRUM IN FEET
C        DW=DRUM WEIGHT IN POUNDS
C        DKI=INERTIA OF FRICTION WHEEL
C        DKF=DIAMETER OF FRICTION WHEEL
C        WF=WEIGHT OF THE FRICTION WHEEL
C        RWA=ROPE WOUND DURING ACCELERATION
C        RWCS=ROPE WOUND DURING CONSTANT SPEED
C        TMUL=MOMENT UP LOAD AT ZERO TURNS
C        TMUR=MOMENT UP ROPE AT START OF ACCELERATION
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C       TMUR1=MOMENT UP ROPE AT TURNS DURING ACCELERATION
C       TMUR2=MOMENT UP ROPE DURING RETARDATION
C       TDCW=MOMENT DOWN COUNTER WEIGHT
C       TDCC=MOMENT TO LOWER THE SKIP
C       TMDR=MOMENT DOWN ROPE (ROPE WOUND DURING ACCELERATION PERIOD)
C       TMO=TOTAL MOMENT AT ZERO TIME
C       TMSA=TOTAL MOENT AT THE START OF ACCELARATION
C       TMEA=MOMENT AT THE END OF ACCELERATION
C       TMCS=TOTAL MOMENT AT THE START OF CONSTANT SPEED
C       TMECS=TOTAL MOMENT AT THE END OF CONSTANT SPEED
C       TMEW=MOMENT AT THE END OF WIND
C       TMDL=MOMENT DOWN LOAD AT ZERO TURNS
C       FM=FRICTION MOMENT
C       FA=FORCE REQUIRED TO START THE SHAFT
C       AM=MOMENT TO ACCELERATE FA
C       RM=RETARDATION MOMENT
C       TNO=NETT MOMENT AT ZERO TURNS
C       TNA=NETT MOMENT DURING ACCELERATION
C       TNC=NETT MOMENT DURING CONSTANT SPEED
C       TND=NETT MOMENT DURING DECCELERATION
C       TMDR=MOMENT DOWN ROPE
C       TMDR1=MOMENT DOWN ROPE AFTER ACCELERATION
C       TMDR2=MOMENT DOWN ROPE AFTER CONSTANT SPEED
C       WHS=WEIGHT OF THE HEAD SHEAVE IN POUNDS
C       TNOC=MOMENT AT ACCELERATION PERIOD
C       TNAC=MOMENT AT THE CONSTANT SPEED PERIOD
C       TNCC=MOMENT AT THE END OF CONSTANT SPEED
C       TNDC=MOMENT AT THE END OF DECCELERATION
C       FA1=FORCE TO ACCELERATE DRIVE SHAFT
C       FM1=FRICTION MOMENT
C       AM1=ACCELERATION MOMENT
C       RM1=RETARDATION MOMENT
C       HPO=HORSE POWER AT ZERO TURNS
C       HPA=HORSE POWER AT START OF ACCELERATION
C       HPE=HORSE POWER AT THE END OF ACCELERATION
C       HPC= HORSE POWER AT THE END OF CONSTANT SPEED
C       HPEC=HORSE POWER AT END OF DECCELERATION
C       HPEW=HORSE POWER AT THE END OF WIND
C       HPTA=HORSE POWER SECOND DURING ACCELERATION
C       HPTC=HORSE POWER SECONDS AT END OF CONSTANT  SPEED
C       HPTD=HORSE POWER SECONDS  DURING DECCELARATION
C       HPT=HORSE POWER SECOND PER TON OF ORE HOISTED
C       HPO1=HORSE POWER AT THE START OF WIND
C       HPA1=HORSE POWER AT THE START OF ACCELERATION
C       HPE1=HORSE POWER AT THE START OF CONSTANT SPEED
C       HPEC1=HORSE PPOWER AT THE END OF DECCELERATION
C       HPC1=HPORSE POWER AT THE END OF CONSTANT SPEED
C       HPEW1=HORSE POWER AT THE END OF WINDING
C       HPTA1=HORSE POWER SECONDS DURING ACCELERATION
C       HPTC1=HORSE POWER SECONDS AT THE CONSTANT SPEED PERIOD
C       HPTD1=HORSE POWER AT THE DECCELERATION PERIOD
C       HTA=NETT HORSE POWER SECONDS DURING ACCELERATION
C       HTC=NETT HORSE POWER SECONDS DURING CONSTANT SPEED PERIOD
C       HTD=HORSE POWER SECONDS DURING THE DECCELERATION PERIOD
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C       PHP=PEAK HORSEPOWER FOR THE WIND
C       HPT=HORSEPOWER SECONDS PER TON OF ORE HOISTED
C       RMSHP=ROOT MEAN SQUARE HORSEPOWER FOR THE HOIST
```

APPENDIX II

List of Expressions Used for Drum Hoist and Friction Hoist Calculations

Drum Hoist

AT	=	(VL)/(AL)	(1)
AD	=	$(0.5)\ (AL)\ (AT)^2$	(2)
CD	=	(D)-(2) (AD)	(3)
CT	=	(CD)/(VL)	(4)
TP	=	(4)(AT) + (2)(CT) + (2)(RT)	(5)
TN	=	(H)(3600)/(TN)	(6)
OT	=	(PR)/(TN)	(7)
OTR	=	(1.1)(OT)	(8)
SW	=	(OTR)/(2)	(9)
CW	=	(SW) + (OTR)/(2)	(10)
TDL	=	(OTR+SW)(G+AL)(FS)/(G)	(11)
BST	=	$(-1.5424)(RD)^3+(38.2263)(RD)^2-(0.3694)(RD)+(0.1325)$	(12)
WR	=	$(1.5654)(RD)^2+(0.1185)(RD) - (0.06596)$	(13)
TLR	=	(D)+(G+AL)(WR)(FS)/(G)(2000)	(14)
TTDL	=	(TDL)+(TLR)	(15)
DD	=	(7.5)(RD)	(16)
TAN	=	$(D)/(\pi)(DD)$	(17)
V	=	(TAN)/(TP/2 - RT - AT)	(18)
P	=	(RD+0.25)	(19)
FW	=	(TAN+3.0)(P)/(12.0)	(20)
DW	=	$(DD)(\pi)(FW)(160)$	(21)
TMUL	=	(SW+OTR)(DD)(1000)	(22)

$$TMUR = (D)(WR)(DD)/(2) \tag{23}$$

$$TMUR1 = (D-RWA)(WR)(DD)/(2) \tag{24}$$

$$TMUR2 = (RWA)(WR)(DD)/(2) \tag{25}$$

$$TDCW = (CW)(DD)(1000) \tag{26}$$

$$TNO = (TMUL+TMUR-TDCW) \tag{27}$$

$$TNA = (TMUL+TMUR1-TDGW-TMUR2) \tag{28}$$

$$TNC = (TMUL+TMUR2-TDCW-TMUR1) \tag{29}$$

$$TND = (TMUL-TDCW-TMUR) \tag{30}$$

$$FM = (TMUL+TDCW+TMUR)(0.1) \tag{31}$$

$$WHS = (0.5576)(DD)^2 + (560.4531)(DD)-(1811.7024) \tag{32}$$

$$FA = ((CW+SW+OTR)(2000)+(D+250)(WR)(2)+DW+(2)\ (WHS)\ (AL))/(G) \tag{33}$$

$$AM = (FA)(DD)/(2) \tag{34}$$

$$TMO = (TNO+FM+AM) \tag{35}$$

$$TMSA = (TNA+FM+AM) \tag{36}$$

$$TMCS = (TNC+FM) \tag{37}$$

$$TMECS = (TNC+FM+RM) \tag{38}$$

$$TMEA = (RNA+FM) \tag{39}$$

$$TMEW = (TND+FM+RM) \tag{40}$$

$$Z = (2)(\pi)(V)/(550) \tag{41}$$

$$HPO = (TMO)(Z) \tag{42}$$

$$HPA = (TMSA)(Z) \tag{43}$$

$$HPE = (TMEA)(Z) \tag{44}$$

$$HPC = (TMCS)(Z) \tag{45}$$

$$HPEC = (TMECS)(Z) \tag{46}$$

$$HPEW = (TMEW)(Z) \tag{47}$$

HPTC = (HPE+HPC)(CT)/(2) (48)

HPTA = (HPO+HPA)(AT)/(2) (49)

HPTD = (HPEC+HPEW)(AT)/(2) (50)

HPTO = (HPTC+HPTD+HPTA) (51)

TUCR = (TDCW) (52)

TUR = (TMUR) (53)

TUR1 = (TMUR1) (54)

TUR2 = (TMUR2) (55)

TDCC = (SW)(2000)(DD)/(2) (56)

TDR1 = TMUR2 (57)

TDR2 = TMUR1 (58)

TDR = TMUR (59)

TNOC = (TUCR+TUR-TDCC) (60)

TNAC = (TUCR+TUR1-TDCC-TDR1) (61)

TNCC = (TUCR+TDR1-TDCC-TDR2) (62)

TNDC = (TUCR-TDCC-TUR) (63)

FA1 = ((CW+SW)(2000)+(D+250)(WR)(2)+(DW)+(2)(WHS)) (64)
(AL)/(G)

FM2 = (TUCR+TDCC+TMUR)(0.1) (65)

AM1 = (FA1)(DD)/(2) (66)

HPO1 = (TNOC+FM1+AM1)(Z) (67)

HPA1 = (TNAC+FM1+AM1)(Z) (68)

HPE1 = (TNAC+FMI)(Z) (69)

HPEC1= (TNCC+FM1+RM1)(Z) (70)

HPEW1= (TNDC+RM1+FM1)(Z) (71)

HPTA1= (HPO1+HPA1)(AT)/(2) (72)

$$HPTC1 = (HPE1+HPC1)(CT)/(2) \quad (73)$$

$$HPTD1 = (HPEC1+HPEW1)(AT)/(2) \quad (74)$$

$$HPT1 = (HPTA1+HPTC1+HPTD1) \quad (75)$$

$$HPT = (HPTO+HPT1)/(OTR) \quad (76)$$

$$PHP = (HPO+HPA)/(2) \quad (77)$$

$$RMSHP = [[(HPA^2(AT)+HPC^2+(HPE)(HPC)[CT+HPEC^2(AT)]/[AT+CT+.25(RT)]]^{1/2}$$

$$TP = (2)(AT)+CT+RT \quad (79)$$

$$V = (TAN)/(TP-RT-AT) \quad (80)$$

$$TNO = (TMUL+TMUR-TMDL) \quad (81)$$

$$TNA = (TMUL+TMUR1-TMDL-TMUR2) \quad (82)$$

$$TNC = (TMUL+TMUR2-TMDL-TMUR1) \quad (83)$$

$$TND = (TMUL-TMDL-TMUR) \quad (84)$$

$$FM = (TMUL+TMDL+TMUR)(0.1) \quad (85)$$

$$FA = (4000(SW)+2000(OTR)+(D+250)(WR)(2)+2(WHS))(AL)/(G) \quad (86)$$

* When solving for Drum Hoist with Counter Weight use expressions 1 through 77. For Drum Hoist with Two Skips use Expressions 79 through 86, as well as Equations 1 through 77 except Equations 5, 18, 26-39, and 54-75.

<u>Friction Hoist</u>

$$VO = [(A)(D)]^{1/2} \quad (87)$$

$$V = (VO)/2 \quad (88)$$

$$AT = (V)/(A) \quad (89)$$

$$AD = (A)(AT)^2/(2) \quad (90)$$

$$CD = (D-(2)(AD)) \quad (91)$$

$$RW = (RN)(WR) \quad (92)$$

$$TU = (SW+OTR)(2000)+(RW)(D+50) \quad (93)$$

$$TL = (SW)(2000)+RW(D+50) \quad (94)$$

$$TS = (TU)/(TL) \quad (95)$$

$$DKF = 7.5(RD) \quad (96)$$

$$DKI = 0.0395\ (DKF)^6 + 1.6191\ (DKF)^5 + 27.6288\ (DKF)^4 - 230.7825\ (DKF)^3 + 1125.88\ (DKF)^2 - 333.7235\ (DKF) + 2545.5254 \quad (97)$$

$$VR = TAN(AT+CT) \quad (98)$$

$$TMUL = (SW+OTR)(DKF)1000 \quad (99)$$

$$TMUR = (D+50)(RW)(DKF)/(2) \quad (100)$$

$$TMDL = (SW)(DKF)(1000) \quad (101)$$

$$TNO = (TMUL-TMDL) \quad (102)$$

$$FA = (4000(SW)+2000(OTR)+(D+50)(RW)(2)+WF)(A)/(G) \quad (103)$$

$$AM = (FA)(DKF)/(2) \quad (104)$$

+ For Friction Hoist with Two Skips use Expressions 1-103 except 1-5, 9-12, 12-40 and 52-86.

$$TDCW = (CW)(DKF)(1000) \quad (105)$$

$$FA = ((CW+SW+OTR)(2000)+(D+50)(RW)(2)+(WF))(AF)/G \quad (106)$$

$$FA1 = ((CW+SW)(2000)+(D+50)(RW)(2)+(WF))(A)/(G) \quad (107)$$

** For Friction Hoist with Counterweight use Equations 1 through 107 except 1-4, 15-21.

APPENDIX III

Computer Program Used for the Friction Hoist Using 2 Skips with 1 Pair of Ropes and for 2 Skips with 4 Pairs of Ropes

```
C     FRICTION HOISTING IN BALANCE FROM 250 TO 5000 FEET
      DIMENSION PR(20),D(20)
      READ(1,54)RN
      READ(1,25)(PR(J),J=1,16)
      READ(1,26)(D(I),I=1,20)
      WRITE(3,19)
      WRITE(3,22)(PR(J),J=1,16)
      WRITE(3,17)
      WRITE(3,23)(D(I),I=1,20)
      WRITE(3,56)
      WRITE(3,100)
   55 DO 5 J=1,16
      DO 5 I=1,20
      RD=0.25
      FS=4.0
      RT=12.0
      G=32.2
      H=7.0
      A=3.5
   47 VO=SQRT(A*D(I))
      V=0.5*VO
      AT=V/A
      AD=0.5*A*AT**2.0
      CD=(D(I)-2.0*AD)
      CT=CD/V
      TP=2.0*AT+CT+RT
      TN=H*3600.0/TP
      OT=PR(J)/TN
      OTR=OT*1.1
      SW=0.5*OTR
    4 WR=(-659.67674330E-04)+(118.52413335E-03)*RD
     1+(156.53931681E-02)*RD**2
      RW=RN*WR
      TDL=(SW+OTR)*(G+A)*FS/G
      BST=(132.56165299E-03)-(369.36228827E-03)*RD+
     1(382.26287669E-01)*RD**2-(154.23359881E-02)*RD**3
      TLR=(D(I)+50.0)*(G+A)*RW*FS/(G*2000.0)
      TTDL=TDL+TLR
      IF(RN*BST-TTDL)2,3,3
    2 IF(RD-0.625)7,6,6
    7 RD=RD+0.0625
      GO TO 4
```

```
    6 IF(RD-2.125)16,36,36
   16 RD=RD+0.125
      GO TO 4
   36 RD=RD+0.250
      GO TO 4
    3 TU=(SW+OTR)*2000.0+RW*(D(I)+50.0)
      TL=SW*2000.0+RW*(D(I)+50.0)
      TS=TU/TL
      IF(TS-1.50)65,65,5
   65 TD=TS*(G+A)/(G-A)
      IF(TD-1.87)91,91,67
   67 A=A-0.05
      IF(A-1.0)5,47,47
   91 DKF=7.5*RD
      DKI=(254.52538644E+01)-(333.72349421E-00)*DKF
     1+(112.50284830E+01)*DKF**2-(230.78253002E-00)*DKF**3
     1+(276.28800686E-01)*DKF**4-(161.90592751E-02)*DKF**5
     1+(395.09828625E-04)*DKF**6
      WF=4.0*DKI*G/(DKF**2)
      TAN=D(I)/(3.141*DKF)
      VR=TAN/(AT+CT)
      TMUL=(SW+OTR)*DKF*1000.0
      TMUR=(D(I)+50.0)*RW*DKF*0.50
      TMDL=SW*1000.0*DKF
      TNO=TMUL-TMDL
      FM=(TMUL+TMDL+TMUR)*0.1
      FA=(4000.*SW+2000.*OTR+(D(I)+50.)*RW*2.+WF)*A/G
      AM=FA*DKF/2.0
      RM=-AM
      Z=2.0*3.141*VR/550.0
      HPO=(TNO+FM+AM)*Z
      HPA=(TNO+FM+AM)*Z
      HPE=(TNO+FM)*Z
      HPC=(TNO+FM)*Z
      HPEC=(TNO+FM+RM)*Z
      HPEW=(TNO+FM+RM)*Z
      HPTA=(HPO+HPA)*0.5*AT
      HPTC=(HPE+HPC)*0.5*CT
      IF(HPEC+HPEW)34,34,35
   34 HPTD=0.0
      GO TO 30
   35 HPTD=(HPEC+HPEW)*0.5*AT
   30 HPT=(HPTA+HPTC+HPTD)/OTR
      PHP=HPA
      RMSHP=SQRT((HPA**2*AT+HPC**2*CT+HPEC**2*AT)/(AT+CT+0.25*RT))
      WRITE(3,101)D(I),PR(J),OTR,RD,AT,PHP,HPT,RMSHP
    5 CONTINUE
```

```
      IF(RN-4.0)57,58,58
   58 RN=1.0
      WRITE(3,103)
      GO TO 55
   57 CALL EXIT
   54 FORMAT(F10.3)
   56 FORMAT(20X,'FRICTION HOISTING WITH FOUR ROPES IN BALANCE')
   25 FORMAT(4F10.3)
   26 FORMAT(4F10.3)
   17 FORMAT(20X,'DEPTH IN FEET')
   22 FORMAT(12X,4F10.1)
   19 FORMAT(20X,'PRODUCTION IN TONS')
   23 FORMAT(12X,4F10.1)
   29 FORMAT(20X,'PRODUCTION IN TONS='F6.1)
  100 FORMAT(15X,'D',7X,'PR',4X,'OTR',4X,'RD',5X,'AT',5X,'PHP',6X,'HP
     15X,'RMSHP')
  101 FORMAT(12X,F7.1,1X,F7.1,1X,F5.1,1X,F6.3,1X,F5.1,1X,F8.1,1X,F8.1
     11X,F8.1)
  103 FORMAT(20X,'FRICTION HOIST IN BALANCE WITH ONE ROPE')
      END
```

INPUT DATA FOR CALCULATIONS

PRODUCTION IN TONS

250.00	500.00	750.00	1000.00
1250.00	1500.00	1750.00	2000.00
2250.00	2500.00	2750.00	3000.00
3250.00	3500.00	3750.00	4000.00

DEPTH IN FEET

250.00	500.00	750.00	1000.00
1250.00	1500.00	1750.00	2000.00
2250.00	2500.00	2750.00	3000.00
3250.00	3500.00	3750.00	4000.00
4250.00	4500.00	4750.00	5000.00

COMPUTER OUTPUT USING 4 ROPES AND 2 SKIPS

FRICTION HOISTING WITH FOUR ROPES IN PARALLEL

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
5000.0	1000.0	4.6	0.750	18.9	3078.7	31734.0	2009.4
4750.0	1250.0	5.7	0.750	18.4	3309.9	29205.9	2233.9
5000.0	1250.0	5.8	0.750	18.9	3474.8	30841.8	2350.0
4750.0	1500.0	6.8	0.875	18.4	3844.2	29668.4	2663.9
5000.0	1500.0	7.0	0.875	18.9	4044.7	31342.5	2806.0
5000.0	1750.0	8.1	0.875	18.9	4440.9	30761.1	3158.7
4750.0	2000.0	9.1	1.000	18.4	4817.1	29599.1	3460.3
5000.0	2000.0	9.3	1.000	18.9	5075.2	31267.5	3646.9
4750.0	2250.0	10.2	1.000	18.4	5194.6	29189.1	3800.8
5000.0	2250.0	10.5	1.000	18.9	5471.4	30823.6	4004.4
