6-1953

The Effect of Some Variables on the Numerical Evaluation of Printing Quality

James G. Dunlap Jr.
Western Michigan University

The Effect of Some Variables on the Numerical Evaluation of Printing Quality

A Senior Thesis

Curriculum of Pulp and Paper Technology

Western Michigan College

Kalamazoo, Michigan

June, 1953

James G. Dunlap, Jr.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Mr. Robert Elias for all the time and assistance given to this thesis. He also wishes to thank Mr. Hugh Kemmerling of Sutherland Paper Company for his helpful suggestions in the operation of the proof press, as well as the Crescent Engraving Company who provided the electrotype.

TABLE OF CONTENTS

Introduction

The desire for specific information concerning those qualities of paper, which tend toward satisfactory results in printing, has become of great interest to papermakers and paper consumers. To the paper mill, this information is important in preventing the production of unsatisfactory printing paper. To the printer, such information enables him to determine unsatisfactory paper before it reaches the presses, and also permits him to tell the papermaker in advance the characteristics that are desired in the paper.

Kantrowitz (1) states that until recent years, most of the paper testing was devoted to determining those properties of paper which are of greater importance to the papermaker than to the printer, such as composition and strength of the paper; however, consideration of paper by printers is dependent upon properties and functions which, as far as paper testing is concerned, must have a direct bearing upon the printing quality and its use requirements for durability and permanence. He further states that the evaluation of paper properties from the printers standpoint may be grouped into three classes: chemical tests for evaluating the permanence, physical tests for determining durability, and tests for evaluating the printing properties (1). This Thesis will be restricted entirely to the latter class.

"A large proportion of the paper manufactured is printed, but there is not a great deal of literature on the technical problems connected

with the printing quality of paper." This statement, made in 1934 by Prior (2) and repeated in 1942 by Weymouth (3), presents an insight as to how recent is the present day trend in both industries. A few of the men responsible for this change of view are Bekk, Diehm, Larocque, Kantrowitz, Prior, Weymouth, and Wehmhoff.

"Printability" and "printing quality" - just what do these terms mean? According to Edge (4) and Roestler (5), printability is synonymous with the following factors: low ink consumption, rapid drying of prints, and uniform appearance of the printed matter. As is aptly stated by another author (6): "printability is like that bug-a-boo in calculus - a variable that is a function of, and dependent on, other variables such as ink, stock, printing process, press, plate, job, atmospheric conditions, and sometimes the condition of the pressman himself." Printing quality, on the other hand, is concerned with the appearance of halftones, solids, and type matter (6), (7), (8).

The following is a list of the more important characteristics which are generally agreed upon to have a definite bearing on the printability and printing quality of paper: smoothness, oil absorption (surface penetration and complete penetration), softness, and surface bonding strength. Although some authors place the emphasis on one characteristic, while others place it on another, they all seem to agree that printability and printing quality can not be determined from one individual aspect of the paper. A thorough knowledge of the paper, as well as the process by which it is to be printed, must be known before any indication as to the printability and the printing

quality under actual conditions can be determined.

In 1939, International Printing Ink attempted correlations by such instrumentation studies as smoothness, oil absorption, softness, and surface bonding strength; this investigation led to the proof press as the final check on printability and printing quality (3). It is the general opinion that the proof press is the ultimate method for checking these properties (2), (3), (7), (8), (9), (10), (11), (12), (13). As yet there is no way of determining printability numerically. The general method of printability determination is to compare visually the results obtained by printing two different sheets, side-by-side and under the same conditions, on a proof press (2), (3), (8), (9), (10), (11). Printing quality determinations seem to have eliminated this visual comparison to a large extent. By using a printing plate, which shows different tones in different screen ranges and examining the finished product with a hand lens, the printing quality of a sheet can be given a numerical evaluation (7).

Smoothness

Printing smoothness is defined as the smoothness or levelness of paper under approximately the same pressure exerted on it at the time of impression (14). Approaching it from another angle, Kantrowitz (1) states that smoothness may be regarded as an index of the facility of a paper to make close contact with a printing surface under the influence of pressure. These clarifications of the term indeed show its importance with regard to the finished product. Without the aid of a certain degree of surface smoothness, it would be utterly impossible to place an even deposit of ink on the paper.

In order to obtain a full-toned clean impression from a plate, it is necessary to use a paper of great smoothness and even surface; as these qualities deteriorate, so will the printed result, in exact ratio (15). On the other hand, however, Neilson (16) and Wehmhoff (9) say that smoothness can be so high and absorption so low that poor printing quality will be the result. Smoothness obtained by too heavy calendering is usually responsible for this latter defect in printing papers (1), (16). Neilson (16) further states that it would be much more desirable to print on a less smooth, but more easily compressible and absorptive paper. The effects of printing on smooth and rough surfaces will be clearly shown in the following statement: "in printing smooth papers, the ink is squeezed out at the edges of the surface of contact, thus magnifying the contact surface concentrically; while in printing rough papers, the ink penetrates into the nearest recesses, thus largely destroying the contoures of the contact surface and the details of the illustration" (17).

An ideal printing paper would be one which is sufficiently smooth to allow a satisfactory contact with the printing element during impression (18), (19), (20). In relation to screen fineness of a printing plate, the smoothness should be such that every dot or cell from the plate prints or transfers onto the paper being printed. If any of these dots are missing, or even imperfectly transfered, they detract from the quality and fidelity of reproduction (6).

Niemczyk (8) has stated that smoothness test results appear to correlate with press results fairly in the majority of cases. However, the main complaints as to the use of the smoothness testers for the determ-

ination of printability and printing quality are that they don't measure the smoothness under the actual printing pressures (3); and that they don't provide for or have any means of indicating the presence or depth, and extent of indentations in the paper (11), (22). The Bekk (21); Williams (22), (23); and Gurley-Hill (20), (24) smoothness testers are used in this realm of testing. Further information as to the use of these instruments will be found in the TAPPI Standards, T 479 sm-48.

Oil Absorption

Oil absorption is a direct measure of the ease of penetration of printing ink into paper, and hence is an important contributing factor in such printing troubles as strike-through, show-through, offset, lack of gloss, and lack of binding pigments to paper (20), (25), (26), (27), (28). Lack of absorption is responsible for the tendency of ink to flow laterally, both on the plate and on the paper; and thus to disturb the configuration of the pattern on the printing plate (29). With regard to this lateral flow of ink on non-ink-receptive papers, Birchard (30) says that the ink will be deposited on the paper in the form of beads.

When studying oil absorption in relation to printing, there are two phases of oil absorption to be considered: surface penetration and complete penetration (14), (20). Surface oil absorption is especially important with regard to papers which are very oil resistant; that is, bonds, ledgers, coated papers, and imitation parchments (20). In most cases, oil absorption tests give a good indication as to the actual

printing performance of paper (1), (31). As the rate of absorbency increases, there is a tendency toward strike-through and show-through on lighter weight papers; however, on coated papers this results in dull, lifeless printing (1), (3), (8). On the other hand, as the rate of absorbency decreases, poor drying and offset occur (1), (8).

