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An Investigation of the Effects of Pressure, Packing and Nip Area on the Results of the IGT Pick Test

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AN INVESTIGATION OF THE EFFECTS OF PRESSURE, PACKING, AND NIP AREA ON THE RESULTS OF THE IGT PICK TEST

by

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ABSTRACT

The object of this thesis was to determine whether the pick scatter found in the IGT pick test was a result of the different packings or the different pressures used in the paper industry. The results showed that these two factors are not the significant ones which cause the inconsistency so often found in industry. There are other factors, such as contact angle and sector velocity, which may play a far more important role in the forces prevailing in this test. It is recommended that further study be made on these factors, but also standardization of the packing is required for it does have a minimal effect on the pick measurement.

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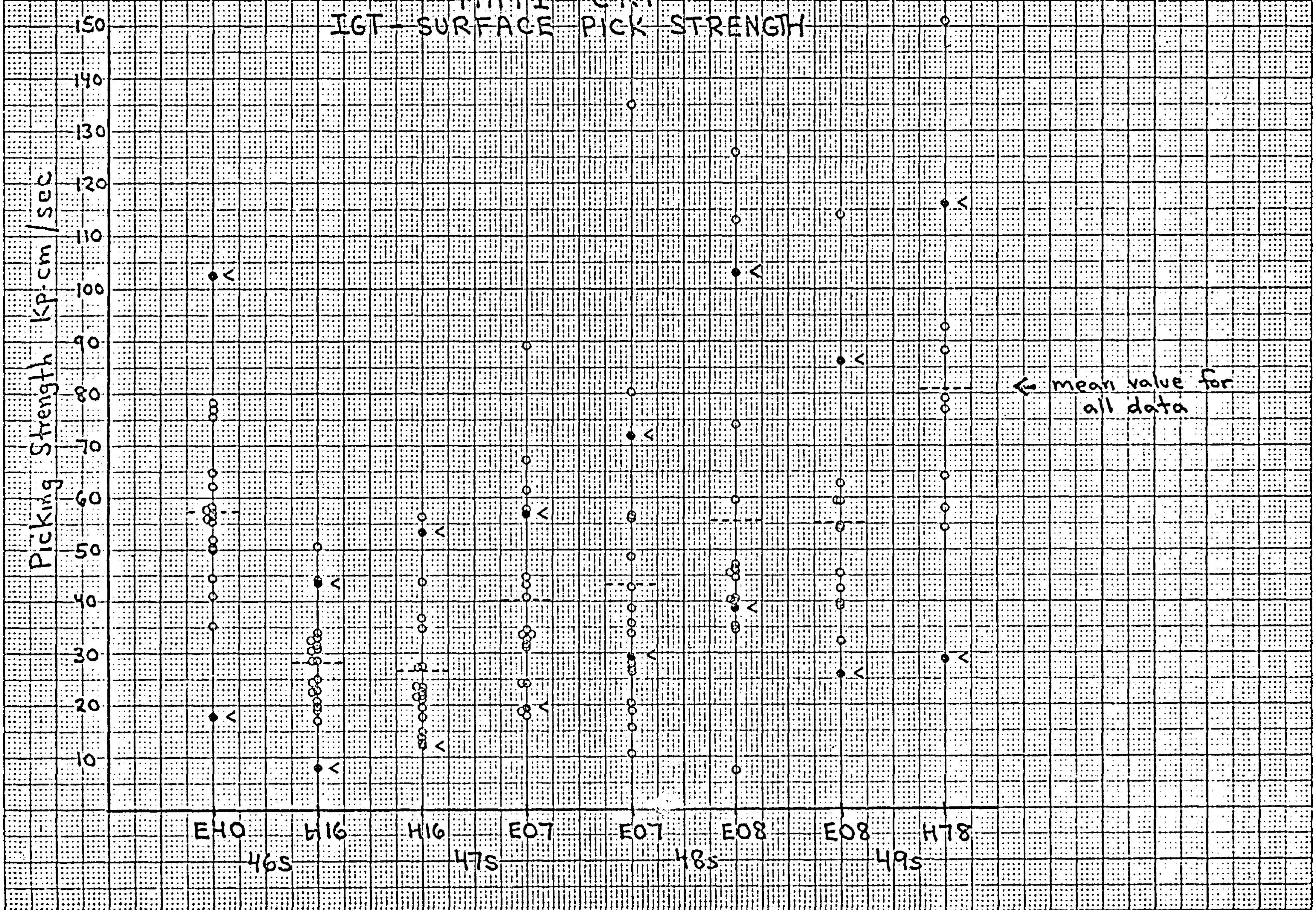
INTRODUCTION

The increasing use of coated papers and faster press speeds in the printing industry has brought with it the need for predicting whether an ink and a paper will run properly without picking and causing a machine shutdown.[1] A shutdown could cost both the printer and the papermaker valuable time and money; thus, it would be advantageous for the papermaker to have a standardized test to measure the paper's pick strength.

Pick strength or restance to pick is defined as the ability of the paper to withstand the forces involved in splitting ink films in printing processes.[2] By simulating the action of a printing press on the laboratory scale, an adequate test of the paper's preformance was designed to check it's quality before it was shipped to the printer. The instrument used is the IGT Printability Tester.

The IGT Printability Tester has been used for many years by both papermakers and printers, however, it has serious flaws. The device has many variables which weren't standardized, making the test difficult to compare amoung company branches and between companies. An example of this problem showed up as the results of a round robin test run by TAPPI. The data plotted in figure 1 shows the diffusion of pick results on a numerical scale around the mean. The deviation from the mean was more than 80% in some cases. Figure 1 indicates that a numerical rating



IGT - SURFACE PICK STRENGTH
Picking Strength Kp·cm/sec
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
EHO
H16
H16
E07
E07
E08
E08
H78
46s
47s
48s
49s
← mean value for all data

of coating pick for a paper sample is so inaccurate that the printability cannot be given one rating for all IGT Printability Testers.

In the study of the IGT Printability Tester, an attempt was made to find the relationship of some of the variables which cause scatter in the pick results. The variables under study were the pressure in the nip, the packing on the sector, and the nip area. By using common samples and by keeping constant all variables but one, the relation of each variable under study to the coating pick values was found.

BACKGROUND INVESTIGATION

The printing industry runs tests on the paper they receive to be sure it meets the required standards.

> "These tests encompass checks on dimensional stability to ensure that materials have been delivered the right size, thickness, grammage, and grain directionand, since we are concerned with sheet-fed offset lithographic printing, we also check surface pH, oil absorbancy, pick resistance, surface smoothness, moisture content, dimensional stability and degree of edge dust."(3)

The tacky inks used by printers pull away pieces of coating or clumps of fiber during printing operations.(4) If the paper surface isn't strong enough, it can cause machine breakdown and delay operations. This is a big dilema to the printer. Thus, it is the duty of the paper producer to deliver strong enough paper to withstand the stresses in the printer's operations.

A known cause of coating pick is the loss of binder into the body of the paper.[5] Paper producers want to add just enough binder to meet requirements because the goal of the producer is to make the paper with the required strength at the lowest cost. Thus, too much binder would be excess cost to the producers. In addition, all printing operations do not require the same strengths in the coating or paper's surface.

Letterpress requires less pick strength than the offset printing process and more pick strength than the gravure type process. This is attributed to lower speeds[6] and thicker ink films used in letterpress which cause less stress on the paper than thinner films associated with offset. In relation to gravure type printing, the paper's pick resistance with respect to base paper, coating-to-base paper bond, and pigment particle-to-particle bond, has to be improved above the gravure requirement by increasing the ratio of adhesive to pigment.[5]

Lithographic printing, on the other hand, requires a higher wet and dry pick strength of paper and coating to withstand the tackier inks used and the weakening effects of the water used in the process.[7]

> "Modern methods of printing, particularily in the sheet-fed and web-fed offset lithographic processes, subject the printing paper to considerable bending stresses and tensions at higher speeds. Close register colour printing, especially requires that the paper should have sufficient bonding strength to withstand the forces arising from the tack of the ink and the bending at the point of peel"[8]

Thus, A much stronger paper surface is required of the paper in the lithographic printing operations. Not only can the ink be tackier, but the printing blanket itself has some tack, so this only adds to the tack of the ink.[5] Lithographic printing makes the highest demand on paper pick of all the processes, but fortunately, papermakers can generally meet pick specifications when they are forewarned.[6]

THE IGT USE:

The IGT, developed in Amsterdam, was first used in the mid-50's to calculate the amount of binder needed to give the sheet a required pick resistant coating. This is important because, "in addition to increasing the cost of the coating, the binder reduces the solids content at which the coating can be applied, reduces the brightness and hiding power of the dried coat, and renders calendering more difficult."[9] The machine first used is pictured in figure 2. Figure 2A shows the inking system and fig. 2B is one of the printability testers required by the International Organization for Standardization. A more detailed picture of figure 2B is presented in figure 3. Another printability tester which is also used by the International Organization for Standardization (ISO) is pictured in figure 4. This is the electric model and was used for this thesis.

