Carl Smith
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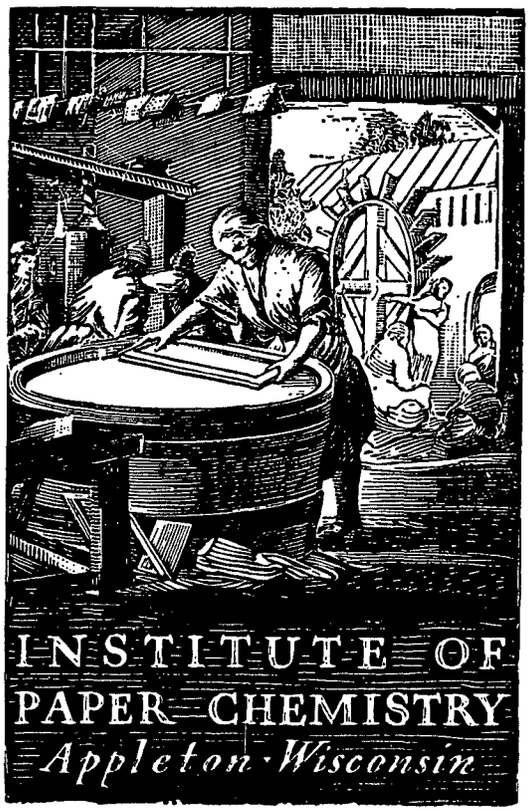

COMPARATIVE EVALUATION OF GRAIN FLOUR AND PEARL CORN CORRUGATING ADHESIVES

Project 2696-13

Report One

A Progress Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

May 3, 1974

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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SUMMARY

The Lauhoff Grain Company has developed a corrugating adhesive formulation based on the use of dry milled grain flour. Starch flour obtained by the dry mill process contains a substantial amount of protein. Past attempts to substitute dry milled grain flour for pearl cornstarch have met with only limited success because of the foaming and thickening attributed to the protein content. However, in the Lauhoff process, both the starch and protein are converted to an adhesive. Because of the possible advantages associated with the use of grain flour, this study was initiated to comparatively evaluate corrugating adhesives based on (a) the conventional two-tank pearl cornstarch formulation, and (b) the Lauhoff grain flour. For this purpose a series of corrugating trials were carried out on the Institute's corrugator using the two adhesives.

The grain flour adhesive was prepared under the guidance of the Lauhoff representatives. The solids content was 25.0%. The Stein-Hall viscosity was 40 sec at the start of the runs and 45 sec at the end of the runs. The gel points were 143 and 146°F at the start and end of the runs, respectively. It may be noted that the above viscosities were higher than expected because of an error in the formulation directions.

The conventional pearl corn corrugating adhesive had a solids content of 20.8%, a viscosity of 30 sec and a gel point of 138-139°F.

The following results were obtained:

1. In general, it appears that the Lauhoff Grain Company's grain flour formulation performed equally as well as the conventional corn flour adhesive although there are some unresolved questions in the study relative to its performance at high corrugating speeds or "subnormal" corrugating roll temperatures. A more detailed summary of the results is as follows:

2. At the same adhesive roll clearances, significantly higher adhesive consumptions were obtained with the Lauhoff grain flour adhesive as compared to the pearl corn adhesive in runs at 300 fpm. This was caused, in part, by the higher solids and viscosity of the grain flour adhesive.

3. At 300 fpm, the pin adhesion strengths obtained with the grain flour adhesive were generally somewhat higher than were obtained with the pearl corn adhesive. However, when the results were adjusted to equivalent adhesive consumption levels, it appeared that the two adhesives exhibited roughly equal adhesion strengths.

4. When corrugating speed was increased up to 750 fpm, the pin adhesion strengths obtained with the grain flour adhesive decreased at a faster rate than was the case with pearl corn adhesive; however, the differences were less marked at the lower adhesive clearance level studied. Decreasing the corrugating roll temperature from 350 to 300°F also caused greater losses in pin adhesion strength with the grain flour adhesive than were obtained with the pearl corn adhesive. Thus, the Lauhoff grain flour adhesive appears to be more sensitive to corrugator heat supply than the conventional pearl corn adhesive. This may be only the reflection of the higher gel point at which the Lauhoff grain flour was formulated. Also the

higher adhesive consumption at corresponding roll clearances would be expected to increase the heat demand. Because of the higher adhesive consumptions obtained with grain flour adhesive at corresponding adhesive roll clearances they would be expected to require more heat to gel the adhesive. Thus, it appears that the effects of speed and corrugating roll temperature may be partially related to the adhesive consumption and gel point differences of the two adhesives at equal transfer clearances. Additional trials at equal consumption levels would be required to clarify this point.

INTRODUCTION

Conventional starch corrugating adhesive employs a starch which is obtained by the wet mill process — e.g., pearl corn. Wet milled starch is characterized by its low protein content. In contrast, starch flour which is obtained by a dry mill process contains a substantial percentage of protein. Attempts to substitute starch flour for pearl cornstarch in corrugating adhesive formulations in the past have met with only limited success because of the foaming and thickening attributed to the significantly higher protein content. Protein, when properly "converted," has good adhesive properties; however, in past attempts to use grain flours, no effort was made to convert the protein portion of the flour and thereby utilize its contribution to the adhesive mix.

Recently, the Lauhoff Grain Company, Danville, Illinois, developed a corrugating adhesive formulation based on the use of grain flour which embraces a conversion to an adhesive of both the starch and the protein fractions of the flour. Patents have been granted on two processes and although copies of the patents are not yet available, they were issued November 27, 1973 and have been assigned the following patent numbers: U.S. 3,775,144 and U.S. 3,775,145.

One of the attractions of grain flour in the past in contrast to pearl cornstarch has been the lower cost — in the neighborhood of one dollar per bag. However, at the present time the grain market is fluctuating so rapidly that it is difficult to determine if this advantage exists today.

