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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

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
Erwin Milton Campbell
1960



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AND THE DEVELOPMENT OF A VELOCITY CONTROLLING FEATURE FOR,
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AN ABSTRACT

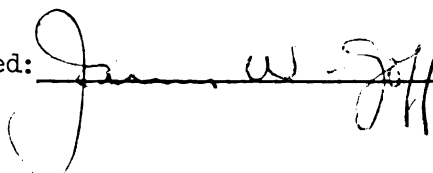
Submitted to the College of Agriculture of
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Forest Products

1960

Approved: _____

A handwritten signature, likely "James W. Giff", is written over a horizontal line. The signature is in cursive and includes a large initial "J" and a stylized "G".

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^l 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

CHAPTER 1.1

The first step in the process of creating a new product is to identify a market need. This involves conducting market research to understand the current market landscape, including the size of the market, the number of competitors, and the specific needs and preferences of the target audience. Once a market need has been identified, the next step is to develop a concept for a new product that addresses this need. This process often involves brainstorming and prototyping to refine the idea and ensure it is feasible and desirable. The third step is to create a business plan, which outlines the financial and operational aspects of the new product. This includes determining the cost of production, the pricing strategy, and the distribution channels. The business plan also serves as a roadmap for the company's growth and provides a clear picture of the potential return on investment. After the business plan is complete, the next step is to secure funding. This can be done through various means, such as seeking venture capital, crowdfunding, or applying for government grants. Once funding is secured, the company can move forward with the development and production of the new product. The final step in the process is to launch the product and monitor its performance in the market. This involves tracking sales, customer feedback, and market trends to ensure the product is meeting its goals and making necessary adjustments as needed.

consists essentially of a huge 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 reduction of static or kinetic friction encountered

1. *Die Bedeutung der Kunst für die Menschheit*
Die Kunst ist ein Spiegelbild der menschlichen Seele und ihrer inneren Welt. Sie ist ein Ausdruck der menschlichen Existenz und ihrer Sehnsucht nach dem Unendlichen. Die Kunst ist ein Mittel, um die menschliche Erfahrung zu teilen und zu verstehen. Sie ist ein Werkzeug, um die menschliche Identität zu finden und zu festigen. Die Kunst ist ein Weg, um die menschliche Freiheit zu erlangen und zu bewahren. Sie ist ein Licht, das die menschliche Dunkelheit erhellt und die menschliche Hoffnung befestigt. Die Kunst ist ein Schatz, der die menschliche Kultur bereichert und die menschliche Zukunft sichert. Sie ist ein Geschenk, das die Menschheit verdient und das die Menschheit verdient.

2. *Die Kunst als Ausdruck der menschlichen Seele*
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3. *Die Kunst als Werkzeug zur menschlichen Identifizierung*
Die Kunst ist ein Werkzeug, um die menschliche Identität zu finden und zu festigen. Sie ist ein Spiegelbild der menschlichen Existenz und ihrer Sehnsucht nach dem Unendlichen. Die Kunst ist ein Mittel, um die menschliche Erfahrung zu teilen und zu verstehen. Sie ist ein Werkzeug, um die menschliche Identität zu finden und zu festigen. Die Kunst ist ein Weg, um die menschliche Freiheit zu erlangen und zu bewahren. Sie ist ein Licht, das die menschliche Dunkelheit erhellt und die menschliche Hoffnung befestigt. Die Kunst ist ein Schatz, der die menschliche Kultur bereichert und die menschliche Zukunft sichert. Sie ist ein Geschenk, das die Menschheit verdient und das die Menschheit verdient.

