THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

BEHAVIOR OF FIBROUS AND NONFIBROUS COMPONENTS IN THE CORRUGATING OPERATION

PART IV-B. EFFECT OF FINGER DESIGN AND CLEARANCE ON FLUTE PROFILE OF SINGLE-FACED BOARD

Project 1108-22

Report Seven

A Progress Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

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TABLE OF CONTENTS

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SUMMARY

A study has been carried out for the purpose of determining the effect which the design of the finger and the clearance between the finger and the bottom corrugating roll may have on flute uniformity. Previous studies have established that all single-faced board exhibits a fairly regular pattern of alternate flutes being high and low. It was theorized that possibly the design and/or the clearance of the fingers may have an affect on flute uniformity since it may be expected that with too great a clearance there might be a greater tendency for greater disparity in flute height.

The results of this study in so far as finger design and finger clearance affected flute uniformity were as follows:

1. Finger clearance did not appear to have a significant effect on semi-chemical or bogus medium in so far as caliper and flute height disparity was concerned. In the case of kraft corrugating medium, the smaller clearances appeared better.

2. Varying the finger clearance at the pressure roll did not appear to have any marked effect on the formation of high-low corrugations or caliper.

3. There was no apparent trend for the uniformity of flutes to vary with the degree of finger relief except for the kraft mediums. At 600 f.p.m. the kraft mediums exhibited more intense high-low corrugations at the smaller and larger clearances used.

4. The transfer roll clearance did not appear to have a significant effect on caliper or high-low corrugations.

5. In all cases the high-low corrugations became more pronounced at the higher speed. This confirms previous findings.

6. The results obtained in this study were not anticipated and apparently do not agree with industry opinion. The literature, however, does not contain any reference to a similar study on production-size equipment. Further, it is difficult to see why commercial-size equipment would in this case exhibit a different effect. It was observed that as the clearance increased, the tendency for the medium to flutter increased.

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INTRODUCTION

For sometime the Institute of Paper Chemistry has been concerned with various aspects of the corrugating operation and the quality of corrugating mediums. One of the goals of this study is the determination of the causes of high-low flutes and fractured flute. The presence of either one of these two conditions is in most cases the limiting factor in how fast a medium can be corrugated.

Prior studies in this general area have been concerned with (a) an analysis of the stress-strain environment to which the medium is subjected prior to and in the labyrinth (1), (b) the general behavior of the medium during the corrugating and single-facing operations (2), (c) the behavior of the top corrugating roll and the role of transverse compression (3), and (d) a comparative study of the flute height profile of A-, B- and C-flute boards produced on commercial corrugators (4). The latter study showed that single-faced boards made on commercial units all exhibited a periodicity of alternating high-low flute formation even on satisfactory board. The difference in height was not sufficient to cause difficulty in double-facing. The results implied that the corrugating operation may impose a basic pattern of high-low flutes. Further, an understanding of the cause of the noted flute height periodicity may provide a clue as to the manner in which objectionable high-low flutes are formed.

Previous studies have indicated that the difference in flute height did not appear to be related to the stress environment prior to the center of the labyrinth of the corrugating rolls. However, it was observed that after the board emerges from the labyrinth the height of the flute may vary considerably. It was

reasoned that possibly this formation of different height flutes may be functionally related to the dimensions and positioning of the fingers. At the FEFCO meeting held in Sorrento, Italy in May, 1962, Werner Peters, an associate of the Peters Corrugated Machinery Company, stated that the presence of the alternating high-low flutes was due to the finger arrangement (4).

The present study is directed to an investigation of the effects of finger design, position and clearance on the height of flute. For purposes of this study, corrugating trials were carried out using four different mediums. These mediums were corrugated at different speeds under conditions representing a variety of finger designs, dimensions, and clearances and their effect on flute height noted.

GENERAL PROCEDURE

FABRICATION

The first series of trials were carried out using the Institute's "slice" corrugator (1-inch face width), equipped with Langston conventional A-flute design rolls. This equipment was used initially because its design is such that the action of the medium can be readily photographed. However, this equipment was abandoned in subsequent trials in favor of the Institute's regular experimental corrugator [because it was feared that the action taking place on such a narrow roll (only one finger centrally located across face) might not be representative of the action on a wider roll involving regularly spaced fingers].

The variables included in this study were:

a. Effect of finger clearance with relief.

b. Effect of finger clearance with no relief.

c. Effect of finger clearance at pressure roll nip.

d. Effect of finger relief.

e. Effect of finger clearance in area of labyrinth.

f. Effect of transfer roll clearance.

The standard finger used on the slice corrugator misses being a full semi-circle by only a few degrees. The relief in the finger corresponds to a maximum displacement of .070 inch. The relief extends over a chord distance of 2.75 inches and corresponds to the point of minimum clearance between the adhesive transfer roll and the bottom corrugating roll.

In order to study the effect of finger clearance, runs were made with the finger positioned at various clearances when measured at a point corresponding to 90° from the center of the labyrinth. The dimensions of the standard finger are such that when the clearance is .012 at the measuring point, one has a .012 normal clearance all way round. Thus, when the clearance is increased or decreased, the greatest effect is at the middle.

The effect of finger relief was carried out with a finger with no relief, a standard finger, and fingers with enlarged reliefs. The 3/32 enlarged relief was obtained by relieving the standard relief by 3/32 of an inch over the entire relief area. The extended 3/32-inch relief was obtained by removing 3/32 inches from the finger with the 3/32 enlarged relief, from the point of relief to the pressure roll end of the finger. The clearance at the labyrinth was varied by building up or removing substance from the finger in this area.