5000.0	2500.0	11.6	1.125	18.9	6162.0	31319.1	4517.1
4500.0	2750.0	12.2	1.125	17.9	5885.0	27670.6	4378.7
4750.0	2750.0	12.5	1.125	18.4	6220.4	29307.1	4627.2
5000.0	2750.0	12.9	1.125	18.9	6558.1	30951.3	4876.8
5000.0	3000.0	13.9	1.250	18.9	7299.8	31434.1	5411.1
4750.0	3250.0	14.8	1.250	18.4	7294.3	29457.3	5474.9
5000.0	3250.0	15.1	1.250	18.9	7696.0	31114.0	5771.8
4750.0	3500.0	15.9	1.250	18.4	7671.8	29203.9	5819.5
5000.0	3500.0	16.3	1.250	18.9	8092.2	30839.6	6133.7
5000.0	3750.0	17.4	1.375	18.9	8882.1	31297.7	6687.8
4750.0	4000.0	18.2	1.375	18.4	8790.9	29394.7	6686.9
5000.0	4000.0	18.6	1.375	18.9	9278.3	31046.1	7049.9

COMPUTER OUTPUT USING 1 ROPE AND 2 SKIPS

FRICTION HOIST IN BALANCE WITH ONE ROPE

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
5000.0	250.0	1.2	0.750	18.9	1367.7	41281.6	801.6
4750.0	500.0	2.3	1.000	18.4	1685.5	31424.5	1038.7
5000.0	500.0	2.3	1.000	18.9	1762.5	33091.8	1088.9
5000.0	750.0	3.5	1.250	18.9	2272.3	31434.1	1487.4
4750.0	1000.0	4.5	1.375	18.4	2623.7	29394.6	1785.4
5000.0	1000.0	4.6	1.375	18.9	2756.6	31046.1	1879.2
4750.0	1250.0	5.7	1.500	18.4	3100.1	29224.3	2170.4
5000.0	1250.0	5.8	1.500	18.9	3259.8	30861.7	2285.2
4750.0	1500.0	6.8	1.625	18.4	3594.6	29147.9	2565.5
5000.0	1500.0	7.0	1.750	18.9	3928.9	31334.7	2772.2
5000.0	1750.0	8.1	1.875	18.9	4495.8	31265.2	3205.6
5000.0	2000.0	9.3	2.000	18.9	5090.7	31243.3	3649.2
4750.0	2250.0	10.2	2.000	18.4	5210.1	29169.3	3802.9
5000.0	2250.0	10.5	2.125	18.9	5719.4	31253.2	4104.2
4750.0	2500.0	11.4	2.125	18.4	5806.5	29218.2	4234.5
5000.0	2500.0	11.6	2.375	18.9	6710.2	31739.4	4701.9
4750.0	2750.0	12.5	2.375	18.4	6746.8	29659.9	4797.1
5000.0	2750.0	12.8	2.375	18.9	7106.3	31333.3	5055.4
4500.0	3000.0	13.3	2.375	17.9	6748.4	27707.7	4861.9
4750.0	3000.0	13.6	2.375	18.4	7124.3	29347.3	5135.9
5000.0	3000.0	13.9	2.375	18.9	7502.5	30994.9	5411.2
4750.0	3250.0	14.8	2.625	18.4	8289.8	29779.9	5772.6
5000.0	3250.0	15.1	2.625	18.9	8726.1	31463.1	6082.1
4500.0	3500.0	15.5	2.625	17.9	8214.9	27851.2	5783.1
4750.0	3500.0	15.9	2.625	18.4	8667.3	29503.4	6108.0
5000.0	3500.0	16.3	2.625	18.9	9122.3	31163.8	6434.4
4500.0	3750.0	16.6	2.625	17.9	8573.6	27630.8	6103.4
4750.0	3750.0	17.0	2.625	18.4	9044.7	29263.8	6445.3
5000.0	3750.0	17.4	2.875	18.9	10668.1	31622.7	7221.9
4750.0	4000.0	18.2	2.875	18.4	10522.5	29676.2	7187.3
5000.0	4000.0	18.6	2.875	18.9	11064.3	31350.9	7569.4

APPENDIX IV

Computer Program Used for the Friction Hoist Using a Counterweight with 4 Pairs of Ropes And a Counterweight with 1 pair of Ropes

```
C       COUNTER WEIGHT HOISTING FROM 250-5000 FT. PRODUCTION 250-5000
        DIMENSION PR(20),VL(20),AL(20),D(20)
        READ(1,25)(PR(J),J=1,16)
        READ(1,26)(VL(I),AL(I),D(I),I=1,20)
        WRITE(3,19)
        WRITE(3,22)(PR(J),J=1,16)
        WRITE(3,17)
        WRITE(3,23)(VL(I),AL(I),D(I),I=1,20)
        WRITE(3,100)
        DO 5 J=1,16
        DO 5 I=1,20
        RD=0.25
        G=32.2
        H=7.0
        FS=4.0
        RT=12.0
        AT=VL(I)/AL(I)
        AD=0.5*AL(I)*AT**2
        CD=D(I)-2.0*AD
        CT=CD/VL(I)
        TP=4.0*AT+2.0*CT+2.0*RT
        TN=H*3600.0/TP
        OT=PR(J)/TN
        OTR=1.1*OT
        SW=0.5*OTR
        CW=SW+0.5*OTR
        TDL=(OTR+SW)*(G+AL(I))*FS/G
   15   BST=132.56165299E-03-369.36228827E-03*RD+382.26287699E-01*RD**2.
       1-154.23859881E-02*RD**3.0
    4   WR=-659.67674330E-04+118.52413335E-03*RD+156.53931681E-02*RD**2.
        TLR=D(I)*(G+AL(I))*WR*FS/(G*2000.0)
        TTDL=TDL+TLR
        IF(BST-TTDL)2,3,3
    2   IF(RD-0.625)7,6,6
    7   RD=RD+0.0625
        GO TO 15
    6   IF(RD-2.250)16,36,36
   16   RD=RD+0.125
        GO TO 15
   36   RD=RD+0.250
        IF(RD-3.5)15,15,11
    3   DD=7.5*RD
        TAN=D(I)/(3.141*DD)
```

```
      V=TAN/(0.5*TP-RT-AT)
      P=RD+0.25
      FW=(TAN+3.0)*P/12.0
      DW=DD*3.141*FW*160.0
      RWA=AD
      RWR=RWA
      RWCS=CD
      TMUL=(SW+OTR)*DD*1000.0
      TMUR=D(I)*WR*DD/2.0
      TMUR1=(D(I)-RWA)*WR*DD/2.0
      TMUR2=RWA*WR*DD/2.0
      TDCW=CW*DD*1000.0
      TMDR=TMUR2
      TMDR1=TMUR1
      TMDR2=TMUR
      TNO=TMUL+TMUR-TDCW
      TNA=TMUL+TMUR1-TDCW-TMUR2
      TNC=TMUL+TMUR2-TDCW-TMUR1
      TND=TMUL-TDCW-TMUR
      FM=(TMUL+TDCW+TMUR)*0.1
      IF(DD-2.75)77,77,78
   77 WHS=375.00
      GO TO 9
   78 IF(DD-3.75)80,80,88
   80 WHS=500.0
      GO TO 9
   88 WHS=-181.17024280E+01+560.45313382E-00*DD+557.59457933E-03*DD**2.
    9 FA=((CW+SW+OTR)*2000.0+(D(I)+250.)*WR*2.+DW+2.0*WHS)*AL(I)/G
      AM=FA*DD/2.0
      RM=-AM
      TMO=(TNO+FM+AM)
      TMSA=(TNA+FM+AM)
      TMEA=(TNA+FM)
      TMCS=(TNC+FM)
      TMECS=(TNC+FM+RM)
      TMEW=(TND+FM+RM)
      Z=2.0*3.141*V/550.0
      HPO=TMO*Z
      HPA=TMSA*Z
      HPE=TMEA*Z
      HPC=TMCS*Z
      HPEC=TMECS*Z
      HPEW=TMEW*Z
      HPTC=(HPE+HPC)*0.5*CT
      HPTA=(HPO+HPA)*0.5*AT
      IF(HPEC+HPEW)30,30,35
   30 HPTD=0.00

      GO TO 37
   35 HPTD=(HPEC+HPEW)*0.5*AT
   37 HPTO=(HPTC+HPTD+HPTA)
      UP COUNTER WEIGHT DOWN SKIP
      TUCR=TDCW
```

```
C       MOMENT UP ROPE
        TUR=TMUR
        TUR1=TMUR1
        TUR2=TMUR2
C       DOWN SKIP
        TDCC=SW*2000.0*DD*0.5
C       DOWN ROPE
        TDR1=TMUR2
        TDR2=TMUR1
        TDR=TMUR
C       NETT MOMENTS
        TNOC=TUCR+TUR-TDCC
        TNAC=TUCR+TUR1-TDCC-TDR1
        TNCC=TUCR+TDR1-TDCC-TDR2
        TNDC=TUCR-TDCC-TUR
        FA1=((CW+SW)*2000.+(D(I)+250.)*WR*2.+DW+2.*WHS)*AL(I)/G
        FM1=(TUCR+TDCC+TMUR)*0.1
        AM1=FA1*DD*0.5
        RM1=-AM1
        HPO1=(TNOC+FM1+AM1)*Z
        HPA1=(TNAC+FM1+AM1)*Z
        HPE1=(TNAC+FM1)*Z
        HPC1=(TNCC+FM1)*Z
        HPEC1=(TNCC+FM1+RM1)*Z
        HPEW1=(TNDC+RM1+FM1)*Z
        HPTA1=(HPO1+HPA1)*0.5*AT
        HPTC1=(HPE1+HPC1)*0.50*CT
        IF(HPEC1+HPEW1)40,40,45
   40   HPTD1=0.00
        GO TO 47
   45   HPTD1=(HPEC1+HPEW1)*0.5*AT
   47   HPT1=(HPTA1+HPTC1+HPTD1)
        HPT=(HPTO+HPT1)/OTR
        PHP=(HPO+HPA)*0.5
        RMSHP=SQRT((HPA**2*AT+(HPE**2+HPC**2+HPE*HPC)*CT+HPEC**2*AT)/
       1(AT+CT+0.25*PT))
        WRITE(3,101)D(I),PR(J),OTR,RD,AT,PHP,HPT,RMSHP
        GO TO 5
   11   WRITE(3,102)D(I)
        WRITE(3,12)RD
    5   CONTINUE
        CALL EXIT
  100 FORMAT(15X,'D',7X,'PR',4X,'OTR',4X,'RD',5X,'AT',5X,'PHP',6X,'HP
     15X,'RMSHP')
  101 FORMAT(12X,F7.1,1X,F7.1,1X,F5.1,1X,F6.3,1X,F5.1,1X,F8.1,1X,F8.1
     11X,F8.1)
   23 FORMAT(12X,3F10.1)
   22 FORMAT(12X,3F10.1)
   25 FORMAT(4F10.3)
```

```
   26 FORMAT(3F10.3)
   19 FORMAT(20X,'PRODUCTION IN TONS')
   17 FORMAT(20X,'VELOCITY,ACCELERATION AND DEPTH')
  102 FORMAT(20X,'DEPTH IN FEET='F6.1)
   12 FORMAT(20X,'ROPE DIA IS LARGER THAN 3.5 IN. CALCULATED DIA='F5.
      END
```

INPUT DATA FOR CALCULATIONS

PRODUCTION IN TONS

250.00	500.00	750.00	1000.00
1250.00	1500.00	1750.00	2000.00
2250.00	2500.00	2750.00	3000.00
3250.00	3500.00	3750.00	4000.00

DEPTH IN FEET

250.00	500.00	750.00	1000.00
1250.00	1500.00	1750.00	2000.00
2250.00	2500.00	2750.00	3000.00
3250.00	3500.00	3750.00	4000.00
4250.00	4500.00	4750.00	5000.00

COMPUTER OUTPUT USING 4 ROPES AND A COUNTERWEIGHT

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	250.0	0.7	0.250	4.2	529.8	7107.3	327.5
500.0	250.0	0.9	0.250	6.0	764.9	11836.2	478.0
750.0	250.0	1.1	0.250	7.3	951.7	15893.8	595.8
1000.0	250.0	1.2	0.250	8.5	1113.5	19582.2	696.7
1250.0	250.0	1.3	0.250	9.4	1259.5	23027.6	787.0
1500.0	250.0	1.4	0.313	10.4	1145.2	22706.6	701.7
1750.0	250.0	1.5	0.313	11.2	1252.9	25541.7	766.0
2000.0	250.0	1.6	0.313	12.0	1355.5	28299.5	827.0
2250.0	250.0	1.6	0.313	12.7	1454.0	30994.7	885.3
2500.0	250.0	1.7	0.313	13.4	1549.0	33638.1	941.3
2750.0	250.0	1.8	0.375	14.0	1454.8	33673.4	870.6
3000.0	250.0	1.9	0.375	14.6	1538.3	36172.8	919.2
3250.0	250.0	1.9	0.375	15.2	1620.1	38651.6	966.9
3500.0	250.0	2.0	0.375	15.8	1700.5	41113.0	1013.6
3750.0	250.0	2.0	0.375	16.4	1779.7	43559.5	1059.7
4000.0	250.0	2.1	0.375	16.9	1857.7	45993.4	1105.0
4250.0	250.0	2.2	0.438	17.4	1810.8	47220.9	1068.0
4500.0	250.0	2.2	0.438	17.9	1886.5	49694.7	1112.1
4750.0	250.0	2.3	0.438	18.4	1961.6	52167.7	1156.0
5000.0	250.0	2.3	0.438	18.9	2036.3	54640.6	1199.6

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	500.0	1.4	0.313	4.2	465.2	3633.2	271.7
500.0	500.0	1.8	0.313	6.0	689.1	6340.1	404.6
750.0	500.0	2.1	0.375	7.3	767.6	8080.0	445.3
1000.0	500.0	2.4	0.375	8.5	916.9	10268.7	531.9
1250.0	500.0	2.6	0.375	9.4	1055.7	12386.5	612.4
1500.0	500.0	2.8	0.438	10.4	1093.5	13837.4	631.9
1750.0	500.0	3.0	0.438	11.2	1213.9	15838.7	702.6
2000.0	500.0	3.1	0.438	12.0	1330.8	17820.2	771.5
2250.0	500.0	3.3	0.438	12.7	1444.9	19786.9	839.1
2500.0	500.0	3.4	0.500	13.4	1485.5	21388.7	866.0
2750.0	500.0	3.6	0.500	14.0	1594.8	23357.9	932.0
3000.0	500.0	3.7	0.500	14.6	1703.0	25325.5	997.6
3250.0	500.0	3.8	0.500	15.2	1810.2	27292.6	1062.8
3500.0	500.0	4.0	0.563	15.8	1878.1	29333.4	1110.3
3750.0	500.0	4.1	0.563	16.4	1986.2	31362.5	1177.0
4000.0	500.0	4.2	0.563	16.9	2094.0	33397.6	1243.7
4250.0	500.0	4.3	0.625	17.4	2199.2	35988.9	1315.1
4500.0	500.0	4.4	0.625	17.9	2311.1	38125.2	1384.9
4750.0	500.0	4.5	0.625	18.4	2423.2	40272.1	1454.9
5000.0	500.0	4.6	0.750	18.9	2632.3	44899.6	1593.0

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	750.0	2.2	0.313	4.2	505.0	2879.3	286.5
500.0	750.0	2.7	0.375	6.0	672.6	4767.7	381.3
750.0	750.0	3.2	0.438	7.3	798.5	6453.8	454.5
1000.0	750.0	3.6	0.438	8.5	967.7	8324.7	554.6
1250.0	750.0	3.9	0.500	9.4	1067.6	9912.5	618.4
1500.0	750.0	4.2	0.500	10.4	1217.3	11713.3	709.9
1750.0	750.0	4.4	0.500	11.2	1363.0	13502.2	799.9
2000.0	750.0	4.7	0.563	12.0	1460.4	15158.9	868.1
2250.0	750.0	4.9	0.563	12.7	1600.8	16954.2	956.9
2500.0	750.0	5.2	0.563	13.4	1739.8	18750.0	1045.3
2750.0	750.0	5.4	0.625	14.0	1854.7	20620.8	1127.3
3000.0	750.0	5.6	0.625	14.6	1994.4	22461.7	1217.3
3250.0	750.0	5.8	0.625	15.2	2133.6	24308.8	1307.4
3500.0	750.0	6.0	0.750	15.8	2299.4	26949.4	1426.1
3750.0	750.0	6.1	0.750	16.4	2448.6	28938.4	1523.0
4000.0	750.0	6.3	0.750	16.9	2598.4	30940.5	1620.3
4250.0	750.0	6.5	0.750	17.4	2748.7	32955.5	1718.1
4500.0	750.0	6.7	0.750	17.9	2899.7	34983.3	1816.3
4750.0	750.0	6.8	0.875	18.4	3209.4	39092.8	2015.3
5000.0	750.0	7.0	0.875	18.9	3378.5	41339.7	2124.2

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	1000.0	2.9	0.375	4.2	482.2	2321.7	266.7
500.0	1000.0	3.7	0.438	6.0	685.4	4078.3	386.6
750.0	1000.0	4.2	0.500	7.3	850.2	5714.2	489.6
1000.0	1000.0	4.7	0.500	8.5	1042.6	7442.0	608.7
1250.0	1000.0	5.2	0.563	9.4	1184.3	9032.9	705.4
1500.0	1000.0	5.6	0.563	10.4	1360.7	10729.9	818.7
1750.0	1000.0	5.9	0.625	11.2	1504.1	12382.7	920.6
2000.0	1000.0	6.3	0.625	12.0	1675.3	14091.6	1033.2
2250.0	1000.0	6.6	0.625	12.7	1845.0	15803.2	1145.4
2500.0	1000.0	6.9	0.750	13.4	2005.4	17773.7	1266.1
2750.0	1000.0	7.2	0.750	14.0	2180.8	19568.4	1383.2
3000.0	1000.0	7.4	0.750	14.6	2356.2	21373.0	1500.6
3250.0	1000.0	7.7	0.750	15.2	2531.9	23187.7	1618.4
3500.0	1000.0	7.9	0.750	15.8	2708.0	25012.4	1736.5
3750.0	1000.0	8.2	0.875	16.4	2981.0	27864.2	1919.8
4000.0	1000.0	8.4	0.875	16.9	3172.4	29835.0	2047.1
4250.0	1000.0	8.7	0.875	17.4	3365.0	31823.3	2175.1
4500.0	1000.0	8.9	0.875	17.9	3558.7	33839.3	2303.9
4750.0	1000.0	9.1	1.000	18.4	3972.4	37765.9	2562.3
5000.0	1000.0	9.3	1.000	18.9	4188.7	39965.1	2703.8

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	1250.0	3.6	0.438	4.2	480.0	2035.6	264.6
500.0	1250.0	4.6	0.500	6.0	715.0	3709.4	409.6
750.0	1250.0	5.3	0.563	7.3	915.2	5308.8	541.1
1000.0	1250.0	5.9	0.563	8.5	1133.1	6959.2	681.9
1250.0	1250.0	6.5	0.625	9.4	1313.6	8545.1	809.1
1500.0	1250.0	7.0	0.625	10.4	1518.2	10185.9	945.8
1750.0	1250.0	7.4	0.750	11.2	1693.6	11879.5	1079.1
2000.0	1250.0	7.8	0.750	12.0	1897.8	13587.3	1218.1
2250.0	1250.0	8.2	0.750	12.7	2101.3	15351.5	1357.1
2500.0	1250.0	8.6	0.750	13.4	2304.3	17126.6	1496.2
2750.0	1250.0	9.0	0.750	14.0	2507.2	18912.1	1635.5
3000.0	1250.0	9.3	0.875	14.6	2767.0	21303.1	1817.2