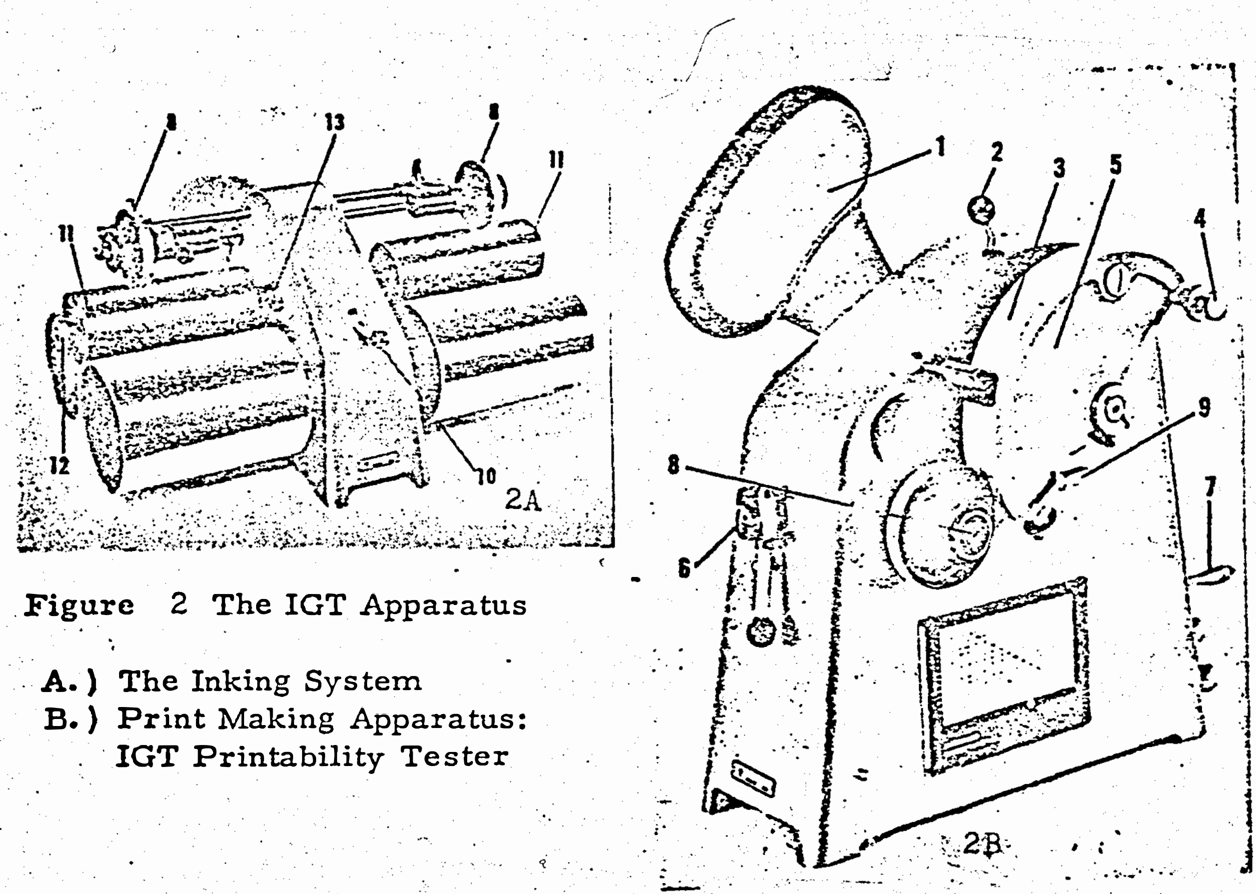


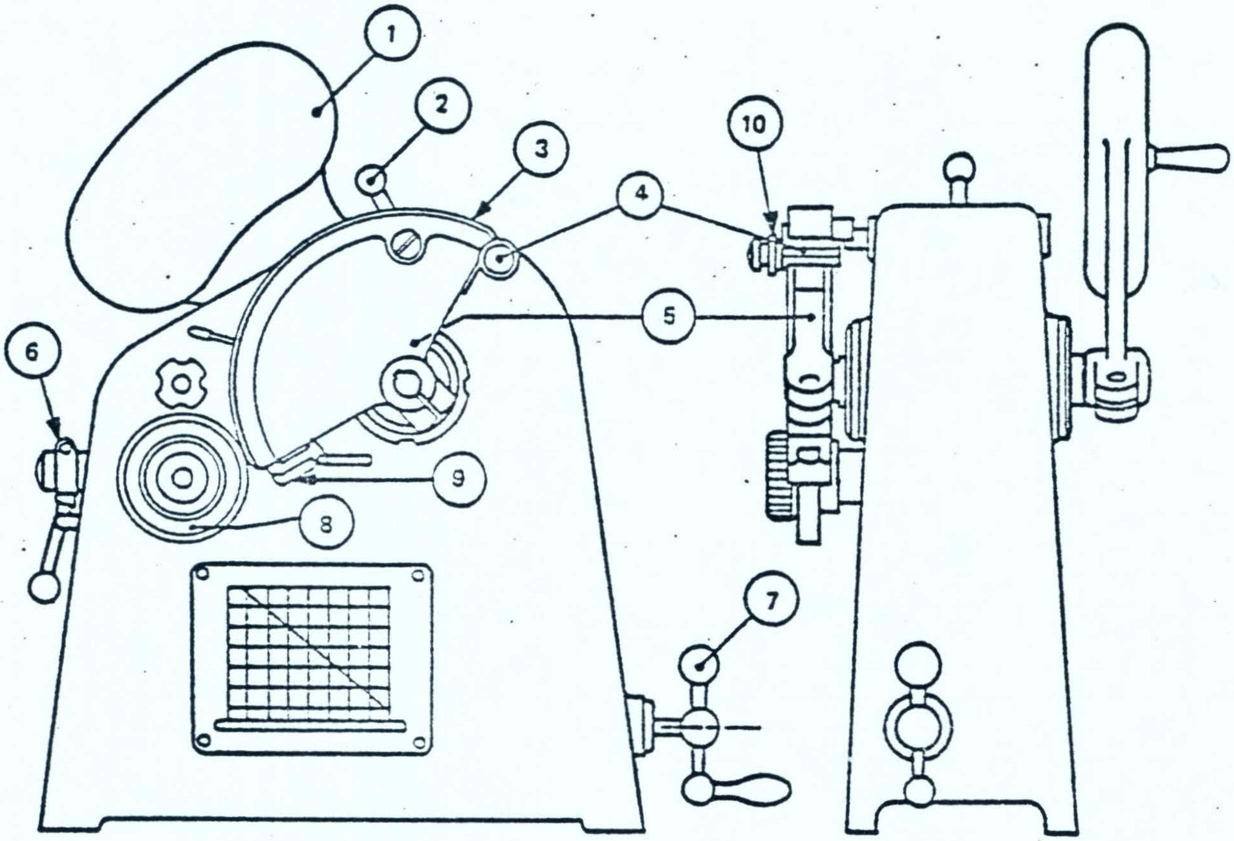
Figure 2 The IGT Apparatus

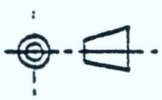
A.) The Inking System
B.) Print Making Apparatus: IGT Printability Tester

The inking systems in figures 5, 6, and 7 are all being used today in running the same test. Since so many systems are in use, this leads to uncertainty as to the comparability along with the many other variables in existence with this test. The inking device used in this thesis for experimentation is pictured in figure 7. It is the Westvaco system with a disc which has a bored down portion to give a more reproducable ink thickness without any need for adjustment. The other inking systems which use blade ink application must be adjusted for thickness and checked frequently as to blade damage. The only problem with the Westvaco disc over the others is that there is no method for measuring the actual ink thickness.