The Case Ink Test (14), (32) which uses a blue oil-soluble dye, ground into a paste with a pigment and a nonoxidizable oil as the testing medium, is an excellent comparison method for determining oil absorption; the deeper the ink is absorbed by the sheet, the more receptive the sheet is to ink. Annis (33) has found that by using a General Electric Reflection Meter to determine the depth of color from the test, a numerical evaluation for the absorption can be obtained. The other important methods which are all numerically evaluated are the oil-drop (8), (34), oil-flotation (8), (34), and the photo-electric absorption meter (9), (31). The oil-drop method which is considerably shorter and appears to yield more reliable and satisfactory information than the oil-flotation method, is best suited for light weight papers (8). The main drawback of the oil-drop method is that the oils are not always representative of the printing inks used (3). The use of the photo-electric absorption meter seems to be more justifiable in the case of coated and heavy super papers (8). This method was introduced by Vallandigham (35); he also introduced the Vanceometer as a means of measuring oil absorption.

Softness

Since we have already seen that ideal contact between the printing

plate and the paper is a must, if good printing is to be obtained, it will be readily understood that the softness of a sheet can play an important roll in the determination of printing quality. The relative softness of a sheet is its ability to yield to pressure with a resultant change in thickness (25); thus, a compressible sheet is more easily brought into contact with the plate to be printed on. Neilson (16) further states that a compressible sheet will perform much better than a hard, glossy sheet.

The Gurley-Hill S-P-S Tester (24) is the instrument used most efficiently in this realm of testing.

Surface Bonding Strength (Picking)

This difficulty in printing is the result of the surface fibers or the coating on the paper being held so loosely that they lift, pick, or pull away from the body stock and adhear to the inked plate. Picking not only leaves small white spots on the printed image (20), (8), which are especially noticable in black or colored areas, but it also is responsible for the transfer of lint particles onto the ink rolls (11). Engelhart (6) defines the resistance to picking by saying that if the surface strength or the pick resistance is of sufficient magnitude, it permits the final act of transfer by allowing the ink film to split or separate away from the plate without surface rupture or pick of the paper itself.

The best known test for picking is the Wax Test (8), (32), (36), which employs the use of sealing waxes that can be stuck to the paper. These waxes have graded adheasive powers, so that when the wax is cooled and pulled from the sheet there is an increase in the amount of pull administered to the surface fibers or coating, and the number of the wax in

the series which breaks the surface of the paper is the numerical rating of pick. Another more recent means of measuring the pick is by the Davidson-Pomper Pick Tester (37); the instrument operates on the principle of a small variable speed printing press.

Interrelationship of Smoothness, Oil Absorption, Softness, and Surface Bonding Strength

Larocque (1), (26) has shown that a better indication of printing quality can be obtained if the results from the smoothness and the softness tests are correlated. It is obviously seen that paper which is smooth at low pressures and soft enough to be readily compressible is capable of giving a good print, because the surface becomes smooth and level at printing pressures. He further showed that if a pair of papers were selected, then the sheet having the highest (smoothness x softness) product almost invariably gave the best looking print (26).

Work performed by the W.F.Hall Laboratory (9) reveals that sheets of high density and smoothness, and low oil absorption are essential for good printing quality; however, oil absorption can be so low and smoothness so high that poor printing quality will result. Latimer (13) has also shown that a smooth sheet with a high oil absorption, as well as a hard-surfaced sheet of low oil absorption will yield poor printing results.

The smoother the surface (that is, the more the natural cohesion of the original surface has been reduced by calendering) the greater will be the picking tendency (38), as is the case in coated papers. Furthermore, parchment, as well as other "closed surfaced" papers, shows high

resistance to picking; however, they lack absorptiveness to printing inks.

Printing Quality Determinations

The most common method of printing quality determination is that of a visual comparison of two different sheets printed side-by-side on a proof press. Prior (2), Larocque (11), Weymouth (3), and Niemczyk (8) have been very active in this phase of work. The two sheets to be compared are placed side-by-side, each being underlined by a sheet of the other, so as to obtain identical impression and cushioning effects on each sheet. Both pairs of sheets are then attached to a third sheet, which acts as a base. By this method, the printing pressure and the speed at which both prints are pulled are the same for both sheets. Provided the ink is applied evenly, this is claimed to be an excellent method for a visual comparison of the printing quality of two different sheets (7), (39).

R.A.Diehm (7) has presented a method which not only gives printing quality a numerical evaluation, but also eliminates, to a large extent, the human element in its determination. Eckhart and Burnett (39) have obtained very satisfactory results with this method. The procedure is as follows: the plate is a typographical electrotype and is designed to show four tones in five different screens. The range of halftone screens covers good newsprint at eighty-five lines to fine coated paper print jobs at 133 lines. Meanwhile, the range in gradations of tone is from ten to ninety per cent; the ten per cent tone represents a high light in a print, meaning that only ten per cent of the paper surface is

covered with ink, while ninety per cent tone approaches a solid color and represents about the maximum color depth without closing the screen. A heavy bodied jet black ink can be sufficiently used in this work.

The first step in analyzing the print consists in determining the ink coverage. This is done by measuring the brightness of all the ten and ninety per cent tones, and obtaining the average for each. The ink coverage (IC) is calculated by:

$$IC = \frac{B\,10 - B\,90}{BP} \times 100$$

Where

B 10 = the brightness of the 10 % tone
B 90 = the brightness of the 90 % tone
BP = the brightness of the paper

Since the difference between the lightest and deepest tones is eighty per cent, a perfect print will have an ink coverage of eighty per cent.

The patterns of the ink-covered areas are equally as important as the amount of ink laid on the surface. The finest screen which lays a perfect pattern suggests the type of printing for which a paper can be used. The next step in this analysis is the evaluation of the screen pattern in such a manner that concise measurements are made.

In the first place, the black dots in the lighter tones and the white dots in the darker tones must all be present for good print fidelity. As has been previously stated, only a few dots need to be absent before the eye can detect loss of fidelity in the print. It has been estimated that a print has little , if any, commercial value when more than twenty-five per cent of the dots are missing.

A value must be assigned to the presence or absence of halftone dots if

concise measurements are to be obtained. When over twenty-five per cent of the dots are missing, the tone is assigned a halftone dot fidelity of zero. If less than twenty-five per cent of the dots are missing, the tone assumes a value of one. When all the dots are present, the value is two. All the twenty tones are evaluated individually, and the values are totaled to obtain the rating for the halftone dot fidelity. A perfect print would have a value of forty.

The dots must be uniform in size in a continuous tone, and must not show distortion or broken contours in any tones, as well as being present if sharp printing is to be obtained. Thus, each of the twenty tones is examined for size of dot uniformity. When all the dots appear uniform, the tone is given a value of two; when a few show variation in size, it has a value of one; and when over twenty-five per cent show variation in size, the value becomes zero. They are also examined for undistorted and unbroken dot outlines. If such irregularities are absent, the tone has a value of two; when a few are present, a value of one; and when more than twenty-five per cent of the dots are irregular, a value of zero. A perfect print will have values of forty, with respect to uniformity in size and irregularities of the dots. The above observations can be carried out with any hand lens that will permit a clear perspective of the dot size and shape.

