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Development of a Testing Procedure for Gloss Ink Holdout

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DEVELOPMENT OF A TESTING PROCEDURE

FOR

GLOSS INK HOLDOUT

by

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ABSTRACT

There is currently no standard acceptable method used to evaluate gloss ink holdout. Four methods are investigated to evaluate holdout. Heat set ink is used to reduce absorption effects. The K&N ink smear test and the Vanceometer absorption tester are both discounted as inappropriate tests since they look at absorption alone and have widely varied results. The IGT printability tester is an improvement because it involves another major influence to holdout, printing pressure, but does not hold the ink film thickness constant. The Vandercook Proof Press procedure is judged the most valuable since it takes into account printing pressure and absorption, and holds the ink film thickness constant. It also is the closest approximation to the industrial setting.

TABLE OF CONTENTS

OBJECTIVES

The objective of this study is to develop a testing procedure to predict the gloss ink holdout characteristics of a sheet of paper that will relate well to industrial situations. This will be accomplished by a comparative study of tests presently used and the possible evolution of a new procedure as a result of the laboratory findings.

1) The test must be simple and rapid.

2) The test must be free from human error and judgment.

3) The test must correlate well with industrial results (1).

A good test for gloss ink holdout must fulfill these criteria.

THEORY

The gloss of a surface may be defined as its degree of approach to a mirror surface. A mirror surface is usually used as a standard in gloss measuring devices. The end result of gloss depends on the light reflectance properties of the ink film in its final dried state. Gloss is a function of the smoothness and the refractive index of the surface (2). It is influenced by absorption rate, printing pressure, ink film thickness, and speed (3), as well as the viscosity, opacity, and drying time of the ink (4).

The absorption of the specimen varies with the degree of ink transfer, the rate of setting, and the final degree of penetration (4). Two types of absorbency may be classified as surface absorbency and equilibrium or internal absorbency. Surface absorbency is the absorption that takes place in the nip, under pressure, in a period of time that may be considered null (2).

The surface absorbency alone is of significant concern. Ink layers of merely 10 μ penetration are considered thick in printing circles. A piece of lightweight airmail paper has a thickness of 60 U. Comparison of the thicknesses indicates that we need only be concerned with the surface layers of the sheet. The deeper layers play no significany role in ink penetration (5). The rate of penetration due to the nip pressure is approximated by the Hagen-Poiseruille law for laminar flow:

$$v = \frac{r^2 \Delta P}{8\ n l}$$

where v= mean velocity of flow

r= pore radius

ΔP= pressure drop

n= dynamic viscosity

l= thickness of the penetrated layer (12).

Printing conditions also affect the gloss obtained in printing.The ink film thickness. is the most influential factor. In J.M. Fetsko's studies no single test could give a good correlation at all ink film thicknesses. Since industry uses the thinnest film practical to obtain acceptable results, thin films should be used in developing a testing procedure. Fetsko suggests the need for research at several ink film thicknesses to study the differences in trends. Pressure has little effect on low absorbency stock (2). Pressure also has little effect on coated papers, but increased pressure decreases the gloss of uncoated papers somewhat (6). Speed in itself, is believed to have no effect on gloss, but the slower the speed the greater the amount of ink transfer, thus giving thicker ink films at lower speeds. Ambient room conditions can be critical. High temperatures bring a drop in gloss by decreasing the viscosity of the ink. Drying time not only effects the degree of ink holdout

(by stopping the penetration of the ink into the sheet) but also may effect the entire order in which a series of stocks are rated for gloss tendency (2).

The amount of vehicle which penetrates into the paper is due in part, to the characteristics of the ink used. To produce a high gloss, the ink should have fine sized, well dispersed pigment (2). Once on the paper the ink develops a capilary system. The papers' capilary system and the inks' capillary system then compete for the vehicle. If the pore radius of the pigment particle is smaller than the pore radius of the paper, then no vehicle would flow from ink to paper. This is an oversimplified case, however, since neither the pore size of the paper nor the pore size of the pigment system is uniform. Still, the particle size of the ink pigment is a definite factor and one would expect better ink holdout with a fine pigment ink that with a course pigment ink (5).

The characteristics of the ink must provide for a sufficiently short drying time to curtail penetration, yet exibit good flow to level out into a smooth surface (2).