Figure 3

DIAGRAM OF IGT PRINTABILITY TESTER (PENDULUM MODEL)



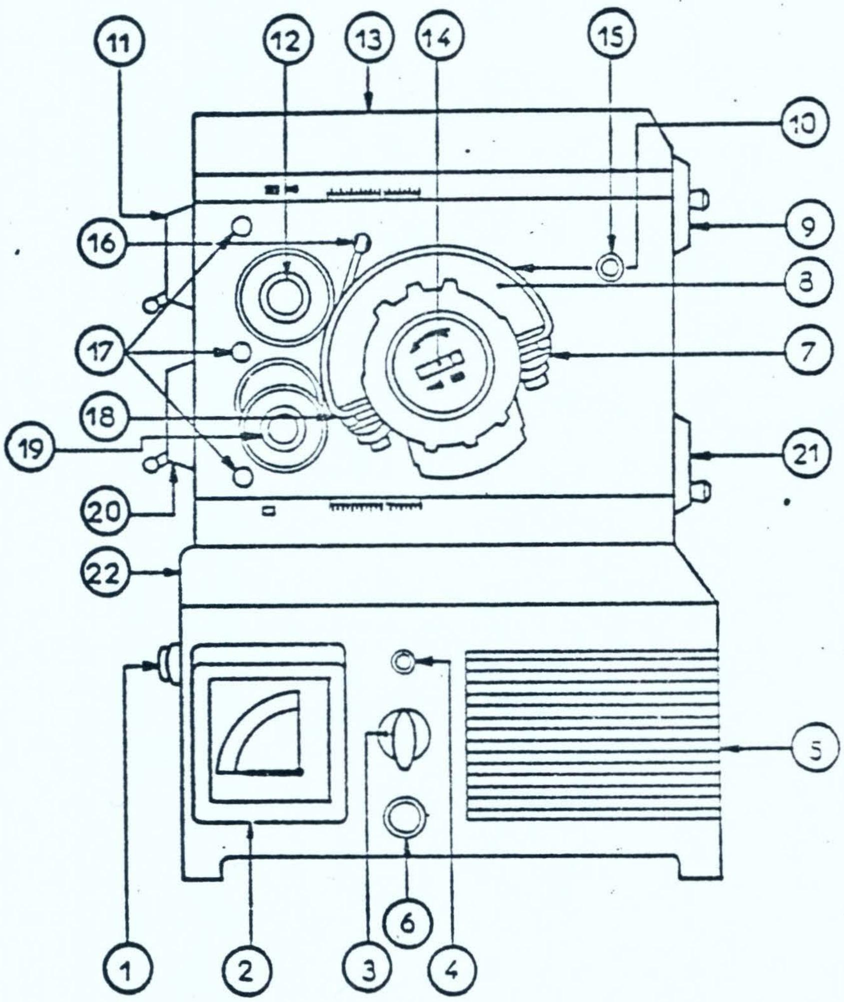


KEY

1 Pendulum
2 Lever
3 Packing
4 Tensioning bar
5 Sector
6 Handle to move disc
7 Handle to adjust printing pressure
8 Printing disc
9 Packing clip
10 Lock nut

Figure 4

DIAGRAM OF IGT PRINTABILITY TESTER (ELECTRIC MODEL)



KEY

1 Sector starting button. Pressing only has any effect when 6 is depressed and when 15 is alight

2 Velocity indicator

3 Main switch and selector switch for velocity. This switch has three positions, namely :

L – constant velocity up to 1,7 m/s and increasing velocity up to 4 m/s

H – constant velocity up to 5 m/s

O – in this position the tester is switched off.

4 Pilot lamp. Lights only when switch 3 is in position L or H

5 Velocity control with locking button

6 Motor starting button. When pilot lamp 4 is alight the motor is switched on by pressing this button

7 and 18 Packing and paper clamp; the packing is held in the clamps, and the paper can be clamped separately

8 Sector or impression cylinder

9 Pressure control for top printing-disc

10 Packing

11 Top printing-disc lifter; with this the printing-disc can be lifted off the secotr, and in addition the distance between the top printing-disc shaft and the sector can be varied.

12 Top printing-disc shaft

13 Pressure scale for top printing-disc

14 Selector pin for type of velocity

15 Pilot lamp. Lights only when the sector is in its starting position

16 Brush (detachable)

17 Holes for attachment of accessories

18 See 7

19, 20; **21, 22** — As 12, 11, 9, 13, but for the lower printing disc.

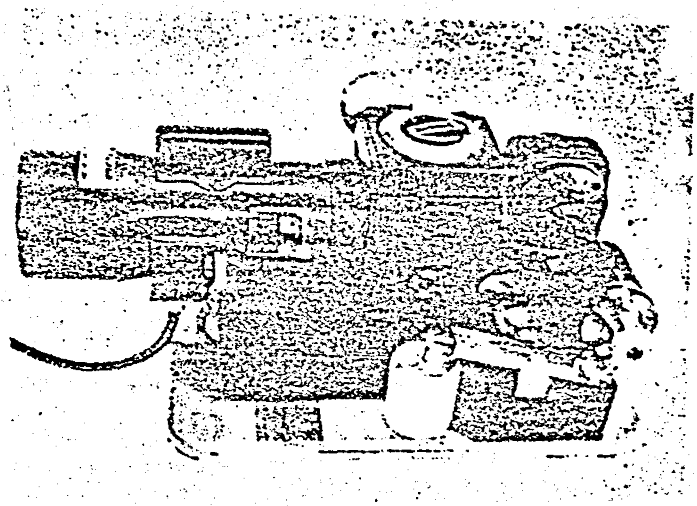


Figure 5
The Diamond Gardner
Inking Device

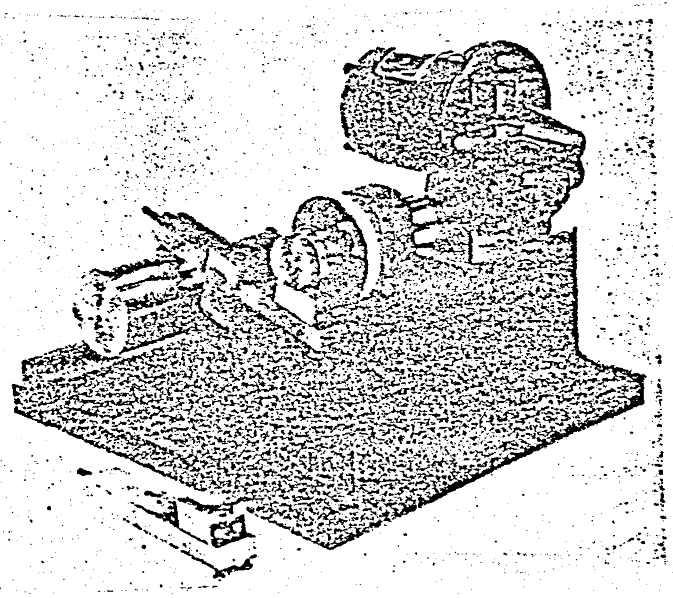


Figure 6
The Fox River
Inking Device

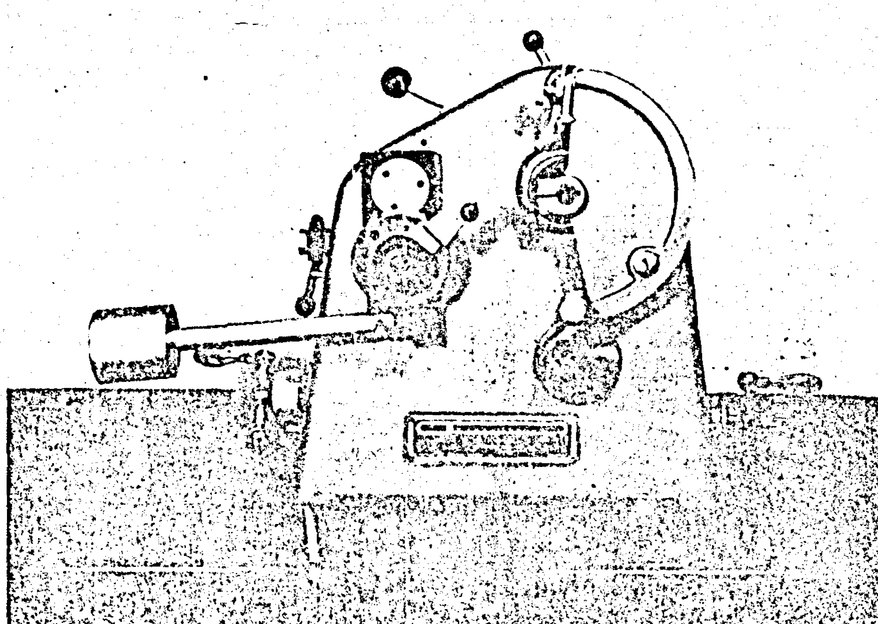


Fig. 7 IGT Printability Tester set up with Westvaco Disk.