Trials carried out using the slice corrugator were made at 80 and 150 feet per minute. The trials carried out on the experimental corrugator were made at 150

and 600 feet per minute. All other conditions were held constant except the specified variable under study.

MATERIALS USED

The preliminary trials carried out on the slice corrugator involved one semichemical medium and the speed for all the trials was maintained at 80 f.p.m. The second group of trials involved four different mediums (two semichemicals, one bogus, and one kraft) and the speed was held at 150 f.p.m.

Because of insufficient material it was necessary to use four different rolls of medium for the trials on the Institute's experimental corrugator; however, they were of the same grades and types as were used for the trials on the slice corrugator.

EVALUATION

Each single-faced board was evaluated in terms of the maximum, minimum, and average difference in the height of consecutive flutes as well as the caliper of the board.

DISCUSSION OF RESULTS

The results obtained on the slice corrugator using various finger clearance, finger relief, and finger dimensions are given in Tables I and II for speeds of 80 and 150 f.p.m., respectively.

When the data tabulated in Tables I and II are considered, it may be noted that varying the clearance of the finger (with relief) from .006 to .018 inch had no significant effect on the average difference in the height of consecutive

TABLE I

EFFECT OF FINGER POSITION ON UNIFORMITY OF FLUTE SHEET

(Semichemical Medium of 80 f.p.m. on Slice Corrugator)

Run No.	Description of Variable	Finger Clearance, in.	Glue Roll Clearance, in.	Individual Flute Height, Av. Diff. Consecutive Flutes, pt.	Individual Flute Height, Max. Diff., pt.	Single-faced Board Caliper, pt. Av.	Max.	Min.
			EFFECT OF FINGER CLEARANCE WITH RELIEF					
2	Small clearance	0.006	0.016	1.9	8.2	200.6	208.0	196.8
1-24	Normal clearance	0.012	0.016	1.7	8.5	200.5	206.4	196.1
3	Wide clearance	0.018	0.016	2.6	8.9	200.5	208.5	196.6
			EFFECT OF FINGER CLEARANCE WITH NO RELIEF					
6-19	No finger relief	0.012	0.008	1.7	7.8	201.5	205.8	198.1
15-18	No finger relief	0.080	0.008	1.0	5.4	200.9	204.4	198.0
16-17	No finger relief	0.080	0.040	0.9	3.2	201.6	204.1	199.1
			EFFECT OF FINGER CLEARANCE AT PRESSURE ROLL NIP					
7-25	End of finger contoured to pressure roll-tight	0.012	0.016	2.0	8.2	200.1	206.6	196.8
1-24	Normal - Std. finger	0.012	0.016	1.7	8.5	200.5	206.4	196.1
4	Rotated Std. finger 1/2 flute out of pressure nip.	0.012	0.016	2.9	10.7	200.9	207.1	196.4
5	Rotated Std. finger 1 flute out of pressure nip.	0.012	0.016	1.1	6.4	200.8	204.0	197.6
			EFFECT OF FINGER-RELIEF					
6-19	No finger relief	0.012	0.008	1.7	7.8	201.5	205.8	198.1
1-24	Std. finger relief	0.012	0.016	1.7	8.5	200.5	206.4	196.1
11-23	Enlarged radius of relief 3/32 in.	0.012	0.016	1.0	4.6	200.0	204.2	196.5
14-20	Enlarged radius of finger beyond center line of relief 3/32 in.	0.012	0.016	1.2	6.1	201.4	206.4	198.7
			EFFECT OF FINGER CLEARANCE IN AREA OF LABYRINTH					
9	0.005 in. clearance at labyrinth	0.012	0.016	2.0	7.2	198.9	203.4	192.1
1-24	Std. clearance (.012) at labyrinth	0.012	0.016	1.7	8.5	200.5	206.4	196.1
8	0.024 in clearance at labyrinth	0.012	0.016	1.9	7.5	199.7	207.0	196.0
10	0.070 in clearance at labyrinth	0.012	0.016	1.0	7.6	199.6	203.5	195.2
			EFFECT OF TRANSFER ROLL CLEARANCE					
11-23	Std. finger + 3/32 enlarged relief radius	0.012	0.016	1.0	4.6	200.0	204.7	196.5
12-21	Std. finger + 3/32 enlarged relief radius	0.012	0.031	1.1	7.6	200.3	205.9	196.4
13-22	Std. finger + 3/32 enlarged relief radius	0.012	0.070	1.2	6.5	201.9	202.2	198.2

TABLE II

EFFECT OF FINGER DESIGN AND CLEARANCE ON FLUTE UNIFORMITY

(Slice Corrugator - 150 f.p.m.)