The presence, and the size and shape of the dots are all important in making a good print of good fidelity. Since it would be exceedingly difficult to determine their relative importance, they all are given equal values of performance in this test. Therefore, the sum of all the fidelity ratings is 120 for a perfect print.

Printing quality can thus be defined in a new way with regard to the above facts, based on ink coverage and print fidelity. Printing quality is the per cent ink coverage attainable in perfect print fidelity. It is expressed numerically by:

$$PQ = \frac{IC \times PF}{96} \times 100$$

Where

PQ = printing quality
IC = ink coverage
PF = printing fidelity
96 = constant (per cent ink coverage in perfect fidelity in 100% printing quality, that is, 80% of 120)

This method of evaluating printing quality does not lend itself to routine mill control during a given mill run because of the time required to make the tests. However, it is very informative for perfecting or varying later runs as well as for providing the converter with information which will help him when he actually prints the paper.

James G. Dunlap

END

Literature Cited

1. Kantrowitz, M. S., <u>Paper Trade J.</u> 128, no. 25:84-87(June 23, 1949)
2. Prior, P. H., <u>Paper Trade J.</u> 101, no. 5:39-44 (Oct. 10, 1935)
3. Weymouth, F. A., <u>Paper Trade J.</u> 114, no. 15:37-40 (April 9, 1942)
4. Edge, S. R. H., <u>Paper Maker</u> 96, Annual no.:8,10,72D (1938)
5. Roestler, F., <u>Paper Progress</u> 2, no. 10:24-25 (May, 1939)
6. Engelhart, L. F., <u>Tappi</u> 34, no. 9:112A-121A (Sept., 1951)
7. Diehm, R. A., <u>Tappi</u> 33, no. 2:42A,44A,46A (Feb., 1950)
8. Niemczyk, J., <u>Paper Trade J.</u> 102, no. 18:31-33 (April 30, 1936)
9. Wehmhoff, B. L., <u>Paper Trade J.</u> 100, no. 6:41-44 (Feb. 7,1935)
10. Gardner, A. T., <u>Pulp Paper Mag. Canada</u> 47, no. 9:78-79 (Aug., 1946)
11. Larocque, G. L., <u>Pulp Paper Mag. Canada</u> 39, no.2:99-105 (1938)
12. Grantham, H. H., and Ure, W., <u>Paper Trade J.</u> 101, no. 12:29-33 (Sept. 19, 1935)
13. Latimer, K. B., <u>Tappi</u> 32, no. 11:72A (Nov., 1949)
14. Wehmhoff, B. L., <u>Ninth Graphic Arts Production Yearbook</u> , page 296 (1950)
15. Monday, C., <u>Eighth Graphic Arts Production Yearbook</u> , page 232 (1948)
16. Neilson, M. O., <u>Pulp Paper Mag. Canada</u> 40, no. 10:519-522 (Aug., 1939)
17. Annon., <u>Paper Printing Digest</u> 5, no. 4:12-15 (April, 1939)
18. Harrison, V. G. W., <u>The Penrose Annual</u> 44:134-137 (1950)
19. Annon., <u>Paper Trade J.</u> 12, no.3:22 (Sept., 1949)
20. Simmons, R. H., <u>Tappi</u> 22, no. 1:469-473 (Feb., 1939)
21. Boyce, D. H., and Simmons, R. H., <u>Paper Trade J.</u> 96, no. 4:36-40 (Jan. 26, 1933)
22. Williams, F. M., <u>Paper Trade J.</u> 100, no. 23:37-39 (June 6, 1935)

Literature Cited

23. Williams, F. M., Paper Trade J. 105, no. 8:43-47 (Aug. 19, 1937)

24. Gurley, L. E., and W., Paper Trade J. 106, no. 14:31 (April 7, 1938)

25. Kantrowitz, M. S., Eighth Graphic Arts Production Yearbook , page 208 (1948)

26. Larocque, G. L., Tappi 22, no. 1:341-345 (1939)

27. Larocque, G. L., Pulp Paper Mag. Canada 39, no. 2:106-119 (Feb., 1938)

28. Engelhart, L. F., Tappi 34, no. 9:112-121A (Sept., 1951)

29. Annon., Pulp Paper Mag. Canada 45, no. 8:605-609 (July, 1943)

30. Birchard, W. H., Pulp Paper Mag. Canada 51, no. 13:88-91 (Dec., 1950)

31. Vallandigham, V. V., Tappi 29, page 523-525 (June, 1946)

32. Kirkpatrick, W. A., Paper Trade J. 109, no. 12:36-38 (Sept. 21, 1939)

33. Annis, H. M., Method proposed to paper testing committee TAPPI.

34. Reed, E. O., Paper Trade J. 86, no. 14:(March 22, 1928)

35. Vallandigham, V. V., Paper Trade J. 123, no. 17:39-41 (Oct. 24, 1946)

36. Annis, H. M., Paper Trade J. 96, no. 2:32-34 (Jan. 12, 1933)

37. Waldron Pick Tester, Davidson-Pomper Model, John Waldron Corp. P. O. Box 791, New Brunswick, New Jersey

38. Bekk, J., Zellstoff und Papier 17, no. 7:294-298 (July, 1937) Abstracted B. I. P. C. 7:433

39. Burnett, L. K., and Eckhart, C., TAPPI (unpublished report)

Experimental Outline

Purpose:

The main purpose of this thesis will be to investigate the effect of varying smoothnesses on the printing quality of a sheet of paper. Other factors to be studied with regard to varying smoothness are oil absorption, softness, and surface bonding strength. This thesis will also try to show just how well the results from these physical tests can be correlated with the observed printing quality.

Samples:

Four different grades of paper will be investigated; namely, coated offset, uncoated book, newsprint, and rag content map paper. These samples will be conditioned in the relative humidity room (72 F. and 50 % R.H.) for at least twenty-four hours before they will be supercalendered.

Testing:

A. Smoothness - The Bekk Smoothness Tester will be used to determine the degree of smoothness obtained by supercalendering. These tests will be performed as prescribed in TAPPI Standards method T 479 sm-48.

B. Oil Absorption - The Vanceometer will be used to forcast oil absorption; the absorption function will be represented by the microampere reading obtained at the end of twenty seconds. This reading is commonly referred to as the printing number.

C. Softness - The Gurley-Hill S-P-S Tester will be used to determine the softness of the paper.

D. Surface Bonding Strength - A set of Dennison Waxes will be used in the determination of all surface strength measurements. The tests

will be carried out as prescribed in TAPPI Standards method T 459 m-48.

E. Printing Quality - A Vandercook 4 Proof Press equipped with a patent base will be used to proof the samples. A 7½ x 9 inch typographical electrotype which is divided into five different screens (60, 85, 100, 110, and 133 lines) and six different tone ranges (5, 10, 30, 50, 70, and 90 %) will be used in the proffing operation. A heavy bodied jet black ink will be used to ink the plate.

