THE DETERMINATION OF THE DEGREE OF ANGULARITY OF, AND THE DEVELOPMENT OF A VELOCITY CONTROLLING FEATURE FOR, STORAGE CHUTES IN AN AUTOMATIC ORDER PICKING DEVICE

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Erwin Milton Campbell

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AN ABSTRACT

Submitted to the College of Agriculture of
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Forest Products

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AN ABSTRACT

This project was undertaken in an effort to determine the degree of angularity of and the development of a velocity controlling feature for storage chutes in an automatic device that dispenses various products in corrugated cases.

The factors studied consisted of five degrees of elevation (13° through 17°), four weights of products (2.2, 9.4, 21.9, and 24.6 pounds per linear foot), and three types of plastic covered runners.

The test results indicated that 17° was the optimum choice for the angle of incline. Runner type C was far superior to types A and B as a runner for light packages, but was not efficient enough to be used on heavier packages. Both runners A and B were too efficient to be used as runners for heavier packages.

In this report runners are rated according to their ability to resist the movement of packages sliding down the chute. The most efficient runners being those offering enough resistance to prevent any unassisted package movement.

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I. INTRODUCTION

The problems involved in a shipping warehouse are, as one would imagine, many and quite complex. Not the least of these are the high costs of labor and the total time required to assemble for shipment to a customer any given order. As is often the case in industry, the shipping center is viewed as a manufacturing operation that produces customer orders as a product. In this respect the shipping manager is given a budget with which he must manufacture this product. As in all manufacturing operations, spiralling costs force the manager to continually strive to be more efficient by the reduction of any number of such things as space, labor, paper work, inventory or any combinations of these and other items in order to stay within the allowed budget.

Over the past few years there have been many great advances in the techniques of materials handling now in use in the shipping centers of American industry. Mechanization and automation are the key words of progress and as a result such things are seen as smaller, more powerful fork-lift trucks doing a wider variety of jobs, miles and miles of conveyors of various types transporting goods from the more remote sections of the warehouse, closed circuit T.V. systems greatly facilitating location and inspection functions, and electronically guided towing systems that move whole trains of loaded cars without the benefit of an operator. These are only a few of the hundreds of items that could have been mentioned.

Perhaps the most revolutionary innovation in recent years in the materials handling field was the design and construction of an automatic device for the mechanized selection of orders. This machine

consists essentially of a hugh steel structure supporting several tiers of inclined storage chutes. From these gravity-fed chutes, cases of various products are discharged by an electro-mechanical release mechanism. A slightly modified standard business machine interprets data cards, into which the customer's order has been punched, and through a complex timing network provides the electrical impulse to cause the chute containing the right product to release the required number of packages. These packages are then conveyed to the shipping dock and into a highway trailer for the trip to the buyer.

Whole volumes could be written about the many possibilities and economies presented by this type of system. The scope of this thesis will be limited to cover some of the problems encountered during the design of the storage chute.

Purpose of Study

The purpose of this study is to develop a workable method to be used in controlling the velocity of packages sliding down the storage chutes. It is proposed that this be accomplished by coordinating the effects of two unique variables. They are as follows:

1. The angle of incline of the storage chute.
2. The surface condition of the chute on which the package must slide.

The interrelationship of these two variables on the velocity of a sliding package is readily apparent. That is to say that, for a given package, the steeper the angle of incline the easier it is to overcome inertia and sliding friction. And, on the other hand, any surface change resulting in a reluction of static or kinetic friction encountered

by the package could bring about a proportional reduction in the angle of incline, if all other factors are held constant.

The storage chutes are, of course, filled from the upper end. In order for the corrugated cases to freely slide to the lower or dispensing end of the chute a certain amount of friction must be overcome. This friction occurs in two situations. The first situation being when a particular chute is empty and the first package must slide the entire length of the chute and then the next package must travel one package length less than the preceding package and so on until the chute is completely filled. The second situation occurs then when individual packages are released from a full chute and the remainder of the stored packages must slide down one package length to take up the space previously occupied so as to be in a releasing position for the next selection impulse should a package from that chute be required.

