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Brush Finishing of Coated Paperboard

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BRUSH FINISHING OF COATED PAPERBOARD

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INTRODUCTION

It would seem apparent that a brief explanation of the term "brush finishing of paper" is in order before dealing extensively with our literature survey. Although brush finishing is not a new term, it has never been dealt with in its true sense as a means of finishing paper in the paper industry.

Brush-enamel papers were developed and used extensively in the second half of the 19th century and early part of the 20th century. The new development came from Germany and as the art of paper coating had been developed there to a high degree, the brush-polishing process which was first used for single sheets and later on full webs by the Germans soon was brought to the United States.

This was the first instance which involved coating the sheet with a compound which could be burnished to a high polish by the brush machine. But, as in several other cases using the brush finisher or brush polisher, a supercalender effect was desired to put an extra gloss on the finished sheet.

PART I.

LITERATURE SURVEY

Calender and Supercalender Finishing of Paper

While the process of calendering paper is probably as old as the art of papermaking itself, within the past decade interest in this phase has been broadened and intensified with the advent of on-the-machine coating of paper. The success of calendering this grade of paper at high productive speeds has attracted the attention of those interested in the conversion of older and well established grades of calendered paper as the possibilities of more economical production in finishing their product.

To introduce the subject of calendering, it may be a good plan to state briefly the basic fundamentals, as discussed by E. E. Thomas(1).

1. Calendered paper is transformed from its prepared state and values to another state of values by mechanical methods and, therefore, conversion merely reflects in its results the standard of quality of the paper and its coating.

2. Calendering action consists of a combination of three elements; pressure, plastic flow, and temperature.

3. Coated paper possesses the internal properties of the paper itself plus the external properties of the applied coating.

4. The standard in attainment of results is a matter of balance between the responsiveness of the paper and coating to the amount of calendering action provided.

5. There is a critical point in calendering action beyond which further effects on paper properties will be reflected in a decrease in standard or quality, rather than increase.

Any sheen or gloss resulting from calender action originates from such paper physical properties as plasticity or bulkiness which create a creep action and relative motion between paper surfaces and roll necessary to produce gloss or polish. Therefore, a calender possesses only the power to squeeze or compress the paper and change caliper.

A study concerning the mechanical properties of paper by H. F. Rance(2) reveals that the main and desired effect of calendering treatment are consolidation of the sheet, as was recognized by E. E. Thomas(1), and a glazing of its surfaces. In addition, however, the drastic action of the pressure nip can significantly alter the internal structure of the sheet, and thus alter its planar properties.

Rance(2) goes on to say that calendering can thus affect significantly the rheological properties of the sheet in all main directions, in addition to altering its optical properties and its "tactile" roughness.

In another article by Thomas(3), he explains the behavior of filled rolls under operation as a manifestation of the law governing the behavior of resilient or elastic bodies which he calls "rolling friction", and explains as follows:

"When an inert roll is pressed against a resilient roll a depression is created in the softer roll at the point of contact and the material is pushed out on either side of the arc of contact. If the rolls are rotated the resilient material will start to creep or flow in a direction opposite to the direction of rotation causing a sliding of material against the inert roll surface and producing a burnishing or polishing action." Intensity is governed by the amount of resiliency provided, the relative diameter of rolls in contact, the nip contact pressure, and the speed of rotation.

Wheeler(4) also feels that the basic action of the nip is the basic action of the supercalender. He states that as the pressure is applied to the rolls, a distortion of the cotton or paper filled roll reduces the diameter of the roll, which creates a condition of slowing the surface to a maximum reduction at the center of the nip, then as the roll re-expands to original size as it leaves the nip, the speed accelerates back to original surface speed.

During this process there is a rubbing action on the surface of the sheet, which tends to polish the sheet, or give it finish. In correlation, Casey(5) maintains that the smaller the metal rolls in the stack, the greater the polishing effect, because small metal rolls cause greater deflection of the fiber roll.

As cotton-filled rolls do not compact the sheet as much as paper-filled rolls(5), the cotton roll will be used in the laboratory calender between the two metal rolls to give a combination of high finish and high bulk to the coated paper.