Because of the reported success which has been voiced for the Lauhoff process, Project 2696-13 was initiated to carry out a comparative study of (1) conventional two-tank corrugating adhesive formulation based on pearl cornstarch, and (2) Lauhoff process grain flour corrugating adhesive. The comparative study

was directed to comparing the above two formulations in terms of degree of adhesion, heat requirement, adhesive consumption, speed, etc. For this purpose two samples of corrugating mediums were corrugated into A-flute board using a 42-lb kraft linerboard board and each adhesive under a variety of corrugating roll temperatures, adhesive application amounts, and corrugating speeds. The conditions used are outlined below.

MATERIALS

A. Adhesive

1. Two-tank formulation based on pearl corn at 20.8% solids.
2. Lauhoff formulation based on grain flour at 25.0% solids.

B. Fibrous components

1. Corrugating medium
   a. 26-lb southern semichemical medium, Code U.
   b. 26-lb northern semichemical medium, Code F.
2. Linerboard
   a. 42-lb unbleached kraft.

C. Corrugating conditions

1. Corrugating roll temperature
   a. 350°F
   b. 300°F
2. Adhesive application
   a. Relative speed, bottom corrugating roll-transfer 95%.
   b. Clearance, bottom corrugating roll-transfer 0.010-in.
   c. Clearance, doctor-transfer roll, in.
      (1) At all corrugating speeds
         (a) 0.013
         (b) 0.009

(2) At 300 fpm

(a) 0.007

(b) 0.009

(c) 0.011

(d) 0.013

(e) 0.015

3. Corrugator speed

300-750 fpm in increments of 150 fpm

4. Steam showers

a. Before preheater 1 psi

b. Regular shower 14 psi

5. Preheater conditions

Preheat on both medium and linerboard.

FABRICATION TRIALS

A. Adjustment of corrugator conditions.

Auxiliary rolls of medium and liner were used to adjust the corrugator at an adhesive roll clearance of 0.013-in. prior to carrying out the comparative trials.

B. Experimental runs

1. Series 0.013 in. adhesive roll clearance and 350°F roll temperature trials.

a. After the machine was adjusted and running properly, the auxiliary medium was replaced with the roll of Medium U. Using the pearl starch adhesive formulation experimental single-faced board was made at 300, 450, 600, and 750 fpm.

b. Replaced Medium U with Medium F and repeated a above.

c. Replaced pearl starch adhesive with Lauhoff flour formulation. Other conditions remained the same; repeated b above.

d. Replaced Medium F with Medium U and repeated c above.

2. Series 0.009 in. adhesive roll clearance and 350°F corrugating roll trials.

a. Made run using Medium U and Lauhoff flour formulation adhesive.

b. Replaced Medium F with Medium U and repeated a above.

c. Replaced Lauhoff flour formulation adhesive with pearl corn adhesive formulation and repeated b above.

d. Replaced Medium U with Medium F and repeated c above.

3. Adhesion consumption trials — 350°F

a. Medium U, pearl corn adhesive formulation, speed of 300 fpm and adhesive roll clearance of 0.007-in.

b. Medium U, pearl corn adhesive formulation, speed of 300 fpm and adhesive roll clearance of 0.011-in.

c. Medium U, pearl corn adhesive formulation, speed of 300 fpm and adhesive clearance of 0.015-in.

d. Medium U, Lauhoff flour adhesive formulation, speed of 300 fpm and adhesive roll clearance of 0.007-in.

e. Medium U, Lauhoff flour adhesive formulation, speed of 300 fpm and adhesive roll clearance of 0.011-in.

f. Medium U, Lauhoff flour adhesive formulation, speed of 300 fpm and adhesive roll clearance of 0.015-in.

4. Trials at 300°F corrugating roll temperature and adhesive roll clearance of 0.013-in. [Note: temperature of pressure roll and preheaters also reduced to 300°F.]

a. Medium U with Lauhoff flour adhesive formulation at 300, 450, 600, and 750 fpm.

b. Medium U with pearl corn adhesive formulation at 300, 450, 600, and 750 fpm.

SAMPLING AND EVALUATION

1. Sampling:

Each sample consisted of approximately 50 lineal feet of each experimental board — stored flat.

2. Evaluation

The following test characteristics were determined.

a. Adhesive consumption: 2 determinations per clearance level at 300 fpm (dye method).

b. Flat crush: 5 tests per trial condition.

c. Pin adhesion: 5 tests per trial condition.

d. Single-faced ring compression: 5 tests per trial condition. The specimen size was 1 1/4-inches x 8.70 inches. The specimen was formed into a cylinder around a 2.37 in. diameter mandrel. The vertical edges were taped together using 30-lb paper tape (1 x 1-in.) and the loading edges were wax reinforced with Mobilwax D.

PREPARATION OF ADHESIVES

One batch of each type of adhesive was prepared the morning of the trial. All the trials were made on one day using the abovementioned batches of adhesive.

The pearl corn adhesive formulation was a conventional Stein-Hall two-tank adhesive prepared with pearl corn and had the following characteristics:

1. Viscosity (Stein-Hall cup at 100°F)
   - Start: 30 sec
   - End: 30 sec
2. Gel point, °F
   - Start: 139
   - End: 138
3. pH: 12.2

The Lauhoff adhesive was prepared under the guidance of the Lauhoff representatives as follows:

1. Primary
   a. Add 3.125 lb Lauhoff No. 711 corn flour to 4.8 liters of water.
   b. Mix with small Lightnin' mixer for five minutes.
   c. Process in jet cooker at 310°F. Dwell time in cooker was six sec.
   d. Set aside 1.5 liters of jet processed flour to be used later if necessary to adjust viscosity.
   e. To balance of jet processed flour, add 1.0 liter of water containing 0.7 lb caustic.
   f. Add 2.8 liters water for cooling.

2. Secondary

   a. Add 0.475 lb borax to 37.85 liters of water at 100°F and agitate until all borax is dissolved.

   b. Slowly add 27.5 lb No. 711 corn flour and agitate until the flour is uniformly mixed.

3. Combining of primary and secondary

   a. Temperature of secondary should be 90°F or higher at time of combining otherwise viscosity will be too high for adequate mixing.

   b. Slowly add primary to secondary with brisk agitation. The combining period should be about fifteen minutes.