TESTS CURRENTLY USED

K & N

The TAPPI suggested method for predicting gloss ink holdout is the K & N ink wipe test. The test is designed to indicate the " rate of printing ink varnish absorption at the surface of the paper ". (See Appendix for procedure.)

This test has been used in a slightly modified form by Fetsko. Instead of a "thick film" a .030 inch thick plate was used with a 1½" square opening. This plate was placed on the specimen and filled with ink to give a uniform and reproducible ink smear each time. This method was also used with Hull red and black inks (4).

VANCEOMETER

Ink holdout seems to depend on a balance between the pore structure and drying time. This suggests the use of a test of penetration with time, the vanceometer oil absorption test. (See Appendix for procedure)

The vanceometer test has several shortcomings. The method of spreading the oil film with the metal roller is inadequate. The film produced is too thick and nonuniform to compare to an actual printing situation.

The transparency of the oil film permitted the base gloss of the specimen influenced the results. A thinned ink overcomes this transparency problem but when the ink is thinned sufficiently to be used on the vanceometer it is no longer representative of the composition of ink used in industrial situations (2). Vanceometer tests to date have produced widely varied results (4).

The results obtained from different gloss meters do not always correlate well. When gloss values from the vanceometer were compared to the photovolt, gloss values were rated in the same order, but the photovolt values were higher. The vanceometer and photovolt correlated differently with different sets of points. It could be dangerous for a customer to use a different type of gloss meter than his supplier. (2)

VANDERCOOK PROOF PRESS

There does not seem to be any given method for using the vandercook proof press as a testing instrument for gloss ink holdout. (See Appendix, fig. 1.) The instrument can be used at constant pressure and speed. It is also useful to regulate the ink film thickness from sheet to sheet. The printed samples can then be rated for gloss on a gloss meter (9).

The proof press has been used with a clock mounted on it to be activated at the moment of impression as a means to evaluate gloss with respect to time.

Results were disapointing however since no measurements could be taken for the first ten to twenty seconds after printing. A gloss meter with an extremely rapid response time is desirable (2).

IGT PRINTABILITY TESTER

The IGT printability tester lends itself well for use as a printer for samples in a gloss ink holdout test. This IGT procedure has been used industrially to predict gloss ink holdout. (See Appendix for procedure).

When using the IGT tester, printing pressure is mainly a function of the pressure applied by the impression cylinder and the hardness of the blanket of packing material. The pressure is independent of the caliper of the specimen being printed (11).

It has been suggested that a heating element could be utilized on the tester with a heat set ink to simulate the industrial environment of rapid drying (9).

END POINT METHOD

In the end point method of determining surface tension an organic liquid containing no pigment is brought in contact with the specimen of paper. The time for complete penetration is measured. By taking into account the thickness, the penetration velocity can be calculated from the strike through time. For homogeneous papers, the penetration depth and volume of liquid penetrated are proportional to the square root of the time required (5).

BACK SIDE OPTICAL METHOD

This test registers the transparency of reflection of the back side of a sheet during penetration. The results are difficult since the optical properties are not wholly dependent on the volume of oil taken up. Inter-

pretation of results are even more difficult when the paper layers vary in composition and density (5).

DISCUSSION

The literature stresses that the critical elements of gloss ink holdout occur near the surface of the sheet. This suggests the need for a test that would evaluate a sheet's absorbent qualities near the surface under pressure. As noted, the work previously done on the Vandercook proof press failed for lack of a means of immediate evaluation after printing. If a heater were attached to the press and a heat set ink used, the need for rapid evaluation could be eliminated and the industrial setting more closely approximated. This could also be an appropriate alteration of the IGT procedure. At any rate the tests must be compared and rated with a single test emerging as the most desirable.

EXPERIMENTAL PROCEDURES

K & N (1)

Apparatus

Standard K & N ink, small spatula, stop-watch, and clean soft cloth.

Test Specimens

Flat uncreased sample of any convenient size.

Procedure

Place specimen on a flat working surface, with the side to be tested uppermost. Work the test ink. Smear a thick film on specimen with the spatula and start the stop-watch at the time of application. The ink film must be thick enough to remain glossy for at least two minutes. At the end of two minutes quickly scrape off the excess ink with the spatula and wipe the specimen clean with the soft clean rag.