The influence of speed on finishing has never been too seriouly considered. Although Thomas(3) stated that the intensity of the burnishing or polishing action is governed in part by the speed of rotation, Wheeler(4) believed that as we approach the higher speeds being run and desired today we may come to an end point based on a speed above which we do not give the sheet, fibre, binder, or pigment, time to be properly relocated and finished. He emphasizes this point by stating that if we use a speed of 1000 feet per minute, and remember that the average nip width is only $\frac{1}{4}$ inch, we find that the time sheet is being worked on is something like 1/800 of a second. As our laboratory supercalender travels at a speed in the range of 36 feet per minute, the working time on the coated sheet will be somewhat greater than that stated above.

Of greater importance is the coating specifications for the paper to be experimented with and worked on. Thomas(3) feels that the general specifications covering coating requirements from a supering viewpoint call for a uniform application of a well dispersed pigments and adhesives possessing the necessary bonding properties and having resilient and stretch. Also important in supercalendering is that the paper have the proper moisture content, is free of mechanical defects from the machine wet end, driers, coaters, or after driers. Hannigan(6) states that if all these conditions exist, everything will run smoothly, the only thing one must watch out for is marks in the filled rolls, overheating filled rolls, scale, water-drops, bursts, blow cuts, calender cuts, doctor marks, etc.

While this description by no means covers the vast material published on the action of supercalenders to paper, it does give an insight as to the purpose and properties of the supercalender. Referring to an undergraduate thesis by R. C. Walker(7) dealing with the effect of roll pressure during supercalendering on the physical properties of paper reveals that for an increase in nip pressure, the properties of paper are affected as follows:

1.) Opacity decreases.

2.) Brightness decreases.

3.) Tensile increases slightly.

4.) Smoothness increases substantially.

5.) Fold increases in machine direction for coated paper, but decreased in the across machine direction.

6.) Burst increased.

Some of these facts will be used as a guide in investigating similar properties of the brush finished sheet.

PART II.

Brush Finishing of Paper

The first brush machine in use was on the cylinder or drum principle. Heywood(8) describes this type of brush finisher as a machine having a drum of some 48 to 60 inches in diameter with six or eight cylinder brushes around its periphery. The coated paper is fed around the drum with the drum traveling with the paper. The brushes are adjustable so that the pressure they exert on the paper passing under them can be varied. This pressure is only sufficient to make the tips of the brushes just whip the paper surface. The brushes are then driven at high speed in counter direction to the flow of the paper. The brush speed may range from 2000 peripheral feet per minute to nearly 7,000 peripheral feet per minute on some modern instillations. The paper may be run through the brush machine at 200 to 500 feet per minute.

F. W. Egan(9) describes another type of brush finisher or brush polisher which has more brush action than either the drum or flat bed brush machine due to the fact that the web of paper passes around more of the surfaces of the brush, the brushes being stacked like calender rolls. These rolls are also supported in bearings that can be individually adjusted to the amount of pressure applied to each brush.

He goes on to say that the object of brush polishing paper is that the action of the brushes on the surface of the coated paper has a tendency to increase the gloss. There is a small amount of working of the coating on the surface of the sheet, which may be do to the mechanical action of the brush polisher, and some of it may be caused by the friction that is created between the bristles and the surface of the coating on the paper.

Choice of coating pigment is a problem worth considering in the brush finishing of coated papers. Heywood(8) believes that the pigment particles must not be too hard or sharp or excessive brush wear will result. If the pigment is too soft or insufficiently bound, excessive dust is produced resulting in dusty paper and reduced finish. Lubricants are sometimes used to ease these effects, but it is not a general practice.

The moisture content of the sheet should be high enough to prevent excessive static.

The brushes are generally graded from a fairly stiff hair bristle for the first one contacting the paper to a soft badger hair for the last. Today nylon is tending to replace the natural bristles. It wears better and if the ends of the bristles are rounded it seems to impart a burnishing action which improves the finish.

All these treatments of coated paper by the brush polisher or finisher are described in the literature as a preliminary action on the surface of the paper to produce a gloss which will be increased by the use of the super-calender. Casey(10) describes it as imparting a velvety or suede finish to the coating, and is used mostly on high-grade coated papers containing satin white as part of the pigment.