The target viscosity (Stein-Hall cup) was 20-25 sec; however, due to an error, double the amount of borax was used. This resulted in too high a viscosity and even after the addition of 3.5 liters of water, the viscosity of the mix was 40.0 seconds at 100°F. The pH and gel points were 12.1 and 143°F, respectively. At the end of the corrugating trial, the viscosity was 45.0 seconds at 100°F and the gel point 146°F.

DISCUSSION OF RESULTS

As previously mentioned, this study was undertaken for the purpose of comparatively evaluating two different starch corrugating adhesives under a variety of operating conditions in terms of degree of adhesion, adhesive consumption, relative heat requirement, effect of speed, etc. The two adhesive formulations were (1) conventional two-tank Stein-Hall formulation using pearl corn, and (2) a recently developed Lauhoff Grain Company process employing grain flour. All experimental boards were made on an A-flute Langston corrugator and were evaluated in terms of pin adhesion, flat crush, adhesive consumption, and single-face ring compression. The results obtained are shown in Table I.

For the purpose of comparing the relative efficiency of the two adhesives when used to fabricate two different mediums at progressively higher speeds at each of two adhesive roll settings, the appropriate results in Table I have been retabulated in Table II. It may be noted (see Fig. 1) that at the same adhesive roll clearance, the adhesive consumption was significantly greater for the Lauhoff grain flour formulation. This reflects, in part at least, the higher solids and viscosity of the Lauhoff grain flour formulation. When the pin adhesion results at the different corrugator speed levels are compared, it may be observed (see Fig. 2 and 3) that at the 300 and 450 fpm levels, the Lauhoff grain flour formulation generally produced the higher adhesion strength; however, at 600 and 750 fpm levels, the conventional pearl corn formulation gave the higher pin adhesion values even though the pearl corn adhesive consumptions were significantly lower at 300 fpm (and presumably, at higher speeds) than for the Lauhoff process formulation.

TABLE I

PHYSICAL PROPERTIES OF EXPERIMENTAL SINGLE-FACED BOARDS

Trial No.	II-B-1-a	II-B-1-b	II-B-1-c	II-B-1-d	II-B-2-a	II-B-2-b	II-B-2-c	II-B-2-d
Corr. Temp. °F	350	350	350	350	350	350	350	350
Medium:	U	F	F	U	U	F	F	U
Adhesion: Type :	Pearl Corn	Pearl Corn	Grain Flour	Grain Flour	Grain flour	Grain flour	Pearl Corn	Pearl Corn
Adhesive Clearance, in.	0.013	0.013	0.013	0.013	0.009	0.009	0.009	0.009
Corr. Speed fpm				Flat Crush, psi				
300	32.8	28.5	27.1	31.8	32.6	28.3	27.9	33.3
450	--	28.7	27.6	--	--	28.2	28.5	--
600	--	28.4	28.1	--	--	28.0	29.0	--
750	--	27.9	27.6	--	--	29.0	29.5	--
				Single-face Ring, lb/in.				
300 300	38.7	37.1	37.2	40.2	38.8	37.1	37.0	38.1
450	--	36.8	36.7	--	--	37.0	36.3	--
600	--	36.5	37.6	--	--	35.8	35.3	--
750	--	36.0	36.1	--	--	33.2	35.1	--
				Single-face Pin Adhesion, lb/6 in.^{2}				
300	82.6	72.4	78.6	90.4	80.4	70.8	60.0	74.6
450	78.2	71.8	74.8	85.2	63.4	65.0	59.8	66.2
600	78.2	61.8	54.0	59.2	57.2	49.6	52.0	68.8
750	58.8	51.0	37.6	31.0	43.0	39.4	44.2	53.4
				Single-face Pin Adhesion, Failure Type %, (LL-LA-AA-CA-CC)[a]				
300	20-0-0-30-50	0-0-0-80-20	10-0-0-50-40	30-0-0-70-0	20-80-0-0-0	0-30-0-70-0	10-0-0-50-40	30-0-0-50-20
450	0-0-0-50-50	0-10-0-70-20	0-0-0-60-40	10-50-0-40-0	20-40-0-40-0	0-20-0-80-0	10-30-0-30-30	30-50-0-20-0
600	20-0-0-50-30	0-0-0-90-10	0-0-20-80-0	0-60-0-40-0	0-80-0-20-0	0-70-0-30-0	30-10-0-50-10	50-10-0-30-10
750	20-10-0-70-0	0-0-0-100-0	0-0-100-0-0	0-40-50-10-0	0-40-50-10-0	0-20-80-0-0	0-40-10-40-10	10-60-0-20-10
				Adhesion Consumption, lb/M ft^2				
300	1.14	1.19	1.33	1.51	0.87	0.77	0.62	0.74

[a] See end of table for footnotes.

TABLE I (Continued)

PHYSICAL PROPERTIES OF EXPERIMENTAL SINGLE-FACED BOARDS

Trial No.	II-B-3-a	II-B-3-b	II-B-3-c	II-B-3-d	II-B-3-e	II-B-3-f	II-B-4-a	II-B-4-b
Corr. Temp. °F	350	350	350	350	350	350	300	300
Medium:	U	U	U	U	U	U	F	F
Adhesion:	Pearl Corn	pearl Corn	Pearl Corn	Grain Flour	Grain Flour	Grain Flour	Grain Flour	Pearl Corn
Type : Adhesive Clearance, in.	0.007	0.011	0.015"	0.015"	0.011"	0.007"	0.013"	0.013"
				Flat Crush, psi				
Corr. Speed fpm								
300	33.6	31.8	31.0	31.4	31.6	32.8	28.6	29.3
450	--	--	--	--	--	--	--	--
600	--	--	--	--	--	--	--	--
750	--	--	--	--	--	--	--	--
				Single-face Ring, lb/in.				
300	38.3	38.2	39.1	40.2	39.0	35.6	36.2	34.9
450	--	--	--	--	--	--	--	--
600	--	--	--	--	--	--	--	--
750	--	--	--	--	--	--	--	--
				Single-face Pin Adhesion, lb/6 in.^{2}				
300	60.4	82.8	89.2	99.8	89.8	65.6	72.8	69.6
450	--	--	--	--	--	--	48.0	60.8
600	--	--	--	--	--	--	25.4	37.4
750	--	--	--	--	--	--	15.2	22.0
				Single-face Pin Adhesion, Failure Type %, (LL-LA-AA-CA-CC)[a]				
300	20-30-0-50-0	30-0-0-30-40	0-0-0-60-40	0-20-0-70-10	20-10-0-60-10	20-80-0-0-0	60-30-0-0-10	50-20-0-20-10
450	--	--	--	--	--	--	30-50-20-0-0	70-30-0-0-0
600	--	--	--	--	--	--	0-0-100-0-0	0-30-70-0-0
750	--	--	--	--	--	--	0-0-100-0-0	0-0-100-0-0
				Adhesion Consumption, lb/M ft^2				
300	0.38	0.74	1.24	1.64	1.34	0.68		

