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THE EFFECT OF MATERIAL PROPERTIES ON MATERIALS HANDLING PROCESSES

R. W. Heins, et al

Wisconsin University

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THE EFFECT OF MATERIAL PROPERTIES ON MATERIALS HANDLING PROCESSES

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October 1972

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13. ABSTRACT

In order to better understand the fundamental aspects of a belt conveyor materials handling system, a model system has been constructed. Evaluation and measure of performance of the various factors of the belt conveyor system will be made by using a statistical experimental design approach.

Numerous problems have been encountered with the system. These problems and their solutions are detailed in this report. Numerous modifications have been made and the system now appears to be workable.

The results of the first set of 16 tests are reported. These test results have been analyzed using the statistical experimental design technique. While the results are only preliminary in nature, several tentative conclusions can be drawn. For example, both the inclination of the belt and the weight of the material per foot length of the belt suggests that the power required to carry the material on the belt changes very rapidly and increases as these two variables increase. Several plots and tables of these results are presented.

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APRIL - SEPTEMBER 1972

THE EFFECT OF MATERIAL PROPERTIES ON MATERIALS HANDLING PROCESSES

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I-C

PREFACE

This report covers the first six months accomplishments on Contract No. H0220042 in the research program entitled, "The Effect of Material Properties on Materials Handling Processes," R. W. Heins, Principal Investigator.

SUMMARY

A closed circulation belt conveyor materials handling system using a model (small size) conveyor has been constructed. The model conveyor can be run at various speeds up to 750 feet per minute and with a belt inclination up to 20° above the horizontal. The return belt is 18 inches wide and runs at constant speed. This system was constructed at the University of Wisconsin's Physical Sciences Laboratory.

Numerous problems which affect the operation of the system have been observed since delivery of the machines. For example, the drive pulleys on both belts were out of alignment as evidenced by the poor tracking characteristics of both belts. Proper alignment solved these problems. Major problems of material transfer at both ends of the system resulted in complete redesign and modification of the system at these points. Several additional modifications are suggested and work on these is in progress.

The results of the initial 16 tests using a bank sand material are reported. Several graphs and tabulations of these experimental data have been analyzed using the statistical experimental design technique. While the results are only preliminary, several tentative conclusions have been made. For example, it has been shown that increases in belt inclination and weight of material per foot length of the belt cause rapid changes in the power required to carry the material with power increasing as the two variables increase.

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THE EFFECT OF MATERIAL PROPERTIES ON MATERIALS HANDLING PROCESSES

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October 1972

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CHAPTER 1

RESEARCH OBJECTIVES AND PLANS

INTRODUCTION

The development of large diameter tunnelling machines marks a new era in tunnelling practice. While these machines are capable of excavating hard rock rapidly and continuously, new designs of even greater capacity are being developed and tested. With prototype excavators of extremely high capacity in the testing stage, the problems of materials handling associated with rapid excavation processes are enormous.

The present tunnelling machines are an outgrowth of the continuous mining machines developed in the late 40's and early 50's by the coal producers. In need of high productivity per man hour, these companies fostered the development of continuous mining machines which literally rip the coal from the face. The continuous mining machines are equipped with loading devices that move the mined material away from the face and onto an extensible belt conveyor or to a shuttle car behind the miner. The same machines that were developed for coal can also be used for soft rock excavations, for example, in potash.

Having shown that continuous mining equipment was practical, various manufacturers began working on designs for equipment systems that could be used to mine rock of higher compressive strengths. The machines currently in use represent a breakthrough in that rocks with compressive strengths in excess of 25,000 pounds per square inch can be excavated continuously. Tunnelling no longer suffers from the constraints imposed by the cyclic drill-blast method.

The volume of rock produced by continuous excavating machines is largely a function of the speed of the cutting head and the thrust on the cutting head. Together with the type of cutter head, these parameters control the rate of advance. A number of types of cutter designs have been proposed and tried in practice. These designs have drawn heavily on the technology developed by the oil industry in deep drilling practices through very hard rock formations. The particle size distribution and particle shape of the excavated material are, in part at least, dependent on the type of cutter used as well as the relative strength of the material in place. The linear or disc cutter as applied to soft to medium hard formations produces larger particles which tend to be plate-like in shape. In contrast, the tungsten carbide insert cutter which is used in very hard formations tends to produce fine chips of more equal dimensions. Thus, it can be seen that both cutter design and rock strength influence chip shape and size distribution. These can be controlled variables if it can be shown that these properties have an important influence on the materials handling properties.

RESEARCH OBJECTIVES

Although the physical properties of bulk materials influence their conveying in all materials handling systems, the emphasis of this study is directed to rapid excavation during tunnelling.

A better understanding of the fundamental aspects of the materials-system interface and interactions must be obtained in order to achieve the materials handling capabilities required. In particular, the effect of the physical properties of the excavated material on the handling system must be investigated. The selection of equipment based on experience, tradition or intuition is no longer valid but must be based in part on an analysis of the physical properties of the material to be handled.

The purpose of this research is to identify the variables which control the material handling processes. It is the hope of the research team that optimum material characteristics will be found which will enhance the output. Since these materials are the products of extraction and essentially man-made, it should be possible to modify their properties at or near the face of the excavation to improve their handleability.

While it is speculative at this point, an attempt will be made to determine the influence of such material properties as particle shape, particle size distribution, angle of internal friction, and moisture content on the way the materials behave on a conveyor belt. Materials handling systems might be disigned around those properties and variables which are shown to be important in the handling process.

RESEARCH PLAN

A small size (model) conveyor has been designed and built for a test system. The model conveyor, which is equipped with an eight-inch belt, is connected to an 18-inch belt, which serves as the return system, thus establishing a closed loop materials handling system. The small model belt was selected in order to reduce the total amount of material required to fill the system. Numerous problems have developed with the system and these are detailed in a subsequent chapter of this report. Included are the details of how these problems have been solved.

A statistical experimental design has been employed for conducting the experimental investigation. This program is very flexible and variables can be added or deleted as necessary during the testing program. Regardless of the number of important variables that are finally formed in the testing program, this method of experimental design will optimize the amount of significant data that can be obtained from a given number of experimental runs. The statistical experimental design offers the best hope of maximizing the evaluation of a multiple-variable experimental system.

In an effort to reduce the size of the test system, several ideas for a conveyor belt simulator have been proposed. One of the designs has been built and will be studied simultaneously with the closed-loop belt conveyor system.

CHAPTER 2

PROBLEMS ASSOCIATED WITH MODEL CONVEYOR SYSTEM

INTRODUCTION

The technology of conveyor system design is quite well developed at the present time. However, designs are generally based on knowledge acquired through experience and empirical relationships developed early by trial and error procedures. Conveyor equipment manufacturers have standarized major system links and, as a rule, only minor modifications are made to suit the practical requirements of the particular installation.

Most of the research carried out in the field of belt conveyor systems as a means of a material handling system has been carried out by private manufacturers in the field, and directed toward technical developments and improvements of the various components of the system. As a result, comparatively little literature, pertaining to optimization analytical studies of conveyor systems, is presently available.

The objectives of this investigation were deliberately broadly formulated at the time the construction of the closed-loop experimental model conveyor system was started. Most of the components were designed, constructed and modified as the need arose. Conveyor equipment manufacturers were consulted occasionally in connection with some of the problems that developed during construction.

The design requirements of the model conveyor system imposed many restrictions on the use of standard equipment in the system. A case in point is the requirement of adjustability of the inclination of the model conveyor bed. In order to meet this specification, an elaborate telescopic chute design was required and, at the same time, the possibility of using standard chute components was eliminated. Because of the unusual requirements of the system, construction was considerably delayed. When the construction of the equipment was completed, it was decided to accept the delivery of the equipment on the University of Wisconsin campus and modify the system components as and when it became necessary.