SUMMARY OF LITERATURE SURVEY

In summarizing the literature survey conducted on the thesis topic "Brush Finishing of Coated Paperboard," it would seem apparent that at this time the brushing process is used only as an enhanceing action for adding gloss in the supercalendering operation. There was no indication as to the possibilities of using brush finishing as a comparable means to that of the supercalender process, but this does not mean that it has never been experimented with or can not be done.

In conducting the experimental work in this field, it is hoped that some practical aspect of brush finished paper can be found and lead to the use of this process as a final finishing operation.

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EXPERIMENTAL OUTLINE

The experimental procedure consists of four main parts.

Part I

Description of Finishing Operations and Apparatus

A. Laboratory supercalender

B. Brush finishing apparatus

1. Description of brushes

Part II

Description of Coated Paperboard

A. Jet coat

B. Champion coat

Part III

Description of Testing Procedures

A. Brightness

B. Gloss

C. Smoothness

D. Print Quality

Part I.

Finishing Operations and Apparatus

A. The Laboratory Supercalender

The laboratory supercalender is located in the constant temperature-humidity room of the Pulp and Paper Department of Western Michigan University, Kalamazoo, Michigan.

The two steel rolls are 10.5 inches in diameter and the middle cotton filled roll is 12.0 inches in diameter. The nip between the cotton and steel rolls is 13.6 inches long. Air pressure may be applied with cylinders on each bearing of the rolls which are extended on lever arms capable of inducing a force upwards to 33,000 pounds on the rolls. This is equivalent to 2,450 pounds per lineal inch at the nip. Speeds range in the area of 36 feet per minute.

In the experimental work using the laboratory supercalender, the coated paperboards were supercalendered at pressures of twenty pounds per square inch. The coated paperboards were subjected to five and ten nips. This should provide a finish similar to paperboard supercalendered in the paper mill.

B. The Brush Finishing Apparatus

The brush finishing apparatus used to brush the coated board was simply a lathe powered by an electric motor capable of producing speeds up to 700 revolutions per minute. The different types of brushes were fitted to metal cores and attached to the lathe horizontally. A wooden platform under the attached brush provided a clearance of about an inch and a half. The board samples were placed under the brush and drawn countercurrent to the rotation of the bristles. The pressure exerted by forcing the board against the bristle of the brush could be controlled only by feel, but even with this crude "pressure gauge", a brushing technique was acquired to give the maximum brush finish to the sample. The number of nips which the samples underwent were also estimated to provide the best possible surface, this usually consisted of an average of three to five nip passes per sample.

All brush finishing operations were conducted at the Gus Reidel and Son Brush Company, located at 829 Woodward Avenue, Kalamazoo, Michigan, manufactures of all types of industrial brushes.

I. Description of Brushes

Type I

C and S Brush

This type of brush is a Chinese and Siberian hog bristle brush, tufted, individually plastic set. It has a 1 13/16 inch trim, and is fairly stiff. Because of its tufted set, this brush has less density of bristle and, unlike the bristles described below, is more aerated to give better dissipation of heat.

Type II

W. L. Brush

This type of brush is also a Chinese and Siberian hog bristle brush called a Waldorf Long bristle. It is rope-wound with a 2 1/2 inch trim. This type of wound bristle provides a dense bristle, less aerated.

Type III

W. S. Brush

The Waldorf Short Chinese and Siberian hog bristle brush has a 2 3/16 inch trim. It is rope wound and has a dense bristle per unit area. This, like the brushes described above, is used in the paper industry primarily as dampening brushes, throwing a misty haze of moisture into the air which the paper adsorbs to raise its moisture content before shipping.

Type IV

"N" Brush

This type of brush is made from the nylon bristle and has a trim of 2 1/4 inches. It is a rope-type, and is very stiff. Because of the nature of the bristle, much dissipation of heat resulted.

Part II

Description of Coated Paperboard

The coated paperboard used in this thesis was obtained from the Sutherland Paper Company of Kalamazoo, Michigan. The samples had been machine calendered and were 12 x 18 inches in size.