The design of the overall steel structure must conform to, among other requirements, the available space within the warehouse and the angle of incline at which the storage chutes are to be supported. While this paper is not necessarily concerned with the overall height requirements, the angle of the chute has a direct effect upon the velocity of the corrugate case as it slides down the chute.

II. PROCEDURE

Preliminary investigations showed that on a bare metal chute with no surface improvement, other than dusting, an angle of at least 20° was required to allow packages to easily overcome both frictional restrictions. This condition gave no control over impacts and it was therefore decided to test at 13° to 17° with some type of surface improvement so that packages could be slowed down or speeded up as required.

Due to the wide variation in the dimensions and weights of packages that would be handled in this type of machine, it was originally felt that controls for at least two situations would be needed. Light weight packages would, in most cases, need a surface condition that would tend to keep friction at a minimum and offer as little resistance as possible to package movement. Heavier packages, conversely, would need a surface condition that would tend to slow them down in order to prevent the impacts from causing product damage. The delineation point between a light and a heavy package, based on previous experience, was set at twelve pounds.

Runner Specifications

In order to keep friction at a minimum for light packages, it was felt that some type of runners, either triangular or circular in cross-section, would be most suitable. These two shapes would, in theory, allow for only a line of contact between the runner and the packages. The area of contact would be slightly modified due to runner indentation on the package or by relaxation of the package structure caused by high

humidity or longer than usual storage time.

The material selected must either be rigid or fastened in a manner so as to allow little lateral motion, thereby preventing packages from becoming wedged between the runners or between one runner and the side of a chute and, of course, the material used must be easily installed, physically and chemically stable, and economical to obtain.

A wire, stretched the length of the chute, on which could be strung various types of plastic tubing, appeared to fit all specifications. It was decided to test and compare three types of such plastic covered runners as follows:

Type A - High Density Polyethylene with 5% Carbon Black

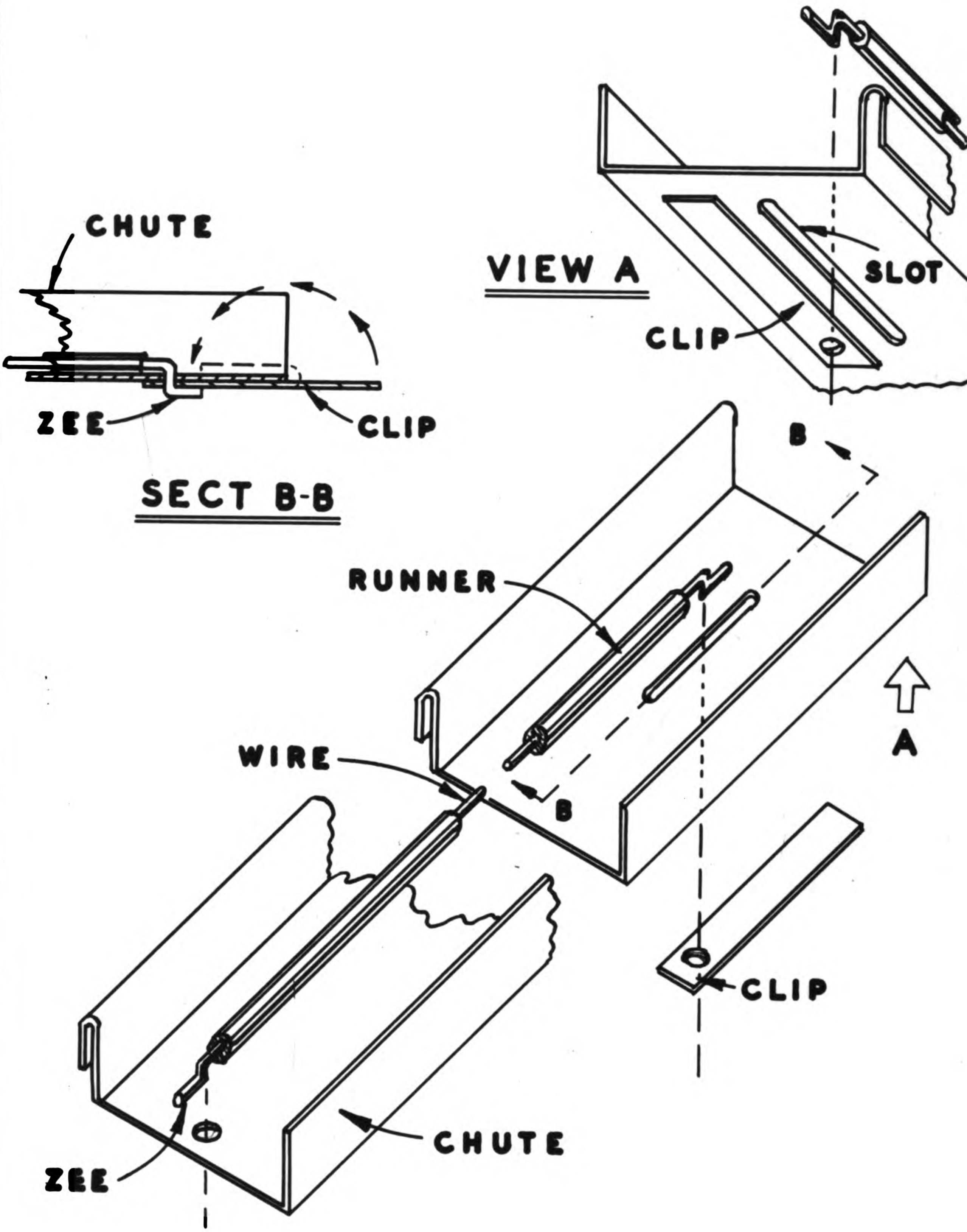
Type B - Nylon

Type C - High Density Polyethylene

Runners are to be installed in pairs, as shown in Figure One, with a minimum of two runners per chute. Wider chutes will have as many pairs of runners as are required to support the wider packages.

Testing Device

A laboratory testing device was constructed as shown in Figure Two. The various cross members upon which the chutes are supported are adjustable so as to accommodate several degrees of inclination. A short, powered belt-conveyor was located at the discharge end so that packages could automatically be released and removed in order to test the action of the runners during intermittant operation. The runners in the chutes, as well as the chutes themselves, are wholly interchangeable on this testing device.



DIAGRAMATIC VIEW OF RUNNER INSTALLATION

LABORATORY

TESTING RACK

Products Tested

The packages used for testing were selected to be a representative group. Both the length and the weight of the package are critical factors, therefore, the number of pounds per linear foot of carton was used as a measuring classification. The lightest package tested weighed 2.2 pounds per foot. The next heavier package weighed 9.4 pounds per foot. The third package weighed 21.9 pounds per foot and the heaviest package weighed 24.6 pounds per foot (See Table I). It was anticipated that the more troublesome items would be the heavier packages and, therefore, a low heavy package was tested as well as a tall heavy package. No attempt was made to classify cartons by either the Mullen test or by the carton manufacturers, except that all test cartons for any given product were made of similar material by the same manufacturer. The effect of these qualities on the tests is not known but is assumed to be negligible.

Statistical Design

An automatic machine such as described earlier in this paper would be capable of selecting and dispensing cartons at speeds of fifty cartons per minute or faster. In order to fully utilize these speeds to advantage, the runners should not be so efficient[1] so as to cause the packages to take more than twenty seconds to travel the length of the chute. On the other hand, the packages should not be allowed to gain sufficient momentum that would cause heavy packages to damage the release mechanism or light packages to jump out of the chute on impact.

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[1]For the purposes of this paper, the most efficient type of runner is defined as one whose physical and/or chemical make-up is such that packages will not slide on them unaided.

TABLE I

DIMENSIONS AND WEIGHTS OF TEST SPECIMENS

PRODUCT	DIMENSIONS L	W (Inches)	H	WEIGHT Wt. (Pounds)	$\frac{12\ (wt)}{L}$ (lbs/ft)
1.	12-3/4	11	6-1/2	26	24.6
2.	11-1/2	9-1/4	7-3/4	9	9.4
3.	13-3/4	12-3/4	10	25	21.9
4.	16-1/4	13-1/4	10-1/2	3	2.2

As a measure to test the effectiveness of combinations of runner, product, and degree of incline for this report, the time required for a package to travel the length of the chute was used.