Procedure:

The following is only a tentative procedure of operation; however, this procedure will be followed as closely as possible. After conditioning, a wide range of finishes will be produced on each grade of paper by the supercalender; the extent of supercalendering will be held as close to that of commercial operations as possible. Smoothness tests will then be run to determine the actual degree of smoothness obtained by the calendering operation. The next step will be to select the degrees of smoothness which will represent the widest acceptable range; following this, the samples will be tested for oil absorption, softness, and surface bonding strength. The samples are now ready to be proofed; however, the proof press will have to be prepared before the actual proofing can take place. The amount of preparation will depend on the caliper and the type of sheet involved. Such things as the height of the printing plate and the amount of impression on the plate will have to be ascertained before any printing quality determinations can be made; these variances will be corrected by "packing", that is, by placing tympan or paper under the printing plate or on the proof press cylinder

One of the largest variables in this type of proofing will be the

determination of the proper amount of ink to be used. Due to the absorbency of the different grades of paper, the amount of ink to be used will have to be determined by a trial and error method. Once the amount of ink to be used is known, however, an Ink Volumeter will be used to measure out like amounts for further proofings.

Once the press is ready for operation, from three to five proofs will be pulled for each degree of smoothness; by obtaining this number of proofs, it will be possible to check results with regard to printing quality determinations.

Evaluation of Prints:

The method to be used is that of Robert A. Diehm which was previously discussed in the literature survey. The first step in the evaluation of results obtained by this method will be to determine the ink coverage (IC); this will be accomplished by measuring the brightnesses of all 10 and 90 % tones, averaging each, and then subtracting the 90 % average from the 10 % average. This difference will then be divided by the brightness of the paper and multiplied by 100 in order to obtain the ink coverage.

$$IC = \frac{Br.\ 10\% - Br.\ 90\%}{Br.\ paper} \times 100$$

The next step will be the evaluation of the fidelity of reproduction of the plate image on the paper by the ink. Each tone will be observed with a suitable magnifying glass and given a value according to the three specific rules. (1) If all dots are present, a value of two will be assigned; if up to one-fourth of the dots are missing, a value of one will be given; and if more than one-fourth of the dots are missing, the tone will receive zero. (2) If all dots are unbroken and undistorted, the tone will be assigned a value of two; if up to one-fourth of the

dots are broken and distorted, a value of one will be given; and if more than one-fourth of the dots are broken and distorted, the tone will receive a value of zero. (3) If each dot is uniform in size, a value of two will be assigned; if up to one-fourth of the dots are nonuniform in size, a value of one will be given; and if more than one-fourth of the dots are nonuniform, the tone will be zero. Thus, it will be to obtain a fidelity rating of 150 for a perfect print. The five per cent tone range is not used to calculate fidelity ratings.

By interrelating (IC) and (PF) it will thus be possible to obtain a numerical evaluation for printing quality (PQ); that is, printing quality is the per cent ink coverage attainable in perfect print fidelity.

$$(PQ) = \frac{(IC) \times (PF)}{120}$$

The constant 120 is the product of perfect ink coverage, which is the difference between the lightest and deepest tones (.90 - .10 = .80), and perfect print fidelity.

$$150 \times .80 = 120$$

Abstract

The main purpose of this thesis is to study the relationships between different smoothnesses (as obtained by calendering) and the printing quality of coated paper. The relationships of oil absorption, softness, and surface bonding strength to printing quality are to be studied also. The results indicate that (over the range of nip pressures employed) smoothness and oil absorption can be correlated fairly well with printing quality; however, softness does not seem to have such a distinctive effect and there is no correlation whatever with surface bonding strength.

Experimental Work

In the experimental work, seventy-three pound "coated folder" paper (25 x 38- 500) was used; this paper was cut to the size, 13 x 23 inches. The paper was then conditioned for twenty-four hours in the relative humidity room which is kept constant at 72° F. and 50 % R.H. Bekk Smoothnesses were then run on the paper (as prescribed in TAPPI Standards method T 479 sm-48) until sixty sheets had been obtained with smoothnesses in the range of twenty-eight to thirty-four seconds. The next step was to divide the sheets into six groups and mark each group by means of a code letter, A, B, C, D, E, or F. These code letters were used to signify the nip pressure under which each group would be calendered; that is, A = 0 pounds per lineal inch, B = 257 pounds per lineal inch, C = 578 pounds per lineal inch, D = 857 pounds per lineal inch, E = 1285 pounds per lineal inch, and F = 1714 pounds per lineal inch. The sheets in each group were then numbered from

one to ten in order that the sheets printed under identical conditions might be observed as separate groups later on; that is, all number one sheets would be observed as a single group, all number two sheets would be observed as another group, etc.

The calendering operations were carried out on a laboratory three-roll sheet supercalender which was built by the Wheeler Roll Company. The supercalender has a paper-filled middle roll and two polished chilled iron rolls; the rolls are 10.5 inches in diameter and have a fourteen inch face. The supercalender is driven by a 2 H.P. electric motor at a constant speed of 34.4 feet per minute. Pressure is pneumatically applied to both ends of the top chilled iron roll by means of air cylinders which are connected to lever arms. Air entering each cylinder is controlled by separate reducing valves; the pressure of the air in each cylinder is indicated by gages in pounds per square inch. The nip pressure in pounds per lineal inch can be calculated from the gage pressures; the maximum nip pressure that can be obtained on this supercalender is 2785 pounds per lineal inch.

Each sheet in the groups was then calendered by passing it through one nip of the supercalender at the designated group pressure. All sheets were then tested for oil absorption, softness, and surface bonding strength. These results, as well as those for smoothness determinations, are shown in Table 1.

A Vandercook 4 Proof Press, equipped with a typographical electrotype

credits to whom?

was used to print the sheets. The ink used in the printing operations was an oil base ink, commonly referred to as "everyday bond black". Figure 1 is a sample of the sheets which were printed.

The printing procedure is as follows: (1) Ten notches of ink were measured in an "Ink Volumeter" and applied to the automatic inking system of the press. (2) The inking system was allowed to distribute the ink for fifteen minutes, after which the inking rollers were passed over the electrotype twice. (3) The first proof was then pulled. (4) The plate was subjected to the inking rollers twice more and the second proof was pulled. (5) This procedure was continued until all ten sheets of the group had been printed; the only exception to this was that after the fifth proof had been pulled, one notch of ink was added to the inking system.

Printing quality was determined as previously prescribed in the experimental outline, page 17. The only addition to this procedure was that the dots were observed through a celluloid card; this card had a 1 mm wide slit in it which could be placed diagonally over the tone being inspected. Tables 2 and 3 show the results of these determinations. The effect of nip pressure on printing quality as well as smoothness, oil absorption, and softness is shown in Table 4 and Figure 2. The effects of smoothness, oil absorption, and softness on printing quality are shown in Figures 3, 4, and 5 respectively; data for these Figures can be found in Tables 1 and 3. High smoothness is indicated by high time readings, high oil absorption is indicated by low microampere readings, and high softness is indicated by high time readings.