A. Jet Coat

This type of coated paperboard has a basis weight of 225 pounds per thousand square feet and is coated with a Waldron coating machine. The coating color contains Stellar and HT clays, plus titanium dioxide. The average brightness of these samples is 72.8 according to the Photovolt Brightness Tester. The gloss is 43.7 on the Photovolt, and the smoothness of the coated board is 100.1 Sheffield units according to the Sheffield Smoothness Tester.

B. Champion Coat

This type of board was coated on the Champion coater and also contains Stellar and HT clays plus titanium dioxide. The average brightness is 77.4 (Photovolt), the gloss is 34.6 (Photovolt) and the smoothness is 98.2

Sheffield units (Sheffield). It has a basis weight of 216 pounds per thousand square feet.

Part III.

Testing Procedures

The following physical tests of the calendered, supercalendered, and brushed finished paperboard samples were conducted in the constant temperature-humidity room of the Department of Paper Technology of Western Michigan University, Kalamazoo, Michigan

A. Brightness (Photovolt)

The brightness or reflectance tests indicated in this thesis were done in accordance with the suggested method T 452 m-48 of the Technical Association of the Pulp and Paper Industry, using the Photovolt brightness tester. The brightness of the coated paperboard samples was taken as ten readings per sample and ten samples per average brightness for the calendered, supercalendered, and brush finished paperboard.

B. Gloss (Photovolt)

The gloss tests were taken with the Photovolt gloss unit which measures the specular reflectivity at a 75 degree angle of incidence in accordance with TAPPI Standard T 480 m-51. The gloss of the calendered, supercalendered, and brushed finished coated paperboard was taken as ten readings per sample and ten samples for an average reading.

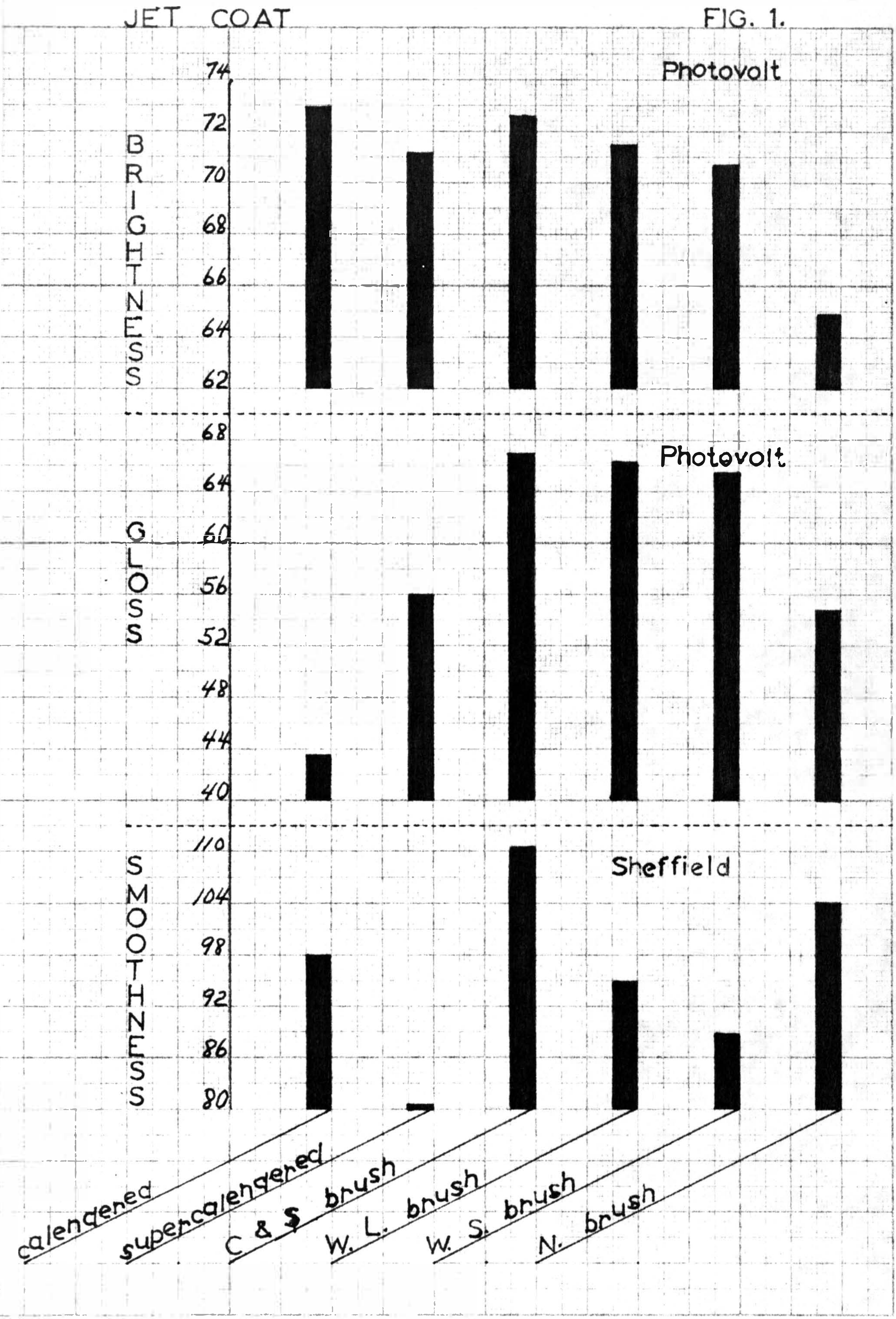
C. Smoothness (Sheffield)