For each three way combination of product, runner, and degree of incline, five time trials were observed and recorded.

Testing Procedure

The test packages were placed on the upper end of the chute and held until a signal was given. At that time the packages were released and started down the chute. When the package reached the bottom of the chute the elapsed time was recorded to the nearest one-hundredth of a minute. If at the end of five minutes, however, the package had not yet reached the bottom, that particular trial was stopped and a time of 5.0 minutes was entered. A total of three hundred time trials were recorded.

Testing was started with the rack set at 13° with type A runners. After the required number of time tests, the runners were changed to type B and then to type C. After finishing the tests on the C runners, the angle of inclination was raised one degree at which point all three runner types were tested again. This process was then repeated until all three hundred tests were conducted (See Tables II through VI).

TABLE II

ELAPSED TIMES

	13^{o}			
	PRODUCTS			
RUNNERS	1	2	3	4
A	2.80	1.70	5.00	5.00
	2.00	5.00	5.00	5.00
	1.10	5.00	5.00	5.00
	1.60	5.00	4.00	5.00
	2.00	2.00	2.70	5.00
B	5.00	0.17	0.18	0.22
	5.00	0.18	0.17	0.14
	0.31	0.14	0.14	0.13
	0.31	0.12	0.12	0.13
	1.60	0.14	0.13	0.13
C	0.11	0.19	0.16	0.25
	0.17	0.11	0.10	0.28
	0.13	0.14	0.11	0.30
	0.17	0.16	0.12	0.23
	0.17	0.13	0.11	0.19

TABLE III

ELAPSED TIMES

	14°			
	PRODUCTS			
RUNNERS	1	2	3	4
A	5.00	0.89	0.14	5.00
	1.60	0.92	0.12	0.95
	1.70	5.00	0.20	0.88
	5.00	5.00	0.12	0.75
	2.30	1.70	0.21	0.87
B	0.10	0.10	0.18	0.23
	0.12	0.13	0.13	0.15
	0.10	0.16	0.10	0.14
	0.12	0.10	0.12	0.11
	0.16	0.13	0.16	0.20
C	0.10	0.10	0.10	0.11
	0.11	0.09	0.10	0.10
	0.14	0.10	0.11	0.10
	0.12	0.10	0.07	0.12
	0.15	0.11	0.13	0.12

TABLE IV

ELAPSED TIMES

	15°			
	PRODUCTS			
RUNNERS	1	2	3	4
A	0.18	0.10	0.17	0.48
	0.25	0.15	0.16	0.75
	0.15	5.00	0.11	0.21
	5.00	5.00	0.18	0.68
	5.00	0.27	0.30	0.13
B	5.00	0.20	5.00	5.00
	0.58	0.10	0.12	5.00
	5.00	0.10	0.50	5.00
	0.11	0.11	0.14	5.00
	0.09	0.95	0.11	0.13
C	0.09	0.09	0.08	0.12
	0.08	0.09	0.08	0.09
	0.10	0.10	0.10	0.10
	0.09	0.09	0.08	0.10
	0.10	0.10	0.09	0.09

TABLE V

ELAPSED TIMES

16°

	PRODUCTS			
RUNNERS	1	2	3	4
A	0.16	0.10	0.12	0.14
	5.00	0.09	0.12	0.15
	0.28	0.11	0.11	0.13
	0.13	0.11	0.10	0.15
	0.17	0.15	0.13	0.17
B	0.22	0.15	0.18	5.00
	5.00	0.12	0.15	5.00
	0.36	0.09	0.07	5.00
	0.09	0.08	0.08	0.09
	0.10	0.08	0.08	0.08
C	0.08	0.08	0.07	0.08
	0.09	0.09	0.07	0.08
	0.09	0.08	0.08	0.08
	0.10	0.06	0.07	0.08
	0.11	0.13	0.10	0.09