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

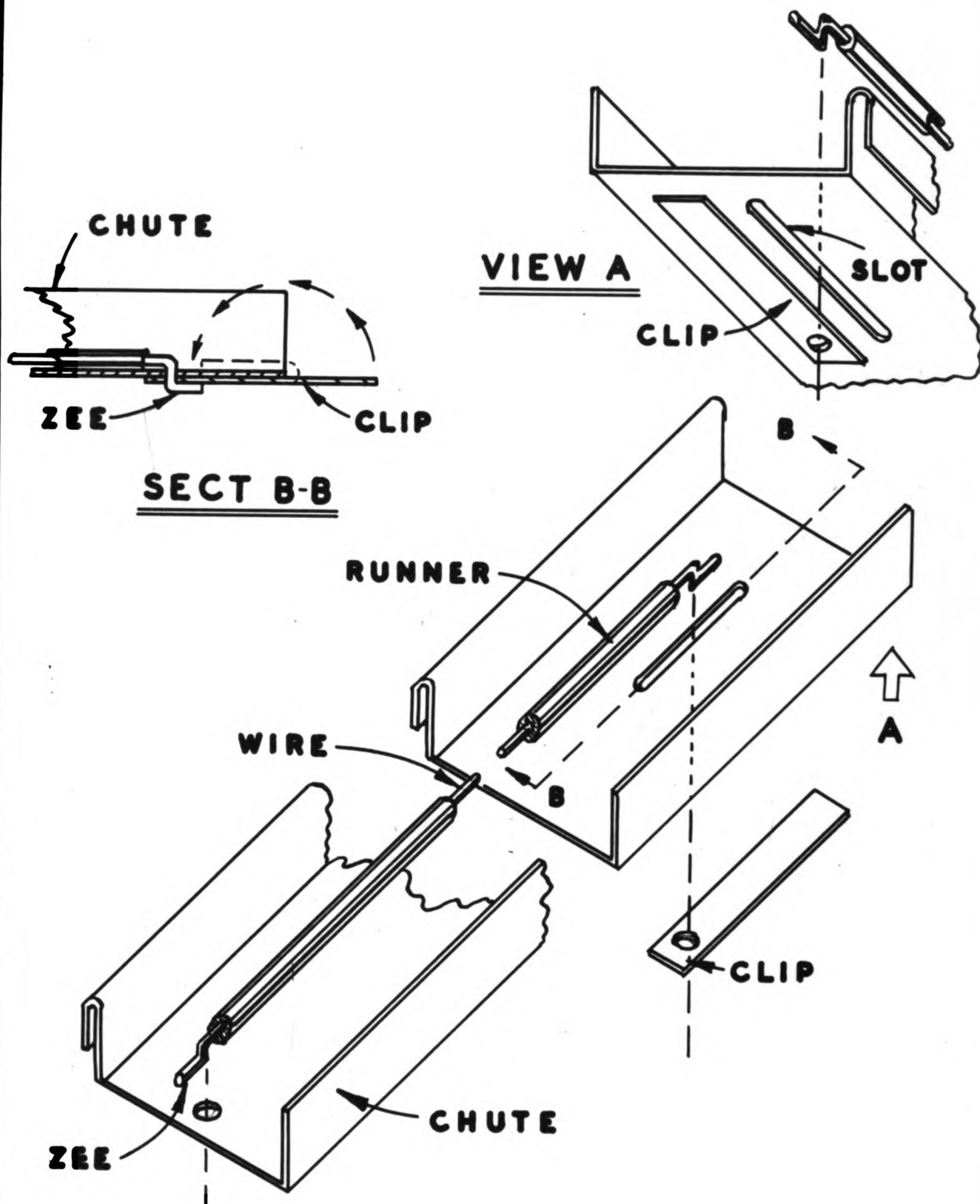
Type B - Nylon

Type C - High Density Polyethylene

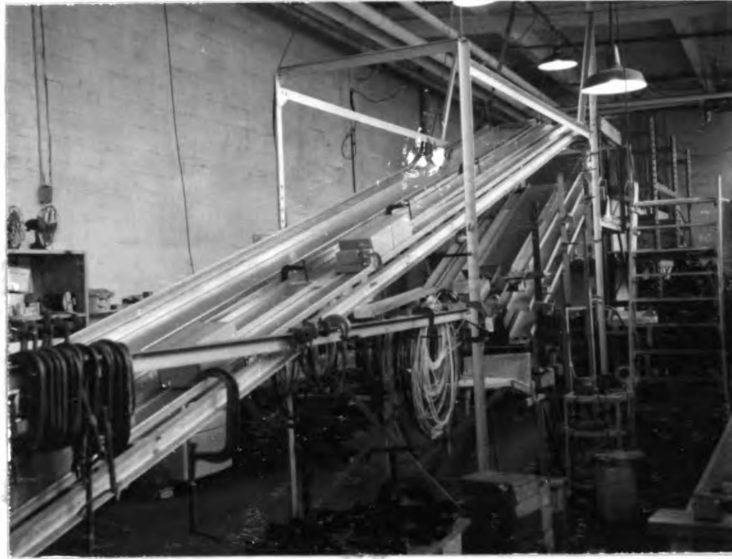
Runners are to be installed in pairs, as shown in Figure One, with a minimum of two runners per chute. Wider chutes will have as many pairs of runners as are required to support the wider packages.