Run No.	Type Medium	Finger Clearance, in.	Transfer Roll, Clearance, in.	Individual Flute Height, pt. Av. Diff. Consecutive flutes	Individual Flute Height, pt. Max. Diff.	Single-faced Board Caliper, pt. Av.	Single-faced Board Caliper, pt. Max.	Single-faced Board Caliper, pt. Min.
			Regular Finger - Standard Relief					
2	K-7061 - Semi-chem. - P.	0.006	0.016	2.1	6.8	196.0	198.6	192.1
1	K-7061 - Semi-chem. - P.	0.012	0.016	1.1	3.2	195.3	197.4	193.5
3	K-7061 - Semi-chem. - P.	0.040	0.016	1.5	5.3	196.6	199.2	193.2
4	K-7061 - Semi-chem. - P.	0.080	0.016	1.3	4.4	197.2	199.2	194.8
5	K-7061 - Semi-chem. Repeat of Run 1	0.012	0.016	1.4	4.2	197.0	198.9	194.6
2	K-7068 Semi-chem - G.	0.006	0.016	1.8	5.0	195.3	198.0	193.0
1	K-7068 Semi-chem - G.	0.012	0.016	1.2	4.4	194.7	196.9	192.8
3	K-7068 Semi-chem - G.	0.040	0.016	1.5	5.0	195.7	198.0	193.0
4	K-7068 Semi-chem - G.	0.080	0.016	1.8	5.1	195.7	198.2	192.5
5	K-7068 Semi-chem Repeat of Run 1	0.012	0.016	1.1	4.0	195.1	197.0	192.5
2	K-6989 Bogus	0.006	0.016	1.7	4.9	194.5	197.1	191.1
1	K-6989 Bogus	0.012	0.016	1.5	4.0	194.7	196.8	192.1
3	K-6989 Bogus	0.040	0.016	1.4	3.3	195.0	197.3	192.8
4	K-6989 Bogus	0.080	0.016	1.3	5.1	195.1	197.5	192.2
5	K-6989 Bogus Repeat of Run 1	0.012	0.016	1.1	4.2	195.2	197.5	193.0
2	K-6911 Kraft	0.006	0.016	1.6	4.7	194.4	196.9	191.3
1	K-6911 Kraft	0.012	0.016	2.5	6.2	194.0	196.8	190.6
3	K-6911 Kraft	0.040	0.016	4.5	8.5	194.3	198.5	190.0
4	K-6911 Kraft	0.080	0.016	4.9	8.5	194.5	198.8	189.8
5	K-6911 Kraft Repeat of Run 1	0.012	0.016	2.8	7.7	194.7	198.2	191.5

TABLE II (Continued)

EFFECT OF FINGER DESIGN AND CLEARANCE ON FLUTE UNIFORMITY

(Slice Corrugator - 150 f.p.m.)

Run No.	Type Medium	Finger Clearance, in.	Transfer Roll, Clearance, in.	Individual Flute Height, pt. Av. Diff. Consecutive flutes	Individual Flute Height, pt. Max. Diff.	Single-faced Board Caliper, pt. Av.	Single-faced Board Caliper, pt. Max.	Single-faced Board Caliper, pt. Min.
			No Relief in Finger					
2	K-7061 - Semi-chem - P.	0.006	0.016	2.1	6.8	196.0	198.6	192.1
1	K-7061 - Semi-chem - P.	0.012	0.016	1.1	3.2	195.3	197.4	193.5
3	K-7061 - Semi-chem - P.	0.040	0.016	1.5	5.3	196.6	199.2	193.2
4	K-7061 - Semi-chem - P.	0.080	0.016	1.3	4.4	197.2	199.2	194.8
5	K-7061 - Semi-chem. Report at Run 1	0.012	0.016	1.4	4.2	197.0	198.9	194.6
2	K-7068 Semi-chem - G.	0.006	0.016	1.8	5.0	195.3	198.0	193.0
1	K-7068 Semi-chem - G.	0.012	0.016	1.2	4.4	194.7	196.9	192.8
3	K-7068 Semi-chem - G.	0.040	0.016	1.5	5.0	195.7	198.0	193.0
4	K-7068 Semi-chem - G.	0.080	0.016	1.8	5.1	195.7	198.2	192.5
5	K-7068 Semi-chem. Repeat of Run 1	0.012	0.016	1.1	4.0	195.1	197.0	192.5
2	K-6989 Bogus	0.006	0.016	1.7	4.9	194.5	197.1	191.1
1	K-6989 Bogus	0.012	0.016	1.5	4.0	194.7	196.8	192.1
3	K-6989 Bogus	0.040	0.016	1.4	3.3	195.0	197.3	192.8
4	K-6989 Bogus	0.080	0.016	1.3	5.1	195.1	197.5	192.2
5	K-6989 Bogus Repeat of Run 1	0.012	0.016	1.1	4.2	195.2	197.5	193.0
2	K-6911 Kraft	0.006	0.016	1.6	4.7	194.4	196.9	191.3
1	K-6911 Kraft	0.012	0.016	2.5	6.2	194.0	196.8	190.6
3	K-6911 Kraft	0.040	0.016	4.5	8.5	194.3	198.5	190.0
4	K-6911 Kraft	0.080	0.016	4.9	8.5	194.5	198.8	189.8
5	K-6911 Kraft Repeat of Run 1	0.012	0.016	2.8	7.7	194.7	198.2	191.5

flutes. The same trend may be noted for maximum difference in consecutive flute height as well as single-faced board caliper.

The results obtained for the trials involving the effect of finger clearance with a finger which had no relief (normal relief extends over a chord distance of approximately 2.75 inches and a maximum displacement of approximately .070 inch) indicate that varying the clearance from .012 to 0.080 inch introduced no marked change in the average height of consecutive flutes or single-faced board caliper. Contrary to expectation, the greater finger clearance (and glue roll clearance) produced board with the lowest average difference in height of consecutive flutes. The same trend may be noted for the maximum difference.

In order to study the effect of finger clearance in the area of the pressure roll the end of the finger was ground to the contour of the pressure roll. The clearance was varied by rotating the finger about the bottom corrugating roll, thereby maintaining the same clearance between the inside arc of the finger and the bottom corrugating roll. It may be observed from the data tabulated in Table I that varying the clearance at the pressure roll had no significant effect on the average difference in the height of consecutive flutes or the caliper of the single-faced board. The maximum difference in the height of consecutive flutes was greatest when the finger was rotated one-half flute out from pressure roll; however, it is questionable because the corresponding value for the case where the finger was rotated a full flute was much lower.