THE LOCATION OF THE MODEL CONVEYOR SYSTEM

Some difficulty was encountered in finding a suitable location for the model conveyor within existing facilities of the College of Engineering. The original location selected for the set-up in the laboratories of the Department of Engineering Mechanics had to be abandoned because of Professor Christensen's resignation from the department. An alternate location was subsequently found using a portion of a laboratory in the Department of Metallurgical and Mineral Engineering with the stipulation that appropriate measures be taken to minimize dust and noise during the experimentation. Because of the length of the model conveyor bed a portion of a partition wall had to be removed to facilitate installation in the laboratory. Those working on the project assisted in the disassembly of the conveyor equipment at the Physical Science laboratory workshop and in the reassembly of the equipment on the campus. Figure 1 shows two photographs of the conveyor system in its present location.

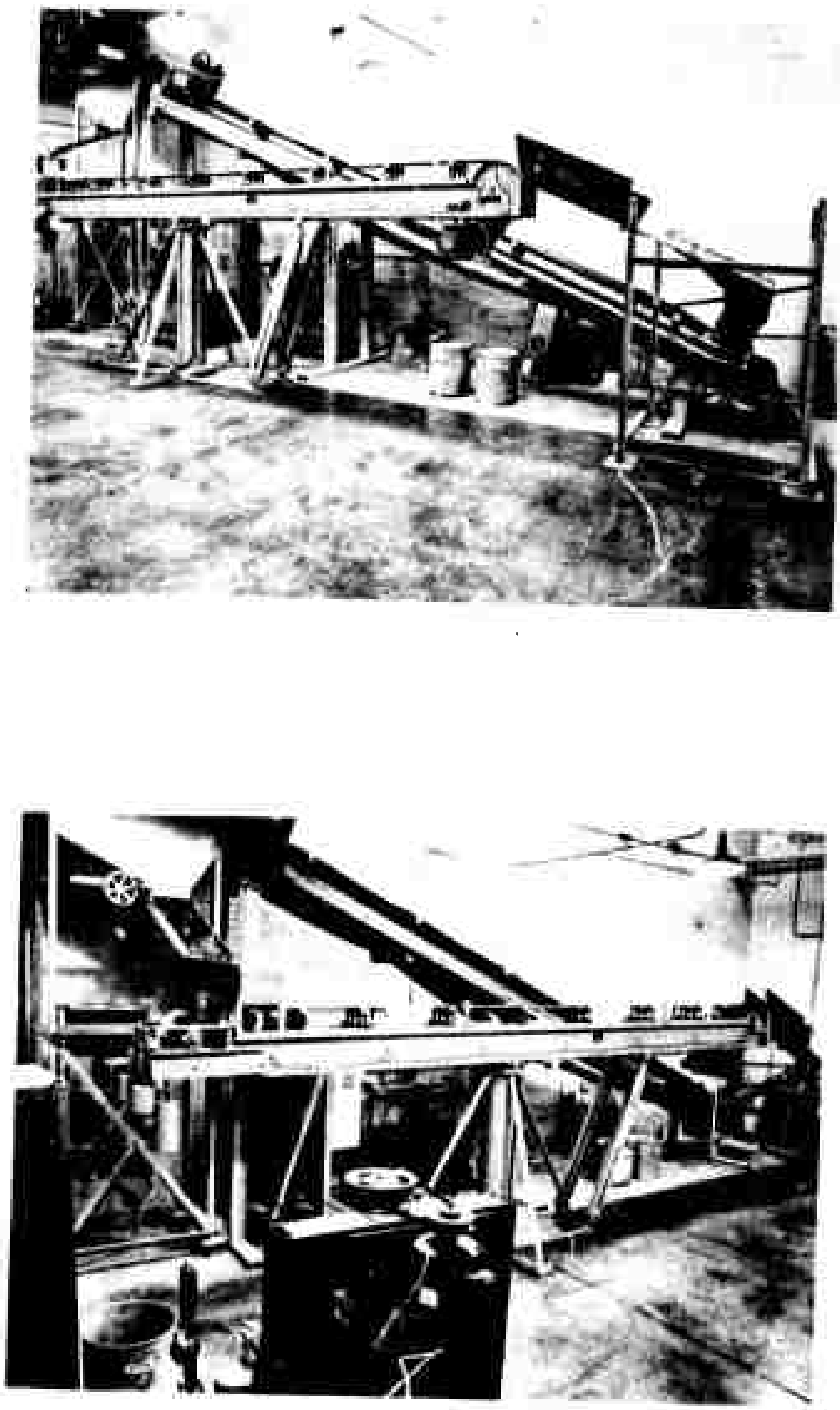


Figure 1. Model Conveyor System.

MODIFICATIONS OF THE MODEL CONVEYOR EQUIPMENT

After all electrical connections were made, the conveyor was ready for initial shake-down tests. Several minor adjustments and modifications were required to get the equipment in working order. Alignment of the idlers on the bed of the model conveyor caused some difficulty and, since the belt was relatively new and the required amount of belt tension load had been misjudged in the initial design, tracking problems developed with the belt. In order to solve the problem, the belt tension was reduced to half the original value and special training idlers were mounted on the model conveyor bed. Figure 2 shows a sketch of the training idlers in position. However, after the training idlers were mounted, appreciable rubbing on one side of the model conveyor belt was observed even at lower speeds of the belt. This suggested that the drive pulley may have become misaligned during transportation of the equipment. Subsequent adjustment of the alignment of the drive pulley solved the tracking problem. Similar adjustments were also required on the return conveyor.

It was necessary to use materials other than the bulk samples during the calibration tests in order to avoid using up or segregating the partical size distribution of the prepared muck samples prior to the actual production tests. Up to this point the model conveyor system had not been tested with material in the system. The result was that several additional problems in the component design were discovered during a short period of operation of the system with sand as the material medium. The problems encountered in maintaining a steady flow of material through the system were centered in two main areas:

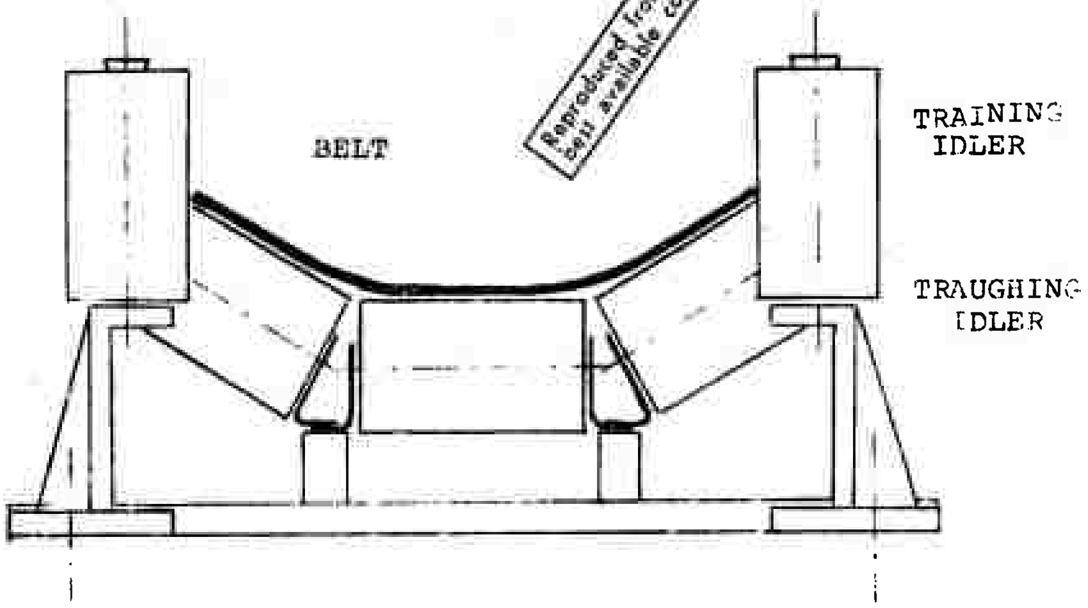


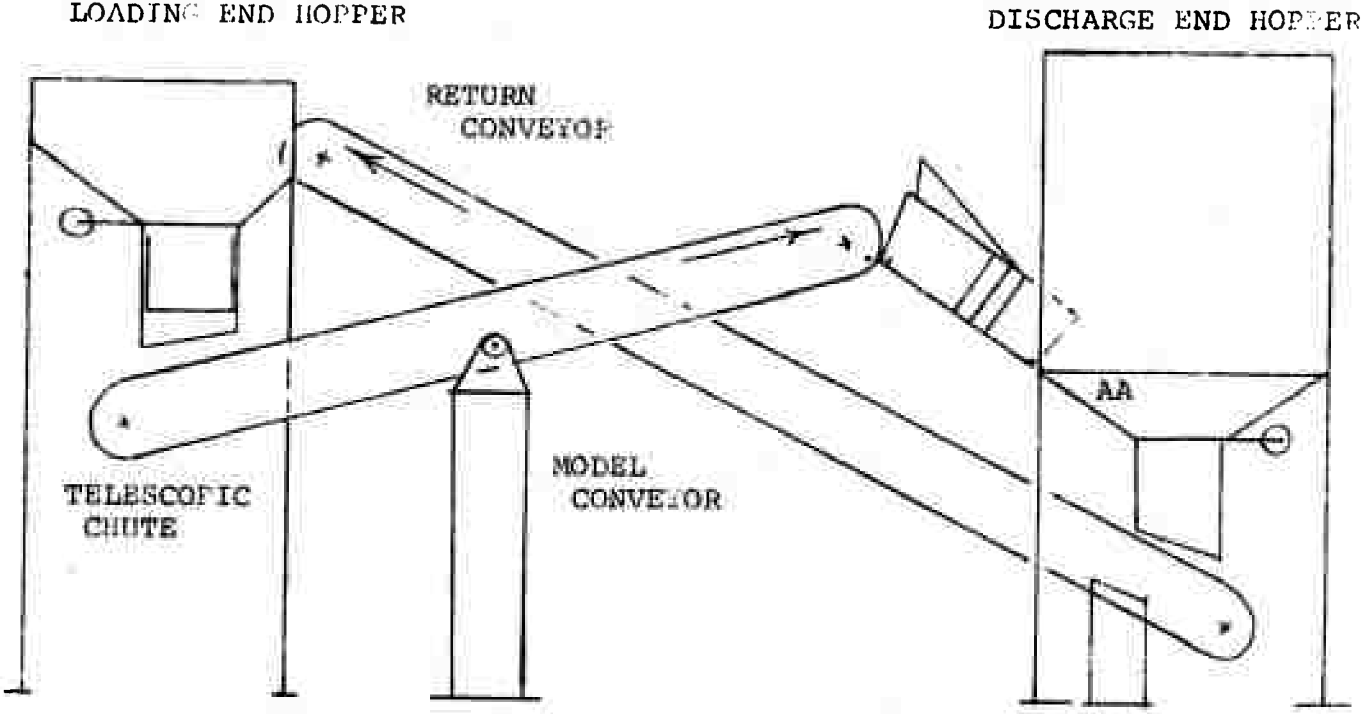
FIGURE 2 TRAINING IDLER IN POSITION.
POSITIVE ACTION TYPE.

(1) at the discharge end of the model conveyor and (2) at the loading end of the model conveyor. Figure 3 shows a schematic diagram of the model conveyor system before modification.

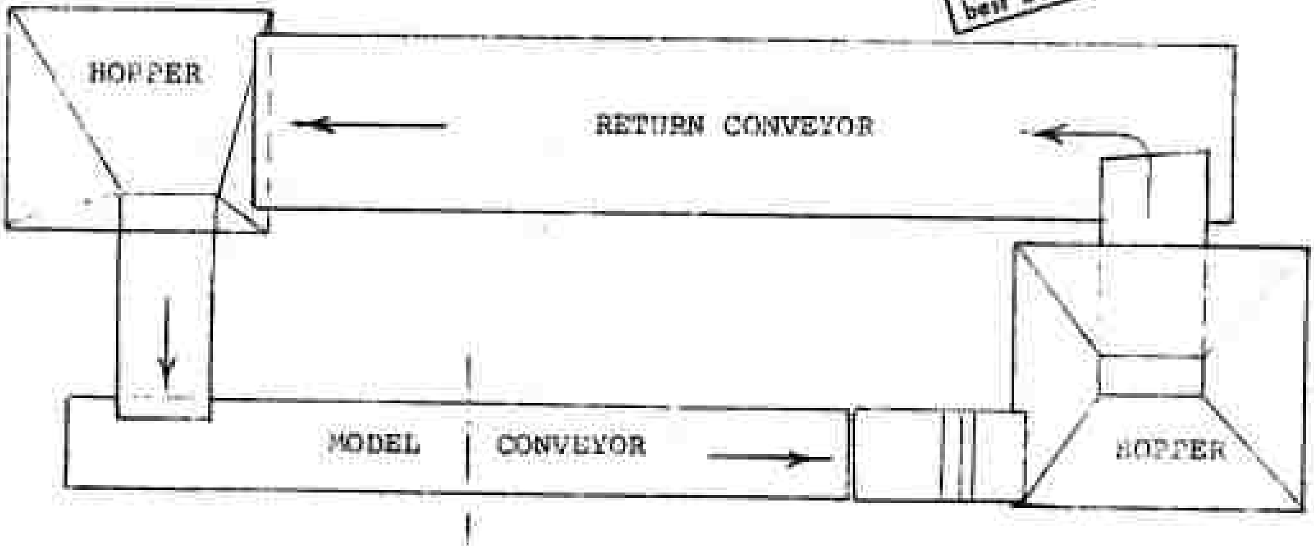
Problems encountered at the discharge end of the model conveyor.

The first major problem was created by the original design of the receiving hopper. The inclination of the walls of the hopper bottom were designed on the assumption that the angle of repose for the dry material would be 20°, whereas the actual angle of repose for the sand (slightly moist) proved to be approximately 27°. As a result, the hopper walls were not sloped at a sufficiently steep angle and material accumulated in the receiving hopper (Point A, Figure 3). The obvious modification of the existing hopper, i.e., steeping the walls, was impossible since the difference in height between the model conveyor discharge end in the horizontal position and the lower end of the return conveyor is fixed. In order to overcome the problem it was decided to eliminate the receiving hopper and build a loading chute for the return conveyor directly from the end of the telescopic chute. Figure 4 shows a sketch of the modified chute built from light gauge galvanized steel sheets. The new loading chute has been found to be quite satisfactory up to two thirds loading capacity of the model conveyor belt. Further modifications and improvements are necessary.