The smoothness tests run on the calendered, supercalendered, and brush finished coated paperboard were taken with the Sheffield Smoothness Tester. Although this is not a TAPPI method, it does correlate results with the Bekk smoothness tester. With the Sheffield, instantaneous readings can be taken which make it considerably more convenient and time saving. It must be noted that the Sheffield smoothness tester measures the smoothness of the sample being tested in Sheffield units, which means the lower the reading, the smoother the sample. A theoretical reading of zero Sheffield units would mean perfect smoothness.

SUMMARY OF TEST RESULTS

Jet Coated Board

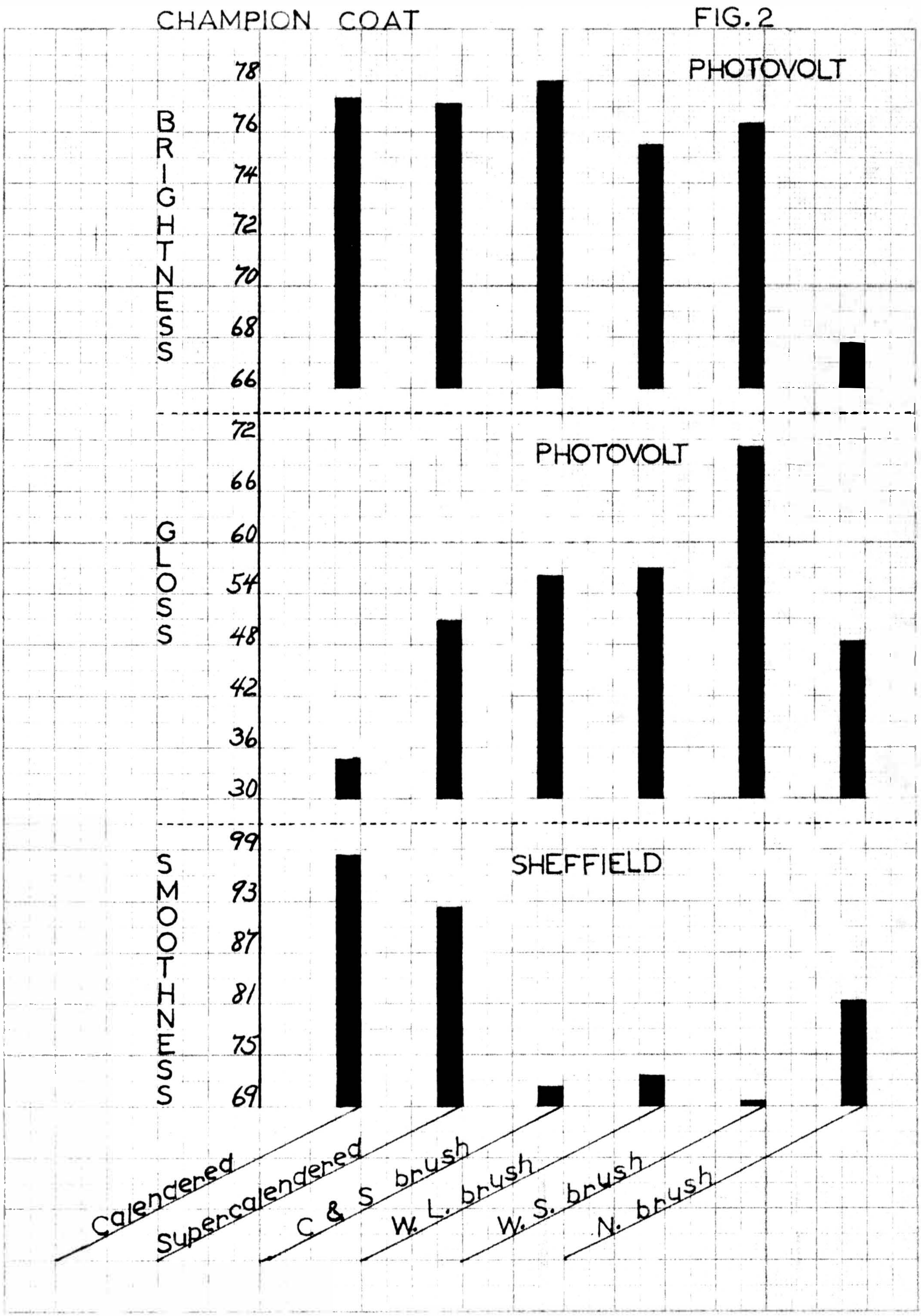
	Brightness (Photovolt)	Smoothness (Sheffield)	Gloss (Photovolt)
Calender	72.8	100.1	43.7
Supercalender			
5 nips 20 psi	71.1	80.8	56.1
10 nips 20 psi	68.8	94.4	59.5
C and S Brush	72.6	112.1	67.6
W. L. Brush	71.5	95.7	66.5
W. S. Brush	70.7	88.6	65.8
Nylon Brush	64.9	107.0	54.7


JET COAT
FIG. 1.
Photovolt
BRIGHTNESS
74
72
70
68
66
64
62
Photovolt
GLOSS
68
64
60
56
52
48
44
40
Sheffield
SMOOTHNESS
110
104
98
92
86
80
calendered
supercalendered
C & S brush
W. L. brush
W. S. brush
N. brush

SUMMARY OF TEST RESULTS

Champion Coat

	Brightness (Photovolt)	Smoothness (Sheffield)	Gloss (Photovolt)
Calender	77.4	98.2	34.6