The results obtained with varying amounts of finger relief show that under two conditions of these trials the greater relief was slightly better in terms of average flute height; however, it is questionable if the differences are

significant. The same trend may be noted for the maximum difference in flute height. The degree of relief did not appear to have any marked influence on single-faced board caliper.

In order to investigate the effect of finger clearance in the area of the labrinth, the fingers were built up slightly since the normal fingers miss being a true semicircle by only a few degrees. The results obtained at various amounts of clearance in the area of the labyrinth indicate that there was no significant change in the average difference in height of consecutive flutes except possibly a smaller difference at the greatest clearance. In general, the maximum difference and average caliper were not influenced to any significant degree.

The clearance between the adhesive transfer roll and the bottom corrugating roll was also varied at a normal finger setting to determine if this clearance had any marked effect on high-low corrugators. It may be noted from the data in Table I that increasing the clearance from .016 to .070 inch had only a slight effect on the dimensional characteristics of the single-faced board.

On the basis of the above results, it appears that large finger clearance or large transfer roll clearance may have beneficial results on the flute height dimension; however, it is very difficult to understand why this should be. As previously mentioned, the initial trials were carried out on the slice corrugator because the design is such that it lends itself more readily to photographing the action, and it was anticipated that high-speed photography would be employed to show the action with different finger settings. However, because the results on the slice corrugator were unlike what had been expected, it was felt desirable to carry out similar trials on the Institute's experimental corrugator which employs

wider rolls and consequently a number of fingers.

To this end, four different mediums were fabricated using the same finger and adhesive transfer roll conditions as were employed on the slice corrugator. In addition, all trials were run at two different corrugator speeds to see if the effect of finger and adhesive transfer with clearance varied with speed. The results are tabulated in Tables III to VIII.

The results of the trials carried out at 150 and 600 f.p.m. in which the finger clearance (using a standard finger with relief) are tabulated in Table III. It may be observed that on the semichemical and bogus mediums, finger clearance does not appear to have a significant effect. In the case of kraft mediums, the smaller clearances appear to be best. In general, high-low corrugation on flutes became more pronounced at the higher speed. These results parallel the trend observed on the trials reported earlier in this report for the slice corrugator.

The effect of the clearance between the end of the fingers and the pressure roll at the two speeds are tabulated in Table IV. It may be observed that varying the finger clearance at the pressure roll did not have any marked effect on the formation of high-low corrugations or caliper regardless of the type of medium used.

The results of the trials made with varying amounts of relief in the finger are tabulated in Table V. The data show that there is no marked trend for the caliper or prominence of high-low corrugations to change systematically with change in finger relief. At 600 f.p.m. the results obtained with no finger relief resulted in the greatest maximum differences in the height of consecutive flutes, i.e., more pronounced high-low corrugations. This trend was

TABLE III

EFFECT OF FINGER CLEARANCE USING STANDARD FINGER

Run No.	Variable	Finger Clearance, inches	Transfer Roll Clearance, inches	Individual Flute Characteristics at 150 f.p.m.							Individual Flute Characteristics at 600 f.p.m.						
				Caliper Average, pt.	Difference in Consecutive Flutes						Caliper Average, pt.	Difference in Consecutive Flutes					
					Av., pt.	Max., pt.	Cumulative Frequency of Differences, %					Av., pt.	Max., pt.	Cumulative Frequency of Difference, %			
							0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up				0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up
				Semichem K-7178 (Poor Runnability)													
7	Small finger clearance	0.006	0.016	195.2	2.7	9.4	62.1	82.1	88.4	11.6	197.1	2.9	8.8	52.6	70.6	86.3	13.7
6	Normal finger clearance	0.012	0.016	195.4	1.0	3.1	100.0	100.0	100.0	0.0	196.1	1.9	8.7	70.5	92.6	96.8	3.2
8	Wide finger clearance	0.040	0.016	195.9	1.3	4.0	97.9	98.9	100.0	0.0	197.0	1.8	6.2	70.5	90.5	98.9	1.1
9	Extra wide finger clearance	0.080	0.016	196.4	1.1	3.4	97.9	100.0	100.0	0.0	197.3	2.2	7.4	72.7	88.5	93.7	6.3
				Semichem K-7181 (Good Runnability)													
7	Small finger clearance	0.006	0.016	194.3	1.8	7.4	75.8	94.7	97.9	2.1	195.3	2.3	8.8	67.4	83.2	91.6	8.4
6	Normal finger clearance	0.012	0.016	196.4	2.3	5.3	73.7	87.4	94.7	5.3	191.2	2.0	5.7	70.5	89.5	96.8	3.2
8	Wide finger clearance	0.040	0.016	194.8	1.6	5.6	85.3	93.7	96.8	3.2	195.3	2.6	9.6	64.2	79.0	82.1	17.9
9	Extra wide finger clearance	0.080	0.016	194.6	1.8	4.3	83.1	96.8	100.0	0.0	195.2	2.3	7.0	68.4	86.3	94.7	5.3
				Bogus K-7265													
7	Small finger clearance	0.006	0.016	195.5	2.2	5.4	66.3	84.2	95.8	4.2	193.9	2.6	6.6	60.0	73.7	87.4	12.6
6	Normal finger clearance	0.012	0.016	193.5	1.8	5.3	86.3	93.7	97.9	2.1	192.7	2.0	6.0	72.7	91.6	95.8	4.2
8	Wide finger clearance	0.040	0.016	195.1	1.8	4.5	77.9	92.6	100.0	0.0	193.5	2.3	7.2	67.4	84.2	91.6	8.4
9	Extra wide finger clearance	0.080	0.016	195.0	1.7	5.7	93.2	93.7	97.9	2.1	193.8	2.4	8.3	61.0	74.8	86.3	13.7
				Kraft K-7266													
7	Small finger clearance	0.006	0.016	195.2	1.6	5.2	82.1	94.8	98.9	1.1	195.7	2.2	6.5	67.4	83.2	94.8	5.2
6	Normal finger clearance	0.012	0.016	194.4	2.4	5.1	66.3	80.0	98.9	1.1	193.4	3.2	8.5	47.4	63.2	76.8	23.2
8	Wide finger clearance	0.040	0.016	195.0	2.8	7.1	52.7	67.4	81.0	19.0	194.5	3.9	10.3	37.9	52.7	69.4	30.6
9	Extra wide finger clearance	0.080	0.016	194.9	2.7	7.5	56.8	70.5	86.3	13.7	196.0	3.0	9.6	51.5	64.2	92.6	7.4