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 intermittent 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 efficient¹ 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.

¹For 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			WEIGHT	
	L	W (Inches)	H	Wt. (Pounds)	$\frac{12 \text{ (wt)}}{L}$ (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				
RUNNERS	PRODUCTS			
	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°				
RUNNERS	PRODUCTS			
	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°				
RUNNERS	PRODUCTS			
	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

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	12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TABLE V

ELAPSED TIMES

16 ⁰				
RUNNERS	PRODUCTS			
	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

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	12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TABLE VI

ELAPSED TIMES

17°				
RUNNERS	PRODUCTS			
	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° .

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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

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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

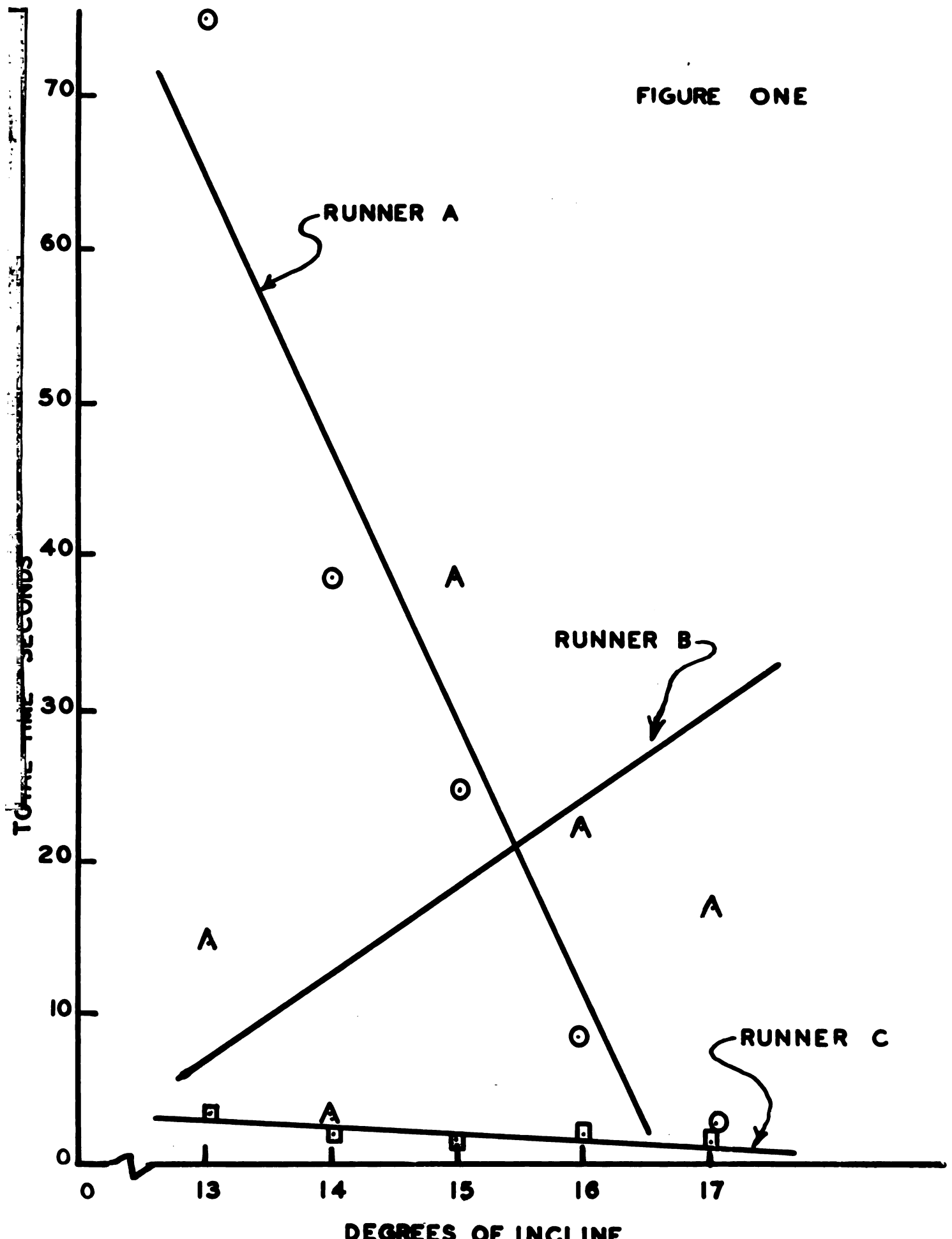
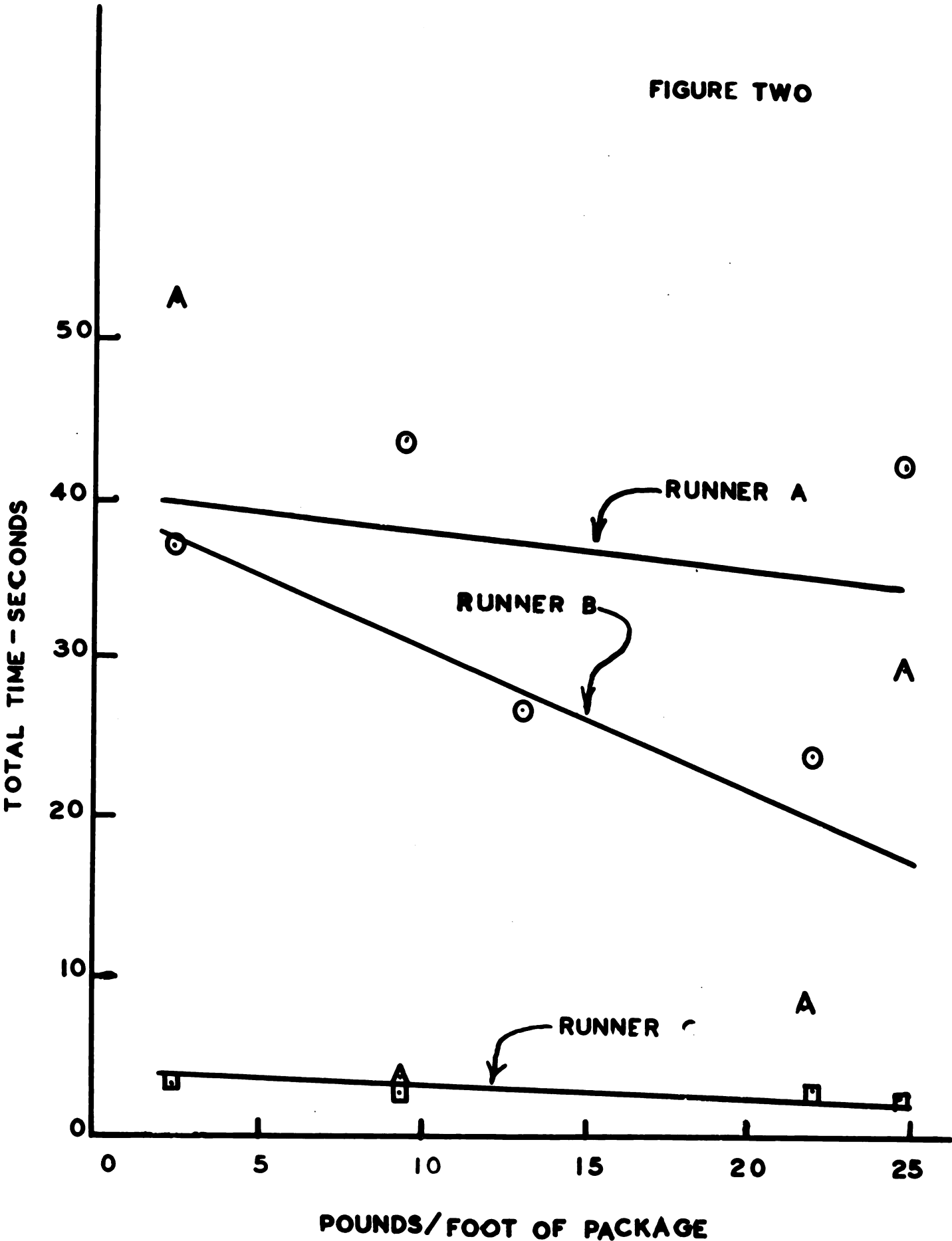


FIGURE TWO



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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