[a]Adhesion failure pattern based on usual assessment.
LL — percentage of area in which failure involved the liner fiber-fiber bond.
LA — percentage of area in which failure occurred at liner-adhesive interface.
AA — percentage of area in which failure occurred within the adhesive-cohesion.
CA — percentage of area in which failure occurred at medium-adhesive interface.
CC — percentage of area in which failure involved medium fiber-fiber bond.

TABLE II

EFFECT OF SPEED AND ADHESIVE ROLL SETTINGS ON BOARD PROPERTIES

Trial no.	II-B-1-a	II-B-1-d	Diff. %[a]	II-B-1-b	II-B-1-c	Diff. %[a]	II-B-2-d	II-B-2-a	Diff. %[a]	II-B-2-c	II-B-2-b	Diff. %[a]
Corrugating roll temp. °F	350	350		350	350		350	350		350	350	
Type adhesive	Pearl corn	Grain flour		Pearl corn	Grain flour		Pearl corn	Grain flour		Pearl corn	Grain flour	
Adhesive roll clearance, in.	0.013	0.013		0.013	0.013		0.009	0.009		0.009	0.009	
Type medium	Medium U	Medium U		Medium F	Medium F		Medium U	Medium U		Medium F	Medium F	
Corrugator speed, fpm	Adhesive Consumption lb/M ft^2											
300	1.14	1.51	32.5	1.19	1.33	11.8	0.74	0.87	18.0	0.62	0.77	24.0
	Single-face Adhesion, lb/6 in.^{2}											
300	82.6	90.4	9.5	72.4	78.6	8.6	74.6	80.4	7.8	60.0	70.8	18.0
450	78.2	85.2	9.0	71.8	74.8	4.2	66.2	63.4	- 4.2	59.8	65.0	8.7
600	78.2	59.2	- 24.3	61.8	54.0	-12.6	68.8	57.2	-16.9	52.0	49.6	- 4.6
750	58.8	31.0	-47.2	51.0	37.6	-26.3	53.4	43.0	-19.5	44.2	39.4	-10.9
	Flat crush, psi											
300	32.8	31.8	- 3.0	28.5	27.1	- 4.9	33.3	32.6	- 2.1	27.9	28.3	1.4
450	--	--		28.7	27.6	- 3.8	--	--		28.5	28.2	- 1.1
600	--	--		28.4	28.1	- 1.1	--	--		29.0	28.0	- 3.4
750	--	--		27.9	27.6	- 1.1	--	--		29.5	29.0	- 1.7
	Single-face Ring Compression, lb/in.											
300	38.7	40.2	3.9	37.1	37.2	0.3	38.1	38.8	1.8	37.0	37.1	0.3
450	--	--		36.8	36.7	- 0.3	--	--		36.3	37.0	1.9
600	--	--		36.5	37.6	3.0	--	--		35.3	35.8	1.4
750	--	--		36.0	36.1	- 0.3	--	--		35.1	33.2	- 5.4

[a] Based on pearl corn results as reference.