Evaluation

The varnish which has penetrated the paper will be shown by a blue stain of varying depth.

Deep discoloration or stain indicates rapid absorption.

Light discoloration or stain indicates slow absorption.

Record brightness of base stock and brightness of smear.

% brightness retained = (print brightness/base stock brightness) x 100

VANCEOMETER (8)

Apparatus

vanceometer

constant viscosity oil

paper towels

6" wide paper specimens

Set up

This tester operates on 120-volt A.C., 60 cycle current only. Place tester on level surface using spirit level to determine best location. To set Vanceometer, clean the glass ramp and lock in place. Adjust meter by running knob on right hand side panel to a reading of 100 (check frequently). The ramp is the standard for setting the tester and should be kept clean at all times.

CAUTION: the same grade of oil must be used on similar grades of paper for uniform results. Use at 70° room temperature.

Procedure

Base gloss: This test will give a numerical reading of the light reflection from the sheet, and thus indicate the difference in finish between one sheet and another.

1. Select sample, 12" x 6". Cut so grain runs lengthwise.
2. Place sheet on ramp with side to be printed uppermost.
3. Raise ramp, lock in place.
4. Record number at which meter needle rests. Lower ramp.

Oil drop test:

5. Leave sample sheet on ramp, with side to be printed uppermost, so that roller will travel in the machine direction.

6. Place the roller on the left hand side of the ramp against the back guard between the two red dots.
7. Using recommended type of oil, drop five drops of oil from a height of one inch above the surface with an eye dropper, at a point directly in line with the left hand side of the oval opening and the red dot and in the center of the path of the roller.
8. Release (BUT DO NOT PUSH) roller immediately after dropping 5th drop of oil. Let roll freely to right-hand side to set off timing mechanism.
9. Raise ramp and lock in place.
10. Take readings at 10 second intervals.