Conclusions

The results from this laboratory work seem to verify statements made earlier in the literature survey (page 8) which say that printing quality increases to a certain degree with increased smoothness and low oil absorption. Figure 3 shows that high smoothness is conducive to good printing quality while low smoothness is indicative of poor printing quality. On the other hand, Figure 4 indicates that low oil absorption tends toward better printing quality than high oil absorption. Figure 5 seems to indicate that in this thesis, there is no direct relationship between softness and printing quality. With respect to the Dennison Wax Numbers, which appear in Table 1, there is no significant effect brought about by the range of nip pressures under observation; thus, it is impossible to correlate them with printing quality.

The data obtained for the groups with code letters D and E (857 and 1285 pounds per lineal inch respectively) were averaged due to the almost identical smoothnesses obtained at each pressure; these data were then plotted as if they existed at 1071 pounds per lineal inch pressure.

Table 1

Calender Nip Pressure (lb./lineal inch)	Sample No.	Smoothness (seconds)	Softness (seconds)	Oil Absorption (microamps) (after 20 sec.)	Dennison Wax No.
0	1	34	43	69	5
257	1	147	37	78	5
578	1	217	43	70	4
857	1	234	46	72	5
1285	1	234	44	73	5
1714	1	245	36	93	4
0	2	---	---	---	---
257	2	147	32	82	5
578	2	215	40	74	4
857	2	263	33	80	5
1285	2	229	43	85	4
1714	2	256	39	89	4
0	3	28	41	71	5
257	3	149	41	72	4
578	3	220	45	81	4
857	3	236	32	83	4
1285	3	237	32	81	4
1714	3	257	38	83	4
0	4	27	44	76	5
257	4	115	33	68	4
578	4	231	39	96	4
857	4	198	38	81	4
1285	4	245	34	92	4
1714	4	217	37	80	4
0	5	34	46	76	5
257	5	143	34	81	5
578	5	210	34	80	4
857	5	201	40	88	4
1285	5	241	41	84	4
1714	5	230	43	85	4
0	6	28	47	71	5
257	6	144	41	83	5
578	6	234	42	80	4
857	6	233	39	90	4
1285	6	215	43	84	4
1714	6	220	42	83	4
0	7	33	45	66	5
257	7	146	46	89	5
578	7	235	34	82	4
857	7	250	36	84	4
1285	7	222	39	89	4
1714	7	233	38	89	4

Table 1 (continued)

Calender Nip Pressure (lb./lineal inch)	Sample No.	Smoothness (seconds)	Softness (seconds)	Oil Absorption (microamps) (after 20 sec.)	Dennison Wax No.
0	8	32	48	72	5
257	8	156	29	88	4
578	8	224	44	80	4
857	8	223	33	80	5
1285	8	233	33	96	4
1714	8	233	39	96	4
0	9	28	39	70	5
257	9	152	48	74	5
578	9	216	41	83	4
857	9	238	30	81	5
1285	9	215	37	90	4
1714	9	258	34	88	4
0	10	29	42	68	5
257	10	153	35	76	5
578	10	222	30	79	4
857	10	241	40	83	4
1285	10	220	37	86	4
1714	10	241	44	87	4

The data obtained at nip pressures of 857 and 1285 pounds per lineal inch were averaged due to the similarities in smoothness of the groups as a whole. These data thus follow as being calendered at 1071 pounds per lineal inch.

1071	1	234	45	72.5
1071	2	246	38	82.5
1071	3	236.5	32	82
1071	4	221	36	86.5
1071	5	221	40.5	86
1071	6	224	41.5	87
1071	7	236	37.5	86.5
1071	8	228	33	88
1071	9	226	33.5	85.5
1071	10	230	38.5	84.5

Table 2

Ink Coverage Data

Calender Nip Pressure (lb./lineal inch)	Sample No.	Avg. Br. 10 % Tones	Avg. Br. 90 % Tones	% Br. Difference	Paper Br.	% Ink Coverage
0	1	----	----	----	----	----
0	2	----	----	----	----	----
0	3	66.4	11.7	54.7	81.5	67.1
0	4	66.4	11.7	54.7	81.0	67.5
0	5	66.5	12.4	54.1	80.0	67.6
0	6	66.4	12.7	52.7	80.0	65.9
0	7	66.1	12.7	53.4	80.5	66.4
0	8	66.0	13.1	52.9	80.0	66.2
0	9	65.6	13.5	52.1	80.0	65.1
0	10	66.0	13.9	52.1	80.0	65.1
257	1	66.5	10.0	56.5	79.0	71.5
257	2	66.6	9.3	57.5	80.0	71.9
257	3	66.5	9.4	57.1	79.5	71.9
257	4	67.1	10.5	56.6	79.5	71.2
257	5	66.7	10.7	56.0	79.0	71.0
257	6	67.6	10.3	57.3	80.0	71.6
257	7	67.5	10.6	56.9	80.0	71.1
257	8	68.4	10.5	57.9	80.0	72.3
257	9	67.2	11.4	55.8	79.5	70.3
257	10	67.9	11.4	56.5	80.5	70.3
578	1	67.0	10.4	56.6	78.0	72.5
578	2	67.0	10.5	56.5	79.0	71.6
578	3	67.5	10.7	56.8	79.5	71.5
578	4	67.9	11.3	56.6	80.0	70.8
578	5	67.9	11.1	56.8	79.5	71.5
578	6	67.4	10.6	56.8	80.0	71.1
578	7	67.4	11.2	56.2	80.0	70.3
578	8	67.9	11.3	56.6	80.0	70.9
578	9	68.6	11.9	56.7	80.0	70.8
578	10	67.9	12.2	55.7	79.5	70.1
857	1	67.5	10.9	56.6	78.5	72.1
857	2	67.9	10.3	57.6	79.0	72.9
857	3	67.5	10.3	57.2	80.0	71.6
857	4	67.5	10.4	57.1	79.5	71.9
857	5	68.4	11.2	57.2	79.5	72.0
857	6	68.3	10.4	57.9	79.0	73.3
857	7	67.8	10.4	57.4	80.0	71.8
857	8	68.0	10.5	57.5	80.0	71.9
857	9	68.2	10.8	57.4	79.0	72.6
857	10	67.9	11.1	56.8	80.0	71.1

Table 2 (continued)

Ink Coverage Data

Calender Nip Pressure (lb./lineal inch)	Sample No.	Avg. Br. 10 % Tones	Avg. Br. 90 % Tones	% Br. Difference	Paper Br.	% Ink Coverage
1285	1	68.4	11.7	56.7	80.0	70.9
1285	2	68.2	11.5	56.7	78.5	72.2
1285	3	68.2	11.4	56.8	78.5	72.4
1285	4	68.0	11.6	56.4	78.5	71.9
1285	5	68.3	12.2	56.1	80.0	70.1
1285	6	68.4	12.3	56.1	80.0	70.1
1285	7	68.8	12.2	56.7	80.5	70.5
1285	8	68.8	12.3	56.5	80.0	70.6
1285	9	68.9	12.7	56.2	79.0	71.1
1285	10	68.2	13.1	55.1	79.0	69.8
1714	1	67.5	10.4	57.1	79.0	72.3
1714	2	67.8	10.2	57.6	80.0	72.0
1714	3	67.6	10.3	57.3	80.5	71.3
1714	4	68.4	11.0	57.4	79.5	72.2
1714	5	68.6	10.9	57.7	80.0	72.1
1714	6	68.0	10.7	57.3	80.0	71.6
1714	7	68.7	11.2	57.5	80.0	71.9
1714	8	67.9	11.2	56.7	79.0	71.8
1714	9	67.2	11.2	56.0	79.0	71.0
1714	10	68.0	11.9	56.1	80.0	70.3