A second problem developed at the transfer point from the loading chute to the return conveyor. The use of a wing take-up pulley on the lower end of the return conveyor led to objectionable vibra-

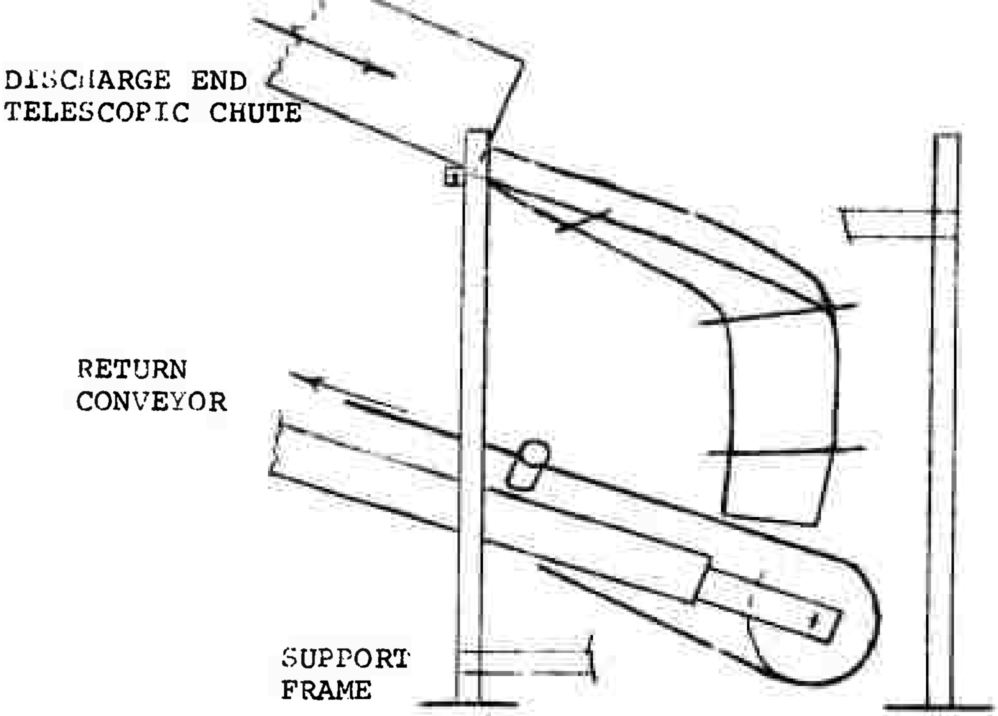


FRONT VIEW

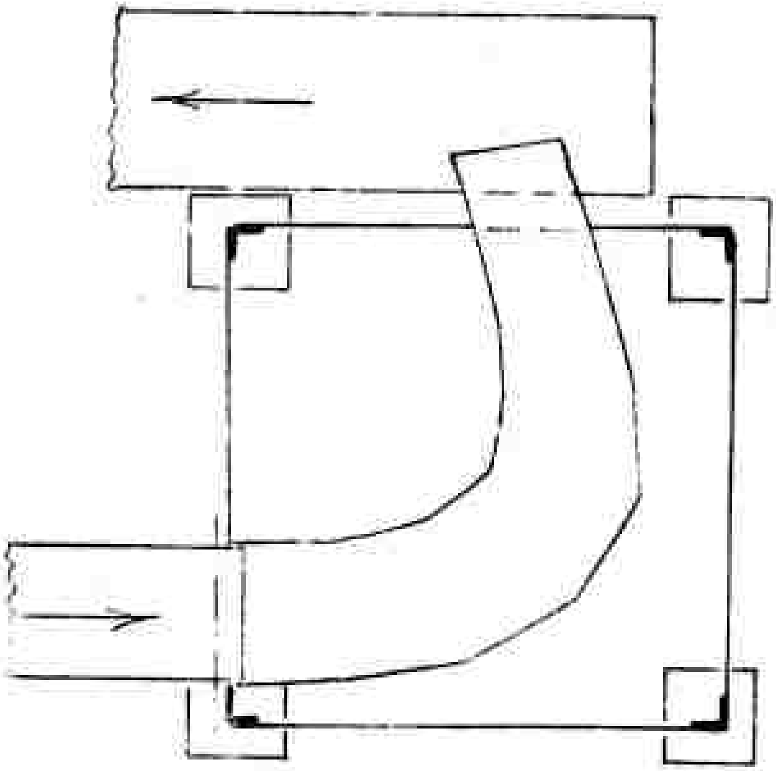


TOP VIEW

FIGURE 3 BLOCK DIAGRAM OF CONVEYOR SYSTEM (BEFORE MODIFICATIONS).



FRONT VIEW



TOP VIEW

FIGURE 4 MODIFIED DISCHARGE END LAYOUT.

tions of the belt at the loading point which, in turn, made it difficult to load the belt without excessive spillage. This problem was solved by mounting a straight roller just beyond the wing take-up pulley which reduced the vibrations to an acceptable level. The same problem occured at the loading end of the model conveyor and was resolved in the same manner.

Problems encountered at the loading end of the model conveyor.

The inclination of the model conveyor bed is adjustable within a range from 0° to 20°. This unusual feature requires the loading end to extend 40 inches downward from the horizontal position for a maximum inclination of 20°. As a result the angle of the telescopic chute connecting the loading end hopper and skirts must vary from 20° to 58° with the horizontal. Consequently, the slope of the telescopic loading chute becomes exceedingly steep with the model conveyor bed inclination as low as 8°, causing the material to impact on the conveyor belt with a very high momentum. Furthermore, the horizontal component of the flow velocity vector is perpendicular to the direction of the belt travel. These conditions made it extremely difficult to load the model conveyor belt uniformly and avoid spillage. The problem was resolved by fabricating adjustable baffle plates on the loading chute. Figure 5 shows the arrangement of baffle plates on the telescopic chute. Except for the somewhat time consuming adjustments required with each change in inclination of the conveyor bed, the loading chute is now functioning satisfactorily.