Schematic of VANDERCOOK PROOF PRESS

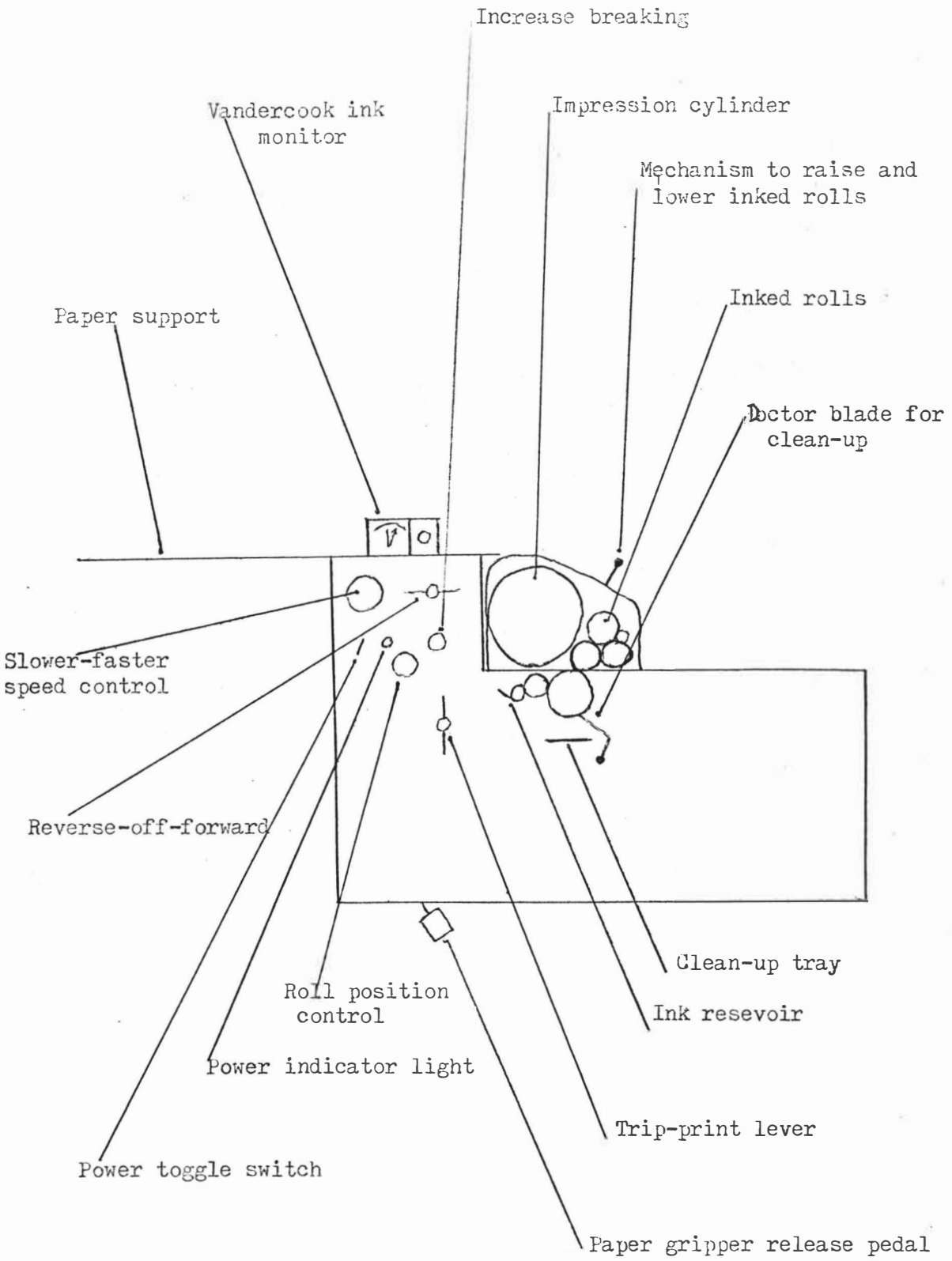


Figure 1.

VANDERCOOK PROOF PRESS

Two applications of the Vandercook proof press were explored.

1. Proof Press without a heating element to dry the samples.
2. Heating element next to the proof press.

The thinnest practical ink film thickness was used that still gave good coverage. A series of prints were run with two different inks, a #2 graded tack black ink and a red litho heat set ink. The procedure follows:

1. Turn on the proof press.
2. Set needle on ink monitor to a "zero" position with no ink on rolls.
3. Ink the rolls.
4. Use coursest paper sample in determining the thinnest possible ink film thickness practical (which was sample B).

For heating element next to proof press --

5. Print the sample with heat set ink.
6. Immediately place print in front of the heating element, a room space heater (1500 BTU).
7. Determine and record the time necessary to dry the ink (30 seconds).
8. Evaluate prints on the Hunterlab gloss meter for base gloss and print gloss.