Supercalender			
5 nips 20 psi	77.3	92.7	51.0
10 nips 20 psi	78.0	96.5	53.5
C and S Brush	76.9	71.1	56.4
W. L. Brush	75.5	72.7	57.0
W. S. Brush	76.3	69.2	71.8
Nylon	67.8	81.4	48.8


CHAMPION COAT
FIG. 2
PHOTOVOLT
BRIGHTNESS
78
76
74
72
70
68
66
PHOTOVOLT
GLOSS
72
66
60
54
48
42
36
30
SHEFFIELD
SMOOTHNESS
99
93
87
81
75
69
Calendered
Supercalendered
C & S brush
W. L. brush
W. S. brush
N. brush

D. Print Quality

The brush finished coated paperboards were tested for printing quality by printing them with the Vandercook number four laboratory printing press. The printing plate used for this test was a half tone plate containing eight sections vertically and four sections horizontally. The first four sections vertically contain 85 lines per inch with 100, 90, 50, and 10 per cent ink coverage for each section respectively. The latter four sections vertically contain 133 lines per inch with 90, 50, 10, and 100 per cent ink coverage respectively. The four horizontal sections vary in printing pressure by the difference of .003 of an inch in height for each of the sections from right to left, there being a resultant pressure increase on the printed material in this direction. Figure 3 illustrates the design of the printing plate and is a reproduction of the printed W. L. brush finished Champion coated paperboard.