The second major difficulty encountered at the loading end of

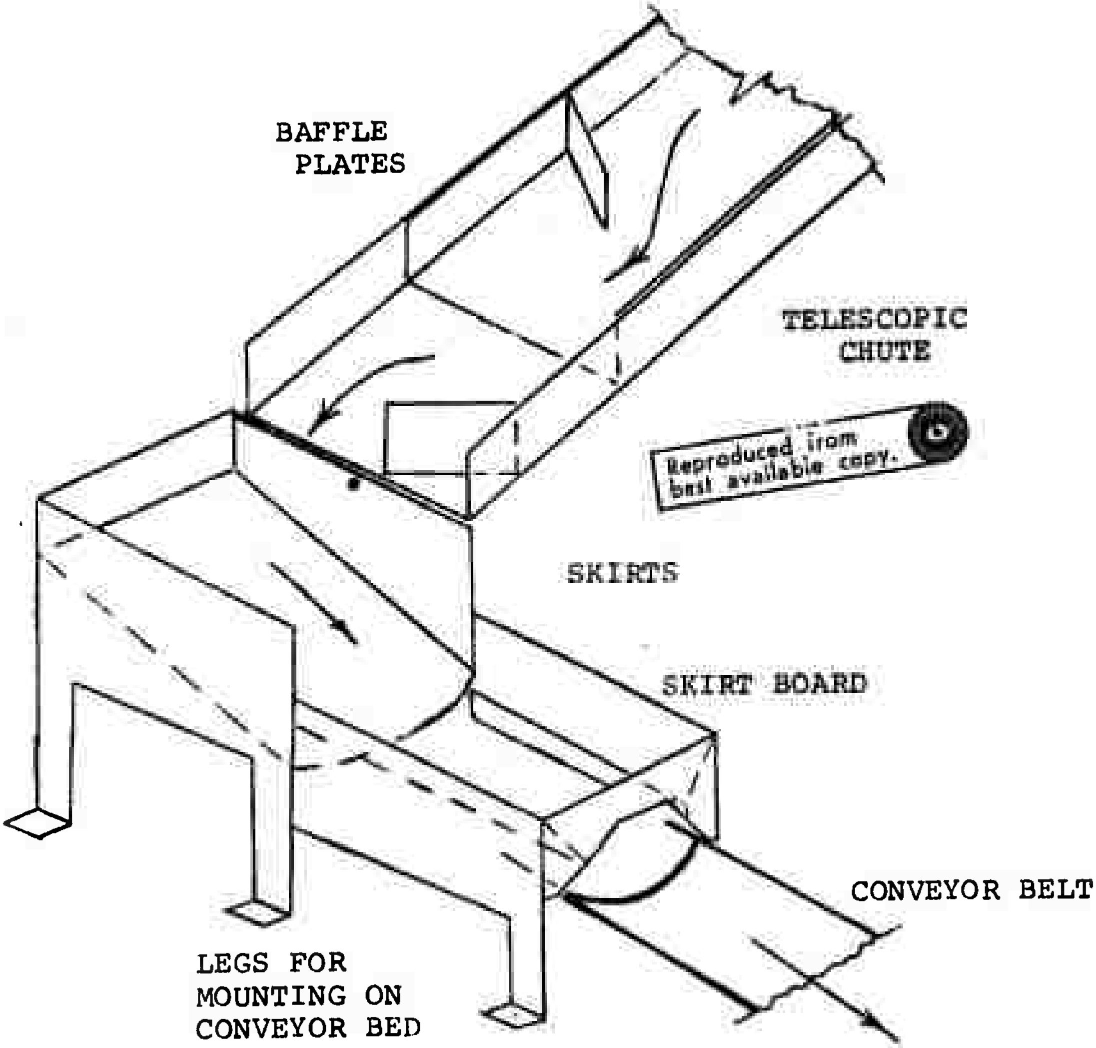


FIGURE 5 MODIFIED LOADING END LAYOUT

the model conveyor involved the design of the skirts and skirt board. Because of the unusually narrow width of the model conveyor belt, standard loading chute design could not be employed. The original chute design did not account for the fact that the momentum of the material approaching the skirts is at right angles to the direction of belt movement. Thus, appreciable loading difficulties, such as uneven loading and excessive spillage, were encountered. Moreover, the length of the skirt board was not sufficient to allow the material to settle down on the belt. An obvious solution to the problem would be to load the material on the belt in the direction of the belt movement. However, the range of slope angles required of the telescopic chute and the overall layout of the system virtually eliminated this possibility. The problem has been temporarily resolved by constructing an additional chute box located behind the skirts as shown in Figure 5. With the present configuration, the material is first dropped in the chute box and from there it feeds onto the belt with a small momentum in the direction of the belt movement. This arrangement has proven to be quite satisfactory and produces uniform loading of the belt over a wide range of belt speeds.

After the necessary modifications in the model conveyor system had been accomplished, a preliminary series of tests was run to evaluate the overall performance characteristics of the conveyor system and the effectiveness of the statistical, experimental design approach as a means of optimizing conveyor design.

A detailed discussion and analysis of these preliminary experiments is presented in the following section of this report.

BELT CONVEYOR SYSTEM SIMULATOR

The design and construction of a belt conveyor system simulator is complete, and a plan for future experimentation has been tentatively laid out. Figure 6 shows the photograph of the belt conveyor system simulator. It is extremely difficult to measure and study the profile of the material on the conveyor belt when the belt is moving at a high speed. With the help of the belt conveyor simulator it could be possible to simulate the profile of the material on the model belt conveyor. Although the design of the simulator is not as versatile as that of the model conveyor, in terms of different variables of the conveyor system, a few of the important variables could be studied for their possible influence on the profile of the material on the conveyor belt. For instance, the belt speeds up to 400 fpm can be simulated, with different troughing angles and fixed idler spacings, on the simulator. It is emphasized here that since a simulation is merely an approximation of the actual conditions, the results obtained must be carefully interpreted.

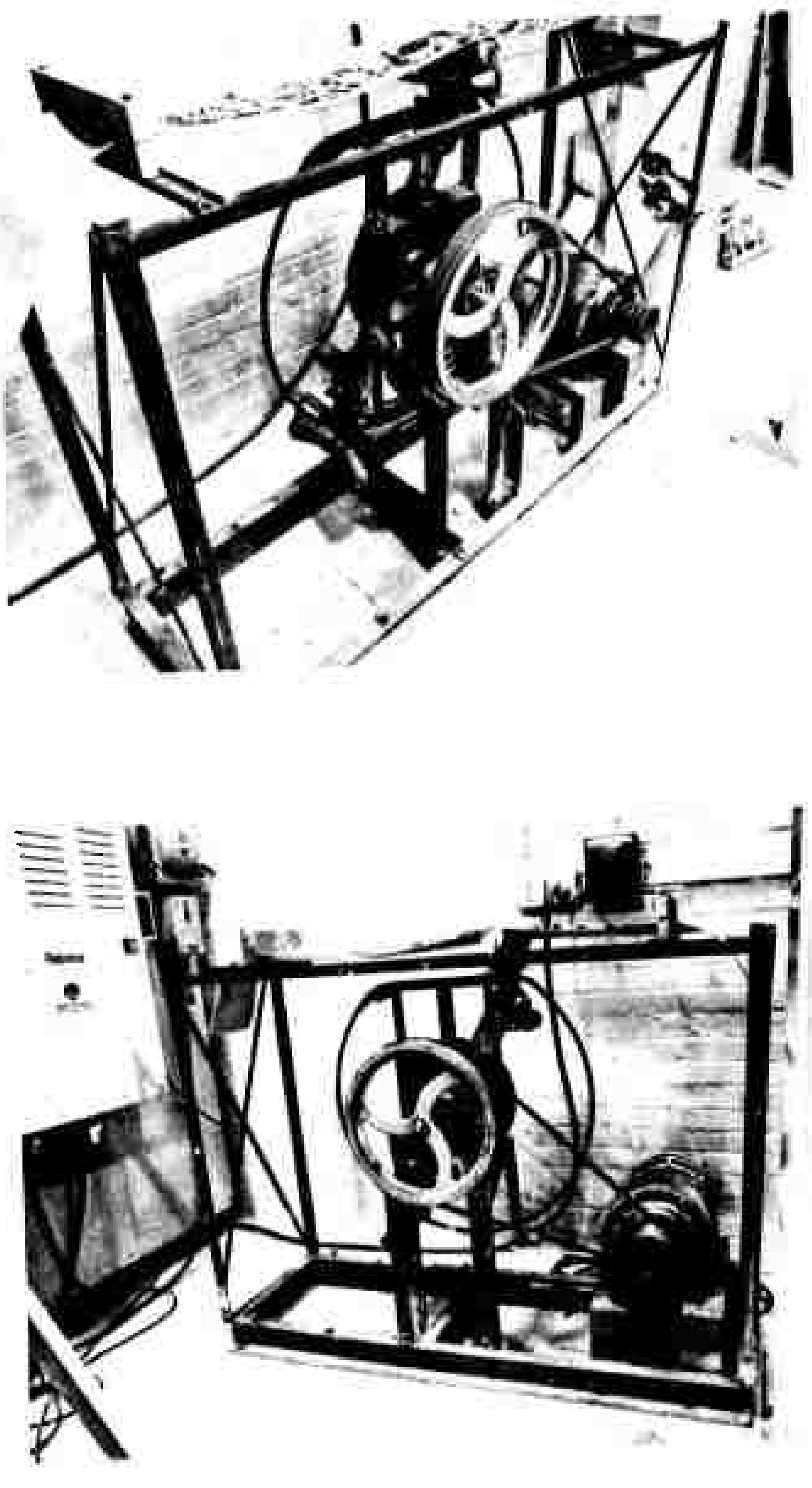


Figure 6. Belt Conveyor System Simulator.

CHAPTER 3

EXPERIMENTAL RESULTS AND ANALYSIS

EXPERIMENTAL DESIGN

A statistical experimental design approach was used to establish a comprehensive fractional factorial experimental design. The advantages derived from statistical experimental design are exhaustive analysis and easier interpretation of the results with high efficiency in time and cost. Because of the uncertainty regarding the number of significant variables in the conveyor system and their effects, it was decided to investigate, initially, only those variables which would provide direction for successive analysis without undo confounding.

Five variables at two levels each were selected as follows:

	Variables	Low level(-)	High level(+)
(A)	Bed Inclination	5°	10°
(B)	Idler Spacing	2'	4'
(C)	Troughing Angle	20°	35°
(D)	Belt Tension	82 lb.	114 lb.
(E)	Total Weight of Material in the System	150 lb.	200 lb.