3250.0	1250.0	9.6	0.875	15.2	2982.6	23186.9	1964.3
3500.0	1250.0	9.9	0.875	15.8	3199.2	25083.2	2112.0
3750.0	1250.0	10.2	0.875	16.4	3416.8	26991.6	2260.4
4000.0	1250.0	10.5	1.000	16.9	3797.1	29979.2	2505.4
4250.0	1250.0	10.8	1.000	17.4	4035.2	32015.7	2665.3
4500.0	1250.0	11.1	1.000	17.9	4275.0	34066.5	2826.3
4750.0	1250.0	11.4	1.000	18.4	4516.6	36131.4	2988.2
5000.0	1250.0	11.6	1.125	18.9	5054.8	39911.0	3316.9

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	1500.0	4.3	0.500	4.2	489.6	1868.1	273.2
500.0	1500.0	5.5	0.563	6.0	755.3	3487.5	443.8
750.0	1500.0	6.4	0.563	7.3	1016.1	5109.7	613.2
1000.0	1500.0	7.1	0.625	8.5	1234.7	6665.6	767.1
1250.0	1500.0	7.8	0.750	9.4	1439.7	8298.6	921.1
1500.0	1500.0	8.3	0.750	10.4	1675.5	10002.9	1083.7
1750.0	1500.0	8.9	0.750	11.2	1909.0	11718.3	1245.6
2000.0	1500.0	9.4	0.750	12.0	2141.2	13443.9	1407.3
2250.0	1500.0	9.9	0.875	12.7	2396.1	15496.4	1591.9
2500.0	1500.0	10.3	0.875	13.4	2637.1	17297.4	1759.6
2750.0	1500.0	10.7	0.875	14.0	2878.7	19110.2	1927.7
3000.0	1500.0	11.2	0.875	14.6	3120.9	20934.4	2096.4
3250.0	1500.0	11.5	1.000	15.2	3474.4	23414.0	2332.7
3500.0	1500.0	11.9	1.000	15.8	3734.7	25338.0	2511.5
3750.0	1500.0	12.3	1.000	16.4	3996.6	27275.1	2691.3
4000.0	1500.0	12.6	1.000	16.9	4260.1	29225.0	2872.0
4250.0	1500.0	13.0	1.125	17.4	4751.8	32289.7	3180.2
4500.0	1500.0	13.3	1.125	17.9	5040.9	34365.9	3374.9
4750.0	1500.0	13.6	1.125	18.4	5332.2	36456.9	3570.9
5000.0	1500.0	13.9	1.250	18.9	5971.9	40140.9	3957.5

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	1750.0	5.1	0.500	4.2	529.3	1797.1	298.9
500.0	1750.0	6.4	0.563	6.0	826.4	3381.2	494.2
750.0	1750.0	7.4	0.625	7.3	1090.5	4926.0	677.9
1000.0	1750.0	8.3	0.750	8.5	1330.6	6571.7	856.9
1250.0	1750.0	9.1	0.750	9.4	1598.6	8249.4	1043.8
1500.0	1750.0	9.7	0.750	10.4	1862.8	9937.5	1229.4
1750.0	1750.0	10.4	0.875	11.2	2130.3	11818.9	1427.1
2000.0	1750.0	11.0	0.875	12.0	2398.9	13567.8	1616.7
2250.0	1750.0	11.5	0.875	12.7	2667.4	15328.1	1806.6
2500.0	1750.0	12.0	0.875	13.4	2936.1	17099.1	1996.7
2750.0	1750.0	12.5	1.000	14.0	3285.2	19306.3	2237.4
3000.0	1750.0	13.0	1.000	14.6	3569.7	21158.9	2436.5
3250.0	1750.0	13.5	1.000	15.2	3855.7	23023.6	2636.5
3500.0	1750.0	13.9	1.000	15.8	4143.3	24900.1	2837.5
3750.0	1750.0	14.3	1.125	16.4	4616.7	27566.1	3141.9
4000.0	1750.0	14.7	1.125	16.9	4928.1	29546.6	3355.7
4250.0	1750.0	15.1	1.125	17.4	5241.9	31540.5	3570.8
4500.0	1750.0	15.5	1.250	17.9	5851.5	34697.0	3945.9
4750.0	1750.0	15.9	1.250	18.4	6195.8	36816.9	4177.5
5000.0	1750.0	16.3	1.250	18.9	6543.1	38952.0	4410.7

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2000.0	5.8	0.563	4.2	546.4	1712.4	315.9
500.0	2000.0	7.3	0.625	6.0	874.2	3268.5	537.4
750.0	2000.0	8.5	0.750	7.3	1157.6	4888.9	744.7
1000.0	2000.0	9.5	0.750	8.5	1460.8	6545.7	957.5
1250.0	2000.0	10.3	0.750	9.4	1757.4	8212.6	1167.8
1500.0	2000.0	11.1	0.875	10.4	2048.5	10014.9	1385.1
1750.0	2000.0	11.9	0.875	11.2	2345.8	11733.5	1597.7
2000.0	2000.0	12.5	0.875	12.0	2642.3	13462.7	1810.2
2250.0	2000.0	13.2	1.000	12.7	2991.4	15474.7	2057.8
2500.0	2000.0	13.8	1.000	13.4	3301.0	17271.8	2277.8
2750.0	2000.0	14.3	1.000	14.0	3611.7	19080.5	2498.5
3000.0	2000.0	14.9	1.000	14.6	3923.7	20900.4	2720.1
3250.0	2000.0	15.4	1.125	15.2	4382.1	23276.3	3023.2
3500.0	2000.0	15.9	1.125	15.8	4716.2	25183.6	3256.6
3750.0	2000.0	16.4	1.125	16.4	5052.5	27103.3	3491.2
4000.0	2000.0	16.9	1.250	16.9	5635.1	29873.2	3857.7
4250.0	2000.0	17.3	1.250	17.4	6000.4	31899.3	4107.7
4500.0	2000.0	17.7	1.250	17.9	6368.7	33939.4	4359.4
4750.0	2000.0	18.2	1.375	18.4	7104.4	37198.4	4806.2
5000.0	2000.0	18.6	1.375	18.9	7508.3	39365.0	5076.9

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2250.0	6.5	0.563	4.2	586.1	1674.5	343.6
500.0	2250.0	8.2	0.625	6.0	945.2	3219.5	590.3
750.0	2250.0	9.5	0.750	7.3	1258.6	4876.0	822.5
1000.0	2250.0	10.7	0.750	8.5	1590.9	6525.5	1059.0
1250.0	2250.0	11.6	0.875	9.4	1908.5	8268.4	1297.4
1500.0	2250.0	12.5	0.875	10.4	2235.8	9962.7	1533.6
1750.0	2250.0	13.3	0.875	11.2	2561.2	11667.2	1769.3
2000.0	2250.0	14.1	1.000	12.0	2926.4	13582.9	2032.9
2250.0	2250.0	14.8	1.000	12.7	3262.7	15346.2	2275.0
2500.0	2250.0	15.5	1.000	13.4	3599.9	17120.4	2517.7
2750.0	2250.0	16.1	1.125	14.0	4047.2	19278.9	2822.3
3000.0	2250.0	16.7	1.125	14.6	4404.2	21127.5	3075.5
3250.0	2250.0	17.3	1.125	15.2	4763.4	22988.0	3329.9
3500.0	2250.0	17.9	1.125	15.8	5124.8	24860.1	3585.5
3750.0	2250.0	18.4	1.250	16.4	5708.7	27417.4	3959.4
4000.0	2250.0	19.0	1.250	16.9	6098.1	29382.3	4229.7
4250.0	2250.0	19.5	1.375	17.4	6798.0	32261.9	4663.1
4500.0	2250.0	20.0	1.375	17.9	7221.4	34335.6	4951.4
4750.0	2250.0	20.4	1.375	18.4	7648.6	36423.9	5241.8
5000.0	2250.0	20.9	1.500	18.9	8520.6	39793.7	5766.1

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2500.0	7.2	0.625	4.2	608.4	1625.2	365.5
500.0	2500.0	9.1	0.750	6.0	985.2	3231.2	635.0
750.0	2500.0	10.6	0.750	7.3	1359.5	4865.6	900.8
1000.0	2500.0	11.8	0.875	8.5	1708.4	6562.9	1162.5
1250.0	2500.0	12.9	0.875	9.4	2067.4	8237.0	1423.4
1500.0	2500.0	13.9	0.875	10.4	2423.1	9921.0	1682.9
1750.0	2500.0	14.8	1.000	11.2	2806.1	11761.6	1963.7
2000.0	2500.0	15.7	1.000	12.0	3169.8	13497.3	2228.2
2250.0	2500.0	16.5	1.000	12.7	3533.9	15243.4	2493.1
2500.0	2500.0	17.2	1.125	13.4	3991.1	17289.4	2810.7
2750.0	2500.0	17.9	1.125	14.0	4373.6	19101.0	3085.3
3000.0	2500.0	18.6	1.125	14.6	4758.1	20923.8	3360.9
3250.0	2500.0	19.2	1.250	15.2	5320.3	23243.3	3730.7
3500.0	2500.0	19.9	1.250	15.8	5730.9	25146.5	4020.0
3750.0	2500.0	20.5	1.250	16.4	6144.5	27062.0	4310.8
4000.0	2500.0	21.1	1.375	16.9	6841.4	29728.4	4749.0
4250.0	2500.0	21.6	1.375	17.4	7288.1	31740.2	5057.2
4500.0	2500.0	22.2	1.375	17.9	7738.6	33765.6	5367.3
4750.0	2500.0	22.7	1.500	18.4	8601.2	36857.7	5891.9
5000.0	2500.0	23.2	1.500	18.9	9091.7	38996.1	6223.2

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2750.0	8.0	0.625	4.2	648.1	1602.8	394.4
500.0	2750.0	10.1	0.750	6.0	1056.3	3226.7	689.5
750.0	2750.0	11.7	0.875	7.3	1444.6	4888.3	978.3
1000.0	2750.0	13.0	0.875	8.5	1838.6	6544.8	1265.4
1250.0	2750.0	14.2	0.875	9.4	2226.3	8211.3	1549.8
1500.0	2750.0	15.3	1.000	10.4	2629.6	9992.3	1849.0
1750.0	2750.0	16.3	1.000	11.2	3021.5	11704.8	2136.6
2000.0	2750.0	17.2	1.000	12.0	3413.2	13427.3	2424.1
2250.0	2750.0	18.1	1.125	12.7	3881.7	15383.1	2755.6
2500.0	2750.0	18.9	1.125	13.4	4290.0	17163.9	3051.8
2750.0	2750.0	19.7	1.125	14.0	4700.1	18955.4	3349.0
3000.0	2750.0	20.5	1.250	14.6	5266.6	21147.2	3728.7
3250.0	2750.0	21.2	1.250	15.2	5701.6	23010.4	4038.7
3500.0	2750.0	21.9	1.250	15.8	6139.6	24885.2	4350.3
3750.0	2750.0	22.5	1.375	16.4	6834.3	27379.1	4794.4
4000.0	2750.0	23.2	1.375	16.9	7304.4	29339.9	5122.5
4250.0	2750.0	23.8	1.500	17.4	8124.0	32119.7	5630.5
4500.0	2750.0	24.4	1.500	17.9	8632.4	34180.1	5978.7
4750.0	2750.0	25.0	1.500	18.4	9145.5	36254.9	6329.4
5000.0	2750.0	25.6	1.625	18.9	10151.3	39468.2	6935.1

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	3000.0	8.7	0.750	4.2	663.5	1605.1	416.1
500.0	3000.0	11.0	0.750	6.0	1127.3	3223.0	744.2
750.0	3000.0	12.7	0.875	7.3	1545.5	4878.7	1057.6
1000.0	3000.0	14.2	0.875	8.5	1968.7	6529.7	1368.6
1250.0	3000.0	15.5	1.000	9.4	2395.4	8262.6	1688.0
1500.0	3000.0	16.7	1.000	10.4	2816.8	9955.0	1999.2
1750.0	3000.0	17.8	1.000	11.2	3237.0	11657.4	2309.9
2000.0	3000.0	18.8	1.125	12.0	3718.4	13539.8	2656.3
2250.0	3000.0	19.7	1.125	12.7	4153.0	15294.4	2974.6
2500.0	3000.0	20.6	1.250	13.4	4704.1	17328.6	3354.5
2750.0	3000.0	21.5	1.250	14.0	5161.0	19146.5	3684.1
3000.0	3000.0	22.3	1.250	14.6	5620.6	20975.9	4015.1
3250.0	3000.0	23.1	1.375	15.2	6286.8	23262.5	4452.0
3500.0	3000.0	23.8	1.375	15.8	6776.6	25168.1	4798.5
3750.0	3000.0	24.6	1.375	16.4	7270.2	27086.1	5146.8
4000.0	3000.0	25.3	1.500	16.9	8083.1	29688.9	5658.0
4250.0	3000.0	26.0	1.500	17.4	8614.1	31696.8	6025.8
4500.0	3000.0	26.6	1.625	17.9	9567.6	34594.0	6609.5
4750.0	3000.0	27.3	1.625	18.4	10142.4	36704.9	7000.3
5000.0	3000.0	27.9	1.750	18.9	11260.0	39942.1	7670.3

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	3250.0	9.4	0.750	4.2	703.2	1604.0	445.8
500.0	3250.0	11.9	0.875	6.0	1181.4	3233.8	796.3
750.0	3250.0	13.8	0.875	7.3	1646.5	4870.5	1137.2
1000.0	3250.0	15.4	1.000	8.5	2101.5	6564.3	1479.1
1250.0	3250.0	16.8	1.000	9.4	2554.3	8238.9	1815.1
1500.0	3250.0	18.1	1.000	10.4	3004.1	9923.5	2149.7
1750.0	3250.0	19.3	1.125	11.2	3500.5	11745.3	2512.2
2000.0	3250.0	20.4	1.125	12.0	3961.9	13477.3	2852.8
2250.0	3250.0	21.4	1.250	12.7	4521.2	15430.3	3245.4
2500.0	3250.0	22.4	1.250	13.4	5003.1	17219.4	3596.3
2750.0	3250.0	23.3	1.250	14.0	5487.5	19019.8	3948.5
3000.0	3250.0	24.2	1.375	14.6	6154.7	21194.6	4393.9
3250.0	3250.0	25.0	1.375	15.2	6668.1	23064.0	4760.8
3500.0	3250.0	25.8	1.375	15.8	7185.2	24945.4	5129.5
3750.0	3250.0	26.6	1.500	16.4	7992.6	27400.1	5645.0
4000.0	3250.0	27.4	1.500	16.9	8546.1	29363.2	6032.4
4250.0	3250.0	28.1	1.625	17.4	9488.4	32079.0	6616.6
4500.0	3250.0	28.8	1.625	17.9	10084.8	34135.7	7026.3
4750.0	3250.0	29.5	1.750	18.4	11185.3	37154.3	7692.7
5000.0	3250.0	30.2	1.750	18.9	11831.1	39317.2	8128.4

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	3500.0	10.1	0.750	4.2	742.9	1603.1	475.7
500.0	3500.0	12.8	0.875	6.0	1252.4	3230.1	851.6
750.0	3500.0	14.8	0.875	7.3	1747.4	4863.5	1216.9
1000.0	3500.0	16.6	1.000	8.5	2231.6	6549.9	1582.8
1250.0	3500.0	18.1	1.000	9.4	2713.2	8218.6	1942.4
1500.0	3500.0	19.5	1.125	10.4	3227.0	9990.0	2322.5
1750.0	3500.0	20.7	1.125	11.2	3716.0	11701.8	2686.0
2000.0	3500.0	21.9	1.125	12.0	4205.3	13423.7	3049.7
2250.0	3500.0	23.0	1.250	12.7	4792.5	15350.8	3464.8
2500.0	3500.0	24.1	1.250	13.4	5302.0	17125.8	3838.5
2750.0	3500.0	25.1	1.375	14.0	5971.6	19206.3	4293.3
3000.0	3500.0	26.0	1.375	14.6	6508.7	21044.3	4680.8
3250.0	3500.0	26.9	1.375	15.2	7049.5	22893.9	5070.1
3500.0	3500.0	27.8	1.500	15.8	7852.2	25223.3	5590.8
3750.0	3500.0	28.7	1.500	16.4	8428.4	27147.5	5998.0
4000.0	3500.0	29.5	1.625	16.9	9360.5	29709.5	6583.8
4250.0	3500.0	30.3	1.625	17.4	9978.5	31719.5	7012.6
4500.0	3500.0	31.1	1.750	17.9	11063.0	34552.2	7676.6
4750.0	3500.0	31.8	1.750	18.4	11729.6	36659.5	8130.7
5000.0	3500.0	32.5	1.875	18.9	12991.9	39803.2	8887.4

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	3750.0	10.8	0.750	4.2	782.7	1602.3	505.6
500.0	3750.0	13.7	0.875	6.0	1323.4	3226.9	907.0
750.0	3750.0	15.9	1.000	7.3	1845.0	4883.7	1300.2
1000.0	3750.0	17.8	1.000	8.5	2361.8	6537.5	1686.7
1250.0	3750.0	19.4	1.125	9.4	2896.3	8266.6	2086.1
1500.0	3750.0	20.9	1.125	10.4	3414.2	9960.3	2473.3
1750.0	3750.0	22.2	1.125	11.2	3931.4	11664.1	2860.0
2000.0	3750.0	23.5	1.250	12.0	4528.6	13529.4	3289.1
2250.0	3750.0	24.7	1.250	12.7	5063.7	15282.0	3684.6
2500.0	3750.0	25.8	1.375	13.4	5736.9	17282.1	4149.8
2750.0	3750.0	26.9	1.375	14.0	6298.0	19092.5	4558.1
3000.0	3750.0	27.9	1.375	14.6	6862.6	20914.1	4968.2
3250.0	3750.0	28.9	1.500	15.2	7662.0	23136.4	5495.1
3500.0	3750.0	29.8	1.500	15.8	8260.9	25026.6	5922.3
3750.0	3750.0	30.7	1.625	16.4	9183.7	27456.8	6510.7
4000.0	3750.0	31.6	1.625	16.9	9823.5	29425.8	6958.7
4250.0	3750.0	32.4	1.750	17.4	10892.9	32099.3	7621.3
4500.0	3750.0	33.3	1.750	17.9	11580.2	34157.9	8093.9
4750.0	3750.0	34.1	1.875	18.4	12821.4	37111.5	8845.1
5000.0	3750.0	34.9	1.875	18.9	13563.0	39270.9	9346.2

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	4000.0	11.6	0.750	4.2	822.4	1601.6	535.7
500.0	4000.0	14.6	0.875	6.0	1394.5	3224.1	962.6
750.0	4000.0	17.0	1.000	7.3	1946.0	4876.7	1380.3
1000.0	4000.0	18.9	1.000	8.5	2491.9	6526.6	1790.8
1250.0	4000.0	20.7	1.125	9.4	3055.2	8247.1	2213.7
1500.0	4000.0	22.3	1.125	10.4	3601.5	9934.4	2624.3
1750.0	4000.0	23.7	1.250	11.2	4210.8	11747.0	3068.5
2000.0	4000.0	25.1	1.250	12.0	4772.0	13479.3	3486.2
2250.0	4000.0	26.3	1.375	12.7	5450.4	15410.6	3962.8
2500.0	4000.0	27.5	1.375	13.4	6035.8	17196.3	4392.3
2750.0	4000.0	28.7	1.375	14.0	6624.5	18993.0	4823.3