TABLE VI

ELAPSED TIMES

	17^{o}			
	PRODUCTS			
RUNNERS	1	2	3	4
A	0.13	0.09	0.10	0.12
	0.13	0.09	0.10	0.13
	0.13	0.11	0.09	0.13
	0.12	0.12	0.09	0.16
	0.11	0.08	0.09	0.11
B	0.16	0.08	0.07	5.00
	0.08	0.07	0.10	0.24
	0.09	0.08	0.07	5.00
	0.09	0.08	0.07	0.08
	0.09	0.07	0.09	5.00
C	0.07	0.07	0.07	0.09
	0.08	0.08	0.07	0.07
	0.05	0.10	0.09	0.09
	0.06	0.07	0.06	0.05
	0.10	0.07	0.05	0.07

III. ANALYSIS OF DATA

The data presented in Tables II through VI were subjected to a three factor analysis of variance including products (1, 2, 3, and 4), degrees (13°, 14°, 15°, 16°, and 17°), and runners (A, B, and C). The techniques and procedures used are those described in references (2), (3), and (4). The results of the analysis are shown in Tables VII and VIII.

The analysis of variance revealed that the three-way interaction, degree x runner x product, to be significantly different from the error term. This led to the use of the three-way interaction mean square as the error term to obtain F test scores. As a result of this test it was found that only two of the three main effects, namely degrees and runners, were significant. Using the Studentized Range Test, the averages for degrees and runners (see Table VII) were tested for significance between themselves.

Angle of Incline

Of the five degree levels tested, only the average at 17° is acceptable for being less than the time limit of twenty seconds as described on page seven. Statistically, however, 17° was not significantly different than 16°. Further cause for rejection for 16°, as well as the more shallow angles, is the number of five minute time trials in each case. This is an unallowable situation. The author is at a loss to explain why 14° of inclination appeared to function better than 15°.

TABLE VII

SUMMARY OF TEST RESULTS
SHOWING AVERAGE ELAPSED TIMES
BY MAIN EFFECTS

Runner	A	1.47
	B	0.94
	C	0.11
Degree of Inclination	13°	1.54
	14°	0.72
	15°	1.07
	16°	0.52
	17°	0.34
Product	1	0.99
	2	0.67
	3	0.47
	4	1.23

TABLE VIII

FINAL ANALYSIS OF VARIANCE

Source	DF	Sum of Squares	Mean Square	F	$F_{0.95}$	$F_{0.99}$
Total	299	790.99				
Degrees	4	54.90	13.73	3.12*	2.78	4.22
Products	3	25.95	8.65	1.96	3.01	
Runners	2	95.10	47.55	10.08**	3.40	5.61
D.P	12	18.21	1.52	0.35	2.18	
D.R	8	148.21	18.53	4.53**	2.36	3.36
P·R	6	42.65	7.11	1.61	2.51	
D·P·R	24	105.81	4.41			
Error	240	300.16	1.25			

*Significant at the 5% level.

**Significant at the 1% level.

Runners

When the runner averages are compared, it is very obvious that only type C performed adequately and that the other two were far too efficient to permit their use in this manner. The studentized Range Test showed that C was significantly different from A and B and that B was significantly different from A.

Two regression curves were calculated for each runner (See Figures 3 and 4). One curve plotted total elapsed time against degree of incline and the second curve plotted total elapsed time against the pounds per linear foot of package. It was hoped that these would result in fan-shaped arrays and except for the erratic behavior of type-B runner this was the case. When other materials are tested, similar curves can be constructed and runner selection could eventually, under ideal conditions, become a graphical procedure.