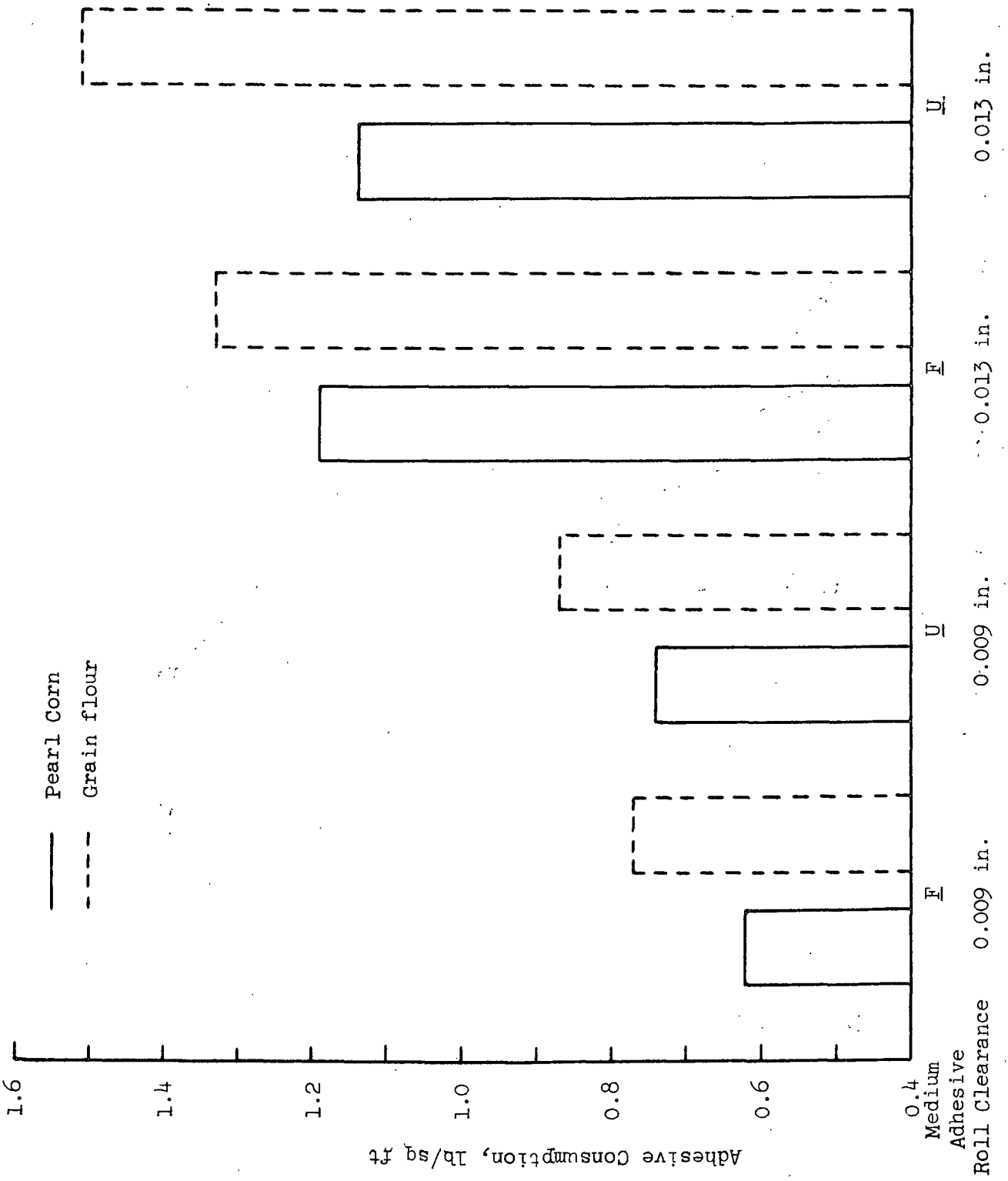

Figure 1. Adhesive Consumption of Pearl Corn and Grain Flour Formulations at 0.009 and 0.013-in. Settings

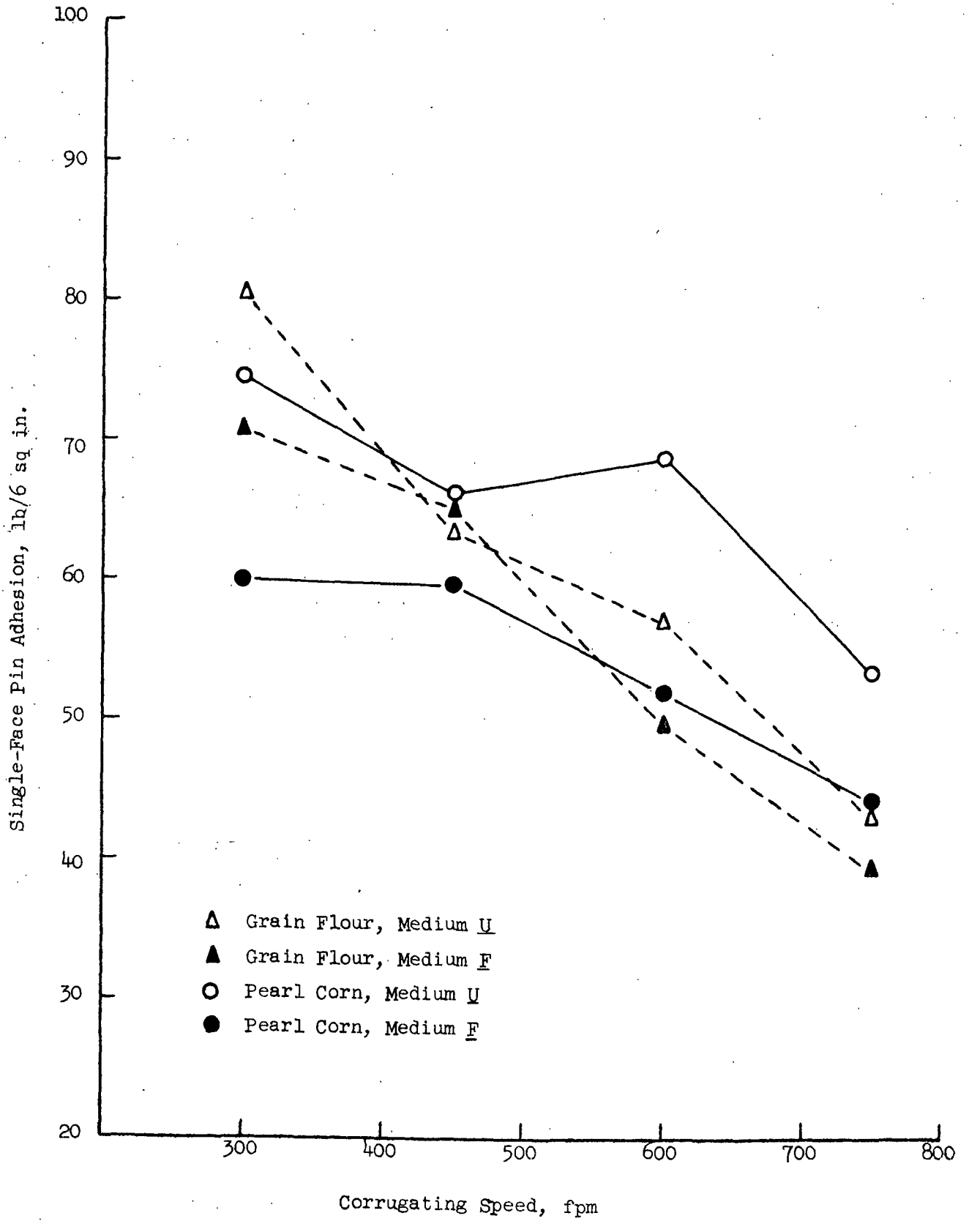

Figure 2. Relationship Between Corrugator Speed and Adhesion (0.009-in. Roll Clearance)