3000.0	4000.0	29.7	1.500	14.6	7421.7	21123.0	5357.3
3250.0	4000.0	30.8	1.500	15.2	8043.3	22983.0	5804.7
3500.0	4000.0	31.8	1.625	15.8	8958.1	25299.4	6396.6
3750.0	4000.0	32.8	1.625	16.4	9619.6	27232.2	6864.0
4000.0	4000.0	33.7	1.750	16.9	10675.0	29767.7	7526.4
4250.0	4000.0	34.6	1.750	17.4	11383.0	31783.4	8017.6
4500.0	4000.0	35.5	1.875	17.9	12604.2	34572.3	8764.5
4750.0	4000.0	36.4	1.875	18.4	13365.6	36681.2	9283.5
5000.0	4000.0	37.2	2.000	18.9	14780.2	39759.4	10130.3

COMPUTER OUTPUT USING 1 ROPE AND A COUNTERWEIGHT

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	250.0	0.7	0.375	4.2	361.4	5137.6	218.5
500.0	250.0	0.9	0.438	6.0	466.6	7939.3	281.4
750.0	250.0	1.1	0.500	7.3	533.7	10146.5	318.9
1000.0	250.0	1.2	0.500	8.5	631.5	12735.1	376.6
1250.0	250.0	1.3	0.563	9.4	670.8	14508.9	396.3
1500.0	250.0	1.4	0.563	10.4	750.6	16836.4	442.8
1750.0	250.0	1.5	0.625	11.2	782.2	18510.8	458.4
2000.0	250.0	1.6	0.625	12.0	853.0	20718.6	499.6
2250.0	250.0	1.6	0.625	12.7	921.8	22900.1	539.5
2500.0	250.0	1.7	0.750	13.4	922.1	24311.1	537.2
2750.0	250.0	1.8	0.750	14.0	986.5	26473.7	574.9
3000.0	250.0	1.9	0.750	14.6	1050.0	28630.6	612.3
3250.0	250.0	1.9	0.750	15.2	1112.7	30783.6	649.3
3500.0	250.0	2.0	0.750	15.8	1174.8	32934.3	686.0
3750.0	250.0	2.0	0.875	16.4	1207.5	35253.3	706.3
4000.0	250.0	2.1	0.875	16.9	1270.6	37497.5	744.1
4250.0	250.0	2.2	0.875	17.4	1333.4	39748.3	781.8
4500.0	250.0	2.2	0.875	17.9	1396.1	42005.9	819.5
4750.0	250.0	2.3	1.000	18.4	1473.0	45547.0	867.6
5000.0	250.0	2.3	1.000	18.9	1539.5	47971.7	907.9

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	500.0	1.4	0.563	4.2	304.2	2691.7	171.0
500.0	500.0	1.8	0.625	6.0	435.6	4687.9	246.5
750.0	500.0	2.1	0.750	7.3	519.9	6378.5	295.9
1000.0	500.0	2.4	0.750	8.5	631.3	8243.3	362.1
1250.0	500.0	2.6	0.750	9.4	736.9	10075.2	425.6
1500.0	500.0	2.8	0.875	10.4	804.5	11708.9	470.1
1750.0	500.0	3.0	0.875	11.2	902.3	13514.9	530.6
2000.0	500.0	3.1	0.875	12.0	998.2	15315.8	590.4
2250.0	500.0	3.3	1.000	12.7	1078.1	17165.0	644.8
2500.0	500.0	3.4	1.000	13.4	1173.4	19004.1	705.3
2750.0	500.0	3.6	1.000	14.0	1268.0	20847.7	765.7
3000.0	500.0	3.7	1.000	14.6	1362.3	22696.2	826.0
3250.0	500.0	3.8	1.125	15.2	1470.0	24987.0	897.7
3500.0	500.0	4.0	1.125	15.8	1567.7	26918.7	960.6
3750.0	500.0	4.1	1.125	16.4	1665.4	28860.2	1023.6
4000.0	500.0	4.2	1.250	16.9	1808.3	31675.3	1115.0
4250.0	500.0	4.3	1.250	17.4	1911.9	33732.2	1181.7
4500.0	500.0	4.4	1.250	17.9	2015.9	35802.1	1248.7
4750.0	500.0	4.5	1.375	18.4	2201.7	39267.5	1363.8
5000.0	500.0	4.6	1.375	18.9	2313.7	41483.2	1435.6

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	750.0	2.2	0.750	4.2	298.9	2080.3	164.7
500.0	750.0	2.7	0.750	6.0	470.0	3887.5	266.4
750.0	750.0	3.2	0.875	7.3	593.1	5513.7	345.3
1000.0	750.0	3.6	0.875	8.5	730.9	7205.7	432.2
1250.0	750.0	3.9	1.000	9.4	845.0	8837.2	509.9
1500.0	750.0	4.2	1.000	10.4	973.9	10518.2	594.1
1750.0	750.0	4.4	1.000	11.2	1100.5	12197.5	677.5
2000.0	750.0	4.7	1.125	12.0	1223.4	13968.6	762.6
2250.0	750.0	4.9	1.125	12.7	1349.9	15683.6	847.0
2500.0	750.0	5.2	1.250	13.4	1491.9	17649.3	942.9
2750.0	750.0	5.4	1.250	14.0	1621.5	19423.8	1029.6
3000.0	750.0	5.6	1.250	14.6	1751.1	21207.3	1116.6
3250.0	750.0	5.8	1.375	15.2	1923.7	23493.9	1229.1
3500.0	750.0	6.0	1.375	15.8	2059.5	25360.2	1319.7
3750.0	750.0	6.1	1.375	16.4	2195.7	27238.3	1410.8
4000.0	750.0	6.3	1.500	16.9	2408.6	29939.1	1544.6
4250.0	750.0	6.5	1.500	17.4	2553.2	31921.3	1640.5
4500.0	750.0	6.7	1.625	17.9	2807.1	35027.1	1795.7
4750.0	750.0	6.8	1.625	18.4	2962.2	37132.1	1897.4
5000.0	750.0	7.0	1.750	18.9	3265.3	40716.9	2078.3

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	1000.0	2.9	0.750	4.2	338.7	1903.1	188.2
500.0	1000.0	3.7	0.875	6.0	517.4	3531.0	302.0
750.0	1000.0	4.2	1.000	7.3	677.2	5120.3	409.1
1000.0	1000.0	4.7	1.000	8.5	843.2	6735.1	519.2
1250.0	1000.0	5.2	1.125	9.4	996.1	8350.5	625.9
1500.0	1000.0	5.6	1.125	10.4	1154.8	9971.4	734.0
1750.0	1000.0	5.9	1.250	11.2	1317.0	11747.0	846.9
2000.0	1000.0	6.3	1.250	12.0	1475.5	13479.3	955.9
2250.0	1000.0	6.6	1.375	12.7	1655.5	15410.6	1078.4
2500.0	1000.0	6.9	1.375	13.4	1817.7	17196.3	1190.0
2750.0	1000.0	7.2	1.375	14.0	1979.9	18993.0	1301.8
3000.0	1000.0	7.4	1.500	14.6	2191.2	21123.0	1440.6
3250.0	1000.0	7.7	1.500	15.2	2360.4	22983.0	1556.4
3500.0	1000.0	7.9	1.625	15.8	2605.7	25299.4	1712.2
3750.0	1000.0	8.2	1.625	16.4	2783.9	27232.2	1833.0
4000.0	1000.0	8.4	1.750	16.9	3071.5	29767.7	2010.0
4250.0	1000.0	8.7	1.750	17.4	3260.9	31783.4	2136.9
4500.0	1000.0	8.9	1.875	17.9	3600.5	34572.2	2340.0
4750.0	1000.0	9.1	1.875	18.4	3803.2	36681.2	2474.1
5000.0	1000.0	9.3	2.000	18.9	4206.2	40007.4	2709.2

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	1250.0	3.6	0.875	4.2	361.0	1758.0	205.8
500.0	1250.0	4.6	1.000	6.0	573.5	3340.6	346.4
750.0	1250.0	5.3	1.125	7.3	768.9	4906.9	481.0
1000.0	1250.0	5.9	1.125	8.5	964.5	6528.8	615.2
1250.0	1250.0	6.5	1.250	9.4	1154.9	8243.4	749.7
1500.0	1250.0	7.0	1.250	10.4	1344.6	9929.4	882.5
1750.0	1250.0	7.4	1.375	11.2	1546.0	11727.0	1023.3
2000.0	1250.0	7.8	1.375	12.0	1736.6	13454.6	1157.4
2250.0	1250.0	8.2	1.500	12.7	1958.0	15357.2	1308.3
2500.0	1250.0	8.6	1.500	13.4	2153.5	17133.4	1445.3
2750.0	1250.0	9.0	1.625	14.0	2402.9	19164.7	1610.0
3000.0	1250.0	9.3	1.625	14.6	2605.9	20996.8	1751.2
3250.0	1250.0	9.6	1.750	15.2	2891.9	23182.1	1933.5
3500.0	1250.0	9.9	1.750	15.8	3105.0	25077.8	2080.2
3750.0	1250.0	10.2	1.875	16.4	3437.2	27443.7	2284.7
4000.0	1250.0	10.5	1.875	16.9	3662.6	29411.3	2437.8
4250.0	1250.0	10.8	2.000	17.4	4052.4	31985.6	2670.2
4500.0	1250.0	11.1	2.000	17.9	4292.4	34033.7	2831.1
4750.0	1250.0	11.4	2.125	18.4	4753.1	36845.5	3098.0
5000.0	1250.0	11.6	2.375	18.9	5604.6	41730.9	3553.3

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	1500.0	4.3	1.000	4.2	389.3	1673.2	228.6
500.0	1500.0	5.5	1.125	6.0	635.7	3230.0	396.0
750.0	1500.0	6.4	1.250	7.3	866.3	4881.1	557.5
1000.0	1500.0	7.1	1.250	8.5	1092.5	6533.4	716.5
1250.0	1500.0	7.8	1.375	9.4	1320.2	8245.5	878.3
1500.0	1500.0	8.3	1.375	10.4	1541.7	9932.3	1036.1
1750.0	1500.0	8.9	1.500	11.2	1782.5	11721.5	1204.6
2000.0	1500.0	9.4	1.500	12.0	2006.0	13447.9	1364.1
2250.0	1500.0	9.9	1.625	12.7	2269.8	15333.3	1543.7
2500.0	1500.0	10.3	1.625	13.4	2499.4	17105.2	1706.6
2750.0	1500.0	10.7	1.750	14.0	2795.4	19107.1	1901.2
3000.0	1500.0	11.2	1.750	14.6	3033.8	20930.8	2068.8
3250.0	1500.0	11.5	1.875	15.2	3371.9	23071.1	2283.1
3500.0	1500.0	11.9	2.000	15.8	3751.2	25319.4	2516.0
3750.0	1500.0	12.3	2.000	16.4	4013.4	27254.5	2695.8
4000.0	1500.0	12.6	2.125	16.9	4457.1	29681.1	2958.8
4250.0	1500.0	13.0	2.125	17.4	4735.3	31688.3	3146.8
4500.0	1500.0	13.3	2.375	17.9	5547.1	35066.2	3580.2
4750.0	1500.0	13.6	2.375	18.4	5860.3	37198.1	3786.2
5000.0	1500.0	13.9	2.375	18.9	6175.8	39347.5	3993.5

D	PR	DTR	RD	AT	PHP	HPT	RMSHP
250.0	1750.0	5.1	1.000	4.2	429.1	1630.1	257.0
500.0	1750.0	6.4	1.125	6.0	706.7	3221.8	449.5
750.0	1750.0	7.4	1.250	7.3	967.2	4865.6	635.4
1000.0	1750.0	8.3	1.375	8.5	1226.2	6539.6	821.2
1250.0	1750.0	9.1	1.500	9.4	1491.4	8251.1	1010.0
1500.0	1750.0	9.7	1.500	10.4	1745.5	9939.7	1193.2
1750.0	1750.0	10.4	1.625	11.2	2026.7	11724.4	1389.7
2000.0	1750.0	11.0	1.625	12.0	2284.0	13451.4	1575.0
2250.0	1750.0	11.5	1.750	12.7	2592.1	15326.1	1783.8
2500.0	1750.0	12.0	1.750	13.4	2856.7	17096.8	1972.9
2750.0	1750.0	12.5	1.875	14.0	3202.4	19079.6	2198.6
3000.0	1750.0	13.0	2.000	14.6	3585.6	21146.4	2440.6
3250.0	1750.0	13.5	2.000	15.2	3872.0	23009.5	2640.7
3500.0	1750.0	13.9	2.125	15.8	4315.0	25217.9	2909.7
3750.0	1750.0	14.3	2.125	16.4	4616.7	27141.5	3117.5
4000.0	1750.0	14.7	2.375	16.9	5390.9	29971.6	3533.5
4250.0	1750.0	15.1	2.375	17.4	5726.4	32007.4	3758.1
4500.0	1750.0	15.5	2.625	17.9	6813.4	36027.6	4322.1
4750.0	1750.0	15.9	2.625	18.4	7192.6	38209.0	4568.6
5000.0	1750.0	16.3	2.625	18.9	7574.5	40408.4	4816.8

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2000.0	5.8	1.125	4.2	461.6	1603.0	283.6
500.0	2000.0	7.3	1.250	6.0	773.4	3225.0	502.9
750.0	2000.0	8.5	1.375	7.3	1069.2	4871.0	715.5
1000.0	2000.0	9.5	1.500	8.5	1364.8	6546.7	928.2
1250.0	2000.0	10.3	1.500	9.4	1650.3	8214.0	1135.9
1500.0	2000.0	11.1	1.625	10.4	1956.1	9949.9	1353.4
1750.0	2000.0	11.9	1.750	11.2	2279.5	11732.4	1578.4
2000.0	2000.0	12.5	1.750	12.0	2571.5	13461.3	1789.7
2250.0	2000.0	13.2	1.875	12.7	2927.0	15329.5	2028.6
2500.0	2000.0	13.8	1.875	13.4	3227.5	17100.8	2244.3
2750.0	2000.0	14.3	2.000	14.0	3627.1	19071.0	2502.4
3000.0	2000.0	14.9	2.125	14.6	4071.1	21119.3	2779.3
3250.0	2000.0	15.4	2.125	15.2	4396.5	22978.8	3007.1
3500.0	2000.0	15.9	2.375	15.8	5135.4	25485.9	3409.6
3750.0	2000.0	16.4	2.375	16.4	5493.5	27439.7	3653.2
4000.0	2000.0	16.9	2.375	16.9	5853.9	29406.9	3898.2
4250.0	2000.0	17.3	2.625	17.4	6927.1	32546.0	4453.9
4500.0	2000.0	17.7	2.625	17.9	7330.6	34610.1	4720.0
4750.0	2000.0	18.2	2.875	18.4	8837.1	39666.9	5492.1
5000.0	2000.0	18.6	2.875	18.9	9295.4	41931.4	5785.5

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2250.0	6.5	1.125	4.2	501.3	1601.6	313.0
500.0	2250.0	8.2	1.375	6.0	843.7	3228.3	558.1
750.0	2250.0	9.5	1.500	7.3	1175.4	4876.5	797.5
1000.0	2250.0	10.7	1.500	8.5	1495.0	6526.4	1031.1
1250.0	2250.0	11.6	1.625	9.4	1827.5	8224.9	1270.8
1500.0	2250.0	12.5	1.750	10.4	2174.5	9961.9	1516.4
1750.0	2250.0	13.3	1.875	11.2	2542.9	11743.9	1770.6
2000.0	2250.0	14.1	1.875	12.0	2870.5	13475.5	2008.4
2250.0	2250.0	14.8	2.000	12.7	3277.2	15340.0	2278.6
2500.0	2250.0	15.5	2.000	13.4	3614.9	17113.1	2521.3
2750.0	2250.0	16.1	2.125	14.0	4073.8	19074.9	2813.5
3000.0	2250.0	16.7	2.375	14.6	4779.8	21339.0	3206.1
3250.0	2250.0	17.3	2.375	15.2	5160.9	23227.5	3469.1
3500.0	2250.0	17.9	2.375	15.8	5544.1	25128.8	3733.3
3750.0	2250.0	18.4	2.625	16.4	6564.0	27740.5	4264.5
4000.0	2250.0	19.0	2.625	16.9	6989.3	29739.3	4548.9
4250.0	2250.0	19.5	2.875	17.4	8419.6	33873.2	5278.3
4500.0	2250.0	20.0	2.875	17.9	8899.0	36005.8	5588.9
4750.0	2250.0	20.4	2.875	18.4	9381.3	38155.0	5901.4
5000.0	2250.0	20.9	3.125	18.9	11447.7	43959.9	6968.0

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2500.0	7.2	1.250	4.2	537.0	1602.8	341.6
500.0	2500.0	9.1	1.375	6.0	914.7	3223.6	613.1
750.0	2500.0	10.6	1.500	7.3	1276.4	4866.2	876.9
1000.0	2500.0	11.8	1.625	8.5	1638.8	6535.3	1140.6
1250.0	2500.0	12.9	1.750	9.4	2011.5	8236.5	1408.1
1500.0	2500.0	13.9	1.875	10.4	2402.3	9975.3	1682.4
1750.0	2500.0	14.8	1.875	11.2	2758.4	11683.1	1943.3
2000.0	2500.0	15.7	2.000	12.0	3183.7	13492.7	2231.6
2250.0	2500.0	16.5	2.125	12.7	3646.6	15355.3	2534.7
2500.0	2500.0	17.2	2.125	13.4	4022.8	17131.1	2804.8
2750.0	2500.0	17.9	2.375	14.0	4727.2	19267.3	3203.5
3000.0	2500.0	18.6	2.375	14.6	5133.7	21114.2	3487.5
3250.0	2500.0	19.2	2.625	15.2	6102.4	23476.1	3998.1
3500.0	2500.0	19.9	2.625	15.8	6549.9	25407.7	4301.0
3750.0	2500.0	20.5	2.625	16.4	6999.8	27352.8	4605.5
4000.0	2500.0	21.1	2.875	16.9	8406.1	30776.0	5320.6
4250.0	2500.0	21.6	2.875	17.4	8909.7	32817.5	5650.5
4500.0	2500.0	22.2	3.125	17.9	10873.1	37827.4	6656.0
4750.0	2500.0	22.7	3.125	18.4	11444.4	40059.1	7018.7
5000.0	2500.0	23.2	3.375	18.9	14160.3	46551.9	8456.3

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2750.0	8.0	1.250	4.2	576.7	1601.7	371.5
500.0	2750.0	10.1	1.500	6.0	988.3	3227.0	669.9
750.0	2750.0	11.7	1.625	7.3	1386.9	4872.3	960.8
1000.0	2750.0	13.0	1.750	8.5	1788.6	6544.5	1252.0
1250.0	2750.0	14.2	1.875	9.4	2204.0	8248.4	1547.9
1500.0	2750.0	15.3	1.875	10.4	2589.6	9936.2	1832.5
1750.0	2750.0	16.3	2.000	11.2	3034.8	11701.3	2139.7
2000.0	2750.0	17.2	2.125	12.0	3514.7	13512.0	2460.2
2250.0	2750.0	18.1	2.375	12.7	4190.7	15493.8	2854.4
2500.0	2750.0	18.9	2.375	13.4	4621.4	17294.3	3158.6
2750.0	2750.0	19.7	2.375	14.0	5053.7	19106.6	3463.9
3000.0	2750.0	20.5	2.625	14.6	6011.2	21334.2	3974.3
3250.0	2750.0	21.2	2.625	15.2	6483.7	23222.1	4297.7
3500.0	2750.0	21.9	2.625	15.8	6958.5	25122.7	4622.6
3750.0	2750.0	22.5	2.875	16.4	8341.2	28006.4	5325.9