A 2^{5-1} fractional factorial, resolution V, design was employed. The design matrix is presented in Table 1. In this design, two factor interactions are confounded with three and higher factor interactions. This type of experimental design is very efficient and it is the next best design in terms of confounding pattern to

Test No.	A	B	C	D	E	AB	AC	AD	AE	BC	BD	BE	CD	CE	DE
1	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+
2	+	-	-	-	+	-	-	-	+	+	+	-	+	-	-
3	-	+	-	-	+	-	+	+	-	-	-	+	+	-	-
4	+	+	-	-	-	+	-	-	-	-	-	-	+	+	+
5	-	-	+	-	+	+	-	+	-	-	+	-	-	+	-
6	+	-	+	-	-	-	+	-	-	-	+	+	-	-	+
7	-	+	+	-	-	-	-	+	+	+	-	-	-	-	+
8	+	+	+	-	+	+	+	-	+	+	-	+	-	+	-
9	-	-	-	+	+	+	+	-	-	+	-	-	-	-	+
10	+	-	-	+	-	-	-	+	-	+	-	+	-	+	-
11	-	+	-	+	-	-	+	-	+	-	+	-	-	+	-
12	+	+	-	+	+	+	-	+	+	-	+	+	-	-	+
13	-	-	+	+	-	+	-	-	+	-	-	+	+	-	-
14	+	-	+	+	+	-	+	+	+	-	-	-	+	+	+
15	-	+	+	+	+	-	-	-	-	+	+	+	+	+	+
16	+	+	+	+	-	+	+	+	-	+	+	-	+	-	-

Table 1. Design Matrix

the full factorial design.

Confounding relationships are obtained by the defining relation,

$$I = -ABCD \cdot E$$

It can be assumed, without loss of generality, that three and higher factor interactions are negligible.

For effective quantitative evaluation of the system it is important to accurately determine the amount of material carried on the belt under various experimental conditions. The possibility of using continuous weighing equipment or collecting material for a known time period was examined. After studying several possible techniques of collecting material from the system, it was concluded that this method of determining the amount of material carried by the belt would be extremely cumbersome and would require additional modifications to the system. Therefore, an alternative method was developed which is believed to be both more efficient and more accurate in the present experimental set-up.

The present experimental set-up constitutes a closed-loop system. If the total amount of material in the system is predetermined and kept constant during the test, then under steady state conditions, the amount of material flowing through a particular section is constant if the belt speed is held constant and there is no accumulation of material at any point in the system (e.g., hopper and chutes).

If T is the period of the system under a given set of conditions, i.e., the time required for a particular particle to pass through one complete cycle, and W is the total weight of material in the system, then $\frac{W}{T}$ is the average rate of flow of material (weight of material per unit time) at any point in the system. Furthermore, T can be expressed as,

$$T = t_m + t$$

where, t_m is the time required for a particle to travel across the model conveyor belt and t is the time required for a particle to travel through the rest of the system. It is apparent that t can be assumed to be constant for a steady state condition. Hence, if t is known and t_m is calculated for a given belt speed, T can be easily determined.

Once the rate of flow of material, $\frac{W}{T}$, is computed, the weight of material per unit length on the model conveyor belt can be evaluated. If V is the belt speed in ft. per min. and T is the period in minutes, then the load per foot of belt length is

$$q = \frac{W}{TV} \quad \text{(lbs. per foot of belt length)}$$

EXPERIMENTAL PROCEDURE

The experimental procedure was carried out in the following manner. Because of the reasons mentioned earlier, sand was used as the material medium in the system. Complete random selection of tests from the design matrix was considered impractical since the amount of material in the system could not be conveniently varied. Therefore, all the tests with the same level of total weight of material in the system were combined into one set. For a selected test, convenient levels of each variable were established in the system. The model conveyor was first operated at various speeds without material on the belt, and "noload" readings of the electrical power required to drive the model conveyor belt were recorded with a watt meter for each belt speed. Then the flow rate control gate on the hopper was gradually opened completely and the flow was maintained until steady state conditions were achieved and it could be determined that there was no material accumulation at any point in the system. After steady state conditions were established, watt meter readings were recorded. This process was repeated for a range of belt speeds. All 16 tests were conducted in a similar manner and the results tabulated. A sample data sheet is presented in Table 2.

RESULTS AND ANALYSIS

Table 4 shows the power required to carry material on the model conveyor belt for a given set of experimental conditions and are listed in the same order as that of Table 1. The power required to carry material is determined by subtracting the "noload" power reading from the "load" power reading. The average period for various belt speeds and the corresponding rate of flow of material are tabulated in Table 3.

The main effects and interaction effects due to all the variables can be computed from Table 4 and Table 1. If the elements of column D in Table 1 are multiplied with the corresponding elements of the columns in Table 4, the algebraic sum of these quantities, divided by eight, yields the main effect due to variable D at a particular belt speed. For example, the main effect due to variable D,

DATA SHEET

BED INCLINATION 5°

IDLER SPACING 4'

TROUGHING ANGLE 35°

MOISTURE CONT. ______

SHEET NO. 7

TOTAL WT. OF MAT. 150 lb.

TYPE OF MAT. SAND

BELT TENSION 82 lb.

OBS. (NO.)	SPEED (R.P.M.)	POWER BELT LOADED (WATTS)	POWER NO LOAD (WATTS)	TIME PERIOD (SEC.)			Q lb./min.	q lb./ft.
				RUN 1	RUN 2	RUN 3		
	60							
	70	190	165	19	18.1		472	1.6
	80	220	190	18	18.5		484	1.4
	90	245	212	17.5	18		503	1.3
	100	275	246	17.3	17.9		513	1.2
	110	308	275	17.1	16.8		521	1.1
	120	345	320	16.3	16.9		530	1.0
	130							
	140							

Table 2. Sample Data Sheet

R.P.M.	BELT SPEED fpm	PERIOD SEC.	Q, lb./min.		q, lb./ft.	
			E(-) 150 lb.*	E(+) 200 lb.*	E(-) 150 lb.*	E(+) 200 lb.*
70	303	19.05	472	661	1.6	2.2
80	347	18.58	484	678	1.4	2.0
90	390	17.90	503	704	1.3	1.8
100	433	17.56	513	718	1.2	1.7
120	520	17.0	530	741	1.0	1.4

* Total weight of material in the system

Table 3. Average periods and rates of flow of material for low and high levels of total weight of material in the system (Variable E).

Test No.	DRIVE PULLEY SPEED, R.P.M. 70	80	90	100	110	120
1	20	21	17	20	20	25
2	37	40	43	43	42	45
3	33	35	40	45	45	46
4	28	30	27	30	27	30
5	22	28	28	23	23	34
6	23	23	25	26	30	28
7	25	30	33	29	33	25
8	40	40	40	40	41	43
9	20	19	25	22	18	18
10	26	27	24	25	25	30
11	15	17	17	18	20	25
12	40	41	48	45	48	50
13	21	18	20	19	24	24
14	32	36	38	35	33	30
15	30	27	35	35	32	32
16	25	27	21	27	23	28

Table 4. Power Required to Carry Material on Conveyor Belt (Watts).

the drive pulley speed of 100 rpm, is calculated as follows:

$$-20 - 43 - 45 - 30 - 23 - 26 - 29 - 40 = X$$

$$22 + 25 + 18 + 45 + 19 + 35 + 35 + 27 = Y$$

main effect of variable D at drive pulley speed of

$$100 \text{ rpm} = \frac{X + Y}{8} = -3.75$$

A complete tabulation of main effects and two factor interactions is presented in Table 5.

The "effect" of a variable is the change in response produced by a change in the level of the variable. When a factor is examined at two levels only, as in the present case, the effect is simply the difference between the average response of all tests conducted at the lower level of the factor and the average response of all tests conducted at the higher level.

The effect of one factor also depends on the level of other factors, and the factors are said to interact. Interpretation of main effects and interactions is a difficult concept and it largely depends upon intuition of the investigator and it is a powerful tool in data analysis of statistical experiments.