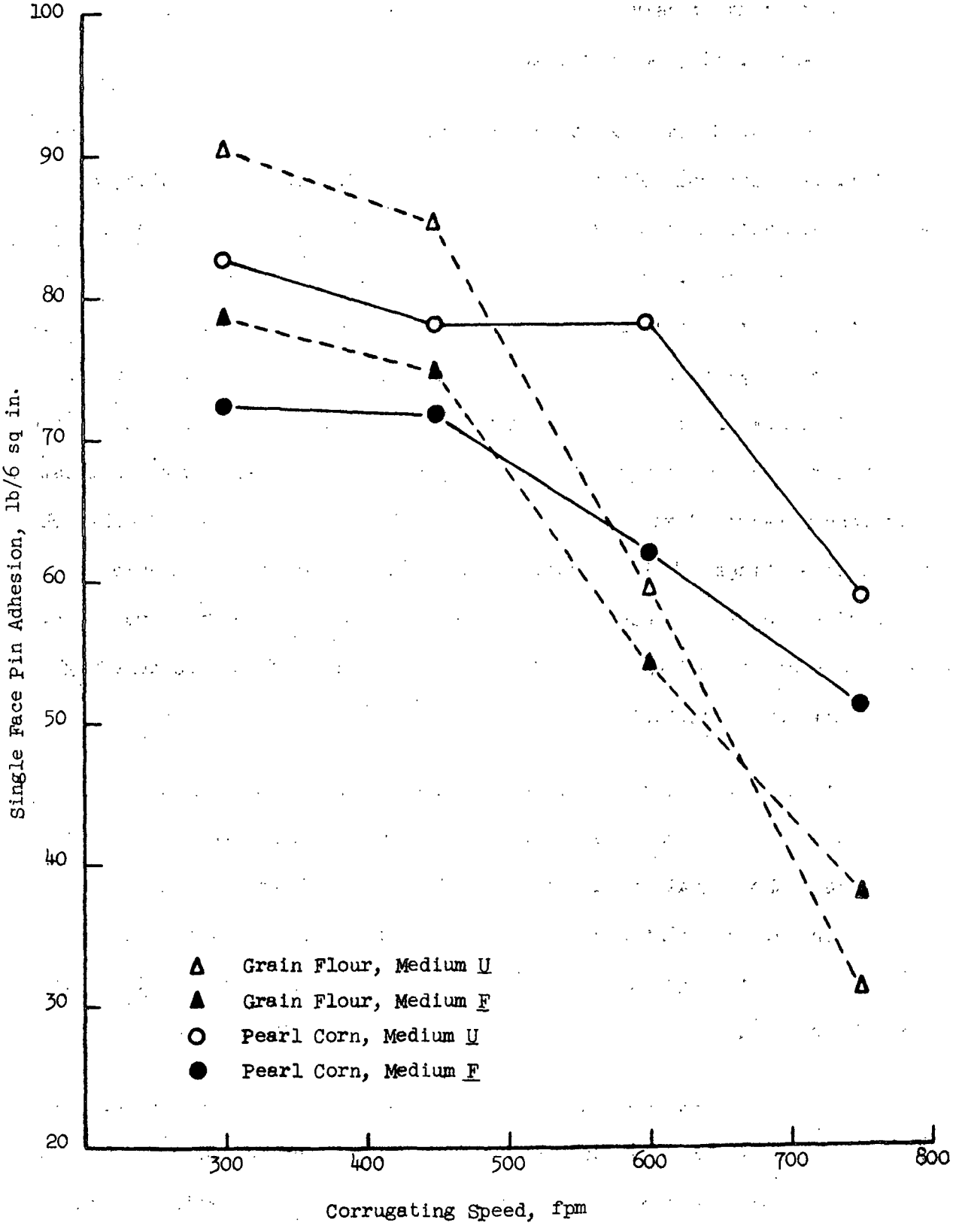

Figure 3. Relationship Between Corrugator Speed and Adhesion (0.013-in. Clearance)

The type of adhesive appears to have no significant effect on flat crush or single-face ring compression.

As mentioned, in order to compare the interrelationship of adhesive consumption, adhesive roll clearance and combined board characteristics, a series of trials with Medium U were carried out at 300 fpm in which the adhesive roll clearance was varied from 0.007 to 0.015 in. in increments of 0.002 inch. The results of these trials given in Table I have been retabulated in Table III for more ready comparison. As may be noted, the adhesive consumption for the Lauhoff grain flour formulation was higher at all adhesive roll clearances (see Fig. 4) than the corresponding values for the conventional pearl corn formulation. The differences ranged from 17.6% for the 0.009-in. to 81.1 for the 0.011-inch adhesive roll settings. This is considerably higher than is accountable on the basis of the approximately 20.2% higher solids of the Lauhoff formulation. However, the viscosity of the grain flour adhesive was also considerably higher than the pearl corn formulation.

When the pin adhesion strength results at corresponding adhesive roll clearances are compared (see Table III), it may be observed that in all instances the Lauhoff grain flour formulation exhibited higher pin adhesion strength. However, as pointed out earlier, at equivalent adhesive roll clearances, the Lauhoff grain flour formulation exhibited significantly higher adhesive consumptions.

In order to take consumption into account, the pin adhesion results in Table III were plotted against adhesive consumption as shown in Fig. 5. When straight lines were statistically fitted to the data for Medium U with each adhesive type, it was found that the grain flour regression line was

TABLE III

RELATIONSHIP BETWEEN ADHESIVE CONSUMPTION, ADHESIVE ROLL CLEARANCE, AND BOARD PROPERTIES

(Medium U, 300 fpm, 350°F Roll Temp.)

Item	Adhesive Roll Clearance, in.	Pearl Corn Adhesive	Grain Flour Adhesive	Diff., %[a]
1. Adhesive Consumption, lb/M ft^2	0.007	0.38	0.68	+78.9
	0.009	0.74	0.87	+17.6
	0.011	0.74	1.34	+81.1
	0.013	1.14	1.51	+32.5
	0.015	1.24	1.64	+32.3
2. Pin Adhesion, lb/6 sq in.	0.007	60.4	65.6	+ 8.6
	0.009	74.6	80.4	+ 7.8
	0.011	82.8	89.8	+ 8.5
	0.013	82.6	90.4	+ 9.4
	0.015	89.2	99.8	+11.9
3. Flat Crush, psi	0.007	33.6	32.8	- 2.4
	0.009	33.3	32.6	- 2.1
	0.011	31.8	31.6	- 0.6
	0.013	32.8	31.8	- 3.0
	0.015	31.0	31.4	+ 1.3
4. Single-face Ring Compression, lb/in.	.007	38.3	35.6	- 7.0
	.009	38.1	38.8	+ 1.8
	.011	38.2	39.0	+ 2.1
	.013	38.7	40.2	+ 3.9
	.015	39.1	40.2	+ 2.8

[a]Based on pearl corn adhesive results as reference.