4000.0	2750.0	23.2	2.875	16.9	8869.1	29973.1	5675.4
4250.0	2750.0	23.8	3.125	17.4	10794.8	34494.5	6654.7
4500.0	2750.0	24.4	3.125	17.9	11390.3	36632.9	7036.2
4750.0	2750.0	25.0	3.375	18.4	14052.0	42468.0	8429.9
5000.0	2750.0	25.6	3.375	18.9	14731.5	44813.6	8852.4

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	3000.0	8.7	1.375	4.2	614.8	1602.9	401.4
500.0	3000.0	11.0	1.500	6.0	1059.3	3223.2	725.3
750.0	3000.0	12.7	1.625	7.3	1487.8	4864.0	1040.6
1000.0	3000.0	14.2	1.750	8.5	1918.7	6529.4	1355.6
1250.0	3000.0	15.5	1.875	9.4	2362.9	8223.9	1674.9
1500.0	3000.0	16.7	2.000	10.4	2829.3	9952.6	2002.1
1750.0	3000.0	17.8	2.125	11.2	3327.5	11720.4	2340.9
2000.0	3000.0	18.8	2.375	12.0	4004.6	13624.2	2744.7
2250.0	3000.0	19.7	2.375	12.7	4461.9	15395.8	3070.8
2500.0	3000.0	20.6	2.375	13.4	4920.4	17178.8	3397.6
2750.0	3000.0	21.5	2.625	14.0	5867.4	19296.1	3909.5
3000.0	3000.0	22.3	2.625	14.6	6365.2	21147.2	4253.6
3250.0	3000.0	23.1	2.625	15.2	6865.0	23010.4	4599.2
3500.0	3000.0	23.8	2.875	15.8	8224.5	25482.9	5292.9
3750.0	3000.0	24.6	2.875	16.4	8777.0	27387.0	5662.3
4000.0	3000.0	25.3	3.125	16.9	10665.2	31502.4	6618.2
4250.0	3000.0	26.0	3.125	17.4	11284.9	33563.0	7018.8
4500.0	3000.0	26.6	3.375	17.9	13892.4	38851.0	8371.9
4750.0	3000.0	27.3	3.375	18.4	14596.2	41100.6	8812.7

DEPTH IN FEET 5000.0

ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	3250.0	9.4	1.375	4.2	654.5	1602.0	431.5
500.0	3250.0	11.9	1.625	6.0	1136.3	3226.6	783.3
750.0	3250.0	13.8	1.750	7.3	1603.3	4870.3	1126.0
1000.0	3250.0	15.4	1.875	8.5	2075.8	6539.1	1469.2
1250.0	3250.0	16.8	2.000	9.4	2565.9	8237.2	1817.8
1500.0	3250.0	18.1	2.125	10.4	3083.8	9969.3	2176.0
1750.0	3250.0	19.3	2.125	11.2	3543.0	11675.5	2514.0
2000.0	3250.0	20.4	2.375	12.0	4248.0	13555.2	2939.1
2250.0	3250.0	21.4	2.375	12.7	4733.2	15312.9	3287.9
2500.0	3250.0	22.4	2.625	13.4	5670.4	17338.6	3802.8
2750.0	3250.0	23.3	2.625	14.0	6193.9	19158.0	4167.9
3000.0	3250.0	24.2	2.875	14.6	7480.6	21364.5	4832.9
3250.0	3250.0	25.0	2.875	15.2	8055.8	23256.4	5220.7
3500.0	3250.0	25.8	2.875	15.8	8633.1	25161.3	5610.1
3750.0	3250.0	26.6	3.125	16.4	10483.9	28772.6	6545.3
4000.0	3250.0	27.4	3.125	16.9	11128.2	30767.2	6965.2
4250.0	3250.0	28.1	3.375	17.4	13681.5	35593.1	8280.8

DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	3500.0	10.1	1.500	4.2	694.8	1603.1	462.3
500.0	3500.0	12.8	1.625	6.0	1207.3	3223.4	839.0
750.0	3500.0	14.8	1.750	7.3	1704.2	4863.4	1206.1
1000.0	3500.0	16.6	1.875	8.5	2206.0	6526.6	1573.0
1250.0	3500.0	18.1	2.000	9.4	2724.8	8217.0	1945.0
1500.0	3500.0	19.5	2.125	10.4	3271.1	9939.0	2326.3
1750.0	3500.0	20.7	2.375	11.2	3978.8	11760.6	2762.9
2000.0	3500.0	21.9	2.375	12.0	4491.4	13496.0	3134.1
2250.0	3500.0	23.0	2.625	12.7	5419.6	15444.7	3653.5
2500.0	3500.0	24.1	2.625	13.4	5969.3	17236.5	4039.9
2750.0	3500.0	25.1	2.875	14.0	7234.0	19344.1	4700.0
3000.0	3500.0	26.0	2.875	14.6	7834.6	21202.1	5108.2
3250.0	3500.0	26.9	2.875	15.2	8437.1	23072.5	5518.0
3500.0	3500.0	27.8	3.125	15.8	10250.7	26249.2	6434.8
3750.0	3500.0	28.7	3.125	16.4	10919.8	28186.9	6874.2
4000.0	3500.0	29.5	3.375	16.9	13418.7	32617.5	8155.2
4250.0	3500.0	30.3	3.375	17.4	14171.6	34716.2	8633.2

DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625

129514

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	3750.C	10.8	1.500	4.2	734.6	1602.3	492.6
500.0	3750.0	13.7	1.750	6.0	1288.2	3226.8	898.1
750.0	3750.0	15.9	1.875	7.3	1825.8	4869.7	1293.2
1000.0	3750.0	17.8	2.000	8.5	2372.3	6536.5	1689.1
1250.0	3750.0	19.4	2.125	9.4	2941.1	8230.8	2091.5
1500.0	3750.C	20.9	2.375	10.4	3653.1	10003.4	2541.2
1750.0	3750.0	22.2	2.375	11.2	4194.3	11718.9	2935.4
2000.0	3750.0	23.5	2.625	12.0	5114.4	13602.3	3460.7
2250.0	3750.0	24.7	2.625	12.7	5690.9	15369.6	3868.9
2500.0	3750.0	25.8	2.625	13.4	6268.2	17148.0	4278.0
2750.0	3750.0	26.9	2.875	14.0	7560.5	19221.1	4954.8
3000.0	3750.0	27.9	2.875	14.6	8188.5	21061.3	5385.2
3250.0	3750.0	28.9	3.125	15.2	9965.1	23890.8	6285.8
3500.0	3750.0	29.8	3.125	15.8	10659.3	25779.3	6745.0
3750.0	3750.C	30.7	3.375	16.4	13103.9	29867.8	7994.0
4000.0	3750.0	31.6	3.375	16.9	13881.7	31905.9	8491.0

DEPTH IN FEET 4250.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	4000.0	11.6	1.500	4.2	774.3	1601.6	523.0
500.0	4000.0	14.6	1.750	6.0	1359.2	3224.0	953.9
750.0	4000.0	17.0	1.875	7.3	1926.8	4863.7	1373.4
1000.0	4000.0	18.9	2.125	8.5	2550.3	6546.4	1808.3
1250.0	4000.0	20.7	2.375	9.4	3269.2	8277.5	2273.0
1500.0	4000.0	22.3	2.375	10.4	3840.4	9974.8	2690.9
1750.0	4000.0	23.7	2.375	11.2	4409.7	11682.5	3108.2
2000.0	4000.0	25.1	2.625	12.0	5357.8	13547.7	3654.2
2250.0	4000.0	26.3	2.625	12.7	5962.1	15303.9	4085.1
2500.0	4000.0	27.5	2.875	13.4	7232.9	17300.3	4759.6
2750.0	4000.0	28.7	2.875	14.0	7887.0	19113.6	5210.9
3000.0	4000.0	29.7	3.125	14.6	9626.6	21666.8	6097.4
3250.0	4000.0	30.8	3.125	15.2	10346.4	23512.0	6576.6
3500.0	4000.0	31.8	3.375	15.8	12736.3	27301.7	7796.0
3750.0	4000.0	32.8	3.375	16.4	13539.7	29286.9	8312.2

DEPTH IN FEET 4000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 4250.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.625

APPENDIX V

Computer Program Used for the Drum Hoist with 2 Skips

```
      BALANCED HOISTING FROM 250-5000 FT.PRODUCTION 250-4000 TONS
      DIMENSION PR(20),VL(20),AL(20),D(20)
      READ(1,25)(PR(J),J=1,16)
      READ(1,26)(VL(I),AL(I),D(I),I=1,20)
      WRITE(3,19)
      WRITE(3,22)(PR(J),J=1,16)
      WRITE(3,17)
      WRITE(3,23)(VL(IJ,AL(I),D(I),I=1,20)
      WRITE(3,100)
      DO 5 J=1,16
      DO 5 I=1,20
      RD=0.25
      FS=4.0
      H=7.0
      RT=12.0
      G=32.2
      AT=VL(I)/AL(I)
      AD=0.5*AL(I)*AT**2
      CD=D(I)-2.0*AD
      CT=CD/VL(I)
      TP=2.0*AT+CT+RT
      TN=H*3600.0/TP
      OT=PR(J)/TN
      OTR=1.1*OT
      SW=0.5*OTR
      TDL=(OTR+SW)*(G+AL(I))*FS/G
   15 BST=132.56165299E-03-369.36228827E-03*RD+382.26287669E-01*RD**2
     1-154.23859881E-02*RD**3.0
    4 WR=-659.67674330E-04+118.52413335E-03*RD+156.53931681E-02*RD**2.
      TLR=D(I)*(G+AL(I))*WR*FS/(G*2000.0)
      TTDL=TDL+TLR
      IF(BST-TTDL)2,3,3
    2 IF(RD-0.625)7,6,6
    7 RD=RD+0.0625
      GO TO 15
    6 IF(RD-2.250)16,36,36
   16 RD=RD+0.125
      GO TO 15
   36 RD=RD+0.250
      GO TO 15
    3 DD=7.5*RD
      TAN=D(I)/(3.141*DD)
```

```
      V=TAN/(TP-RT-AT)
      P=RD+0.25
      FW=(TAN+3.0)*P/12.0
      DW=DD*3.141*FW*160.0
      RWA=AD
      RWR=RWA
      RWCS=CD
      TMUL=(SW+OTR)*DD*1000.0
      TMUR=D(I)*WR*DD/2.0
      TMUR1=(D(I)-RWA)*WR*DD/2.0
      TMUR2=RWA*WR*DD/2.0
      TMDL=SW*DD*1000.0
      TMDR=TMUR2
      TMDR1=TMUR1
      TMDR2=TMUR
      TNO=(TMUL+TMUR-TMDL)
      TNA=(TMUL+TMUR1-(TMDL+TMUR2))
      TNC=(TMUL+TMUR2-(TMDL+TMUR1))
      TND=(TMUL-(TMDL+TMUR))
      FM=(TMUL+TMDL+TMUR)*0.1
      IF(DD-2.75)77,77,78
   77 WHS=375.00
      GO TO 9
   78 IF(DD-3.75)80,80,88
   80 WHS=500.0
      GO TO 9
   88 WHS=-181.17024280E+01+560.45313382E-00*DD+557.59457933E-03*DD**2
    9 FA=(4000.*SW+2000.*OTR+(D(I)+250.)*WR*2.+2.*DW+2.*WHS)*AL(I)/G
      AM=FA*DD/2.0
      RM=-AM
      TMO=(TNO+FM+AM)
      TMSA=(TNA+FM+AM)
      TMEA=(TNA+FM)
      TMCS=(TNC+FM)
      TMECS=(TNC+FM+RM)
      TMEW=(TND+FM+RM)
      Z=2.0*3.141*V/550.0
      HPO=TMO*Z
      HPA=TMSA*Z
      HPE=TMEA*Z
      HPC=TMCS*Z
      HPEC=TMECS*Z
      HPEW=TMEW*Z
      HPTA=(HPO+HPA)*0.5*AT
      HPTC=(HPE+HPC)*0.5*CT
      IF(HPEC+HPEW)34,34,35
   34 HPTD=0.00
      GO TO 30
   35 HPTD=(HPEC+HPEW)*0.5*AT
   30 HPT=(HPTA+HPTC+HPTD)/OTR
      PHP=(HPO+HPA)*0.5
```

```
      RMSHP=SQRT((HPA**2*AT+HPC**2*CT+HPEC**2*AT)/(AT+CT+0.25*RT))
      WRITE(3,101)D(I),PR(J),OTR,RD,AT,PHP,HPT,RMSHP
    5 CONTINUE
      CALL EXIT
   25 FORMAT(4F10.3)
   26 FORMAT(3F10.3)
   22 FORMAT(12X,3F10.1)
   17 FORMAT(20X,'VELOCITY,ACCELERATION AND DEPTH')
   19 FORMAT(20X,'PRODUCTION IN TONS')
   23 FORMAT(12X,3F10.1)
  100 FORMAT(15X,'D',7X,'PR',4X,'OTR',4X,'RD',5X,'AT',5X,'PHP',6X,'HPT'
     15X,'RMSHP')
  101 FORMAT(12X,F7.1,1X,F7.1,1X,F5.1,1X,F6.3,1X,F5.1,1X,F8.1,1X,F8.1,
     11X,F8.1)
      END
```

INPUT DATA FOR DRUM HOIST USING 2 SKIPS

PRODUCTION IN TONS

250.0	500.0	750.0
1000.0	1250.0	1500.0
1750.0	2000.0	2250.0
2500.0	2750.0	3000.0
3250.0	3500.0	3750.0
4000.0		

VELOCITY,ACCELERATION AND DEPTH

16.5	5.5	250.0
20.0	6.0	500.0
24.5	6.7	750.0
27.0	7.0	1000.0
30.0	7.3	1250.0
33.0	8.1	1500.0
35.5	8.2	1750.0
37.5	8.3	2000.0
40.0	8.4	2250.0
42.0	8.5	2500.0
44.0	8.6	2750.0
46.0	8.6	3000.0
48.0	8.7	3250.0
50.0	8.8	3500.0
52.0	8.8	3750.0
54.0	8.9	4000.0
56.5	8.9	4250.0
58.0	8.9	4500.0
60.0	9.0	4750.0
62.5	9.0	5000.0

COMPUTER OUTPUT FOR DRUM HOIST USING 2 SKIPS

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	250.0	0.3	0.250	3.0	53.3	1363.0	29.0
500.0	250.0	0.4	0.313	3.3	112.6	2751.0	51.8
750.0	250.0	0.5	0.375	3.7	212.5	4456.2	89.2
1000.0	250.0	0.6	0.375	3.9	300.8	5979.2	119.4
1250.0	250.0	0.6	0.375	4.1	410.8	7674.6	158.7
1500.0	250.0	0.7	0.438	4.0	621.1	9868.1	227.8
1750.0	250.0	0.7	0.438	4.3	764.0	11786.5	279.2
2000.0	250.0	0.8	0.500	4.5	997.2	14234.4	358.5
2250.0	250.0	0.8	0.500	4.8	1188.7	16498.3	429.2
2500.0	250.0	0.8	0.500	4.9	1382.9	18672.7	496.7
2750.0	250.0	0.9	0.500	5.1	1591.6	20949.2	570.1
3000.0	250.0	0.9	0.563	5.3	1971.0	24488.6	708.0
3250.0	250.0	0.9	0.563	5.5	2211.0	27140.3	798.5
3500.0	250.0	1.0	0.563	5.7	2496.9	29920.5	901.5
3750.0	250.0	1.0	0.625	5.9	3029.9	34640.4	1103.1
4000.0	250.0	1.0	0.625	6.1	3349.2	37899.4	1226.9
4250.0	250.0	1.0	0.750	6.3	4359.3	46690.9	1636.0
4500.0	250.0	1.0	0.750	6.5	4731.9	50154.8	1773.0
4750.0	250.0	1.1	0.750	6.7	5146.7	54438.0	1945.5
5000.0	250.0	1.1	0.750	6.9	5641.4	59680.2	2164.9

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	500.0	0.7	0.375	3.0	92.1	1311.0	53.3
500.0	500.0	0.9	0.438	3.3	182.4	2591.7	90.1
750.0	500.0	1.0	0.500	3.7	320.7	4077.6	141.2
1000.0	500.0	1.2	0.563	3.9	475.6	5571.1	191.8
1250.0	500.0	1.3	0.563	4.1	640.9	7105.8	249.0
1500.0	500.0	1.3	0.625	4.0	938.9	8966.6	341.0
1750.0	500.0	1.4	0.625	4.3	1146.0	10649.4	412.8
2000.0	500.0	1.5	0.750	4.5	1568.3	13030.2	549.4
2250.0	500.0	1.6	0.750	4.8	1857.8	15016.5	652.6
2500.0	500.0	1.7	0.750	4.9	2150.3	16934.1	750.9
2750.0	500.0	1.7	0.750	5.1	2463.6	18927.7	857.5
3000.0	500.0	1.8	0.750	5.3	2785.7	21001.1	970.8
3250.0	500.0	1.9	0.875	5.5	3558.0	24796.4	1250.4
3500.0	500.0	1.9	0.875	5.7	4003.5	27241.6	1407.5
3750.0	500.0	2.0	0.875	5.9	4440.9	29793.8	1570.0
4000.0	500.0	2.0	0.875	6.1	4896.5	32453.5	1742.6
4250.0	500.0	2.0	1.000	6.3	6133.9	38394.8	2238.5
4500.0	500.0	2.1	1.000	6.5	6647.3	41145.4	2423.3
4750.0	500.0	2.1	1.000	6.7	7218.2	44459.5	2656.3
5000.0	500.0	2.2	1.125	6.9	8879.7	52417.0	3352.5

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	750.0	1.0	0.438	3.0	126.4	1310.8	76.9
500.0	750.0	1.3	0.563	3.3	253.2	2542.5	129.1
750.0	750.0	1.5	0.625	3.7	438.2	3976.5	197.8
1000.0	750.0	1.7	0.625	3.9	603.0	5312.9	255.2
1250.0	750.0	1.9	0.750	4.1	902.7	7000.1	348.8
1500.0	750.0	2.0	0.750	4.0	1216.3	8575.5	444.4
1750.0	750.0	2.1	0.750	4.3	1476.2	10153.9	533.0
2000.0	750.0	2.3	0.875	4.5	1964.6	12229.2	683.1
2250.0	750.0	2.4	0.875	4.8	2317.4	14039.5	805.6
2500.0	750.0	2.5	0.875	4.9	2673.0	15794.1	922.1
2750.0	750.0	2.6	1.000	5.1	3420.1	18514.6	1170.3
3000.0	750.0	2.7	1.000	5.3	3860.0	20520.4	1322.6
3250.0	750.0	2.8	1.000	5.5	4308.4	22603.1	1483.6
3500.0	750.0	2.9	1.000	5.7	4835.9	24758.5	1665.2
3750.0	750.0	2.9	1.125	5.9	5972.3	28574.4	2079.3
4000.0	750.0	3.0	1.125	6.1	6576.9	31079.3	2305.9
4250.0	750.0	3.1	1.125	6.3	7260.4	34010.3	2589.3
4500.0	750.0	3.1	1.250	6.5	8722.5	38681.6	3137.0
4750.0	750.0	3.2	1.250	6.7	9463.7	41726.5	3437.0
5000.0	750.0	3.2	1.375	6.9	11420.6	48324.9	4259.7

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	1000.0	1.3	0.563	3.0	165.9	1312.0	101.6
500.0	1000.0	1.8	0.625	3.3	317.7	2504.1	167.7
750.0	1000.0	2.0	0.750	3.7	562.6	3940.7	256.0