Many useful conclusions can be drawn from Table 5. In the first place, the consistency in main effects and interactions over the speed range is quite apparent. This suggests that over a selected belt speed range, the influence on the response, in terms of the power required to carry material, due to all the five variables and their interactions, remains unchanged. Secondly, the main effect due to variable E, the total weight of material in the system, has the largest magnitude and a positive sign. The magnitude

Effects	DRIVE PULLEY SPEED, R.P.M.					
	70	80	90	100	110	120
A	8.125	8.625	6.375	7.5	7.0	6.875
B	4.375	4.375	5.125	7.0	7.0	5.625
C	0.125	-.125	-.125	-1.75	-1.0	-3.125
D	-2.375	-4.375	-3.125	-3.75	-5.0	-4.875
E	8.875	9.125	14.125	11.75	9.75	10.875
AB	-.625	-1.375	-6.875	-3.75	-4.25	-1.125
AC	-2.625	-2.875	-4.375	-2.0	-.75	-3.375
AD	1.125	3.875	2.125	2.0	1.75	2.875
AE	2.875	3.375	3.875	2.0	4.5	2.625
BC	1.125	0.375	1.375	0.0	2.25	3.125
BD	-1.625	-1.375	-1.625	-1.0	-1.25	2.625
BE	3.625	0.625	2.125	3.5	5.5	5.375
CD	1.875	1.125	.125	3.25	1.25	0.875
CE	-1.375	-.875	-3.625	-3.75	-5.0	-1.875
DE	-.125	0.75	1.875	0.25	0.0	-4.625

Table 5. Main Effects and Two Factor Interactions of Five Variables.

of the effect suggests that the power required to carry material on the conveyor belt changes very rapidly with the quantity of material carried on the belt and the positive sign emphasis that power requirements increase with an increase in quantity of material. Another large effect is due to variable A, bed inclination. This can be similarly interpreted.

A very interesting effect is observed due to variable D, belt tension. The negative sign of the main effect suggests that the power required to carry material on the belt reduces with increasing belt tension. Although this characteristic is observed for a selected belt tension range, the result may be of some significance in belt conveyor design. Further detailed discussion and interpretations would be premature at this stage since detailed analyses involving a significance test and regression analysis is required. These analyses will be carried out in the near future.

Graphical representation of the results is also useful in the analysis of the data. The response, in terms of power required to carry material, has been plotted verses conveyor belt speed for three of the variables; namely, bed inclination, idler spacing and total weight of material in the system. These response curves are shown in Figures 7 through 9. Since the rest of the main effects and interaction effects are not appreciably high, their graphical representation will be discussed after further statistical analysis. Each plotted point on the graph is the average of eight points which can be calculated using Table 1 and data similar to that presented in Table 4. The two curves on the graphs distinctly reveal two levels of response for a particular variable. The distance between the two

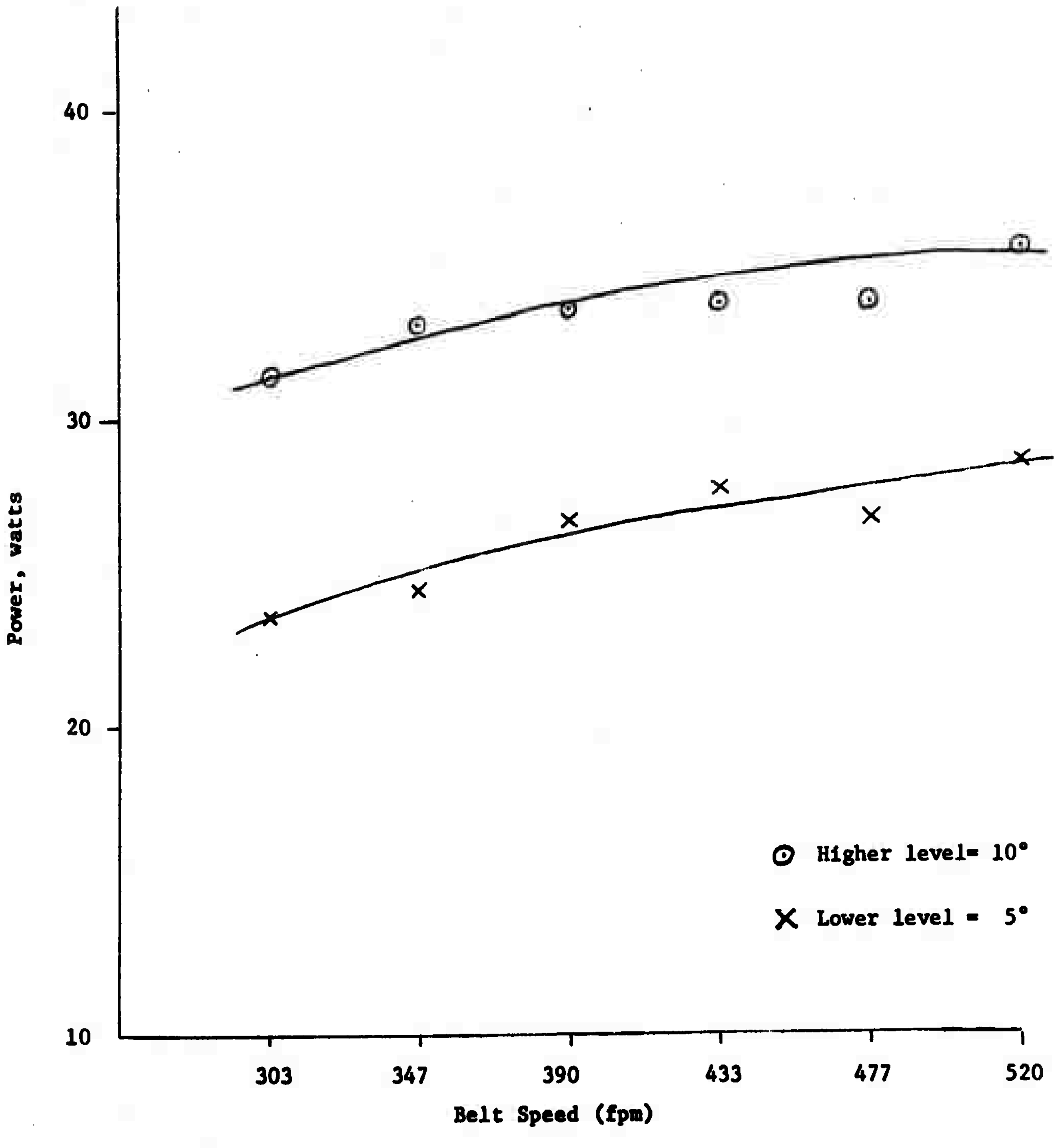


Figure 7. Variable A, Belt Inclination.