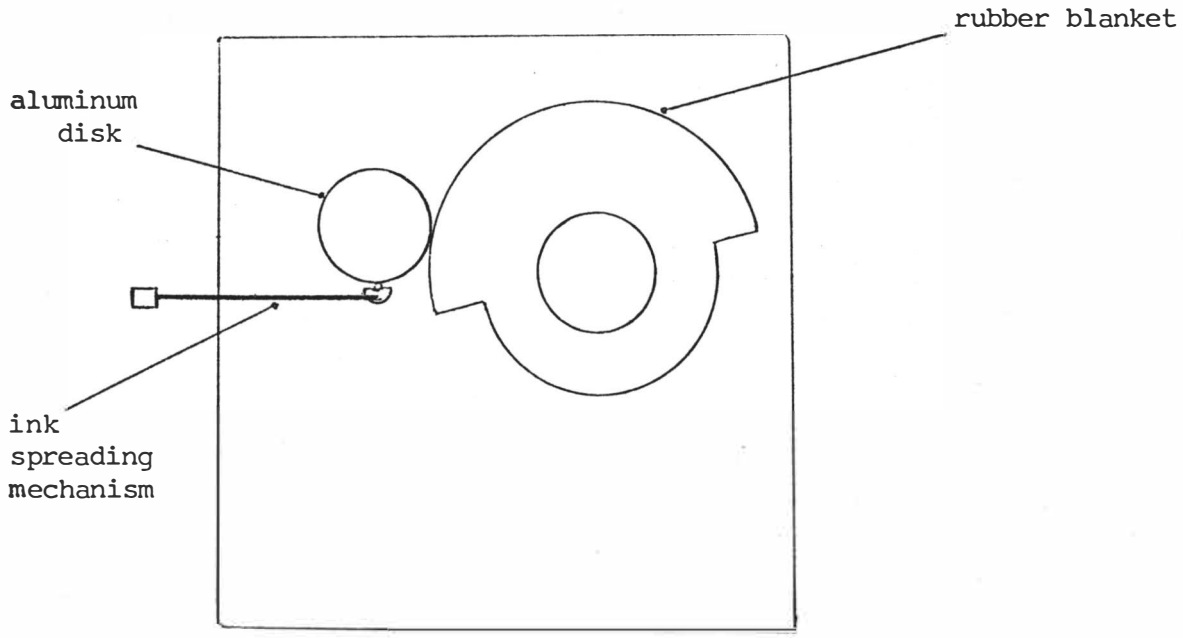
With no heating element --

5. Print the sample with #2 graded tack black ink.
6. Hang in constant temperature humidity room to dry by absorption for 72 hours.
7. Evaluate the prints on the Hunterlab gloss meter for base gloss and print gloss.
8. Clean and shut down the proof press.

IGT PRINTABILITY TESTER

Procedure

1. Set IGT at 35 Kgf and 1.3 m/sec, constant speed.
2. Attach paper sample to rubber blanket.
3. Place small amount of heat set ink on aluminum disk.
4. With ink spreading mechanism in place, rotate aluminum disk five time to spread ink to a uniform thickness.
5. Remove ink spreading mechanism.
6. Move aluminum disk against sample.
7. Start motor and print sample.
8. Remove sample and hang in fromt of space heater for 1 minute.
9. Crank aluminum disk away from rubber blanket.
10. Clean aluminum disk if sample picked during printing.
11. Repeat steps 2 through 10 for subsequent samples.
12. Record base gloss and print gloss for evaluation.



IGT Printability Tester

RESULTS

HEAT SET VANDERCOOK (30 SEC DRY)				
Difference	PRINT BASE	$100-\left(\frac{BASE}{PRINT}\right)100$	PRINT GLOSS	BASE GLOSS
E 26.12	F 2.25	F 55.6	A 71.24	A 51.24
F 24.97	B 2.24	B 55.3	B 43.64	B 19.51
B 24.13	D 1.89	D 46.8	C 69.31	C 55.11
A 20.0	E 1.75	E 42.9	D 38.90	D 20.69
D 18.21	A 1.39	A 28.0	E 60.87	E 34.75
C 14.20	C 1.26	C 20.5	F 44.89	F 19.92
G -1.20	G .98	G 1.9	G 63.58	G 64.78

ABSORPTION VANDERCOOK				
Difference	PRINT BASE	$100-\left(\frac{BASE}{PRINT}\right)100$	PRINT GLOSS	BASE GLOSS
C 15.75	B 1.82	B 45.29	A 64.67	A 52.45
B 15.21	F 1.55	F 35.73	B 33.58	B 18.37
F 12.67	D 1.38	D 27.75	C 73.29	C 57.54
E 12.43	E 1.30	E 23.32	D 35.39	D 25.57
A 12.22	C 1.27	C 21.49	E 53.30	E 40.87
D 9.82	A 1.23	A 18.89	F 35.46	F 22.79
G 8.8	G 1.13	G 11.60	G 75.87	G 67.07

HEAT SET IGT PRINTABILITY				
Difference	PRINT BASE	$100-\left(\frac{BASE}{PRINT}\right)100$	PRINT GLOSS	BASE GLOSS
F 36.19	B 2.74	B 63.5	A 70.58	A 52.05
E 34.36	F 2.66	F 62.4	B 51.84	B 18.94
B 32.90	D 2.00	D 50.1	C 75.05	C 56.73
D 24.07	E 1.88	E 46.9	D 48.01	D 23.94
A 18.5	A 1.36	A 26.2	E 73.19	E 38.83
C 18.32	C 1.32	C 24.4	F 58.02	F 21.83
G -9.82	G 0.85	G 0.2	G 56.49	G 66.31

K&N INK SMEARS		
WMU LAB $\frac{K\&N\ Brt.}{Base\ Brt} \times 100$	MILL $\frac{K\&N\ Brt}{Base\ Brt} \times 100$	MILL PHOTOVOLT BRIGHTNESS
A 86.30		
C 85.74	C 78.6	C 75.0
E 84.51	E 77.4	E 73.0
G 80.75	G 67.7	G 59.0
F 79.41	F 71.7	F 67.0
B 75.89		
D 75.86	D 66.2	D 61.7

Table I. Results.