Roughly 2 1/2 flutes from center

Rough 1 1/2 flutes

TABLE IV

EFFECT OF POSITION OF FINGER AT PRESSURE ROLL

Run No.	Variable	Finger Clearance, inches	Transfer Roll Clearance, inches	Individual Flute Characteristics at 150 f.p.m.							Individual Flute Characteristics at 600 f.p.m.						
					Difference in Consecutive Flutes							Difference in Consecutive Flutes					
							Cumulative Frequency of Differences, %						Cumulative Frequency of Difference, %				
				Caliper Average, pt.	Av., pt.	Max., pt.	0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up	Caliper Average, pt.	Av., pt.	Max., pt.	0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up
	Semichem K-7177 (Poor Runnability)																
14	Countoured toe at pressure roll	0.012	0.016	196.3	1.0	3.6	97.8	100.0	100.0	0.0	196.6	2.2	4.9	68.9	93.3	100.0	0.0
11	Standard finger	0.012	0.016	196.3	1.5	3.5	88.9	100.0	100.0	0.0	196.5	1.9	4.5	80.0	88.9	100.0	0.0
12	Rotate std. finger 1/2 flute out of pressure nip	0.012	0.016	196.4	1.6	5.1	88.9	95.6	97.8	2.2	195.8	2.5	5.4	53.3	80.0	95.6	4.4
13	Rotate std. finger 1 flute out of pressure nip	0.012	0.016	196.2	1.8	4.5	84.4	95.6	100.0	0.0	196.1	2.1	6.3	73.3	88.9	97.8	2.2
	Semichem K-7208 (Good Runnability)																
14	Contoured toe at pressure roll	0.012	0.016	195.7	1.5	4.5	91.1	97.8	100.0	0.0	196.3	2.5	6.9	64.4	77.8	86.7	13.3
11	Standard finger	0.012	0.016	195.4	1.6	4.1	91.1	95.6	100.0	0.0	195.8	2.1	6.9	75.6	84.4	95.6	4.4
12	Rotate std. finger 1/2 flute out of pressure nip	0.012	0.016	195.6	1.7	4.6	82.2	95.6	100.0	0.0	195.9	1.6	6.5	84.4	93.3	95.6	4.4
13	Rotate std. finger 1 flute out of pressure nip	0.012	0.016	195.0	1.8	3.5	84.4	100.0	100.0	0.0	194.8	1.7	5.4	80.0	93.3	97.8	2.2
	Bogus K-7199																
14	Contoured toe at pressure roll	0.012	0.016	195.3	1.8	4.7	80.0	88.9	100.0	0.0	192.8	1.7	7.4	84.4	91.1	93.3	6.7
11	Standard finger	0.012	0.016	194.9	2.3	6.4	71.1	75.6	84.4	15.6	192.2	2.6	8.3	60.0	75.6	86.7	13.3
12	Rotate std. finger 1/2 flute out of pressure nip	0.012	0.016	194.9	2.6	4.9	55.6	82.2	100.0	0.0	192.5	2.8	8.6	62.2	77.8	84.4	15.6
13	Rotate std. finger 1 flute out of pressure nip	0.012	0.016	194.9	1.7	4.4	86.7	97.8	100.0	0.0	191.8	1.7	5.0	82.2	93.3	97.8	2.2
	Kraft K-7145																
14	Contoured toe at pressure roll	0.012	0.016	195.6	2.7	5.5	55.6	73.3	91.1	8.9	195.5	3.7	8.0	33.3	53.3	68.9	31.1
11	Standard finger	0.012	0.016	194.1	2.9	8.4	62.2	75.6	80.0	20.0	194.5	2.4	6.0	60.0	82.2	93.3	6.7
12	Rotate std. finger 1/2 flute out of pressure nip	0.012	0.016	195.8	3.3	5.6	44.4	60.0	84.4	15.6	195.1	2.1	5.5	68.9	86.7	97.8	2.2
13	Rotate std. finger 1 flute out of pressure nip	0.012	0.016	194.5	1.9	5.6	71.1	88.9	93.3	6.7	195.6	5.6	10.3	26.7	33.3	40.0	60.0