Figure 7

THE IGT VARIABLES:

The effect of packing material on the IGT sector is one variable that was examined. The properties of the packing were found to have a pronounced influence on the degree of contact achieved between the surface of the paper and the test film, and, consequently on the test results.[10] The splitting area is increased with a more compressible packing material, improving and extending the contact area, and the value of picking force is increased. The ideal requirements of the packing are smoothness with some compressibility and softness.[1] Some packings used include manila paper, #666 double face tape,[9] tympan paper, rubber, standard IGT paper, a combination of one layer #400 scotch tape plus one layer one ply newspaper pressdraw sheet plus one layer #666 scotch tape,[10] or no packing material at all.[12]

Printing pressure should be expected to influence picking results because it influences distortion in the nip zone. However, experimental data shows that picking is not particularily sensitive to pressure change provided that the minimum pressure for good coverage has been reached.[1] Using a range of pressures found in industrial use, the correlation to coating pick was expected to increase in pick with pressure.

Probably the most overlooked variable in the entire printing operation is the composition of the distribution

rollers. Some systems increase or decrease the viscosity of the ink.[1] Also, disc material is not standard in the IGT test setup. Some examples of disc material used are stainless steel, aluminum and some of its alloys, Dural steel, and chrome. By selecting different discs, this effect on the pick results could be examined.

The width of the sample strip used is also a variable which isn't standardized in the IGT test. Strips from one centimeter to an inch (2.54 cm.) are used and it has been found that the area in the printing nip should effect the pick results also. This variable is determined by the machine being used. The width of the printing disc determines the size of the test strip to be used.

The ink film thickness was found to be the most important[1] since the apparatus is based on the Stephan Equation which is:

$$F = V_s \eta A$$

where: F = splitting force
V_s = separation velocity
η = viscosity
A = area in nip
h = ink thickness

Here, the ink film thickness is a cubic variable which means that its effect would be great compared to a variable with a one-to-one relationship. However, the ink film thickness is not kept constant for even in industry a range is used as standard. This was one variable which was held constant.

EXPERIMENTAL PROCEDURE

The experiment is broken down into three sections: 1.) the measurement of nip area in order to rate packings as to compressibility, 2.) a factorial design of packing and pressure blocked across three days (Experiment I), and 3.). a factorial design of packing and pressure run on the same day (Experiment II). To run this experimentation, three samples, three pressures, and four packing materials were used with the motorized IGT Printability Tester set at 2 meters per second, the Westvaco inking device (Fig. 7), and 960 poise (at $73^{o}F$) polybutene oil. All pick results were viewed under 6.6x magnification with a grazing light source immediately after the test was run. Procedure similar to the ISO/DIS 3783 standard was followed, however, the Westvaco inking device was used instead of the ink distribution system specified. Samples used included thin coated paper, thick coated paper, and coated board. Packings used were metal, standard IGT paper, tympan paper, and offset rubber blanket. The pressures used were 25, 50, and 75 Kgf (1 Kgf = 9.81 Newtons).

AREA IN NIP:

All three samples, thin coated paper, thick coated paper, and coated board were used in this section to find how the nip area between each sample and each packing was effected by pressure. Each packing was placed on the sector (Fig. 4, #8) and fastened. Next, each sample was

clipped onto the sector and the printing disc (Fig. 4, #12) was oiled. The disc was rotated 15 times to apply an even oil coat. The pressure control (Fig. 4, #9) was moved off the far right scale and the printing disc was brought into contact with the sector and released. This was done at three points on the sector, bringing the pressure gauge up to the required pressure (25, 50, or 75 Kgf) each time. These points were then measured under 6.6x magnification and the measurement was converted to area units in square centimeters.

EXPERIMENT I:

This experimental design not only can evaluate the effect of the packing and the effect of the pressure, but it can also consider the day to day changes in the pick by blocking days. Blocking experimental units according to some identifiable characteristics serves to remove this source of variation from the experiment.[14] To reduce the number of observations, only samples 1, the thin paper, and 3, the coated board, were used.

Each sample's pick was run twice at each pressure on each packing. This consisted of 24 pick samplings, 12 from each sample. This was done on each of three days during the same time period, giving three sets of 24 pick samplings. The procedure for running the pick was constant throughout this thesis. The ISO/DIS 3783 standard was followed and the Westvaco inking device was used. When inking the printing disc, the oil was applied and the disc was rotated 15 times to ensure an even distribution.

EXPERIMENT II:

This experiment was run completely on one day to avoid any day effect. The same procedure for pick as in Experiment I was used here, however, the printing disc was different. A different disc of the same type and size was required since the first one rusted during the process of this thesis. Only sample one was used in this experiment.

Sample one, the thin coated paper, was tested for pick at each pressure on each packing three times. This gave a total of 36 pick samplings for this experiment. This data can be used for analysis of both the packing effect and the pressure effect on pick without introducing a day effect which might interfere with the main effects to be studied.