Table 3

Printing Quality Data

Calender Nip Pressure (lb./lineal inch)	Sample No.	Presence of Dots	Distortion of Dots	Uniformity of Dots	Print Fidelity	Printing Quality
0	1	--	--	--	---	----
0	2	--	--	--	---	----
0	3	50	16	35	101	.564
0	4	50	16	34	100	.562
0	5	50	16	35	101	.568
0	6	50	18	39	107	.597
0	7	50	16	36	102	.564
0	8	50	19	36	105	.579
0	9	50	15	34	99	.537
0	10	50	20	37	107	.580
257	1	50	33	41	124	.739
257	2	50	32	38	120	.719
257	3	50	35	35	120	.719
257	4	50	33	37	120	.712
257	5	50	32	37	119	.704
257	6	50	30	37	117	.698
257	7	50	31	37	118	.700
257	8	50	33	39	122	.734
257	9	50	34	39	123	.721
257	10	50	35	38	123	.721
578	1	50	33	38	121	.730
578	2	50	30	39	119	.710
578	3	50	32	38	120	.715
578	4	50	30	36	116	.684
578	5	50	31	37	118	.694
578	6	50	30	37	117	.693
578	7	50	33	37	120	.703
578	8	50	32	40	122	.720
578	9	50	33	37	120	.709
578	10	50	32	39	121	.707
857	1	50	33	37	120	.721
857	2	50	32	36	118	.718
857	3	50	34	36	120	.716
857	4	50	31	38	119	.713
857	5	50	33	39	122	.731
857	6	50	35	40	125	.764
857	7	50	35	40	125	.749
857	8	50	34	40	124	.743
857	9	50	33	40	123	.745
857	10	50	35	41	126	.746

Table 3 (continued)

Printing Quality Data

Calender Nip Pressure (lb./lineal inch)	Sample No.	Presence of Dots	Distortion of Dots	Uniformity of Dots	Print Fidelity	Printing Quality
1285	1	50	39	45	134	.791
1285	2	50	35	42	127	.764
1285	3	50	37	43	130	.785
1285	4	50	37	42	129	.773
1285	5	50	38	42	130	.759
1285	6	50	38	42	130	.759
1285	7	50	36	43	129	.759
1285	8	50	36	42	128	.755
1285	9	50	36	42	128	.760
1285	10	50	36	43	129	.750
1714	1	50	38	42	130	.783
1714	2	50	40	43	133	.798
1714	3	50	38	42	130	.774
1714	4	50	40	45	135	.813
1714	5	50	39	44	133	.799
1714	6	50	38	43	131	.781
1714	7	50	36	42	128	.768
1714	8	50	38	43	131	.784
1714	9	50	40	44	134	.794
1714	10	50	39	41	130	.761

Table 4

Effect of Calender Nip Pressure on Paper Characteristics

Calender Nip Pressure (lb./lineal inch)	Smoothness (seconds)	Softness (seconds)	Oil Absorption (microamps) (after 20 sec.)	Printing Quality
0	30	44	71	.569
257	145	38	79	.717
578	222	39	80	.706
* 1071	230	37.5	84	.750
1714	239	39	87	.768

* - The original data for sheets calendered at 857 and 1285 pounds per lineal inch pressure were averaged to give data at 1071 pounds per lineal inch pressure.

-**- The paper characteristic data are averages of the ten samples calendered at each pressure.