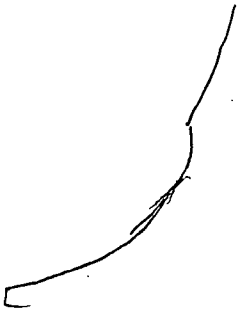

TABLE V

EFFECT OF CHANGE IN FINGER RELIEF

Run No.	Variable	Finger Clearance, inches	Transfer Roll Clearance, inches	Individual Flute Characteristics at 150 f.p.m.							Individual Flute Characteristics at 600 f.p.m.						
				Caliper Average, pt.	Difference in Consecutive Flutes						Caliper Average, pt.	Difference in Consecutive Flutes					
					Av., pt.	Max., pt.	Cumulative Frequency of Differences, %					Av., pt.	Max., pt.	Cumulative Frequency of Difference, %			
							0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up				0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up
	Semichem K-7088 (Poor Runnability)																
22	No relief finger	0.012	0.008	195.9	1.4	4.5	88.9	97.8	100.0	0.0	195.5	2.1	8.7	71.1	88.9	93.3	6.7
11	Standard finger	0.012	0.016	196.0	1.1	3.6	95.6	100.0	100.0	0.0	195.8	2.0	5.7	66.7	88.9	93.3	6.7
18	Enlarged relief by 3/32 inch on radius	0.012	0.016	196.2	1.6	5.2	80.0	97.8	97.8	2.2	196.3	2.1	6.4	75.6	88.9	93.3	6.7
21	Extended relief by 3/32 inch to pressure roll	0.012	0.016	196.1	1.5	4.6	91.1	97.8	100.0	0.0	196.5	1.7	5.1	86.7	93.3	97.8	2.2
	Semichem K-7200 (Good Runnability)																
22	No relief finger	0.012	0.008	194.6	1.6	4.2	91.1	97.8	100.0	0.0	194.6	2.3	11.5	75.6	88.9	91.1	8.9
11	Standard finger	0.012	0.016	195.2	2.2	5.2	62.2	84.4	97.8	2.2	195.4	2.6	7.5	62.2	73.3	84.4	15.6
18	Enlarged relief by 3/32 inch on radius	0.012	0.016	195.4	1.0	4.5	95.6	97.8	100.0	0.0	195.4	2.5	7.7	64.4	73.3	82.2	17.8
21	Extended relief by 3/32 inch to pressure roll	0.012	0.016	194.9	2.1	5.0	73.3	88.9	97.8	2.2	194.5	1.8	7.6	84.4	91.1	95.6	4.4
	Bogus K-7196																
22	No relief finger	0.012	0.008	194.3	2.0	4.3	80.0	93.3	100.0	0.0	192.5	3.0	12.8	66.7	73.3	82.2	17.8
11	Standard finger	0.012	0.016	194.6	2.1	5.2	73.3	86.7	93.3	6.7	192.2	3.0	8.1	57.8	66.7	77.8	22.2
18	Enlarged relief by 3/32 inch on radius	0.012	0.016	194.6	1.9	5.0	80.0	88.9	97.8	2.2	193.5	3.0	9.5	55.6	75.6	80.0	20.0
21	Extended relief by 3/32 inch to pressure roll	0.012	0.016	194.8	1.3	4.1	91.1	97.8	100.0	0.0	192.4	1.4	5.6	93.3	93.3	97.8	0.0
	Kraft K-7144																
22	No relief finger	0.012	0.008	194.5	3.3	7.0	44.5	51.1	66.7	33.3	191.3	6.6	40.0	33.3	40.0	48.9	51.1
11	Standard finger	0.012	0.016	195.4	2.7	6.6	57.8	75.6	88.9	11.1	192.7	4.5	9.4	33.3	40.0	55.6	44.4
18	Enlarged relief by 3/32 inch on radius	0.012	0.016	194.4	2.8	6.9	55.6	64.4	77.8	22.2	194.0	5.6	9.2	6.7	17.8	35.6	64.4
21	Extended relief by 3/32 inch to pressure roll	0.012	0.016	194.0	4.5	8.0	13.3	28.9	57.8	42.2	192.1	3.3	9.5	60.0	66.7	73.3	26.7