1000.0	1000.0	2.3	0.750	3.9	768.6	5259.0	328.0
1250.0	1000.0	2.5	0.875	4.1	1122.7	6871.6	437.1
1500.0	1000.0	2.7	0.875	4.0	1501.8	8399.0	550.8
1750.0	1000.0	2.9	0.875	4.3	1816.4	9930.1	656.8
2000.0	1000.0	3.0	1.000	4.5	2372.8	11857.2	822.4
2250.0	1000.0	3.2	1.000	4.8	2791.2	13585.2	965.0
2500.0	1000.0	3.3	1.000	4.9	3212.2	15263.9	1100.6
2750.0	1000.0	3.5	1.125	5.1	4047.3	17720.2	1369.6
3000.0	1000.0	3.6	1.125	5.3	4560.3	19609.5	1543.9
3250.0	1000.0	3.7	1.125	5.5	5082.9	21565.7	1728.3
3500.0	1000.0	3.8	1.250	5.7	6278.2	24704.9	2140.2
3750.0	1000.0	3.9	1.250	5.9	6945.7	26931.1	2381.3
4000.0	1000.0	4.0	1.375	6.1	8390.4	30723.1	2918.7
4250.0	1000.0	4.1	1.375	6.3	9256.2	33591.5	3276.7
4500.0	1000.0	4.2	1.375	6.5	10014.2	35931.6	3543.1
4750.0	1000.0	4.3	1.500	6.7	11883.2	40804.9	4289.6
5000.0	1000.0	4.3	1.500	6.9	12978.2	44284.2	4763.2

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	1250.0	1.6	0.625	3.0	203.7	1312.0	126.1
500.0	1250.0	2.2	0.750	3.3	397.6	2507.2	208.5
750.0	1250.0	2.5	0.750	3.7	635.3	3834.2	305.2
1000.0	1250.0	2.9	0.875	3.9	938.7	5235.4	401.0
1250.0	1250.0	3.2	0.875	4.1	1236.5	6628.8	503.9
1500.0	1250.0	3.4	1.000	4.0	1795.5	8308.4	658.8
1750.0	1250.0	3.6	1.000	4.3	2166.7	9814.9	782.7
2000.0	1250.0	3.8	1.125	4.5	2793.1	11656.7	965.1
2250.0	1250.0	4.0	1.125	4.8	3279.3	13340.0	1128.8
2500.0	1250.0	4.2	1.125	4.9	3767.9	14977.6	1284.0
2750.0	1250.0	4.3	1.250	5.1	4693.5	17280.1	1575.7
3000.0	1250.0	4.5	1.250	5.3	5282.2	19104.7	1773.1
3250.0	1250.0	4.7	1.250	5.5	5881.6	20990.5	1981.7
3500.0	1250.0	4.8	1.375	5.7	7192.0	23881.8	2425.3
3750.0	1250.0	4.9	1.375	5.9	7949.2	26004.5	2695.5
4000.0	1250.0	5.0	1.500	6.1	9520.0	29454.5	3272.1
4250.0	1250.0	5.1	1.500	6.3	10493.3	32145.2	3670.4
4500.0	1250.0	5.2	1.625	6.5	12329.3	35981.6	4351.7
4750.0	1250.0	5.3	1.625	6.7	13362.8	38735.4	4765.1
5000.0	1250.0	5.4	1.750	6.9	15804.8	44048.7	5793.2

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	1500.0	2.0	0.625	3.0	234.1	1311.2	149.6
500.0	1500.0	2.6	0.750	3.3	448.0	2487.9	245.6
750.0	1500.0	3.0	0.875	3.7	762.9	3839.3	363.7
1000.0	1500.0	3.5	1.000	3.9	1113.2	5227.0	474.1
1250.0	1500.0	3.8	1.000	4.1	1462.6	6614.9	593.9
1500.0	1500.0	4.0	1.000	4.0	1932.9	8055.6	733.3
1750.0	1500.0	4.3	1.125	4.3	2527.0	9753.9	910.0
2000.0	1500.0	4.6	1.125	4.5	2971.4	11221.4	1047.0
2250.0	1500.0	4.8	1.250	4.8	3781.6	13199.4	1295.8
2500.0	1500.0	5.0	1.250	4.9	4340.2	14813.1	1471.4
2750.0	1500.0	5.2	1.375	5.1	5358.7	17017.1	1787.5
3000.0	1500.0	5.4	1.375	5.3	6025.5	18802.9	2008.8
3250.0	1500.0	5.6	1.375	5.5	6704.4	20646.5	2242.7
3500.0	1500.0	5.7	1.500	5.7	8132.9	23377.3	2720.1
3750.0	1500.0	5.9	1.500	5.9	8982.8	25436.3	3020.5
4000.0	1500.0	6.0	1.625	6.1	10682.9	28663.8	3638.6
4250.0	1500.0	6.1	1.625	6.3	11767.3	31243.1	4078.9
4500.0	1500.0	6.3	1.750	6.5	13740.9	34800.6	4804.7
4750.0	1500.0	6.4	1.875	6.7	16043.2	39064.4	5728.1
5000.0	1500.0	6.5	1.875	6.9	17505.3	42314.7	6357.5

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	1750.0	2.3	0.750	3.0	279.8	1312.2	175.3
500.0	1750.0	3.1	0.875	3.3	529.7	2491.0	286.3
750.0	1750.0	3.5	0.875	3.7	835.6	3777.8	414.5
1000.0	1750.0	4.0	1.000	3.9	1205.8	5127.2	534.8
1250.0	1750.0	4.4	1.125	4.1	1694.8	6613.5	684.1
1500.0	1750.0	4.7	1.125	4.0	2234.7	8050.8	842.7
1750.0	1750.0	5.0	1.250	4.3	2897.4	9724.1	1038.5
2000.0	1750.0	5.3	1.250	4.5	3403.6	11185.3	1193.1
2250.0	1750.0	5.6	1.375	4.8	4298.2	13118.6	1465.6
2500.0	1750.0	5.8	1.375	4.9	4929.1	14718.4	1662.2
2750.0	1750.0	6.1	1.375	5.1	5599.7	16362.9	1873.8
3000.0	1750.0	6.3	1.500	5.3	6790.3	18617.2	2250.4
3250.0	1750.0	6.5	1.500	5.5	7551.4	20434.7	2510.5
3500.0	1750.0	6.7	1.625	5.7	9100.9	23054.9	3023.8
3750.0	1750.0	6.9	1.625	5.9	10046.5	25072.9	3355.7
4000.0	1750.0	7.0	1.750	6.1	11879.0	28146.4	4017.6
4250.0	1750.0	7.1	1.875	6.3	14057.8	31825.1	4880.3
4500.0	1750.0	7.3	1.875	6.5	15192.5	34014.8	5274.2
4750.0	1750.0	7.5	2.000	6.7	17653.3	38025.5	6257.2
5000.0	1750.0	7.6	2.125	6.9	20617.5	42851.5	7516.4

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	2000.0	2.6	0.750	3.0	310.2	1311.6	198.8
500.0	2000.0	3.5	0.875	3.3	580.2	2488.4	323.7
750.0	2000.0	4.0	1.000	3.7	966.3	3792.6	472.8
1000.0	2000.0	4.6	1.125	3.9	1384.8	5139.9	607.8
1250.0	2000.0	5.0	1.125	4.1	1808.5	6494.0	755.2
1500.0	2000.0	5.4	1.250	4.0	2544.8	8056.8	952.5
1750.0	2000.0	5.7	1.250	4.3	3055.4	9498.7	1121.3
2000.0	2000.0	6.1	1.375	4.5	3847.8	11172.4	1340.8
2250.0	2000.0	6.4	1.375	4.8	4497.7	12751.2	1553.8
2500.0	2000.0	6.7	1.500	4.9	5534.4	14667.3	1856.3
2750.0	2000.0	7.0	1.500	5.1	6283.9	16303.2	2091.1
3000.0	2000.0	7.2	1.625	5.3	7576.7	18503.9	2497.6
3250.0	2000.0	7.4	1.625	5.5	8422.5	20305.3	2785.0
3500.0	2000.0	7.7	1.750	5.7	10096.0	22846.4	3336.1
3750.0	2000.0	7.9	1.750	5.9	11140.4	24837.5	3700.8
4000.0	2000.0	8.0	1.875	6.1	13108.4	27799.7	4408.8
4250.0	2000.0	8.2	2.000	6.3	15442.3	31328.3	5330.6
4500.0	2000.0	8.4	2.000	6.5	16684.0	33476.0	5759.7
4750.0	2000.0	8.5	2.125	6.7	19306.9	37302.0	6804.9
5000.0	2000.0	8.6	2.250	6.9	22460.8	41886.0	8143.0

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2250.0	3.0	0.875	3.0	356.8	1312.6	224.5
500.0	2250.0	4.0	1.000	3.3	663.7	2491.4	364.2
750.0	2250.0	4.5	1.000	3.7	1039.0	3749.9	524.3
1000.0	2250.0	5.2	1.125	3.9	1477.4	5071.9	670.1
1250.0	2250.0	5.7	1.250	4.1	2046.7	6512.9	845.2
1500.0	2250.0	6.0	1.250	4.0	2682.2	7916.2	1031.4
1750.0	2250.0	6.4	1.375	4.3	3435.9	9514.4	1250.6
2000.0	2250.0	6.9	1.375	4.5	4026.2	10936.0	1430.4
2250.0	2250.0	7.2	1.500	4.8	5028.6	12753.3	1725.9
2500.0	2250.0	7.5	1.500	4.9	5754.6	14294.0	1948.9
2750.0	2250.0	7.8	1.625	5.1	6987.0	16277.1	2312.5
3000.0	2250.0	8.1	1.750	5.3	8384.5	18439.1	2750.5
3250.0	2250.0	8.4	1.750	5.5	9317.8	20231.0	3066.1
3500.0	2250.0	8.6	1.875	5.7	11118.2	22713.6	3657.1
3750.0	2250.0	8.8	1.875	5.9	12264.4	24687.5	4055.7
4000.0	2250.0	9.1	2.000	6.1	14371.1	27566.7	4812.0
4250.0	2250.0	9.2	2.125	6.3	16863.7	30983.4	5795.5
4500.0	2250.0	9.4	2.125	6.5	18215.5	33101.9	6261.2
4750.0	2250.0	9.6	2.250	6.7	21004.0	36788.7	7371.2
5000.0	2250.0	9.7	2.500	6.9	25858.8	42680.7	9438.2

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	2500.0	3.3	0.875	3.0	387.3	1312.0	248.0
500.0	2500.0	4.4	1.000	3.3	714.1	2489.3	401.8
750.0	2500.0	5.0	1.125	3.7	1172.9	3767.8	582.2
1000.0	2500.0	5.8	1.250	3.9	1660.8	5091.9	742.6
1250.0	2500.0	6.3	1.250	4.1	2160.5	6427.4	918.3
1500.0	2500.0	6.7	1.375	4.0	3000.4	7942.2	1141.0
1750.0	2500.0	7.2	1.375	4.3	3593.9	9355.1	1337.6
2000.0	2500.0	7.6	1.500	4.5	4482.4	10962.1	1578.7
2250.0	2500.0	8.0	1.625	4.8	5573.7	12768.7	1900.3
2500.0	2500.0	8.3	1.625	4.9	6376.5	14311.4	2145.3
2750.0	2500.0	8.7	1.750	5.1	7709.1	16274.4	2538.0
3000.0	2500.0	9.0	1.750	5.3	8646.3	17952.0	2839.0
3250.0	2500.0	9.3	1.875	5.5	10237.2	20195.3	3354.0
3500.0	2500.0	9.6	1.875	5.7	11422.1	22026.0	3737.6
3750.0	2500.0	9.8	2.000	5.9	13418.5	24597.1	4420.6
4000.0	2500.0	10.1	2.125	6.1	15667.1	27413.5	5227.3
4250.0	2500.0	10.2	2.125	6.3	17231.7	29811.7	5853.0
4500.0	2500.0	10.5	2.250	6.5	19787.0	32843.1	6778.8
4750.0	2500.0	10.7	2.500	6.7	24119.5	37625.6	8527.2
5000.0	2500.0	10.8	2.500	6.9	26290.4	40682.6	9460.1

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2750.0	3.6	0.875	3.0	417.7	1311.6	271.7
500.0	2750.0	4.8	1.000	3.3	764.5	2487.5	439.7
750.0	2750.0	5.6	1.125	3.7	1245.6	3735.1	634.1
1000.0	2750.0	6.4	1.250	3.9	1753.4	5040.7	805.8
1250.0	2750.0	6.9	1.375	4.1	2404.8	6454.4	1007.8
1500.0	2750.0	7.4	1.375	4.0	3137.8	7837.6	1222.2
1750.0	2750.0	7.9	1.500	4.3	3984.4	9389.7	1466.7
2000.0	2750.0	8.4	1.625	4.5	4950.6	10993.7	1728.5
2250.0	2750.0	8.8	1.625	4.8	5773.3	12533.3	1993.8
2500.0	2750.0	9.2	1.750	4.9	7015.0	14340.1	2344.9
2750.0	2750.0	9.6	1.750	5.1	7950.1	15925.6	2632.2
3000.0	2750.0	9.9	1.875	5.3	9475.6	17968.1	3096.2
3250.0	2750.0	10.2	2.000	5.5	11180.9	20187.5	3648.9
3500.0	2750.0	10.5	2.000	5.7	12471.4	22016.2	4065.8
3750.0	2750.0	10.8	2.125	5.9	14602.7	24550.2	4795.6
4000.0	2750.0	11.1	2.250	6.1	16996.3	27318.2	5654.9
4250.0	2750.0	11.2	2.250	6.3	18689.9	29701.2	6331.5
4500.0	2750.0	11.5	2.500	6.5	22661.7	33661.4	7820.1
4750.0	2750.0	11.7	2.500	6.7	24528.7	36163.3	8559.4
5000.0	2750.0	11.9	2.750	6.9	29878.8	41622.0	10843.0

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	3000.0	3.9	1.000	3.0	465.3	1312.5	297.3
500.0	3000.0	5.3	1.125	3.3	850.0	2490.3	479.8
750.0	3000.0	6.1	1.250	3.7	1382.7	3753.8	691.7
1000.0	3000.0	6.9	1.375	3.9	1941.3	5063.6	877.8
1250.0	3000.0	7.6	1.375	4.1	2518.5	6388.0	1082.0
1500.0	3000.0	8.1	1.500	4.0	3464.2	7872.1	1331.5
1750.0	3000.0	8.6	1.625	4.3	4384.9	9426.5	1596.9
2000.0	3000.0	9.1	1.625	4.5	5128.9	10831.3	1820.9
2250.0	3000.0	9.6	1.750	4.8	6332.6	12575.9	2169.1
2500.0	3000.0	10.0	1.750	4.9	7235.2	14087.4	2442.0
2750.0	3000.0	10.4	1.875	5.1	8691.2	15967.9	2860.4
3000.0	3000.0	10.8	2.000	5.3	10326.5	17998.9	3359.1
3250.0	3000.0	11.2	2.000	5.5	11463.0	19730.4	3736.4
3500.0	3000.0	11.5	2.125	5.7	13547.9	22030.1	4402.4
3750.0	3000.0	11.8	2.250	5.9	15817.1	24535.9	5181.0
4000.0	3000.0	12.1	2.500	6.1	19408.5	28009.2	6494.5
4250.0	3000.0	12.3	2.500	6.3	21349.0	30479.8	7278.6
4500.0	3000.0	12.6	2.500	6.5	23050.0	32556.0	7862.8
4750.0	3000.0	12.8	2.750	6.7	27818.2	37061.2	9793.5
5000.0	3000.0	13.0	2.750	6.9	30310.5	40045.2	10863.3

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	3250.0	4.3	1.000	3.0	495.7	1312.1	320.9
500.0	3250.0	5.7	1.125	3.3	900.4	2488.8	517.7
750.0	3250.0	6.6	1.250	3.7	1455.4	3727.2	743.7
1000.0	3250.0	7.5	1.375	3.9	2033.9	5022.5	941.4
1250.0	3250.0	8.2	1.500	4.1	2768.9	6418.4	1170.9
1500.0	3250.0	8.7	1.500	4.0	3601.6	7788.9	1414.1
1750.0	3250.0	9.3	1.625	4.3	4542.9	9310.7	1685.2
2000.0	3250.0	9.9	1.750	4.5	5609.1	10876.9	1970.9
2250.0	3250.0	10.4	1.750	4.8	6532.2	12391.6	2266.4
2500.0	3250.0	10.8	1.875	4.9	7890.2	14141.2	2643.0
2750.0	3250.0	11.3	2.000	5.1	9451.2	16017.8	3093.0
3000.0	3250.0	11.7	2.000	5.3	10588.3	17658.1	3452.4
3250.0	3250.0	12.1	2.125	5.5	12430.8	19777.8	4036.3
3500.0	3250.0	12.4	2.250	5.7	14651.5	22062.3	4747.9
3750.0	3250.0	12.8	2.500	5.9	18011.2	25162.0	5921.9
4000.0	3250.0	13.1	2.500	6.1	19754.5	27247.9	6547.9
4250.0	3250.0	13.3	2.500	6.3	21716.9	29617.3	7331.7
4500.0	3250.0	13.6	2.750	6.5	26084.5	33395.0	8974.4
4750.0	3250.0	13.9	2.750	6.7	28227.4	35867.3	9823.0
5000.0	3250.0	14.0	3.000	6.9	34089.2	41041.1	12336.4

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	3500.0	4.6	1.000	3.0	526.1	1311.7	344.6
500.0	3500.0	6.2	1.250	3.3	987.6	2491.4	557.6
750.0	3500.0	7.1	1.250	3.7	1528.1	3704.6	796.2
1000.0	3500.0	8.1	1.375	3.9	2126.5	4987.2	1005.8
1250.0	3500.0	8.8	1.500	4.1	2882.7	6364.1	1245.8
1500.0	3500.0	9.4	1.625	4.0	3936.1	7827.5	1523.0
1750.0	3500.0	10.0	1.750	4.3	4953.5	9354.7	1815.2
2000.0	3500.0	10.7	1.750	4.5	5787.5	10746.0	2065.7
2250.0	3500.0	11.2	1.875	4.8	7105.8	12448.0	2442.4
2500.0	3500.0	11.7	2.000	4.9	8561.6	14198.6	2847.4
2750.0	3500.0	12.2	2.000	5.1	9692.3	15762.1	3190.0
3000.0	3500.0	12.6	2.125	5.3	11460.7	17721.5	3718.7
3250.0	3500.0	13.0	2.250	5.5	13422.7	19835.4	4343.4
3500.0	3500.0	13.4	2.250	5.7	14955.3	21617.7	4831.6
3750.0	3500.0	13.7	2.500	5.9	18336.1	24577.2	5984.3
4000.0	3500.0	14.1	2.500	6.1	20100.5	26595.4	6610.0
4250.0	3500.0	14.3	2.750	6.3	24523.5	30397.2	8343.0
4500.0	3500.0	14.7	2.750	6.5	26472.7	32466.5	9013.5
4750.0	3500.0	15.0	3.000	6.7	31690.8	36785.1	11138.1
5000.0	3500.0	15.1	3.000	6.9	34520.9	39731.0	12353.7

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	3750.0	4.9	1.000	3.0	556.6	1311.4	368.3
500.0	3750.0	6.6	1.250	3.3	1038.0	2490.0	595.6
750.0	3750.0	7.6	1.375	3.7	1668.3	3723.6	853.2
1000.0	3750.0	8.7	1.500	3.9	2318.9	5012.0	1077.0
1250.0	3750.0	9.5	1.625	4.1	3139.1	6396.0	1334.2
1500.0	3750.0	10.1	1.625	4.0	4073.5	7758.4	1606.5
1750.0	3750.0	10.7	1.750	4.3	5111.5	9259.1	1904.9
2000.0	3750.0	11.4	1.875	4.5	6279.7	10798.8	2215.7
2250.0	3750.0	12.0	1.875	4.8	7305.4	12296.7	2542.2