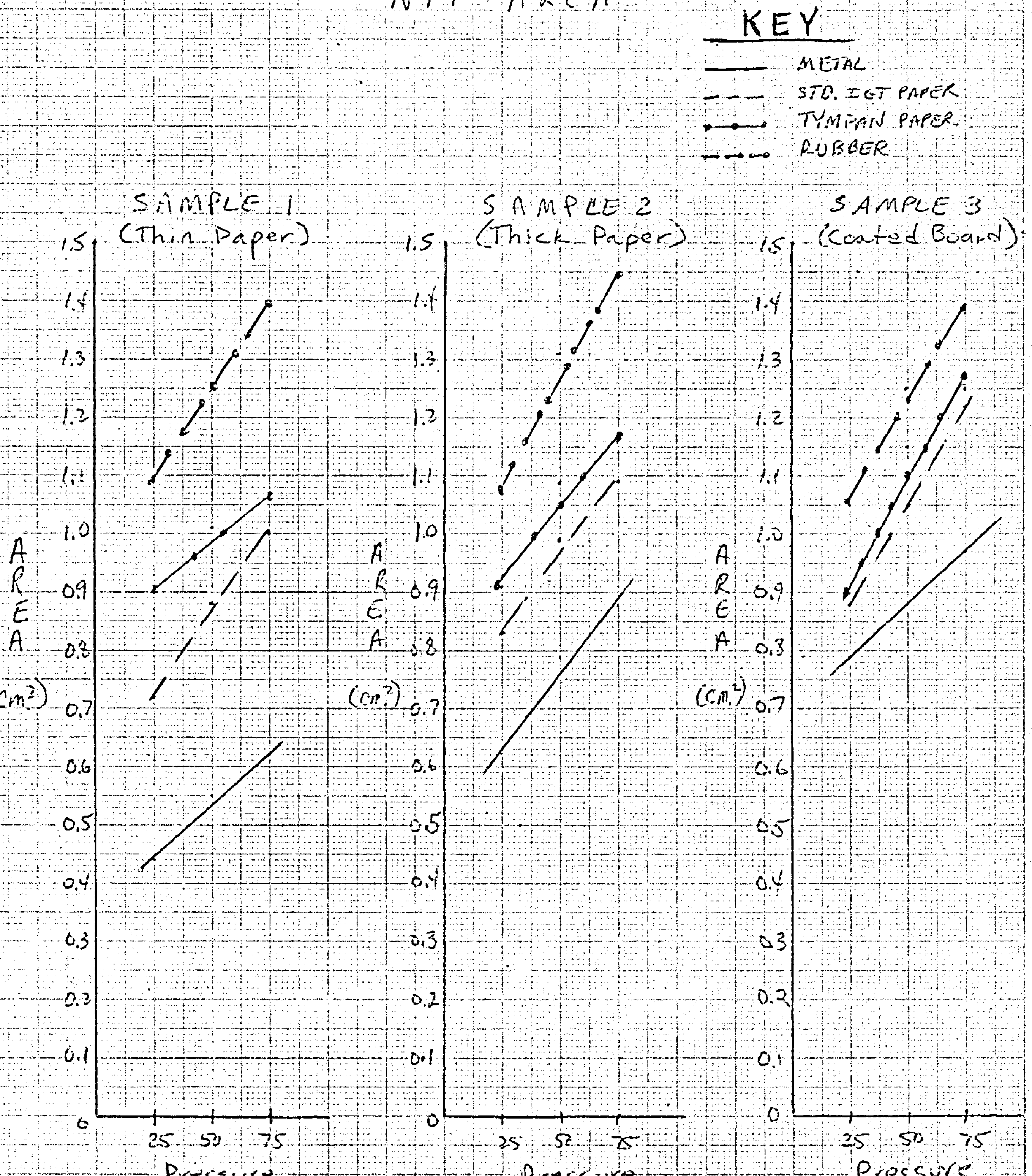
DISCUSSION OF RESULTS

The data for all of the curves in figures 8--12 is contained in the appendix section of this report. Appendix one contains all data pertaining to the measurement of the area in the nip. Appendix two contains all data tables, analysis of variance tables, and regression analysis for Experiment I. Appendix three contains all necessary data for Experiment II.

The area in the nip portion of the thesis was the only part that came out exactly as expected. All of the packings acted in the same manner on the area which can be seen in figure 8. When the pressure was increased,

FIGURE 8.

THE EFFECT OF PRESSURE ON NIP AREA



the nip area increased. Also, the rubber gave the greatest area and the metal gave the least area. And, the tympan paper gave a greater area in the nip with each sample than the standard IGT paper. Thus, the tympan paper would be expected to give a greater force and a lower pick than the standard IGT paper. However, this only occured in Experiment II at lower pressures.

Results from Experiment I after running an analysis of variance proved that indeed, there was an effect on pick due to day of testing. This effect was the only one present on the board sample but not on the thin paper sample. This day effect causes so much of the error which is experienced in this test and hinders standardization and comparability. It is obvious that the factors, packing and pressure, studied here are not the actual factors contributing to the error which was hoped to be resolved.

The board sample, being thick, acts as its own packing under the coating. Thus, no packing or pressure effect was experienced. This was expected in the experiment but had never been proven. From the curves in figure 9, there are some trends which show up. Increasing the pressure on either the tympan paper or the rubber offset blanket gives a slight decrease in the length before pick. This might be attributed to the increase in nip area. However, the opposite happens for both the metal packing and the standard IGT packing, although the slope is slight. Even though the area for every packing always increased with

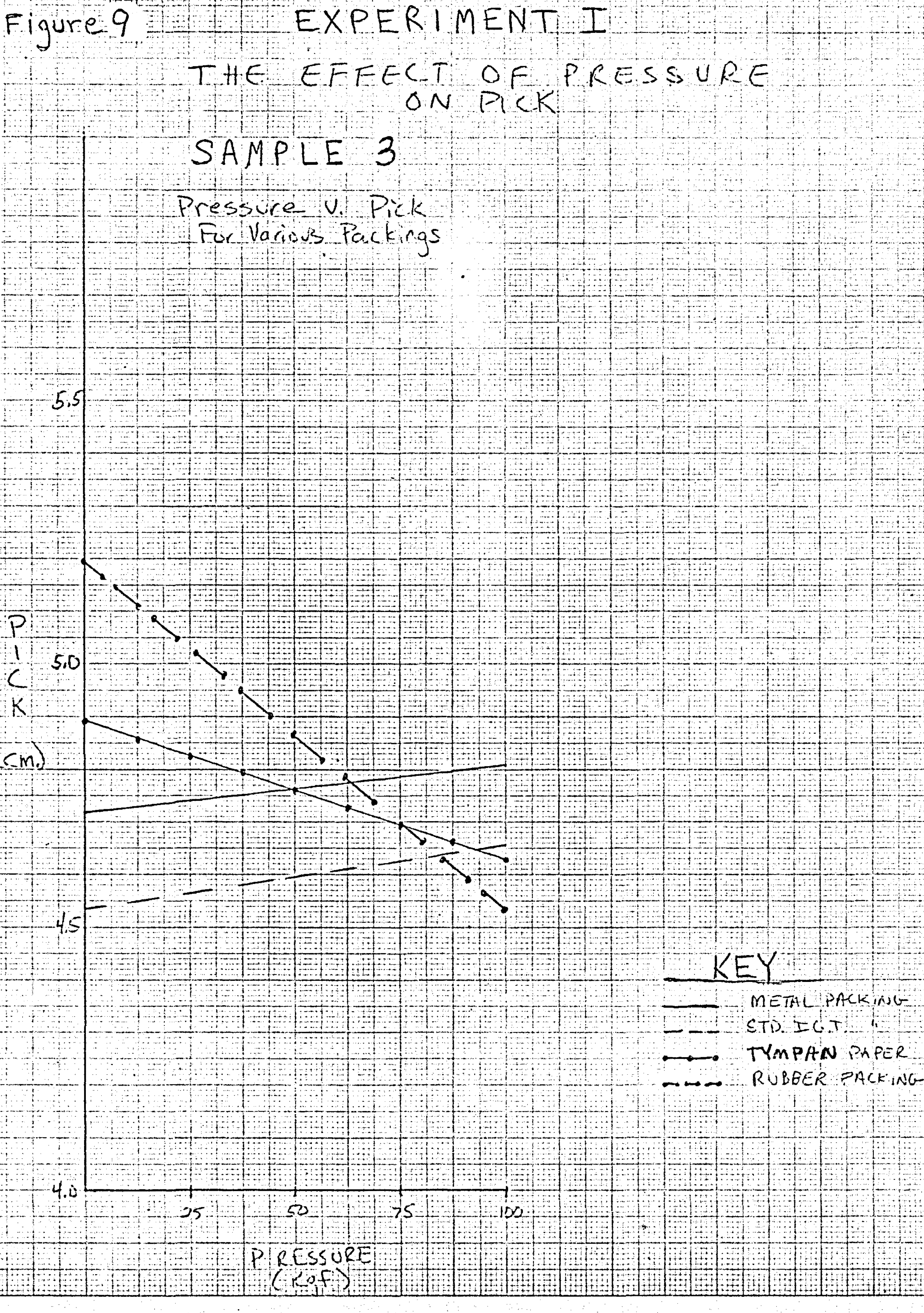


Figure 9
EXPERIMENT I
THE EFFECT OF PRESSURE ON PICK
SAMPLE 3
Pressure v. Pick
For Various Packings
5.5
5.0
4.5
4.0
PICK
cm.)
25
50
75
100
PRESSURE
(Kgf)
KEY
METAL PACKING
STD. I.G.T. "
TYMPAN PAPER
RUBBER PACKING

pressure, the pick on the metal and IGT packing seemed less affected. This shows that the standard IGT paper, like no packing at all, interferes least with the true pick of the sample.