TABLE VI

EFFECT OF CHANGES IN FINGER CLEARANCE IN CORRUGATING LABYRINTH

Run No.	Variable	Finger Clearance, inches	Transfer Roll Clearance, inches	Individual Flute Characteristics at 150 f.p.m.							Individual Flute Characteristics at 600 f.p.m.						
					Difference in Consecutive Flutes							Difference in Consecutive Flutes					
							Cumulative Frequency of Differences, %						Cumulative Frequency of Differences, %				
				Caliper Average, pt.	Av., pt.	Max., pt.	0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up	Caliper Average, pt.	Av., pt.	Max., pt.	0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up
	Semichem K-7087 (Poor Runnability)																
15	0.005-inch clearance in corrugating labyrinth	0.012	0.016	196.4	1.0	3.0	97.8	100.0	100.0	0.0	196.3	2.0	5.4	71.1	91.1	97.8	2.2
11	0.012-inch clearance in corrugating labyrinth (std.)	0.012	0.016	196.0	1.2	4.9	84.4	95.6	100.0	0.0	195.9	2.9	9.1	57.8	68.9	80.0	20.0
16	0.024-inch clearance in corrugating labyrinth	0.012	0.016	195.6	1.8	4.7	73.3	88.9	100.0	0.0	196.3	2.2	8.3	75.6	80.0	86.7	13.3
17	0.070-inch clearance in corrugating labyrinth	0.012	0.016	196.0	1.3	4.0	91.1	95.6	100.0	0.0	196.8	2.0	5.5	73.3	88.9	93.3	6.7
	Semichem K-7274 (Good Runnability)																
15	0.005-inch clearance in corrugating labyrinth	0.012	0.016	195.6	1.4	5.3	88.9	97.8	97.8	2.2	196.4	2.4	7.4	71.1	75.6	86.7	13.3
11	0.012-inch clearance in corrugating labyrinth (std.)	0.012	0.016	195.8	2.1	6.2	60.0	82.2	95.6	4.4	196.8	1.8	8.1	82.2	86.7	91.1	8.9
16	0.024-inch clearance in corrugating labyrinth	0.012	0.016	196.0	1.6	3.6	86.7	100.0	100.0	0.0	196.8	2.2	7.1	71.1	82.2	91.1	8.9
17	0.070-inch clearance in corrugating labyrinth	0.012	0.016	195.6	1.7	4.2	84.4	91.1	100.0	0.0	196.9	2.4	7.5	66.7	80.0	86.7	13.3
	Bogus K-7198																
15	0.005-inch clearance in corrugating labyrinth	0.012	0.016	195.2	1.5	3.4	95.6	100.0	100.0	0.0	192.7	2.0	6.3	71.1	86.7	95.6	4.4
11	0.012-inch clearance in corrugating labyrinth (std.)	0.012	0.016	194.5	1.7	4.1	80.0	95.6	100.0	0.0	191.4	2.5	11.8	75.6	84.4	88.9	11.1
16	0.024-inch clearance in corrugating labyrinth	0.012	0.016	194.1	1.4	4.7	91.1	97.8	100.0	0.0	192.0	2.3	7.2	71.1	80.0	86.7	13.3
17	0.070-inch clearance in corrugating labyrinth	0.012	0.016	194.5	1.8	6.5	80.0	88.9	95.6	4.4	192.5	2.1	8.0	77.8	88.9	88.9	11.1
	Kraft K-7269																
15	0.005-inch clearance in corrugating labyrinth	0.012	0.016	195.7	2.5	4.8	57.8	80.0	100.0	0.0	193.9	6.1	13.4	24.4	35.6	35.6	64.4
11	0.012-inch clearance in corrugating labyrinth (std.)	0.012	0.016	195.3	3.4	7.8	44.4	64.4	80.0	20.0	195.4	2.5	7.8	66.7	77.8	86.7	13.3
16	0.024-inch clearance in corrugating labyrinth	0.012	0.016	194.4	4.0	9.0	44.4	51.1	60.0	40.0	196.4	3.5	10.6	48.9	64.4	75.6	24.4
17	0.070-inch clearance in corrugating labyrinth	0.012	0.016	196.3	2.1	5.8	68.9	93.3	95.6	4.4	196.1	5.1	14.5	26.7	37.8	51.1	48.9

TABLE VII

EFFECT OF FINGER CLEARANCE USING NO-RELIEF FINGER

Run No.	Variable	Finger Clearance, inches	Transfer Roll clearance, inches	Individual Flute Characteristics at 150 f.p.m. Caliper Average, pt.	Difference in Consecutive Flutes Av., pt.	Max., pt.	Cumulative Frequency of Differences, % 0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up	Individual Flute Characteristics at 600 f.p.m. Caliper Average, pt.	Difference in Consecutive Flutes Av., pt.	Max., pt.	Cumulative Frequency of Differences, % 0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up
				Semichem K-7162 (Poor Runnability)													
23	Normal setting using no-relief finger	0.012	0.008	194.0	3.6	5.1	77.8	84.4	93.3	6.7	195.0	2.0	9.3	77.8	84.4	88.9	11.1
24	Increased finger clearance	0.080	0.008	195.8	1.4	5.4	88.9	95.6	97.8	2.2	195.8	2.3	6.6	64.4	84.4	95.6	4.4
25	Increased transfer roll clearance	0.080	0.040	196.0	1.1	3.5	97.8	100.0	100.0	0.0	196.2	2.4	6.5	62.2	84.4	93.3	6.7
				Semichem K-7312 (Good Runnability)													
23	Normal setting using no-relief finger	0.012	0.008	194.9	1.2	3.4	93.3	100.0	100.0	0.0	196.4	2.7	7.0	62.2	75.6	88.9	11.1
24	Increased finger clearance	0.080	0.008	195.1	1.7	4.8	86.7	95.6	100.0	0.0	196.6	1.8	6.0	66.7	71.1	84.4	15.6
25	Increased transfer roll clearance	0.080	0.040	195.5	1.5	5.6	84.4	91.1	97.8	2.2	196.8	1.7	5.3	88.9	91.1	97.8	2.2
				Bogus K-7097													
23	Normal setting using no-relief finger	0.012	0.008	194.1	2.1	6.4	73.3	84.4	91.1	8.9	190.7	2.7	6.3	62.2	73.3	82.2	17.8
24	Increased finger clearance	0.080	0.008	193.7	2.3	5.0	71.1	93.3	97.8	2.2	189.8	2.4	5.5	66.7	86.7	91.1	8.9
25	Increased transfer roll clearance	0.080	0.040	193.8	1.4	5.1	88.9	95.6	95.6	4.4	189.4	2.3	6.4	62.2	82.2	95.6	4.4
				Kraft K-7268													
23	Normal setting using no-relief finger	0.012	0.008	194.5	3.3	6.8	44.4	60.0	73.3	26.7	193.4	4.8	11.2	37.8	44.4	55.6	44.4
24	Increased finger clearance	0.080	0.008	194.2	3.3	8.3	55.6	73.3	82.2	17.8	191.3	5.6	17.5	40.0	46.7	60.0	40.0
25	Increased transfer roll	0.080	0.040	194.6	2.6	7.0	60.0	64.4	80.0	20.0	193.0	4.0	11.2	46.7	64.4	68.9	31.1