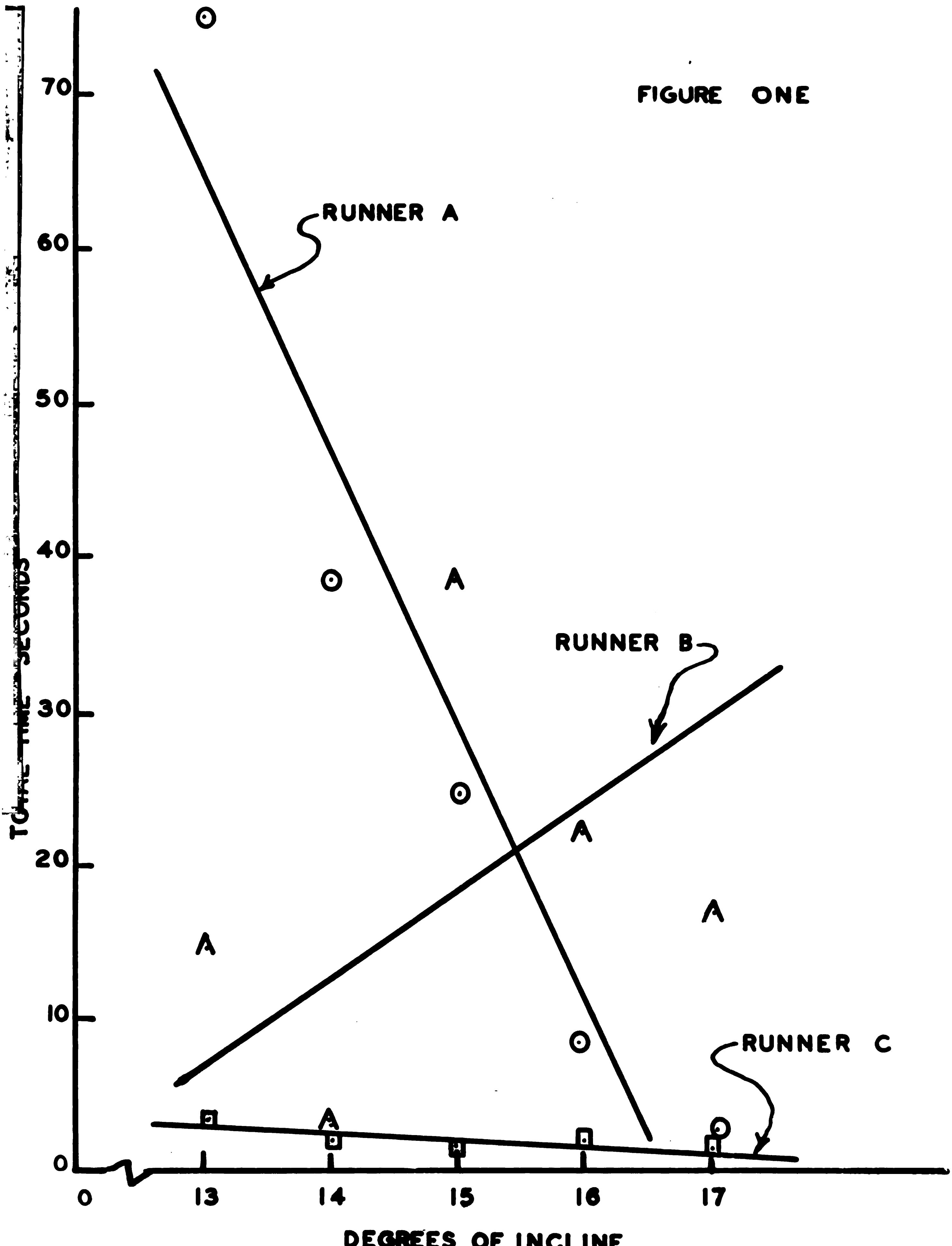
FIGURE ONE
RUNNER A
RUNNER B
RUNNER C
TOTAL TIME SECONDS
0
10
20
30
40
50
60
70
0
13
14
15
16
17
DEGREES OF INCLINE