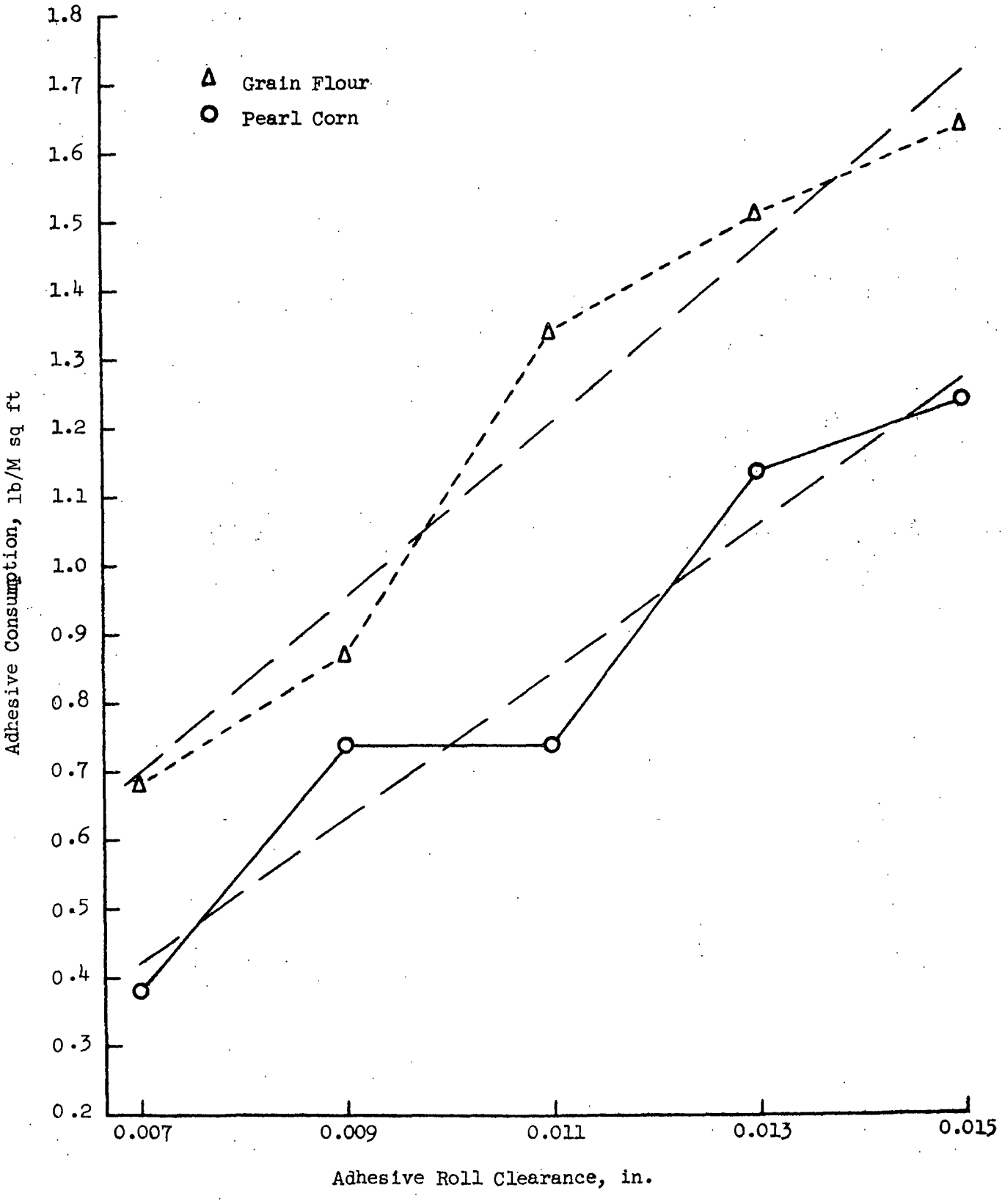

Figure 4. Relationship Between Adhesive Roll Clearance and Adhesive Consumption for Medium U