The main object of this test was to determine the printing quality of each type of brush finished paperboard, and compare them to the printing quality of supercalendered samples. The finished samples were rated in order of printing clarity and ink receptivity.

Essentially it was found that the brushed finished paperboard samples printed very well and were rated in the order of printing quality as follows:

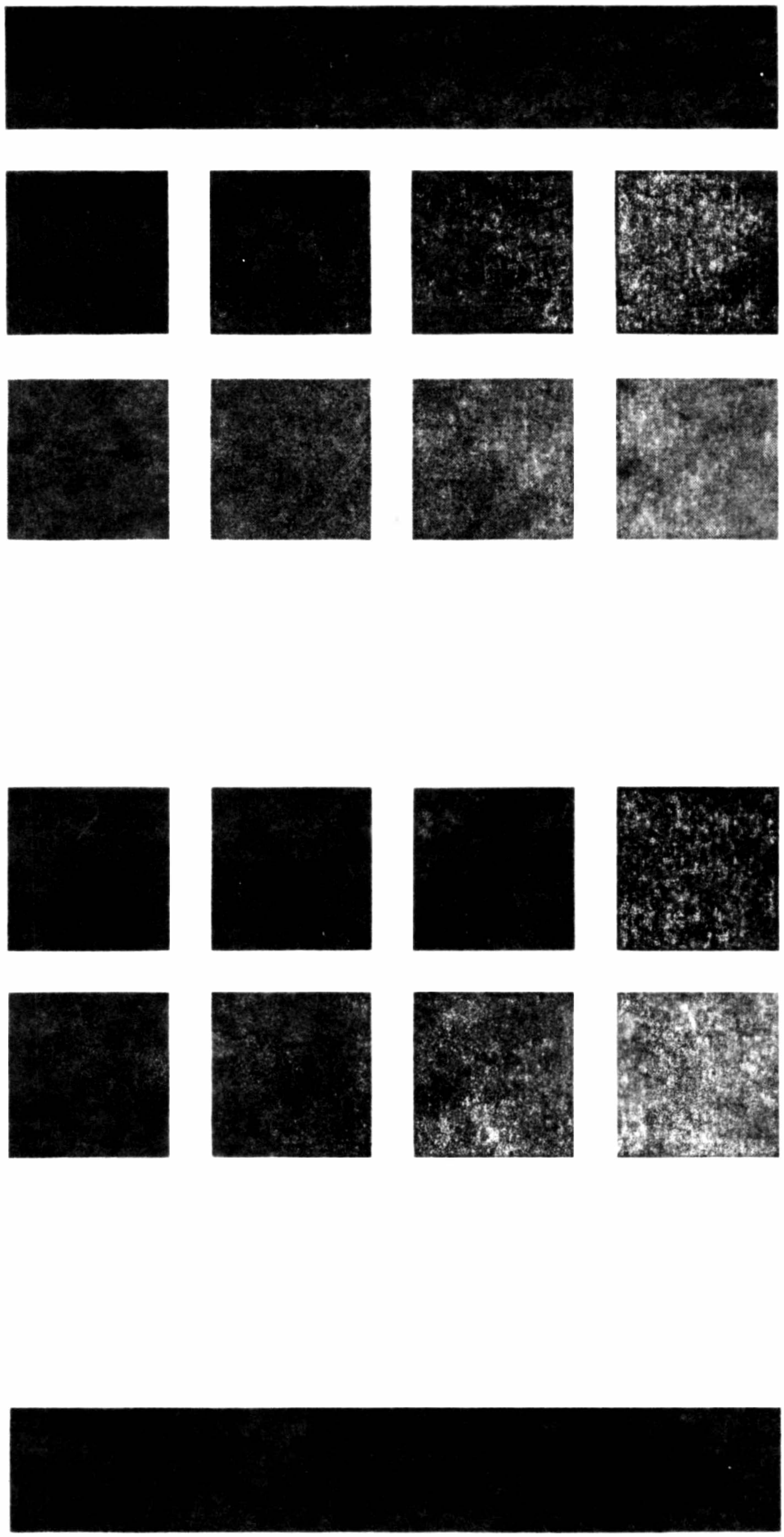
Jet coat;

1. W. L. bristle brush
2. C and S bristle brush
3. W. S. bristle brush
4. Nylon bristle brush
5. Supercalender

Champion coat;

1. W. L. bristle brush
2. W. S. bristle brush
3. C and S bristle brush
4. Supercalender
5. Nylon bristle brush

FIG. 3.