2500.0	3750.0	12.5	2.000	4.9	8781.9	14005.8	2946.0
2750.0	3750.0	13.0	2.125	5.1	10471.2	15831.2	3424.9
3000.0	3750.0	13.5	2.250	5.3	12354.6	17790.4	3991.0
3250.0	3750.0	14.0	2.250	5.5	13704.9	19493.2	4433.9
3500.0	3750.0	14.4	2.500	5.7	16940.0	22166.9	5466.3
3750.0	3750.0	14.7	2.500	5.9	18661.0	24070.3	6054.9
4000.0	3750.0	15.1	2.750	6.1	22645.8	27284.6	7493.1
4250.0	3750.0	15.3	2.750	6.3	24891.4	29655.1	8391.6
4500.0	3750.0	15.7	3.000	6.5	29667.2	33307.4	10198.6
4750.0	3750.0	16.0	3.000	6.7	32100.1	35768.8	11163.8
5000.0	3750.0	16.2	3.250	6.9	38490.2	40746.9	13919.7

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	4000.0	5.3	1.125	3.0	605.0	1312.2	393.8
500.0	4000.0	7.0	1.250	3.3	1088.4	2488.8	633.6
750.0	4000.0	8.1	1.375	3.7	1741.0	3707.0	905.7
1000.0	4000.0	9.2	1.500	3.9	2411.5	4981.8	1141.5
1250.0	4000.0	10.1	1.625	4.1	3252.9	6349.8	1409.5
1500.0	4000.0	10.7	1.750	4.0	4416.2	7798.8	1714.9
1750.0	4000.0	11.5	1.750	4.3	5269.6	9175.5	1997.1
2000.0	4000.0	12.2	1.875	4.5	6458.0	10689.2	2312.2
2250.0	4000.0	12.7	2.000	4.8	7893.3	12360.6	2718.7
2500.0	4000.0	13.4	2.125	4.9	9469.9	14074.5	3151.8
2750.0	4000.0	13.9	2.125	5.1	10712.3	15619.1	3525.3
3000.0	4000.0	14.4	2.250	5.3	12616.3	17526.5	4085.9
3250.0	4000.0	14.9	2.500	5.5	15479.0	19973.3	4981.1
3500.0	4000.0	15.3	2.500	5.7	17243.8	21771.3	5544.3
3750.0	4000.0	15.7	2.750	5.9	20975.7	24682.4	6832.9
4000.0	4000.0	16.1	2.750	6.1	22991.8	26711.4	7549.9
4250.0	4000.0	16.3	3.000	6.3	27845.3	30428.3	9470.2
4500.0	4000.0	16.8	3.000	6.5	30055.4	32500.4	10233.1
4750.0	4000.0	17.1	3.250	6.7	35737.5	36689.3	12562.8
5000.0	4000.0	17.3	3.250	6.9	38921.8	39619.0	13933.3

APPENDIX VI

Computer Program Used for the Drum Hoist Using Counterweight

```
C       FRICTION HOISTING WITH COUNTER WEIGHT FROM 250 TO 5000 FEET
        DIMENSION PR(20),D(20)
        READ(1,54)RN
        READ(1,25)(PR(J),J=1,16)
        READ(1,26)(D(I),I=1,20)
        WRITE(3,19)
        WRITE(3,22)(PR(J),J=1,16)
        WRITE(3,17)
        WRITE(3,23)(D(I),I=1,20)
        WRITE(3,56)
        WRITE(3,100)
     55 DO 5 J=1,16
        DO 5 I=1,20
        RT=12.0
        FS=4.0
        G=32.2
        H=7.0
        A=3.5
        RD=0.25
      4 WR=(-659.67674330F-04)+(118.52413335F-03)*RD
       1+(156.53931681E-02)*RD**2
        RW=RN*WR
     47 VO=SQRT(A*D(I))
        V=0.5*VO
        AT=V/A
        AD=0.5*A*AT**2.0
        CD=(D(I)-AD*2.0)
        CT=CD/V
        TP=(4.0*AT+2.0*CT+2.0*RT)
        TN=H*3600.0/TP
        OT=PR(J)/TN
        OTR=1.1*OT
        SW=0.5*OTR
        CW=SW+0.5*OTR
        TDL=(SW+OTR)*(G+A)*FS/G
     15 BST=(132.56165299E-03)-(369.36228827E-03)*RD+
       1(382.26287669E-01)*RD**2-(154.23859881E-02)*RD**3
        TLR=(D(I)+50.0)*(G+A)*RW*FS/(G*2000.0)
        TTDL=TDL+TLR
        IF(RN*BST-TTDL)2,3,3
      2 IF(RD-0.625)7,6,6
      7 RD=RD+0.0625
```

```
      GO TO 4
    6 IF(RD-2.125)16,36,36
   16 RD=RD+0.125
      GO TO 4
   36 RD=RD+0.25
      IF(RD-3.5)4,4,11
    3 TU=(SW+OTR)*2000.0+RW*(D(I)+50.0)
      TL=CW*2000.0+RW*(D(I)+50.0)
      TS=TU/TL
      IF(TS-1.50)65,65,5
   65 TD=TS*(G+A)/(G-A)
      IF(TD-1.87)91,91,67
   67 A=A-0.05
      IF(A-1.0)5,47,47
   91 DKF=7.5*RD
      DKI=(245.52538644E+01)-(333.72349421E-00)*DKF
     1+(112.55284830E+01)*DKF**2-(230.78253002E-00)*DKF**3
     1+(276.28800686E-01)*DKF**4-(161.90592751E-02)*DKF**5
     1+(395.09828625E-04)*DKF**6
      WF=4.0*DKI*G/(DKF**2)
      TAN=D(I)/(3.141*DKF)
      VR=TAN/(0.5*TP-AT-RT)
      Z=2.0*3.141*VR/550.0
      TMUL=(SW+OTR)*DKF*1000.0
      TMUR=(D(I)+50.0)*RW*DKF*0.50
      TDCW=CW*DKF*1000.0
      FM=(TMUL+TMUR+TDCW)*0.1
      TNO=TMUL-TDCW
      FA=((CW+SW+OTR)*2000.0+(D(I)+50.0)*RW*2.+WF)*A/G
      AM=FA*DKF*0.5
      RM=-AM
      HPO=(TNO+FM+AM)*Z
      HPA=(TNO+FM+AM)*Z
      HPE=(TNO+FM)*Z
      HPC=(TNO+FM)*Z
      HPEC=(TNO+FM+RM)*Z
      HPEW=(TNO+FM+RM)*Z
      HPTA=(HPO+HPA)*0.5*AT
      HPTC=(HPE+HPC)*0.5*CT
      IF(HPEC+HPEW)30,30,35
   30 HPTD=0.0
      GO TO 96
   35 HPTD=(HPEC+HPEW)*0.5*AT
   96 HPTO=(HPTC+HPTA+HPTD)
C     UP COUNTER WEIGHT
      TDCC=SW*1000*DKF
C     NETT MOMENTS
```

```
      TNOC=TDCW-TDCC
      FA1=((CW+SW)*2000.0+(D(I)+50.)*RW*2.+WF)*A/G
      FM1=(TDCW+TDCC+TMUR)*0.1
      AM1=FA1*0.5*DKF
C     RM1=RETARDATION MOMENT
      RM1=-AM1
      HPO1=(TNOC+FM1+AM1)*Z
      HPA1=(TNOC+FM1+AM1)*Z
      HPE1=(TNOC+FM1)*Z
      HPC1=(TNOC+FM1)*Z
      HPEC1=(TNOC+FM1+RM1)*Z
      HPEW1=(TNOC+FM1+RM1)*Z
      HPTA1=(HPO1+HPA1)*0.5*AT
      HPTC1=(HPE1+HPC1)*0.5*CT
      IF(HPEC1+HPEW1)40,40,45
   40 HPTD1=0.00
      GO TO 52
   45 HPTD1=(HPEC1+HPEW1)*0.5*AT
   52 HPT1=(HPTA1+HPTC1+HPTD1)
      HPT=(HPTO+HPT1)/OTR
      PHP=HPA
      RMSHP=SQRT((HPA**2*AT+HPC**2*CT+HPEC**2*AT)/(AT+CT+0.25*RT))
      WRITE(3,101)D(I),PR(J),OTR,RD,AT,PHP,HPT,RMSHP
      GO TO 5
   11 WRITE(3,102)D(I)
      WRITE(3,12)RD
    5 CONTINUE
      IF(RN-4.0)57,58,58
   58 RN=1.0
      WRITE(3,103)
      GO TO 55
   57 CALL EXIT
   54 FORMAT(F10.3)
   12 FORMAT(17X,'ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA='F
  102 FORMAT(26X,'DEPTH IN FEET',F10.1)
   25 FORMAT(4F10.3)
   26 FORMAT(4F10.3)
   17 FORMAT(20X,'DEPTH IN FEET')
   19 FORMAT(20X,'PRODUCTION IN TONS')
   22 FORMAT(12X,3F10.2)
   23 FORMAT(12X,3F10.2)
   29 FORMAT(20X,'PRODUCTION IN TONS='F6.1)
   56 FORMAT(20X,'FRICTION HOISTING WITH FOUR ROPES IN PARALLEL')
  100 FORMAT(17X,'D',8X,'PR',8X,'OTR',7X,'RD',7X,'AT',4X,'PHP',6X,'H
     16X,'RMSHP')
  101 FORMAT(12X,8F9.1)
  103 FORMAT(20X,'FRICTION HOIST WITH COUNTER WEIGHT USING ONE ROPE'
      END
```

INPUT DATA FOR DRUM HOIST USING A COUNTERWEIGHT

PRODUCTION IN TONS

250.0	500.0	750.0
1000.0	1250.0	1500.0
1750.0	2000.0	2250.0
2500.0	2750.0	3000.0
3250.0	3500.0	3750.0
4000.0		

VELOCITY,ACCELERATION AND DEPTH

16.5	5.5	250.0
20.0	6.0	500.0
24.5	6.7	750.0
27.0	7.0	1000.0
30.0	7.3	1250.0
33.0	8.1	1500.0
35.5	8.2	1750.0
37.5	8.3	2000.0
40.0	8.4	2250.0
42.0	8.5	2500.0
44.0	8.6	2750.0
46.0	8.6	3000.0
48.0	8.7	3250.0
50.0	8.8	3500.0
52.0	8.8	3750.0
54.0	8.9	4000.0
56.5	8.9	4250.0
58.0	8.9	4500.0
60.0	9.0	4750.0
62.5	9.0	5000.0

COMPUTER OUTPUT FOR DRUM HOIST USING A COUNTERWEIGHT

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	250.0	0.7	0.375	3.0	65.9	1578.5	50.0
500.0	250.0	0.9	0.438	3.3	126.4	3115.3	86.4
750.0	250.0	1.0	0.500	3.7	216.8	4900.7	131.3
1000.0	250.0	1.2	0.563	3.9	317.0	6702.8	175.9
1250.0	250.0	1.3	0.563	4.1	421.8	8540.0	222.7
1500.0	250.0	1.3	0.625	4.0	613.2	10828.2	291.6
1750.0	250.0	1.4	0.625	4.3	742.3	12855.3	346.5
2000.0	250.0	1.5	0.750	4.5	1020.5	15936.3	451.9
2250.0	250.0	1.6	0.750	4.8	1201.2	18369.3	526.5
2500.0	250.0	1.7	0.750	4.9	1383.1	20714.1	598.2
2750.0	250.0	1.7	0.750	5.1	1577.1	23153.1	674.7
3000.0	250.0	1.8	0.750	5.3	1776.0	25693.2	754.9
3250.0	250.0	1.9	0.875	5.5	2290.2	30828.1	966.3
3500.0	250.0	1.9	0.875	5.7	2567.1	33873.8	1075.2
3750.0	250.0	2.0	0.875	5.9	2839.0	37061.5	1187.8
4000.0	250.0	2.0	0.875	6.1	3121.8	40385.3	1306.4
4250.0	250.0	2.0	1.000	6.3	3954.0	48621.2	1677.2
4500.0	250.0	2.1	1.000	6.5	4276.9	52124.5	1809.0
4750.0	250.0	2.1	1.000	6.7	4635.7	56354.0	1969.4
5000.0	250.0	2.2	1.125	6.9	5769.7	67629.1	2497.8

D	PR	DTR	RD	AT	PHP	HPT	RMSHP
250.0	500.0	1.3	0.563	3.0	121.1	1539.2	97.7
500.0	500.0	1.8	0.625	3.3	228.8	3027.1	168.1
750.0	500.0	2.0	0.750	3.7	401.1	4794.8	255.7
1000.0	500.0	2.3	0.750	3.9	541.8	6381.2	329.5
1250.0	500.0	2.5	0.875	4.1	786.8	8404.7	434.8
1500.0	500.0	2.7	0.875	4.0	1041.8	10270.3	534.8
1750.0	500.0	2.9	0.875	4.3	1250.4	12146.3	630.3
2000.0	500.0	3.0	1.000	4.5	1632.8	14644.1	780.9
2250.0	500.0	3.2	1.000	4.8	1909.3	16795.8	901.0
2500.0	500.0	3.3	1.000	4.9	2186.4	18879.8	1016.9
2750.0	500.0	3.5	1.125	5.1	2763.0	22176.9	1248.4
3000.0	500.0	3.6	1.125	5.3	3101.6	24565.2	1392.2
3250.0	500.0	3.7	1.125	5.5	3446.0	27045.4	1542.5
3500.0	500.0	3.8	1.250	5.7	4277.1	31388.8	1887.3
3750.0	500.0	3.9	1.250	5.9	4718.7	34258.2	2077.8
4000.0	500.0	4.0	1.375	6.1	5737.7	39633.0	2529.3
4250.0	500.0	4.1	1.375	6.3	6314.5	43413.9	2799.6
4500.0	500.0	4.2	1.375	6.5	6819.6	46475.9	3014.8
4750.0	500.0	4.3	1.500	6.7	8155.8	53554.0	3641.4
5000.0	500.0	4.3	1.500	6.9	8889.6	58217.8	3994.4

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	750.0	2.0	0.625	3.0	173.3	1533.3	144.8
500.0	750.0	2.6	0.750	3.3	329.3	2991.6	249.6
750.0	750.0	3.0	0.875	3.7	556.6	4678.9	373.2
1000.0	750.0	3.5	1.000	3.9	807.1	6393.6	495.8
1250.0	750.0	3.8	1.000	4.1	1051.5	8093.0	619.1
1500.0	750.0	4.0	1.000	4.0	1379.0	9857.2	754.2
1750.0	750.0	4.3	1.125	4.3	1796.7	12033.3	931.8
2000.0	750.0	4.6	1.125	4.5	2101.1	13846.3	1068.7
2250.0	750.0	4.8	1.250	4.8	2672.1	16449.4	1305.7
2500.0	750.0	5.0	1.250	4.9	3053.6	18475.7	1471.0
2750.0	750.0	5.2	1.375	5.1	3776.6	21447.0	1769.1
3000.0	750.0	5.4	1.375	5.3	4232.4	23729.4	1968.9
3250.0	750.0	5.6	1.375	5.5	4695.7	26094.5	2177.3
3500.0	750.0	5.7	1.500	5.7	5715.4	29889.7	2606.9
3750.0	750.0	5.9	1.500	5.9	6296.6	32573.4	2863.9
4000.0	750.0	6.0	1.625	6.1	7524.8	37167.6	3415.4
4250.0	750.0	6.1	1.625	6.3	8269.9	40609.8	3769.8
4500.0	750.0	6.3	1.750	6.5	9714.3	45790.8	4429.6
4750.0	750.0	6.4	1.875	6.7	11411.5	52079.4	5248.3
5000.0	750.0	6.5	1.875	6.9	12429.7	56545.6	5748.9

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	1000.0	2.6	0.750	3.0	231.9	1534.1	193.3
500.0	1000.0	3.5	0.875	3.3	431.5	2978.0	331.6
750.0	1000.0	4.0	1.000	3.7	715.0	4628.4	492.0
1000.0	1000.0	4.6	1.125	3.9	1019.3	6290.6	648.3
1250.0	1000.0	5.0	1.125	4.1	1321.8	7951.5	807.0
1500.0	1000.0	5.4	1.250	4.0	1853.9	9931.6	1017.3
1750.0	1000.0	5.7	1.250	4.3	2212.5	11720.4	1193.7
2000.0	1000.0	6.1	1.375	4.5	2782.2	13888.8	1433.5
2250.0	1000.0	6.4	1.375	4.8	3236.6	15878.9	1643.3
2500.0	1000.0	6.7	1.500	4.9	3984.5	18429.1	1955.8
2750.0	1000.0	7.0	1.500	5.1	4508.1	20510.2	2186.2
3000.0	1000.0	7.2	1.625	5.3	5446.6	23516.3	2589.4
3250.0	1000.0	7.4	1.625	5.5	6039.2	25851.7	2862.1
3500.0	1000.0	7.7	1.750	5.7	7259.1	29401.5	3385.9
3750.0	1000.0	7.9	1.750	5.9	7991.8	32023.7	3716.8
4000.0	1000.0	8.0	1.875	6.1	9441.8	36261.0	4378.5
4250.0	1000.0	8.2	2.000	6.3	11170.7	41387.4	5208.3
4500.0	1000.0	8.4	2.000	6.5	12052.6	44281.2	5605.7
4750.0	1000.0	8.5	2.125	6.7	14019.5	49947.6	6565.6
5000.0	1000.0	8.6	2.250	6.9	16389.8	56808.1	7755.9

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	1250.0	3.3	0.875	3.0	291.3	1535.0	242.0
500.0	1250.0	4.4	1.000	3.3	535.3	2973.2	414.1
750.0	1250.0	5.0	1.125	3.7	876.3	4604.1	611.9
1000.0	1250.0	5.8	1.250	3.9	1235.5	6237.1	802.6
1250.0	1250.0	6.3	1.250	4.1	1597.9	7877.9	997.4
1500.0	1250.0	6.7	1.375	4.0	2214.3	9795.7	1247.0
1750.0	1250.0	7.2	1.375	4.3	2637.7	11551.2	1460.8
2000.0	1250.0	7.6	1.500	4.5	3285.0	13627.6	1739.7
2250.0	1250.0	8.0	1.625	4.8	4081.7	16014.8	2086.1
2500.0	1250.0	8.3	1.625	4.9	4653.5	17971.3	2345.5
2750.0	1250.0	8.7	1.750	5.1	5631.8	20620.5	2763.2
3000.0	1250.0	9.0	1.750	5.3	6299.2	22785.0	3067.8
3250.0	1250.0	9.3	1.875	5.5	7476.6	25892.1	3595.5
3500.0	1250.0	9.6	1.875	5.7	8319.9	28288.0	3962.4
3750.0	1250.0	9.8	2.000	5.9	9804.5	31927.9	4633.7
4000.0	1250.0	10.1	2.125	6.1	11488.7	35977.8	5415.2
4250.0	1250.0	10.2	2.125	6.3	12613.1	39248.7	5965.4
4500.0	1250.0	10.5	2.250	6.5	14547.3	43694.8	6873.8
4750.0	1250.0	10.7	2.500	6.7	17914.4	51102.0	8552.7
5000.0	1250.0	10.8	2.500	6.9	19500.3	55428.7	9356.3

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	1500.0	3.9	1.000	3.0	351.5	1535.9	290.9
500.0	1500.0	5.3	1.125	3.3	640.7	2972.8	496.9
750.0	1500.0	6.1	1.250	3.7	1040.5	4592.8	732.7
1000.0	1500.0	6.9	1.375	3.9	1456.0	6208.4	958.3
1250.0	1500.0	7.6	1.375	4.1	1879.7	7838.4	1190.0
1500.0	1500.0	8.1	1.500	4.0	2582.5	9717.4	1480.1
1750.0	1500.0	8.6	1.625	4.3	3260.6	11717.2	1792.7
2000.0	1500.0	9.1	1.625	4.5	3799.2	13472.0	2051.9
2250.0	1500.0	9.6	1.750	4.8	4687.3	15773.8	2443.9
2500.0	1500.0	10.0	1.750	4.9	5338.5	17692.0	2744.6