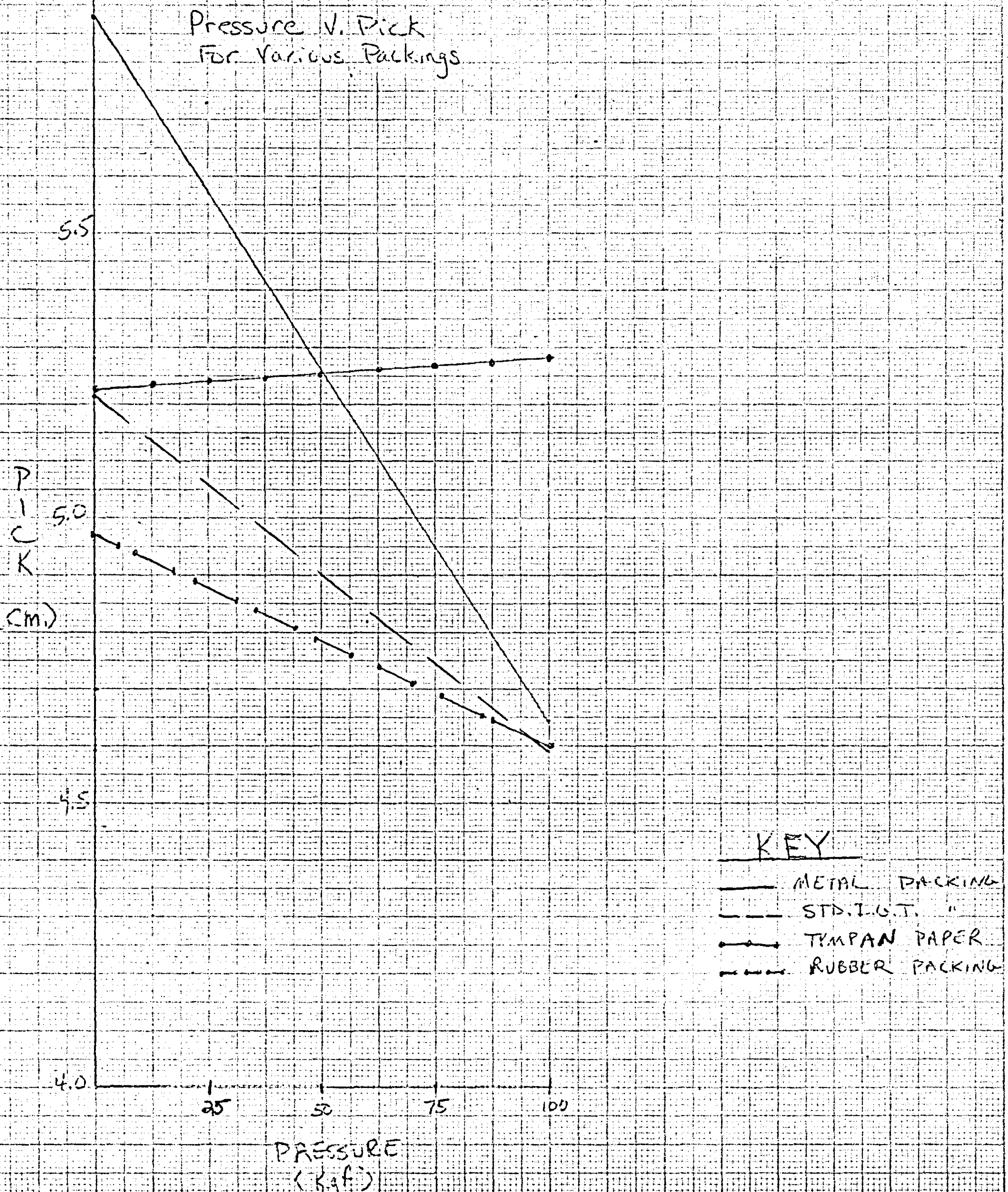
In sample one, the thin coated paper, a different mechanism was present, for no effect of sample thickness was present to disguise the packing effect. Here, at the .01 level of significance, there was still a day effect, but there wasn't enough evidence to show an interaction between the day and the factor (packing or pressure) to interfere with the major effects to be studied. The analysis of variance showed only a packing effect on the thin paper's pick and not a pressure effect. However, running a test for least significant difference on the means for each packing showed that no difference could be statistically found between the metal, standard IGT paper, or the tympan paper, but the rubber could be distinguished as giving the least length before pick. This proves that our method of testing, when calling for standard IGT paper or other similar packings, may not be strict enough since the pick would be higher than for rubber. This could allow paper to be sold which would indeed pick in the presses which consist of rubberized rollers.

The curves in figure 10 do give some trends of the pick on each packing over pressure, but they aren't similar to those noted on sample three in the same experiment.

Figure 10 EXPERIMENT I

THE EFFECT OF PRESSURE ON PICK

SAMPLE 1



Here, all packings effect the pick as expected except the tympan paper. Thus, as the area in the nip increases, the pick decreases in length on the test strip. This is explained by the Stephan Equation noted on page 11, where the area is directly related to the splitting force in the nip. So, increasing the area would increase the force in the nip, and thus the pick.

Another group of curves for sample one were found in Experiment II. Sample three was dropped in this experiment since no measurable effects were found for packing or pressure. Here, the packings caused the pick length to decrease with pressure, except for the rubber packing this time; however, the rubber's pick length was still well below the other packing's pick in the range from 25 to 75 Kgf. The curves in figures 10 and 11 are for the same samples and do tend to be similar, even though a different printing disc was used. This gives some degree of comparison between similar machine types.

Another set of curves are presented in figure 12. These curves show the effect of pressure on the picking velocity. To find this velocity, the centimeters from the test strip beginning to the point of continuous pick is placed on a scale for the specific IGT Printability Tester which converts the centimeters to centimeters per second. The curves in figure 12 are very similar to those in figure 11; however, the slope of the tympan paper changes from negative to positive. This can be explained since