TABLE VIII

EFFECT OF TRANSFER ROLL CLEARANCE USING ENLARGED RELIEF FINGER

Run No.	Variable	Finger Clearance, inches	Transfer Roll Clearance, inches	Individual Flute Characteristics at 150 f.p.m.							Individual Flute Characteristics at 600 f.p.m.						
					Difference in Consecutive Flutes							Difference in Consecutive Flutes					
							Cumulative Frequency of Differences, %						Cumulative Frequency of Differences, %				
				Caliper Average, pt.	Av., pt.	Max., pt.	0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up	Caliper Average, pt.	Av., pt.	Max., pt.	0-2.9 pt.	0-3.9 pt.	0-4.9 pt.	5.0 pt. up
	Finger Relief Enlarged 3/32-inch on Radius			Semichem K-7088 (Poor Runnability)													
18	Standard clearances	0.012	0.016	196.2	1.6	5.2	80.0	97.8	97.8	2.2	196.3	2.1	6.4	75.6	88.9	93.3	6.7
19	Increased transfer roll clearance	0.012	0.032	195.9	1.3	5.1	93.3	95.6	95.6	4.4	196.3	2.8	9.2	53.3	73.3	88.9	11.1
20	Increased transfer roll clearance	0.012	0.070	196.5	2.2	6.3	68.9	86.7	91.1	8.9	196.2	2.9	7.0	53.3	68.9	82.2	17.8
				Semichem K-7200 (Good Runnability)													
18	Standard clearances	0.012	0.016	195.4	1.0	4.5	95.6	97.8	100.0	0.0	195.4	2.5	7.7	64.4	73.3	82.2	17.8
19	Increased transfer roll clearance	0.012	0.032	193.9	2.6	7.6	64.4	77.8	80.0	20.0	195.0	2.2	6.1	66.7	84.4	95.6	4.4
20	Increased transfer roll clearance	0.012	0.070	194.9	2.1	7.1	64.4	88.9	95.6	4.4	195.4	2.4	6.0	57.8	80.0	95.6	4.4
				Bogus K-7196													
18	Standard Clearances	0.012	0.016	194.6	1.9	5.0	80.0	88.9	97.8	2.2	193.5	3.0	9.5	55.6	75.6	80.0	20.0
19	Increased transfer roll clearance	0.012	0.032	194.6	2.6	5.9	62.2	77.8	95.6	4.4	191.8	1.8	7.0	84.4	88.9	97.8	2.2
20	Increased transfer roll clearance	0.012	0.070	194.6	3.6	10.1	46.7	53.3	71.1	28.9	193.1	2.9	6.4	55.6	73.3	82.2	17.8
				Kraft K-7144													
18	Standard clearances	0.012	0.016	194.4	2.8	6.9	55.6	64.4	77.8	22.2	194.0	5.6	9.2	6.7	17.8	35.6	64.4
19	Increased transfer roll clearance	0.012	0.032	194.7	2.0	5.0	75.6	86.7	97.8	2.2	192.0	5.1	17.6	20.0	28.9	40.0	60.0
20	Increased transfer roll	0.012	0.070	194.0	3.2	9.1	57.8	64.4	75.6	24.4	193.1	5.6	16.5	28.9	44.4	53.3	46.7

not evidenced by the corresponding results at 150 f.p.m.

The effects of variation in finger clearances at the labyrinth may be seen from the data in Table VI. It was anticipated that large clearances would be associated with more pronounced high-low corrugations; however, the data do not support this. At 150 f.p.m., clearance appears to have no significant effect on caliper or prominence of high-low corrugations. The same trend may be noted for the data at 600 f.p.m. with the exception of the kraft medium. At 600 f.p.m. the kraft medium exhibited more intense high-low corrugation at the smaller and larger clearances used.

The results on the trials in which the clearance of fingers with no relief was varied are tabulated in Table VII. These results show that, in general, the prominence of high-low corrugations did not vary appreciably with clearance. The same trend may be noted for caliper. The kraft medium used in these trials, particularly at 600 f.p.m., appears to be more sensitive to finger setting.

The trials carried out using fingers with enlarged relief and varying the transfer roll clearance (see Table VIII) show that transfer roll clearance does not appear to have a significant effect on caliper or prominence of high-low corrugation. The kraft medium appears to be more susceptible to high-lows than the other medium, particularly at 600 f.p.m. corrugating speed.

Because of the apparent insensitiveness of high-low corrugations and caliper to variations in finger relief, finger clearance, etc., a few trials were made in which the number of fingers were reduced to see if this would affect the high-low profile.

The Institute's experimental corrugator is a simplex corrugator. There-

fore, in order to use A-, B-, and C-flute rolls in the same unit, the fingers are on two-inch centers for all the fluted rolls. Thus, on the twelve-inch width medium used in this study there were normally five fingers engaged. Trials were carried out with four different mediums in which the number of fingers were varied from five to one. When only one finger was used, it was centrally located. The results are presented in Table VIII for 150 and 600 f.p.m. speeds. Reducing the number of fingers from five to one while maintaining the same clearance did not appear to introduce any marked effect on the caliper or prominence of high-low corrugations. However, when the finger clearance (one finger) increased to 0.150 inch, there was no significant change at 150 f.p.m., but at 600 f.p.m. the flutes were badly damaged by the transfer roll. This was not the case when two fingers were used with a 0.150-inch clearance, except in the case of the kraft medium at 600 f.p.m.

It should be mentioned that the effect of finger design and clearance on the dimensional characteristics of the flute was far less than had been anticipated. It was observed that, as the finger clearances increased, the medium exhibited a greater tendency to "flutter".

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THE INSTITUTE OF PAPER CHEMISTRY

R. C. McKee

R. C. McKee, Chief, Container Section