2750.0	1500.0	10.4	1.875	5.1	6418.3	20223.3	3210.4
3000.0	1500.0	10.8	2.000	5.3	7638.5	23005.1	3751.0
3250.0	1500.0	11.2	2.000	5.5	8461.4	25271.5	4141.3
3500.0	1500.0	11.5	2.125	5.7	10021.9	28490.7	4826.0
3750.0	1500.0	11.8	2.250	5.9	11734.6	32059.2	5614.6
4000.0	1500.0	12.1	2.500	6.1	14518.1	37293.6	6936.7
4250.0	1500.0	12.3	2.500	6.3	15946.0	40729.0	7649.6
4500.0	1500.0	12.6	2.500	6.5	17198.5	43570.0	8232.7
4750.0	1500.0	12.8	2.750	6.7	20948.5	50575.8	10123.6
5000.0	1500.0	13.0	2.750	6.9	22797.6	54834.7	11069.7

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	1750.0	4.6	1.000	3.0	398.0	1534.3	336.8
500.0	1750.0	6.2	1.250	3.3	747.8	2974.9	580.2
750.0	1750.0	7.1	1.250	3.7	1154.8	4520.9	841.5
1000.0	1750.0	8.1	1.375	3.9	1602.5	6095.8	1095.2
1250.0	1750.0	8.8	1.500	4.1	2167.2	7818.4	1384.5
1500.0	1750.0	9.4	1.625	4.0	2958.3	9672.0	1716.3
1750.0	1750.0	10.0	1.750	4.3	3714.6	11636.5	2071.1
2000.0	1750.0	10.7	1.750	4.5	4324.9	13376.6	2369.3
2250.0	1750.0	11.2	1.875	4.8	5306.6	15620.6	2808.6
2500.0	1750.0	11.7	2.000	4.9	6396.9	17955.0	3287.2
2750.0	1750.0	12.2	2.000	5.1	7223.0	19965.0	3667.9
3000.0	1750.0	12.6	2.125	5.3	8553.6	22643.5	4262.2
3250.0	1750.0	13.0	2.250	5.5	10039.6	25582.6	4946.5
3500.0	1750.0	13.4	2.250	5.7	11161.9	27937.5	5447.2
3750.0	1750.0	13.7	2.500	5.9	13782.2	32320.1	6660.0
4000.0	1750.0	14.1	2.500	6.1	15086.9	35063.2	7282.1
4250.0	1750.0	14.3	2.750	6.3	18549.8	40856.0	8995.0
4500.0	1750.0	14.7	2.750	6.5	20006.1	43708.9	9682.4
4750.0	1750.0	15.0	3.000	6.7	24153.0	50451.1	11796.3
5000.0	1750.0	15.1	3.000	6.9	26281.5	54689.4	12895.3

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	2000.0	5.3	1.125	3.0	458.9	1535.3	385.9
500.0	2000.0	7.0	1.250	3.3	825.8	2943.8	657.4
750.0	2000.0	8.1	1.375	3.7	1321.9	4526.5	963.2
1000.0	2000.0	9.2	1.500	3.9	1827.1	6097.2	1252.4
1250.0	2000.0	10.1	1.625	4.1	2460.4	7810.4	1581.0
1500.0	2000.0	10.7	1.750	4.0	3341.9	9647.2	1955.3
1750.0	2000.0	11.5	1.750	4.3	3971.0	11366.7	2286.9
2000.0	2000.0	12.2	1.875	4.5	4862.0	13318.9	2691.6
2250.0	2000.0	12.7	2.000	4.8	5939.6	15522.5	3179.8
2500.0	2000.0	13.4	2.125	4.9	7129.7	17805.9	3708.0
2750.0	2000.0	13.9	2.125	5.1	8046.2	19793.8	4135.0
3000.0	2000.0	14.4	2.250	5.3	9489.5	22397.9	4785.0
3250.0	2000.0	14.9	2.500	5.5	11711.6	25932.2	5801.6
3500.0	2000.0	15.3	2.500	5.7	13022.2	28329.3	6393.5
3750.0	2000.0	15.7	2.750	5.9	15947.1	32662.2	7770.7
4000.0	2000.0	16.1	2.750	6.1	17458.4	35443.5	8499.9
4250.0	2000.0	16.3	3.000	6.3	21297.6	41135.0	10424.0
4500.0	2000.0	16.8	3.000	6.5	22970.1	44012.8	11223.2
4750.0	2000.0	17.1	3.250	6.7	27527.9	50577.1	13570.7
5000.0	2000.0	17.3	3.250	6.9	29952.2	54824.5	14833.3

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2250.0	5.9	1.125	3.0	505.4	1534.1	431.9
500.0	2250.0	7.9	1.375	3.3	934.5	2950.5	741.1
750.0	2250.0	9.1	1.500	3.7	1491.9	4534.2	1085.6
1000.0	2250.0	10.4	1.625	3.9	2055.8	6102.8	1410.9
1250.0	2250.0	11.3	1.750	4.1	2759.4	7810.6	1779.5
1500.0	2250.0	12.1	1.875	4.0	3733.2	9636.1	2197.2
1750.0	2250.0	12.9	1.875	4.3	4434.6	11353.1	2569.6
2000.0	2250.0	13.7	2.000	4.5	5410.7	13286.3	3018.6
2250.0	2250.0	14.3	2.125	4.8	6586.3	15461.0	3557.2
2500.0	2250.0	15.0	2.250	4.9	7878.5	17707.2	4136.4
2750.0	2250.0	15.6	2.500	5.1	9837.3	20606.7	4997.2
3000.0	2250.0	16.2	2.500	5.3	10995.6	22769.6	5549.7
3250.0	2250.0	16.7	2.500	5.5	12173.4	25004.9	6124.7
3500.0	2250.0	17.2	2.750	5.7	14988.2	28750.3	7397.4
3750.0	2250.0	17.7	2.750	5.9	16480.9	31290.0	8112.1
4000.0	2250.0	18.1	3.000	6.1	19959.8	35884.2	9791.5
4250.0	2250.0	18.4	3.000	6.3	21902.8	39128.7	10778.8
4500.0	2250.0	18.9	3.250	6.5	26090.6	44426.5	12855.7
4750.0	2250.0	19.2	3.500	6.7	31073.3	50870.4	15447.2
5000.0	2250.0	19.4	3.500	6.9	33809.6	55146.7	16883.8

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	2500.0	6.6	1.250	3.0	567.1	1535.2	481.1
500.0	2500.0	8.8	1.375	3.3	1012.6	2933.5	818.4
750.0	2500.0	10.1	1.500	3.7	1606.1	4489.7	1195.0
1000.0	2500.0	11.5	1.750	3.9	2288.7	6111.5	1570.7
1250.0	2500.0	12.6	1.750	4.1	2940.5	7706.6	1945.5
1500.0	2500.0	13.4	1.875	4.0	3955.9	9485.3	2389.1
1750.0	2500.0	14.3	2.000	4.3	4907.7	11351.5	2856.0
2000.0	2500.0	15.2	2.125	4.5	5970.8	13271.3	3350.3
2250.0	2500.0	15.9	2.250	4.8	7246.7	15425.2	3940.5
2500.0	2500.0	16.7	2.500	4.9	9064.5	18014.2	4738.0
2750.0	2500.0	17.4	2.500	5.1	10231.4	20033.5	5289.3
3000.0	2500.0	18.0	2.500	5.3	11423.9	22115.5	5862.8
3250.0	2500.0	18.6	2.750	5.5	13939.3	25435.3	7025.3
3500.0	2500.0	19.1	2.750	5.7	15486.8	27770.0	7733.7
3750.0	2500.0	19.6	3.000	5.9	18763.3	31783.7	9283.9
4000.0	2500.0	20.1	3.000	6.1	20528.6	34463.9	10144.7
4250.0	2500.0	20.4	3.250	6.3	24794.7	39671.7	12287.9
4500.0	2500.0	21.0	3.500	6.5	29367.5	44917.2	14580.7
4750.0	2500.0	21.4	3.500	6.7	31746.8	48364.1	15809.4

DEPTH IN FEET 5000.0

ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	2750.0	7.2	1.250	3.0	613.6	1534.2	527.2
500.0	2750.0	9.7	1.500	3.3	1122.9	2939.2	902.4
750.0	2750.0	11.1	1.625	3.7	1779.0	4502.1	1318.2
1000.0	2750.0	12.7	1.750	3.9	2435.2	6048.7	1708.4
1250.0	2750.0	13.9	1.875	4.1	3245.1	7721.4	2145.7
1500.0	2750.0	14.8	2.000	4.0	4355.0	9497.7	2633.7
1750.0	2750.0	15.8	2.125	4.3	5390.4	11358.6	3146.0
2000.0	2750.0	16.8	2.250	4.5	6542.4	13269.1	3686.5
2250.0	2750.0	17.5	2.500	4.8	8283.7	15698.3	4465.5
2500.0	2750.0	18.4	2.500	4.9	9423.8	17606.0	5015.3
2750.0	2750.0	19.1	2.750	5.1	11648.6	20387.5	6006.3
3000.0	2750.0	19.8	2.750	5.3	13013.4	22519.7	6666.3
3250.0	2750.0	20.5	2.750	5.5	14401.1	24721.8	7352.9
3500.0	2750.0	21.1	3.000	5.7	17558.3	28260.3	8790.5
3750.0	2750.0	21.6	3.250	5.9	21163.1	32294.0	10522.6
4000.0	2750.0	22.1	3.250	6.1	23159.9	35032.0	11505.6
4250.0	2750.0	22.5	3.500	6.3	27830.6	40249.5	13881.5

DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	3000.0	7.9	1.375	3.0	676.1	1535.3	576.6
500.0	3000.0	10.6	1.500	3.3	1200.9	2928.8	979.9
750.0	3000.0	12.1	1.750	3.7	1954.8	4514.8	1442.2
1000.0	3000.0	13.9	1.875	3.9	2672.2	6063.9	1869.3
1250.0	3000.0	15.1	2.000	4.1	3555.5	7738.4	2347.8
1500.0	3000.0	16.1	2.125	4.0	4761.7	9514.1	2881.0
1750.0	3000.0	17.2	2.250	4.3	5882.7	11372.2	3439.6
2000.0	3000.0	18.3	2.500	4.5	7430.1	13497.5	4134.5
2250.0	3000.0	19.1	2.500	4.8	8608.7	15404.9	4724.8
2500.0	3000.0	20.0	2.750	4.9	10673.6	17922.1	5645.3
2750.0	3000.0	20.9	2.750	5.1	12042.8	19928.1	6300.4
3000.0	3000.0	21.6	3.000	5.3	14686.3	22924.8	7515.4
3250.0	3000.0	22.3	3.000	5.5	16260.8	25181.6	8299.2
3500.0	3000.0	23.0	3.250	5.7	19735.3	28755.9	9907.0
3750.0	3000.0	23.6	3.250	5.9	21696.8	31295.6	10864.9
4000.0	3000.0	24.1	3.500	6.1	25921.1	35614.2	12941.9
4250.0	3000.0	24.5	3.500	6.3	28435.8	38818.6	14240.0

DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	3250.0	8.6	1.375	3.0	722.6	1534.5	622.6
500.0	3250.0	11.4	1.625	3.3	1312.9	2934.8	1064.3
750.0	3250.0	13.1	1.750	3.7	2069.1	4482.1	1551.7
1000.0	3250.0	15.0	1.875	3.9	2818.7	6014.4	2007.5
1250.0	3250.0	16.4	2.125	4.1	3871.5	7757.3	2551.8
1500.0	3250.0	17.5	2.250	4.0	5176.2	9533.7	3131.1
1750.0	3250.0	18.6	2.500	4.3	6639.5	11562.3	3822.1
2000.0	3250.0	19.8	2.500	4.5	7720.0	13291.3	4372.9
2250.0	3250.0	20.7	2.500	4.8	8933.7	15156.6	4988.2
2500.0	3250.0	21.7	2.750	4.9	11032.9	17583.8	5923.2
2750.0	3250.0	22.6	2.750	5.1	12436.9	19539.3	6600.6
3000.0	3250.0	23.4	3.000	5.3	15114.7	22409.7	7824.9
3250.0	3250.0	24.2	3.250	5.5	18214.4	25642.2	9298.4
3500.0	3250.0	24.9	3.250	5.7	20234.0	28001.4	10241.0
3750.0	3250.0	25.5	3.500	5.9	24214.1	31855.0	12165.4
4000.0	3250.0	26.1	3.500	6.1	26489.8	34542.4	13295.1

DEPTH IN FEET 4250.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750

D	PR	QTR	RD	AT	PHP	HPT	RMSHP
250.0	3500.0	9.2	1.375	3.0	769.1	1533.8	668.7
500.0	3500.0	12.3	1.625	3.3	1391.0	2926.2	1141.7
750.0	3500.0	14.1	1.875	3.7	2247.8	4496.6	1676.5
1000.0	3500.0	16.2	2.000	3.9	3059.9	6032.9	2169.5
1250.0	3500.0	17.7	2.125	4.1	4052.7	7686.8	2718.3
1500.0	3500.0	18.8	2.250	4.0	5398.9	9433.3	3324.0
1750.0	3500.0	20.1	2.500	4.3	6895.9	11413.4	4037.8
2000.0	3500.0	21.3	2.500	4.5	8009.9	13114.6	4614.2
2250.0	3500.0	22.3	2.750	4.8	10025.4	15428.5	5532.8
2500.0	3500.0	23.4	2.750	4.9	11392.3	17293.8	6205.7
2750.0	3500.0	24.3	3.000	5.1	13927.4	19903.9	7346.3
3000.0	3500.0	25.2	3.000	5.3	15543.0	21968.2	8140.9
3250.0	3500.0	26.0	3.250	5.5	18676.2	25066.8	9621.8
3500.0	3500.0	26.8	3.500	5.7	22516.5	28519.4	11411.8
3750.0	3500.0	27.5	3.500	5.9	24747.8	31030.5	12510.9

DEPTH IN FEET 4000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4250.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	3750.0	9.9	1.500	3.0	832.3	1534.7	718.3
500.0	3750.0	13.2	1.750	3.3	1504.6	2932.3	1226.5
750.0	3750.0	15.1	1.875	3.7	2362.1	4469.4	1786.1
1000.0	3750.0	17.3	2.125	3.9	3305.2	6051.6	2332.9
1250.0	3750.0	18.9	2.250	4.1	4374.4	7710.4	2924.0
1500.0	3750.0	20.1	2.500	4.0	6028.3	9579.7	3639.7
1750.0	3750.0	21.5	2.500	4.3	7152.3	11284.4	4255.6
2000.0	3750.0	22.9	2.750	4.5	8943.5	13337.1	5078.0
2250.0	3750.0	23.9	2.750	4.8	10350.4	15211.8	5795.4
2500.0	3750.0	25.0	3.000	4.9	12705.8	17608.9	6860.0
2750.0	3750.0	26.1	3.000	5.1	14321.6	19568.6	7646.3
3000.0	3750.0	27.0	3.250	5.3	17299.3	22383.7	9024.6
3250.0	3750.0	27.9	3.500	5.5	20723.7	25535.7	10668.6
3500.0	3750.0	28.7	3.500	5.7	23015.2	27881.2	11747.5

DEPTH IN FEET 3750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4250.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750

D	PR	OTR	RD	AT	PHP	HPT	RMSHP
250.0	4000.0	10.5	1.500	3.0	878.8	1534.1	764.3
500.0	4000.0	14.1	1.750	3.3	1582.6	2925.0	1304.0
750.0	4000.0	16.2	2.000	3.7	2543.6	4484.8	1911.6
1000.0	4000.0	18.5	2.125	3.9	3451.7	6012.2	2471.1
1250.0	4000.0	20.2	2.250	4.1	4555.5	7651.6	3090.9
1500.0	4000.0	21.5	2.500	4.0	6251.0	9489.0	3831.9
1750.0	4000.0	22.9	2.750	4.3	7947.4	11467.5	4651.1
2000.0	4000.0	24.4	2.750	4.5	9233.4	13179.6	5318.3
2250.0	4000.0	25.5	3.000	4.8	11497.0	15479.7	6364.5
2500.0	4000.0	26.7	3.000	4.9	13065.2	17353.7	7141.7
2750.0	4000.0	27.8	3.250	5.1	15885.5	19930.6	8427.0
3000.0	4000.0	28.8	3.250	5.3	17727.7	21999.0	9340.2
3250.0	4000.0	29.8	3.500	5.5	21185.5	25038.9	10992.5

DEPTH IN FEET 3500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 3750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4250.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4500.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 4750.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750
DEPTH IN FEET 5000.0
ROPE DIA IS MORE THAN 3.5 INCHES CALCULATED DIA= 3.750

VITA

Hemendra Nath Kalia

Hemendra Nath Kalia was born on February 11, 1939, at Amritsar, Punjab, India. He received his primary education at Domchanch Middle School and secondary education at Jhumri-Telaiya High English School. He graduated with a diploma in mining, with honors in mining machinery, from Wigan and District Mining and Technical College, Wigan, Lancashire, England.

The author was awarded a First Class Certificate of Competency in coal, stratified ironstone, fireclay, and shale mining, by the Ministry of Power, England on February 1965.

He has been associate member of the Institution of Mining Engineers, London, England, since February 1965 and an associate member of the Association of Mining, Electrical, and Mechanical Engineers, Manchester, Lancashire, England, since January 1967.

His work experience involved 1 year and 6 months at the Christian Mining Industries, Ltd., mica mines, and 6 months at the New Churulia Coal Company, both in India, and 2 years at the Moor-Green Colliery of National Coal Board of England at Nottingham, and 1 year at other mines (coal, ironstone, anhydrite, and limestone) in England. The summer of 1966 was devoted to work at the Black River Mine of the Marble Cliff Quarries Company in Kentucky.

He is presently pursuing studies toward the degree of Ph.D. in Mining Engineering at the University of Missouri at Rolla.