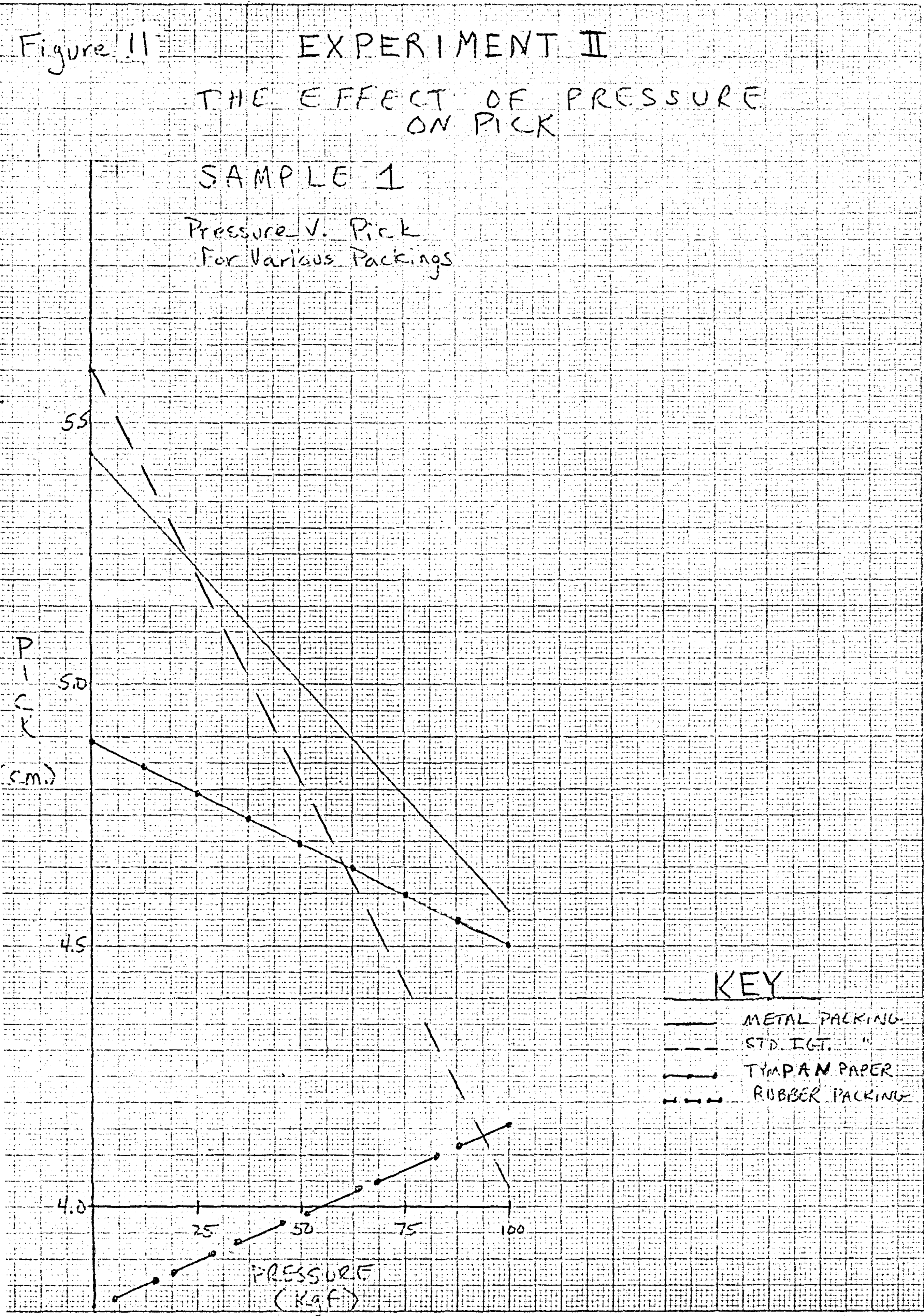
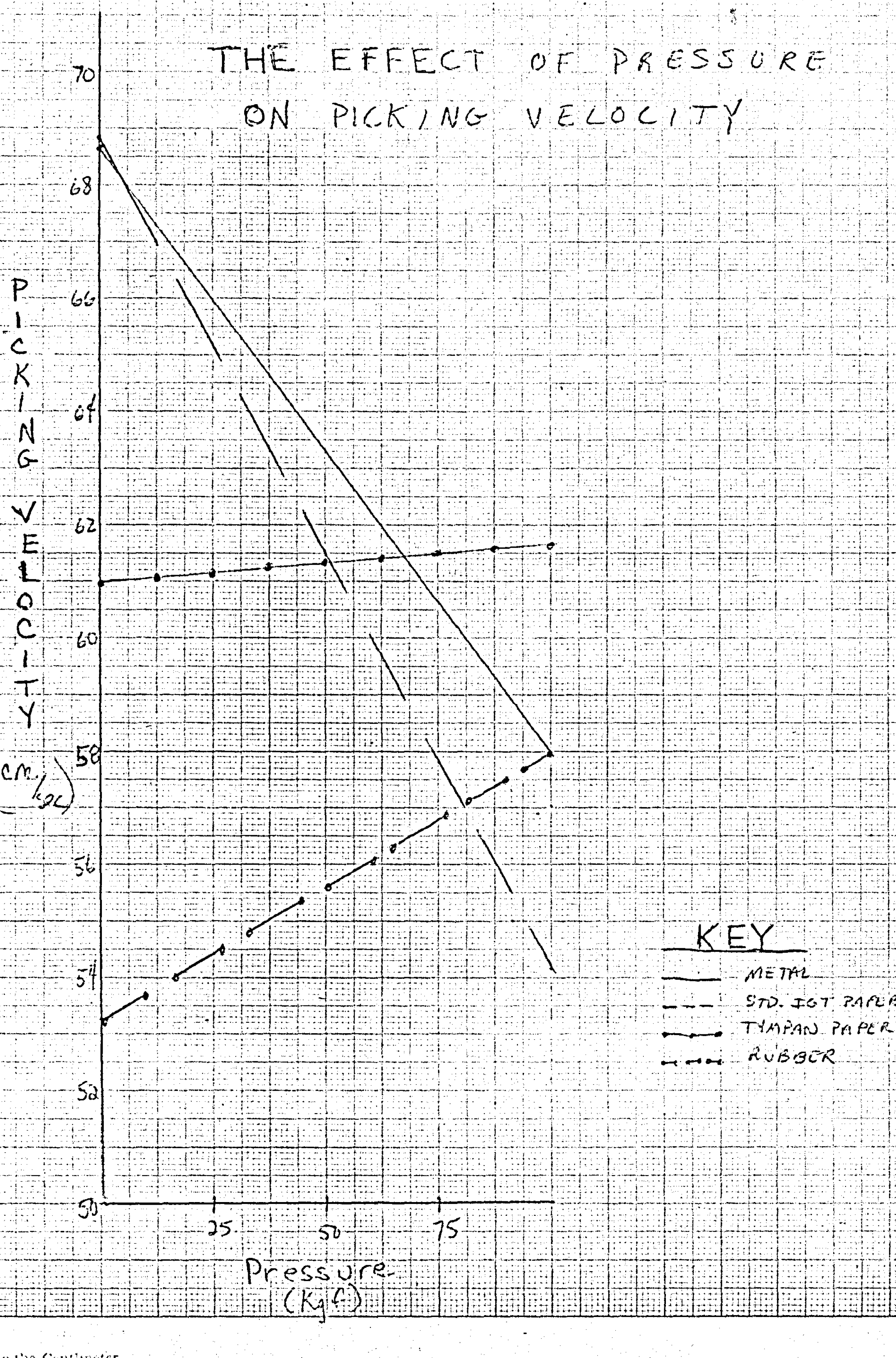


Figure 11
EXPERIMENT II
THE EFFECT OF PRESSURE ON PICK
SAMPLE 1
Pressure V. Pick
For Various Packings
PICK (c.m.)
5.5
5.0
4.5
4.0
25
50
75
100
PRESSURE (Kgf)
KEY
METAL PACKING
STD. IGT. "
TYMPAN PAPER
RUBBER PACKING

FIGURE 12. EXPERIMENT II



each slope in figure 11 increases when converted from pick to picking velocity in figure 12. And, since the tympan paper had a low negative slope, it increased to a low positive slope when converted.

Again, the metal and the standard IGT paper correspond to negative slopes while the tympan and rubber correspond to positive ones. This shows that by adding some compressibility to the packing, the velocity at which the paper will pick is increased. This increase might be related to increased area not increasing the force in the nip, but decreasing the force per area in the nip, thus giving an increase in picking velocity. The two packings with little or no compressibility however, did increase the area but not enough to decrease the force per area, so the pick velocity decreased with pressure.

CONCLUSIONS AND RECOMMENDATIONS

In summary, there are still factors present which effect the pick result scatter even more than the type packing used or the pressures the test is run at. Some of these variables could be the angle of contact and the sector speed. The angle of contact between the sample and the printing disc is not the same as the angle between the printing sector and the printing disc. Even though the sample is clamped down at both ends, it still tends to lift off the sector during the process of the test. This lifting action was noted for both the thin paper sample

and the board sample. The sector speed, though regulated by the gauge (Fig. 4, #2), could still change as more or less pressure is put on the contact point. This could cause the force at that point to vary and give scatter of results. These are only two factors which are known and many more are still unknown.

Even though this thesis just scrapped the surface of the problem, there is still more which should be done. This test is being used widely in Europe with great accuracy and it should be applicable here also. The two factors mentioned above should still be studied using samples that give clear pick. The board sample's pick was very hard to distinguish because of the surface roughness. This could have attributed to the error and the different trends. The thin paper, on the other hand, gave a much clearer pick which made it easier to distinguish the point of continuous pick.

Another factor which might have caused some error was the removal and replacement of the packing from day to day. If one packing could have been kept on throughout and tested separately, this may have removed some error. The tightness of the packing on the sector could have changed with the removal and replacement, changing the effect to nip area, and thus, the pick results.

Since the oil thickness could not be measured, there was only hope that it remained constant. The oil thickness does effect pick and if it wasn't constant, it could have

caused error also.

These are just some problems that must be faced in further studies of the IGT pick test. It still needs to be made more standard so comparisons will be possible and to provide assurance that paper will be sold that will run properly through the printing presses. The paper industry has far to go before it will be protected from returned inventories and loss of sales due to the quality of the paper not meeting the specifications required, but this is just one step toward that day.