PHOTOMICROGRAPHS

Photomicrographs were taken of the brush finished paperboards and compared to photomicrographs of the calender and supercalender finish. The magnification of the microscope was 10 x 10 and slide photos taken in the following order:

(Slides selected for viewing)

Slide no. 1. ------------------ Jet calender finish

Slide no. 3. ------------- Jet supercalender finish

Slide no. 5. ------------- Jet C and S brush finish

Slide no. 6. --------------- Jet W. L. brush finish

Slide no. 8. --------------- Jet W. S. brush finish

Slide no. 9. --------------- Jet Nylon brush finish

Slide no. 10. ------------- Champion calender finish

Slide no. 13. -------- Champion supercalender finish

Slide no. 15. -------- Champion C and S brush finish

Slide no. 16. ---------- Champion W. L. brush finish

Slide no. 18. ---------- Champion W. S. brush finish

Slide no. 19. ---------- Champion nylon brush finish

DISCUSSION OF RESULTS

In discussing the results of this work attention should be drawn to the fact that the coated paperboard samples were machine calendered, consequently providing some initial finishing action to the surface of the sheets. Another important factor to be remembered is that there is no definite measurement of the pressure exerted on the paperboard by the brush, and that the working time of the brush on the surface of the paperboard could only be approximated. These results presented here could be altered to some degree by mechanical correction in the brush finishing operation.

In reviewing the results obtained by brush finishing the Jet coated paperboard, it will be noted that the Waldorf Long Chinese and Siberian hog bristle brush produced an acceptable finish. Although the brightness was increased by only 0.56 per cent, increases of 15.1 and 15.6 per cent were obtained for the smoothness and gloss respectively over those of the supercalender (5 nips, 20 psi) process.

The Chinese and Siberian hog bristle brush also showed brightness increases of 2.07 per cent, and gloss increase of 17.0 per cent, but a decrease in surface smoothness. The Waldorf Short bristle brush bettered the supercalendered sample only in the gloss. The Nylon bristle brush resulted in decreases in all physical tests, the brightness dropping as much as 8.75 per cent.

The printing quality of the Waldorf Long bristle brush samples were better than the other brush samples as well as the supercalendered sheets.

The results of the brush finished process for the Champion coated paperboard also provided physical tests which correlated with results produced on the Jet coated paperboard. Although the brightness of this type of paperboard was decreased by the brushing action, there was a 2.32 per cent maximum decrease for the Chinese and Siberian, Waldorf Short, and the Waldorf Long bristle brushes over that of the supercalender (5 nips, 20 psi) process. The Waldorf Short bristle brush provided the substantial increases of 29.1 per cent in smoothness, and 40.5 per cent in gloss. The other two brushes previously mentioned also showed increases in these areas. Again the nylon brush produced undesirable qualities, giving decreases in brightness of 12.3 per cent.

The printing quality for this type of paperboard showed the Waldorf Long bristle brush samples to be superior to those of the other brushes, with the Waldorf Short bristle brushed samples printing quite well.

CONCLUSION

It can be concluded from the experimental results reported that:

1. the physical tests conducted on the brush finished coated samples indicated that brightness, gloss, and smoothness characteristics could be produced exceeding those of the supercalendered samples in varying degrees.
2. the printing tests conducted on the brush finished paperboard samples were good, and were better than those of the supercalendered samples.
3. this experimental work indicated that the brush best suited for this type of finishing was the Waldorf Long bristle brush, with the Chinese and Siberian, and Waldorf Short bristle brush producing quite similar results. The Nylon brush of the type used in this work was not desirable for the brush finishing operation.

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