FIGURE - 2

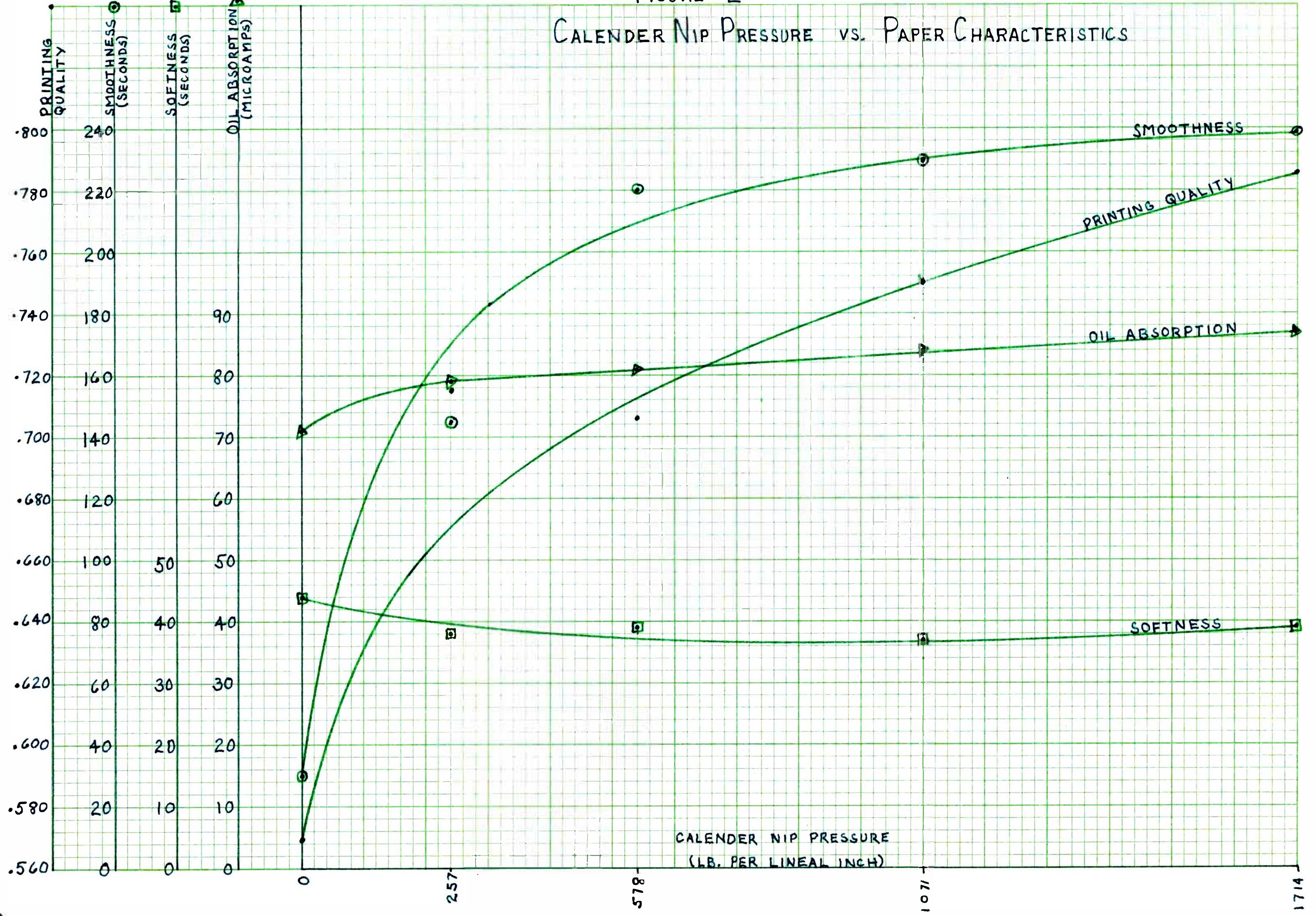

CALENDER NIP PRESSURE VS. PAPER CHARACTERISTICS
PRINTING QUALITY
SMOOTHNESS (SECONDS)
SOFTNESS (SECONDS)
OIL ABSORPTION (MICROAMPS)
SMOOTHNESS
PRINTING QUALITY
OIL ABSORPTION
SOFTNESS
CALENDER NIP PRESSURE
(LB. PER LINEAL INCH)
0
257
578
1071
1714
.800
.780
.760
.740
.720
.700
.680
.660
.640
.620
.600
.580
.560
240
220
200
180
160
140
120
100
80
60
40
20
0
50
40
30
20
10
0
90
80
70
60
50
40
30
20
10
0

FIGURE - 3

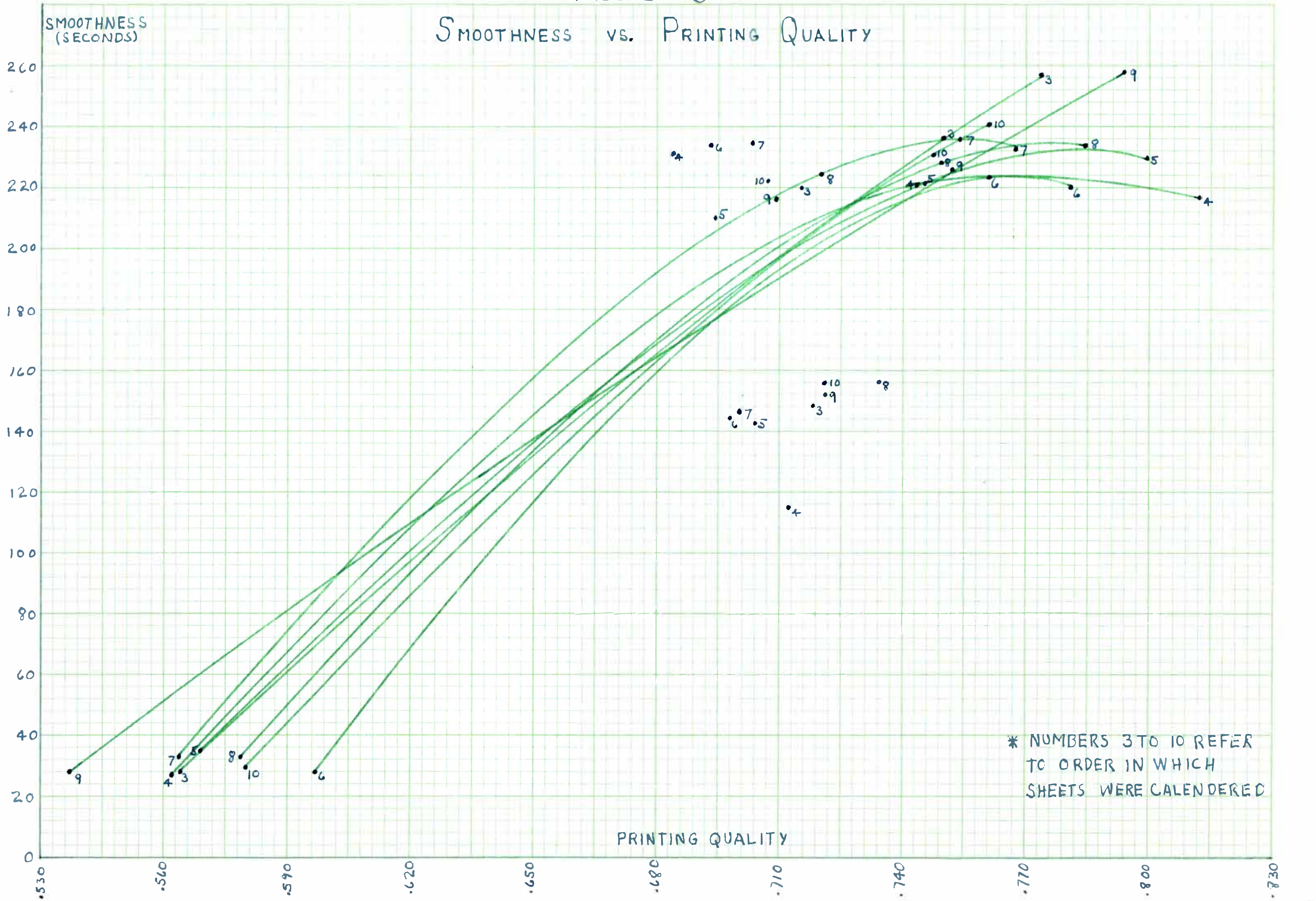

SMOOTHNESS VS. PRINTING QUALITY
SMOOTHNESS (SECONDS)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
PRINTING QUALITY
.530
.560
.590
.620
.650
.680
.710
.740
.770
.800
.830
* NUMBERS 3 TO 10 REFER TO ORDER IN WHICH SHEETS WERE CALENDERED