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APPENDIX SECTION

AVERAGE AREA (CM^2) FOR VARIOUS PACKINGS

A. Standard IGT Paper

Pressure	Sample #1	Sample #2	Sample #3
25	.72	.83	.88
50	.88	.99	1.05
75	1.00	1.09	1.22

B. Tympan Paper

Pressure	Sample #1	Sample #2	Sample #3
25	.90	.91	.90
50	1.01	1.09	1.15
75	1.06	1.16	1.25

C. Offset Rubber Blanket

Pressure	Sample #1	Sample #2	Sample #3
25	1.09	1.07	1.05
50	1.26	1.31	1.25
75	1.39	1.44	1.38

D. Metal

Pressure	Sample #1	Sample #2	Sample #3
25	.44	.62	.79
50	.55	.79	.88
75	.62	.88	.97

APPENDIX TWO

EXPERIMENT I

EXPERIMENTAL DESIGN:

Two Factors:

0 1 2
A. Pressure (25, 50, and 75 Kgf)

0 1 2 3
B. Packing (Metal, Std. IGT Paper, Tympan Paper, and Rubber)

Twelve Treatment Combinations:

	A	B
1.	0	0
2.	1	0
3.	2	0
4.	0	1
5.	1	1
6.	2	1
7.	0	2
8.	1	2
9.	2	2
10.	0	3
11.	1	3
12.	2	3

Blocking = Days

EXPERIMENT I

DATA TABLES: (cm. pick)

<u>Sample one</u>

Day	(00)	(10)	(20)	(01)	(11)	(21)	(02)	(12)	(22)	(03)	(13)	(23)
1	5.72	5.40	4.01	4.84	4.64	5.08	4.80	6.23	5.32	4.41	5.00	4.01
	5.40	4.76	5.20	5.72	5.52	5.48	5.36	5.40	5.40	5.52	5.64	4.84
2	5.95	5.16	5.00	5.40	3.81	3.89	5.00	4.76	4.45	5.16	4.64	4.17
	5.16	5.24	5.08	4.72	3.89	4.33	5.40	4.13	4.88	4.56	5.00	4.52
3	5.64	5.56	5.16	5.24	5.16	5.28	6.39	4.60	6.03	4.45	3.97	5.24
	5.40	5.52	5.20	5.00	5.24	5.00	5.32	4.76	6.35	5.08	4.64	5.28

<u>Sample three</u>

Day	(00)	(10)	(20)	(01)	(11)	(21)	(02)	(12)	(22)	(03)	(13)	(23)
1	6.27	4.64	4.76	5.08	4.33	3.97	5.08	4.29	6.35	4.92	3.85	4.33
	5.52	5.79	4.45	4.33	5.75	6.39	4.96	5.91	4.01	6.03	4.37	4.52
2	4.05	4.76	5.00	4.72	4.76	4.05	4.60	4.01	4.45	4.49	4.60	4.29
	3.73	4.80	4.80	4.29	4.17	4.41	4.05	3.53	3.77	4.96	5.08	4.45
3	4.41	5.24	4.29	4.45	4.76	4.84	5.12	5.79	4.96	4.92	5.99	5.79
	3.89	4.52	4.84	4.37	4.13	3.93	5.08	5.16	4.56	5.04	4.96	5.00

EXPERIMENT I

ANALYSIS OF VARIANCE TABLES

Sample one

Source	df	SS	MS	F_{calc}	$F_{.05}$	$F_{.01}$
Total	72	1858.6897				
Correction Factor	1	1835.2711				
Total Corrected	71	23.4186				
Day	2	3.0181	1.509	9.091	3.266	5.264
Trt. Combination	11	5.6627	.5148	3.101	2.076	2.802
Pressure	2	1.2546	.6273	3.779	3.266	5.264
Packing	3	3.1536	1.051	6.333	2.872	4.390
Pressure x Packing	6	1.2545	.2091	1.260	2.372	3.362
Day x Trt. Combination	22	8.7613	.3982	2.399	1.853	2.402
Day x Pressure	4	2.5791	.6448	3.884	2.642	3.906
Day x Packing	6	2.5116	.4186	2.522	2.372	3.362
Day x Pressure x Packing	12	3.6706	.3059	1.843	2.036	2.732
Error	36	5.9765	.1660			

Sample three

Source	df	SS	MS	F_{calc}	$F_{.05}$	$F_{.01}$
Total	72	1652.7136				
Correction Factor	1	1622.2208				
Total Corrected	71	30.4928				
Day	2	4.4111	2.206	5.897	3.266	5.204
Trt. Combination	11	1.4676	.1334	.3567	2.076	2.802
Pressure	2	.1972	.0986	.2636	3.266	5.264
Packing	3	.6738	.2246	.6005	2.872	4.390
Pressure x Packing	6	.5966	.0994	.2659	2.372	3.362
Day x Trt Combination	22	11.1499	.5068	1.355	1.853	2.402
Day x Pressure	4	1.4835	.3709	.9916	2.642	3.906
Day x Packing	6	4.7774	.7962	2.129	2.372	3.362
Day x Pressure x Packing	12	4.8890	.4074	1.089	2.036	2.732
Error	36	13.4642	.3740			

EXPERIMENT I

REGRESSION ANALYSIS

Sample one

$\bar{x} = 50$

$SS_x = 7500$

	METAL	STD. IGT	TYMPAN	RUBBER
$\bar{y}$ =	5.253	4.902	5.254	4.785
SS_y =	2.9978	5.7955	7.3665	4.1053
SSCP =	-90.5	-46.5	4.00	-28.0
$\hat{\beta}_1$ =	-.0121	-.0062	.00053	-.0037
$\hat{\beta}_0$ =	5.858	5.212	5.2275	4.970

$\hat{Y}_i = B_0 + B_1(x)$

Sample three

$\bar{x} = 50$

$SS_x = 7500$

	METAL	STD. IGT	TYMPAN	RUBBER
$\bar{y}$ =	4.764	4.596	4.760	4.866
SS_y =	7.049	6.787	9.991	5.992
SSCP =	6.750	8.750	-19.75	-49.50
$\hat{\beta}_1$ =	.0009	.00117	-.00263	-.0066
$\hat{\beta}_0$ =	4.719	4.5375	4.8915	5.1960

$\hat{Y}_i = B_0 + B_1(x)$

APPENDIX THREE

EXPERIMENT II

DATA TABLE: (Sample one)

PRESSURE	METAL	STD. IGT	TYMPAN	RUBBER
	5.32	5.16	4.76	3.85
25	5.83	5.60	4.76	3.69
	4.80	4.84	4.60	3.93
	4.68	4.84	5.44	4.60
50	5.24	4.76	4.52	3.93
	4.52	4.92	4.68	3.89
	4.88	3.89	4.09	3.77
75	4.84	4.92	5.00	4.37
	4.92	4.45	4.45	3.85

ANALYSIS OF VARIANCE TABLE:

Source	df	SS			
Total	36	781.09490			
Correction Factor	1	770.89523			
Total Corrected	35	10.19967			
Trt. Combinations	11	7.06367	.6422	4.914	2.21
Pressure	2	.60352	.3018	2.309	3.40
Packing	3	5.34807	1.783	13.64	3.01
Press. x Pack	6	1.11208	.1854	1.419	2.51
Error	24	3.136	.1307		

EXPERIMENT II

LEAST SIGNIFICANT DIFFERENCE TEST FOR BEST TREATMENT

	RUBBER 3.9867	TYMPAN 4.7	STD. IGT 4.82	METAL 5.003
5.003	1.0163 S	.303 NS	.183 NS	
4.82	.8333 S	.12 NS		
4.7	.7133 S			

$$LSD(.05) = t^{24}_{.05} \frac{2(MSE)}{2r} = .357$$

$$LSD(.01) = t^{24}_{.01} \frac{2MSE}{2r} = .528$$

If $LSD(\alpha) < \left| \bar{Y}_{\cdot\cdot j} - \bar{Y}_{\cdot\cdot j'} \right|$, then the pair is significantly different.

EXPERIMENT II

REGRESSION ANALYSIS

Sample one

$x = 50$

$SS_x = 3750$

	METAL	STD. IGT	TYMPAN	RUBBER
$\bar{y}$ =	5.003	4.82	4.7	3.987
SS =	1.268	1.75	1.122	.7172
SSCP =	-32.75	-58.5	-14.5	13.0
$\hat{\beta}_0$ =	5.44	5.6	4.89	3.813
$\hat{\beta}_1$ =	-.0087	-.0156	-.0039	.00347

$\hat{Y}_i = B_0 + B_1(x)$