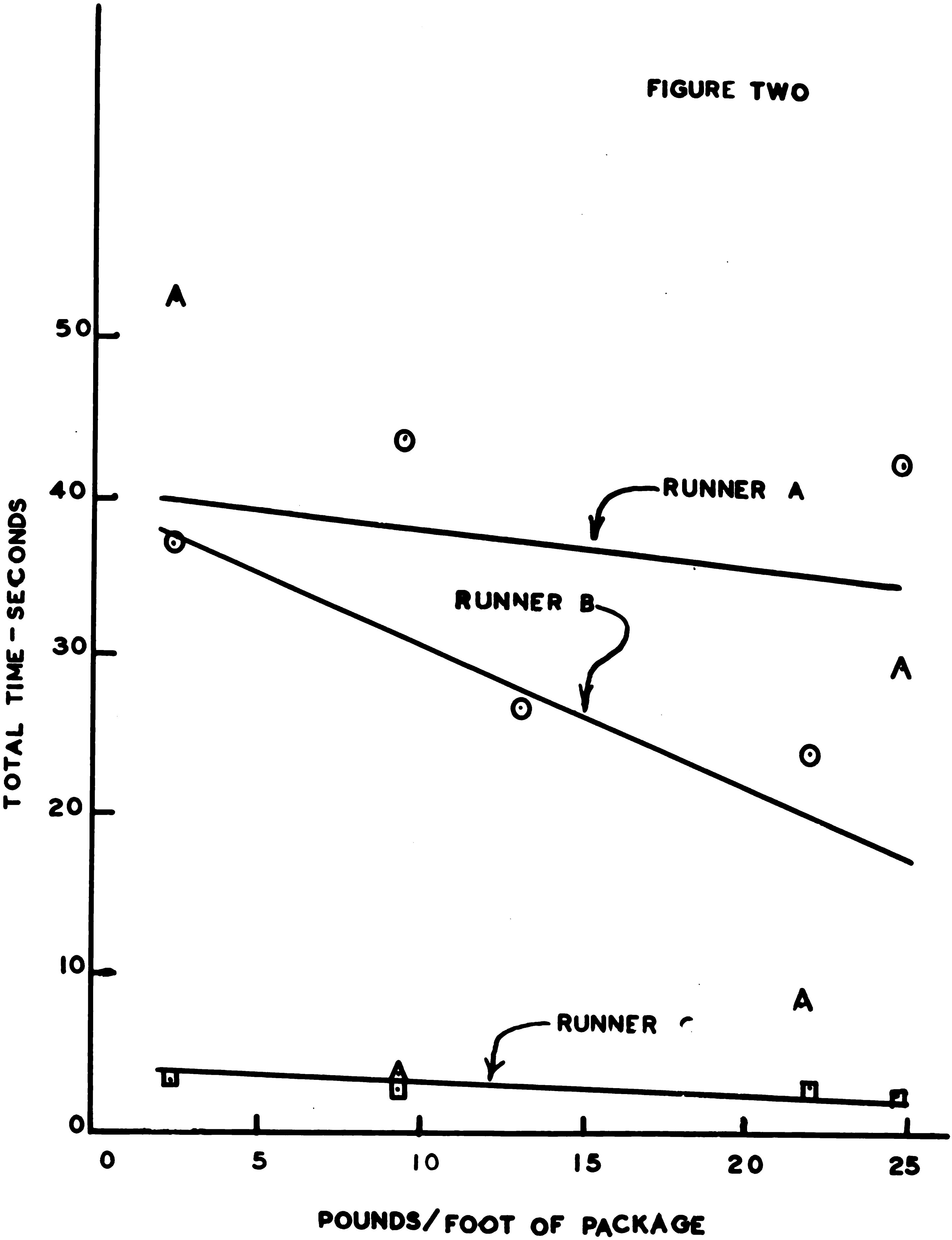
RUNNER A
RUNNER B
RUNNER C
TOTAL TIME - SECONDS
POUNDS/FOOT OF PACKAGE
0
10
20
30
40
50
5
15
25
A

FIGURE TWO

IV. CONCLUSIONS

1. Only two of the three main effects were found to be significant. Of the two, only the effect of the runners was found to be significant at the 1% level while the effect of degrees was significant at the 5% level only.

The effect of products did not seem to be significant.

2. Of the three runners tested, only type C performed in a manner that was considered acceptable. It consistently gave times below the maximum time limit. In fact the runner was so inefficient as to be considered unsafe to use on heavy packages. Runners A and B, however, were found to be so efficient as not to be usable for either weight classification.

V. SUGGESTIONS FOR FURTHER WORK

1. Conduct a similar series of tests to investigate the possibility of using a C runner and an A (or B) runner in the same chute instead of two A (or B) runners for situations requiring a more efficient slow-down than type C.

2. Determine if there is any correlation between the coefficient of friction for a given material and its performance as a runner in an effort to find a rule of thumb to accept or reject potential runner materials.

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