FIGURE - 4

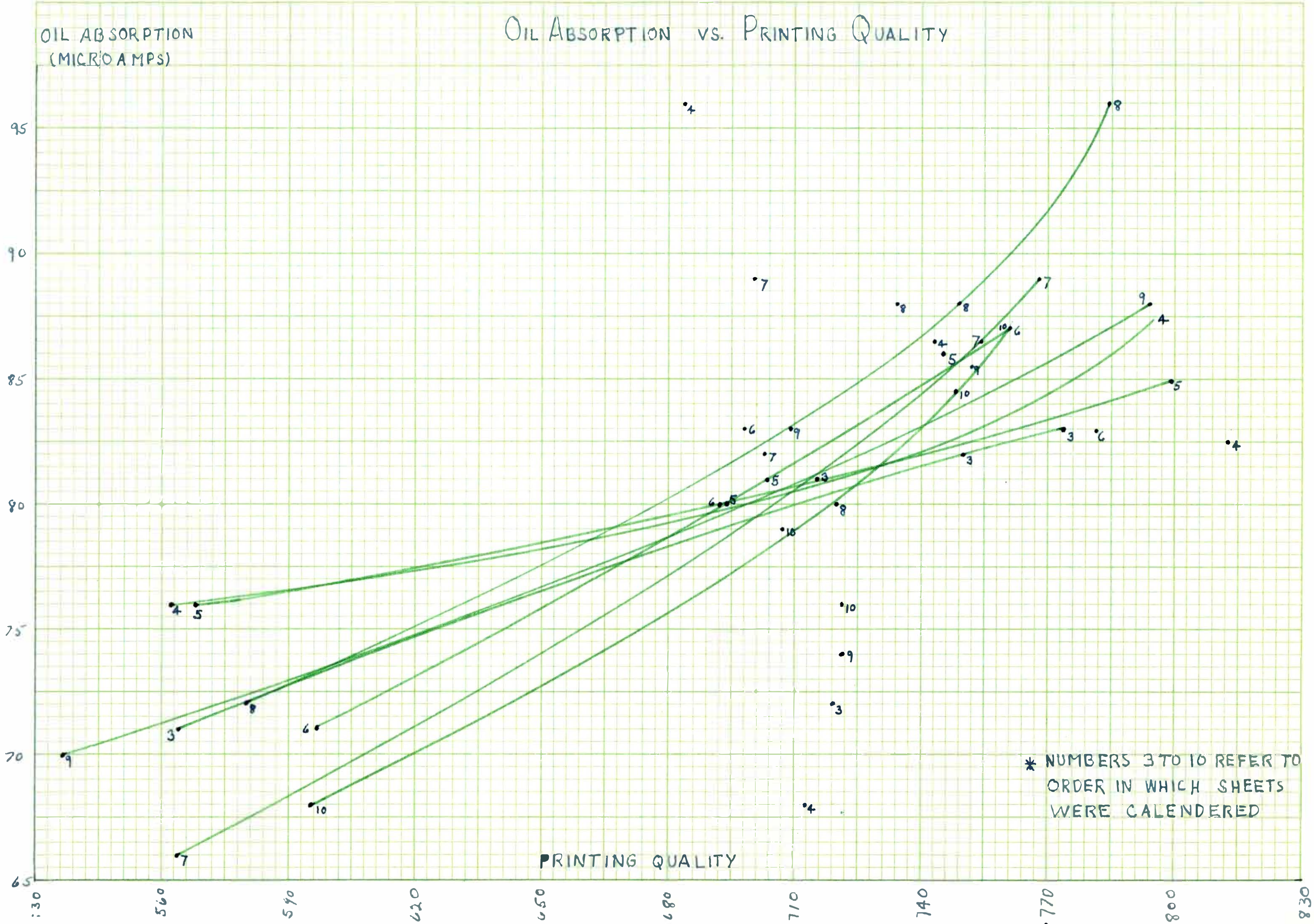
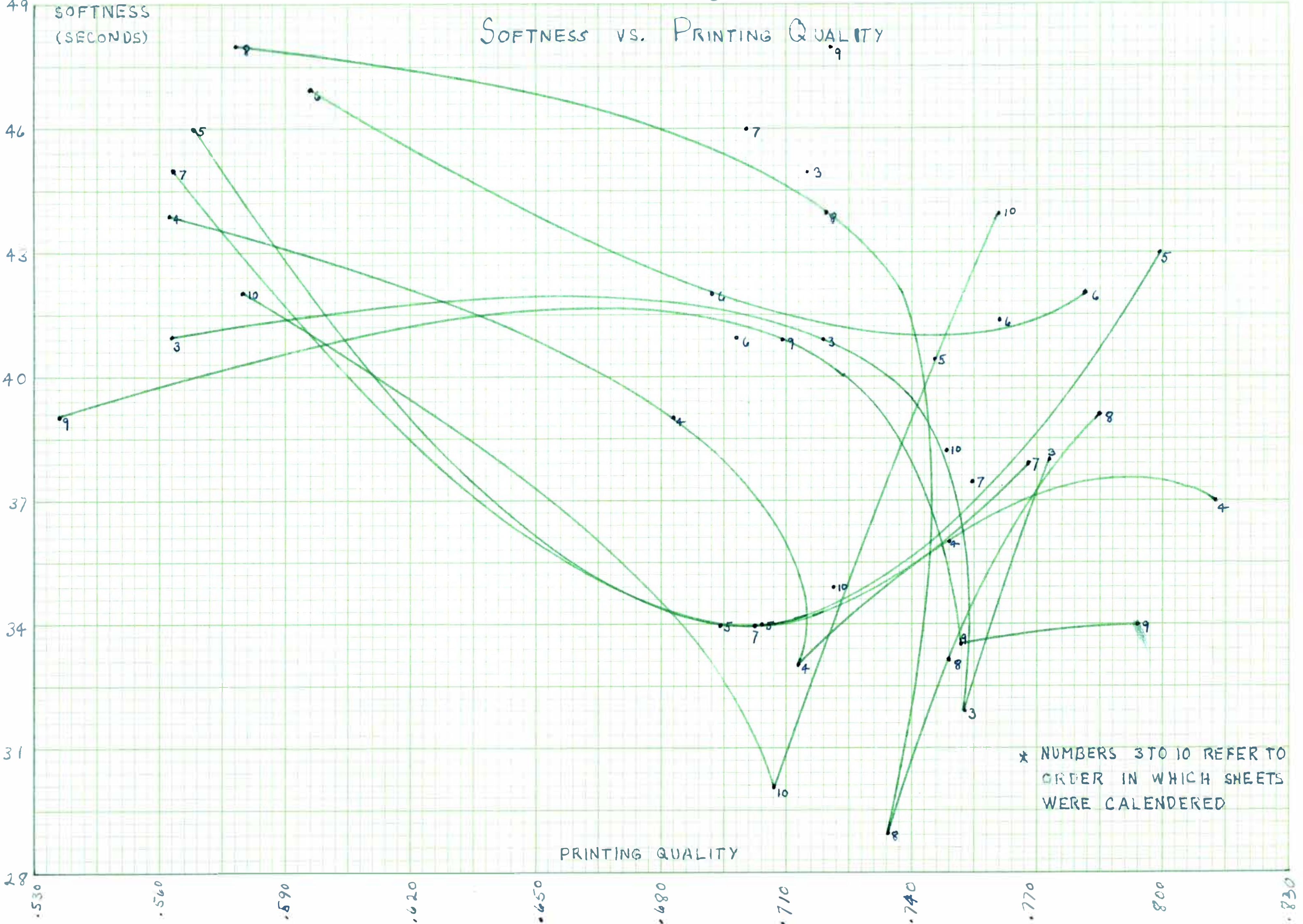

OIL ABSORPTION VS. PRINTING QUALITY
OIL ABSORPTION (MICRO AMPS)
PRINTING QUALITY
* NUMBERS 3 TO 10 REFER TO ORDER IN WHICH SHEETS WERE CALENDERED

FIGURE - 5


SOFTNESS VS. PRINTING QUALITY
SOFTNESS (SECONDS)
49
46
43
40
37
34
31
28
PRINTING QUALITY
.530
.560
.590
.620
.650
.680
.710
.740
.770
.800
.830
* NUMBERS 3 TO 10 REFER TO ORDER IN WHICH SHEETS WERE CALENDERED