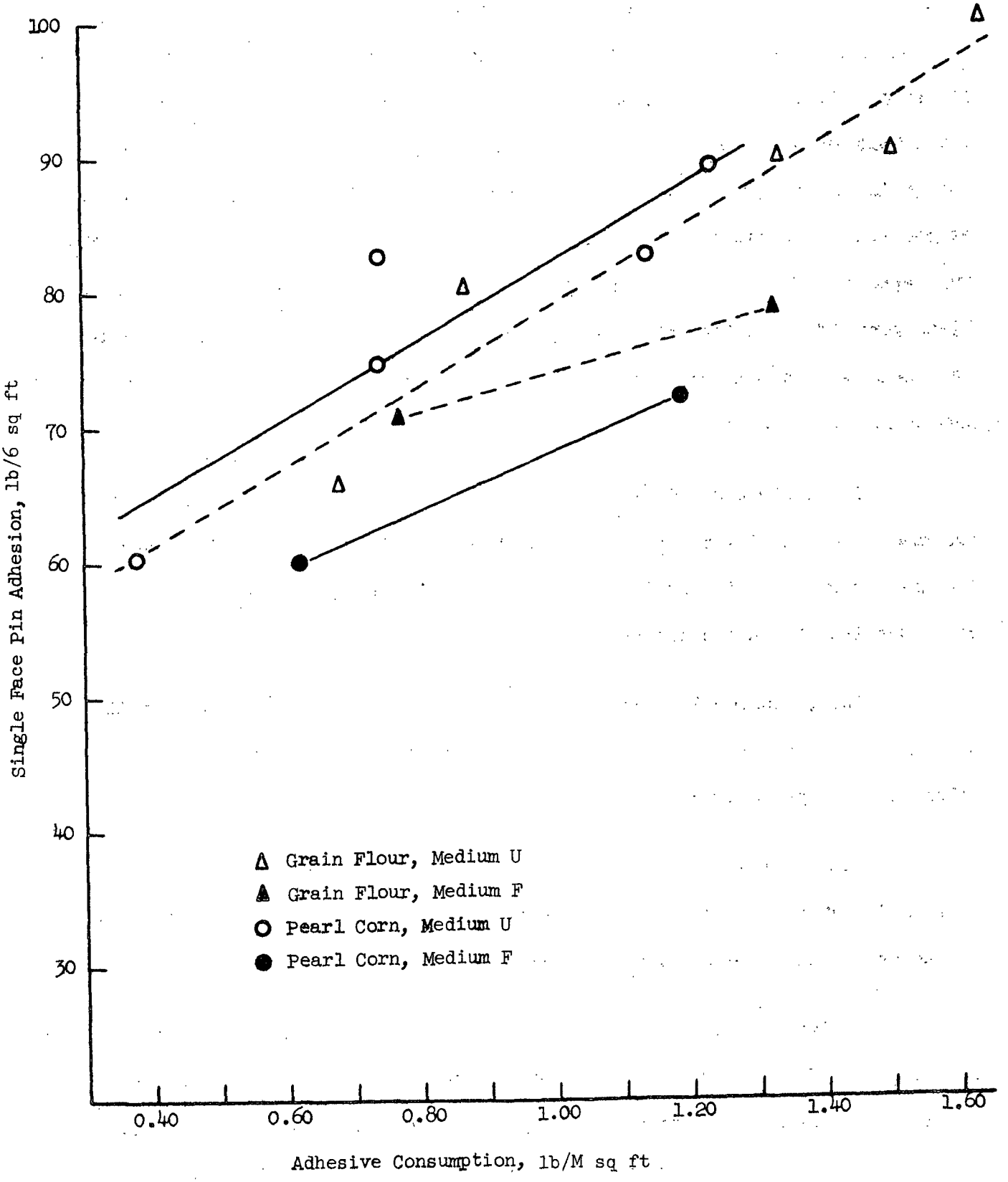

Figure 5. Relationship Between Adhesive Consumption and Pin Adhesion

at a somewhat lower level than the line for the pearl corn adhesive. Pin adhesion values were read from the two regression lines at the adhesive consumption levels obtained with the pearl corn adhesive. These values are summarized in Table IV and show that the pin adhesion strengths obtained with the grain flour adhesion were about 4.5% lower than for the pearl corn adhesive at 300 fpm for Medium U. However, the difference between the intercepts of the two regression lines was not statistically significant when parallel regression lines were fitted to the data. Thus, it appears that the two adhesion formulations gave approximately the same pin adhesion strengths at equal consumption levels for Medium U at 300 fpm.

The 0.009 and 0.013-in. clearance results for Medium F at 300 fpm are also shown in Fig. 5. Inspection of the figure shows that in this case the grain flour adhesive exhibits higher adhesion strengths than the pearl corn adhesive at equal consumption levels.

Thus, considering the results for both mediums, it appears that the two adhesive types exhibit about equal adhesion strength at equivalent adhesive consumption levels.

Examination of the flat crush and single-face ring compression results in Table III reveal that these strength levels were not significantly influenced by the type of adhesive used.

A limited study was made to determine if the two adhesive formulations exhibited a difference in heat demand on the corrugator. For this purpose, trials were made at two levels of corrugator temperature, namely 300 and 350°F. All other adjustments were maintained the same. The results of these trials

TABLE IV

COMPARISON OF PIN ADHESION RESULTS AT EQUIVALENT ADHESIVE CONSUMPTION

(Medium U, 300 fpm)

Adhesive Roll Clearance, in.	Adhesive Consumption, lb/M ft^2 (Pearl Corn)	Adjusted Pin Adhesion,[a] lb/6 sq in.		Diff., %[b]
		Pearl Corn	Grain Flour	
0.007	0.38	64.5	61.0	- 5.4
0.009	0.74	75.0	71.5	- 4.7
0.011	0.74	75.0	71.5	- 4.7
0.013	1.14	86.5	83.0	- 4.0
0.015	1.24	89.5	82.0	- 3.9

[a] Values obtained from pin adhesion vs. adhesive consumption relationships shown in Fig. 5.

[b] Based on pearl corn results as reference.

have been retabulated in Table V for ease of comparison. It may be seen that on the basis of the percentage difference in pin adhesion, the Lauhoff grain flour formulation appears to be more sensitive to heat than the conventional pearl corn formulation. Because of the higher adhesive consumption and gel point associated with the Lauhoff formulation, it would be expected to require more heat.

TABLE V

EFFECT OF CORRUGATOR TEMPERATURE

Trial No.	II-B-1-b	II-B-4-b	Diff., %	II-B-1-c	II-B-4-a	Diff., %[a]
Corr. Roll Temp., °F	350	300		350	300	
Type Adhesive	Pearl corn	Pearl corn		Grain flour	Grain flour	
Adhesive Roll Clearance, in.	0.013	0.013		0.013	0.013	
Type Medium	Medium F	Medium F		Medium F	Medium F	
Corrugator speed, fpm	Adhesive Consumption, lb/M ft^2					
300	1.19	--		1.33	--	
	Single-face Adhesive, lb/6 in.^{2}					
300	72.4	69.6	- 3.9	78.6	72.8	- 7.4
450	71.8	60.8	-15.3	74.8	48.0	-35.8
600	61.8	37.4	-39.5	54.0	25.4	-53.0
750	51.0	22.0	-56.9	37.6	15.2	-59.6
	Flat crush, psi					
300	28.5	29.3	+ 2.8	27.1	28.6	+ 5.5
450	28.7	--		27.6	--	
600	28.4	--		28.1	--	
750	27.9	--		27.6	--	
	Single-face Ring Compression, lb/in.					
300	37.1	34.9	- 5.9	37.2	36.2	- 2.7
450	36.8	--		36.7	--	
600	36.5	--		37.6	--	
750	36.0	--		36.1	--	

[a]Based on 350°F results as reference.

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