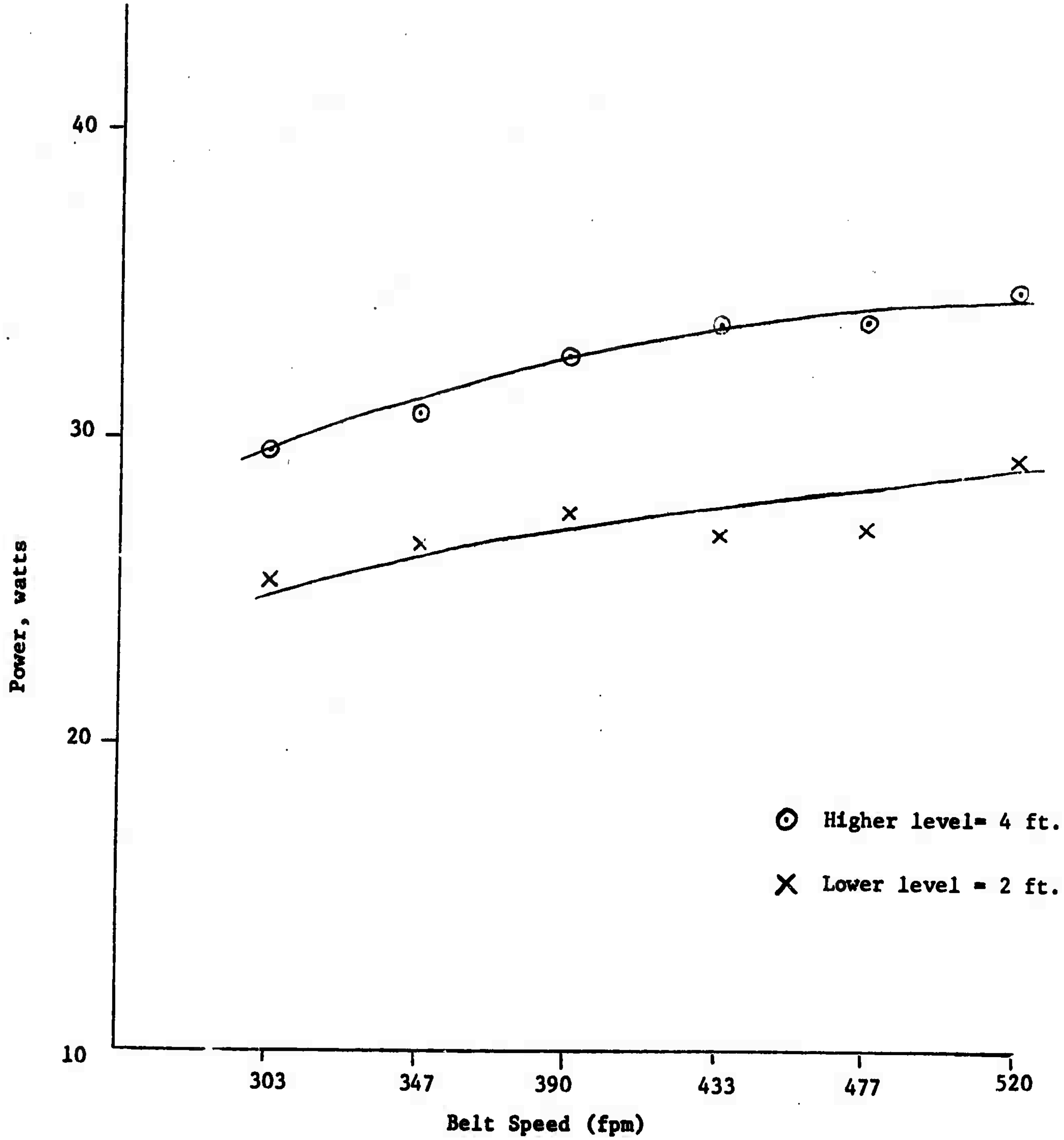


Figure 8. Variable B, Idler Spacing.

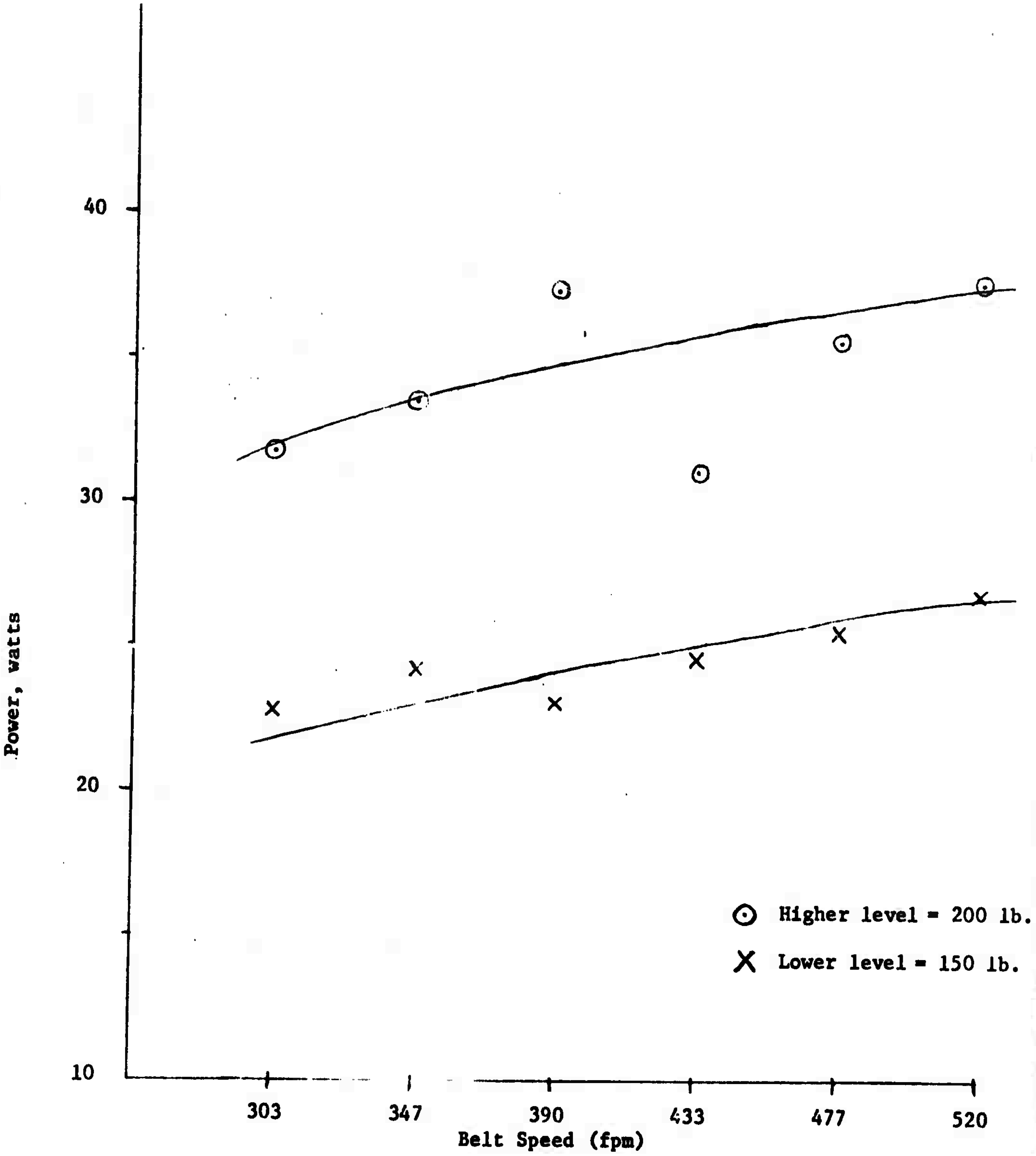


Figure 9. Variable E, Total Wt. of Material in the System.

curves represents the magnitude of the main effect due to that variable. The graphical presentations of the results are consistent with the previous discussion concerning main effects and interactions.

It is important to note that, for a constant total amount of material in the system, the weight of material per foot length decreases as the belt speed increases. It was also observed that the power required to carry material on the belt decreases with a decrease in the amount of material on the belt. Therefore, if the material load per foot of belt length had been kept constant for all speeds, all the curves in Figures 7 through 9 would have been steeper.

FUTURE PLANS

Future plans for experimentation and modifications of the model conveyor system are as follows:

(1) Efforts will be made to achieve maximum possible loading on the model conveyor belt.

(2) A suitable device for obtaining the profile of material on the belt will be developed.

(3) A more refined power measuring device will be employed. The possibility of obtaining a recording type watt meter is being investigated.

(4) Because of the practical considerations, it may become necessary to use artificially prepared material as a conveying medium in the system.

(5) The results of the experiment conducted to date will be exploited in order to devise a more efficient experimental design.

(6) The loading-end and discharge-end chutes will be further modified to accomodate greater quantities of material in the system.