Figure 1

THE FAMILY OF (AVERAGE VALUE) VANCEOMETER CURVES

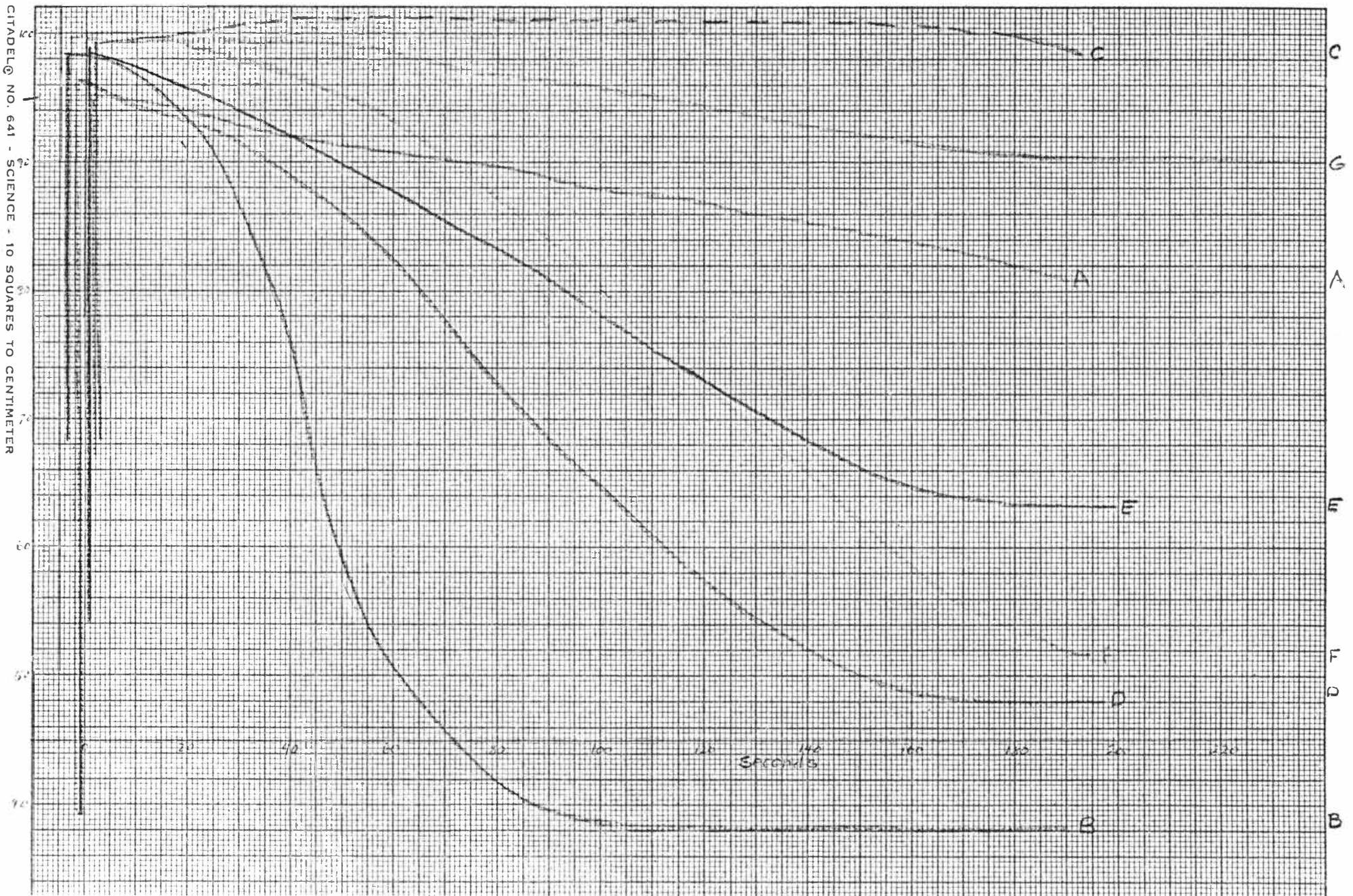


Figure 2

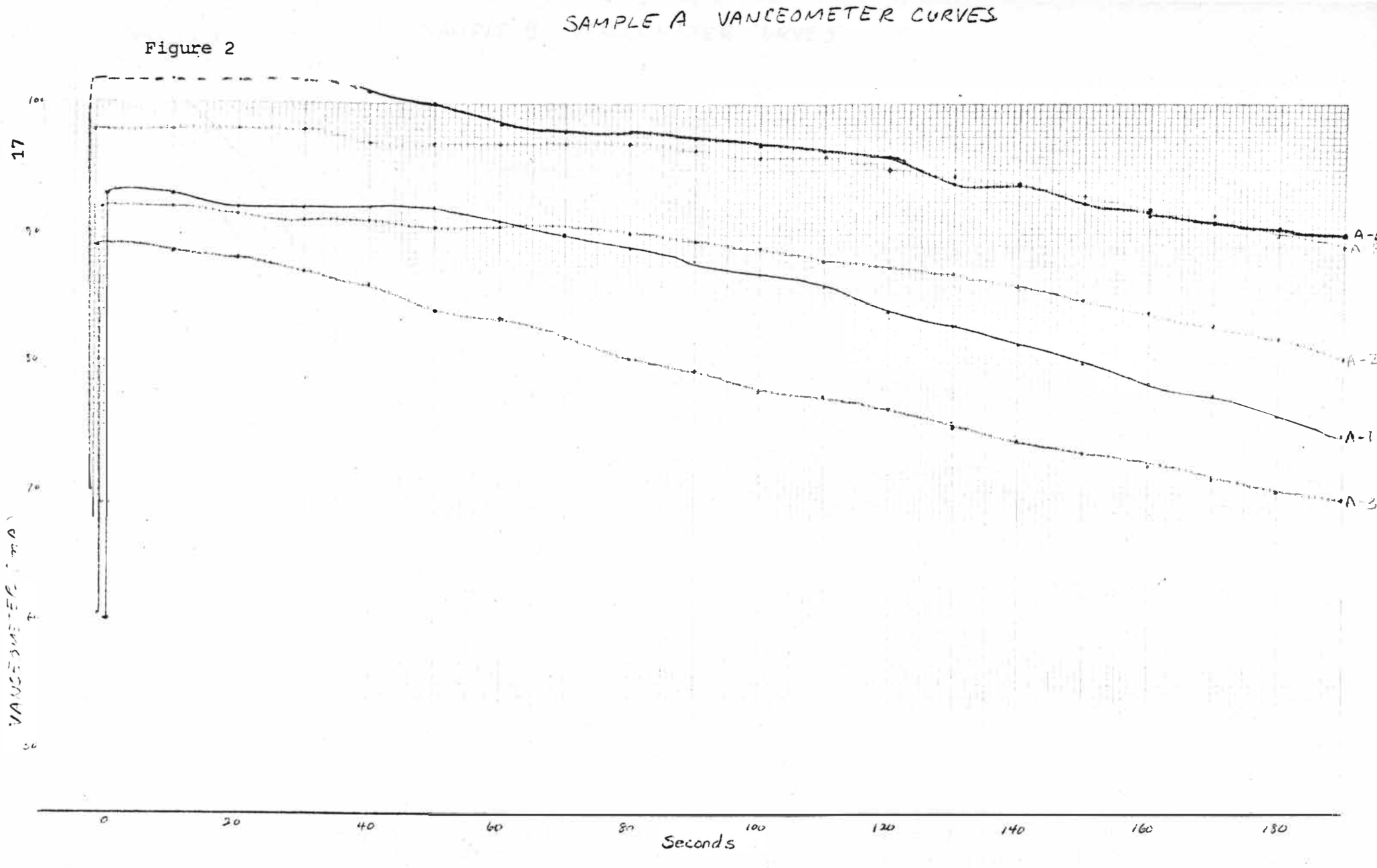

SAMPLE A VANEOMETER CURVES
A-1
A-2
A-3
0
20
40
60
80
100
120
140
160
180
Seconds

Figure 3

SAMPLE B VANCEOMETER CURVES

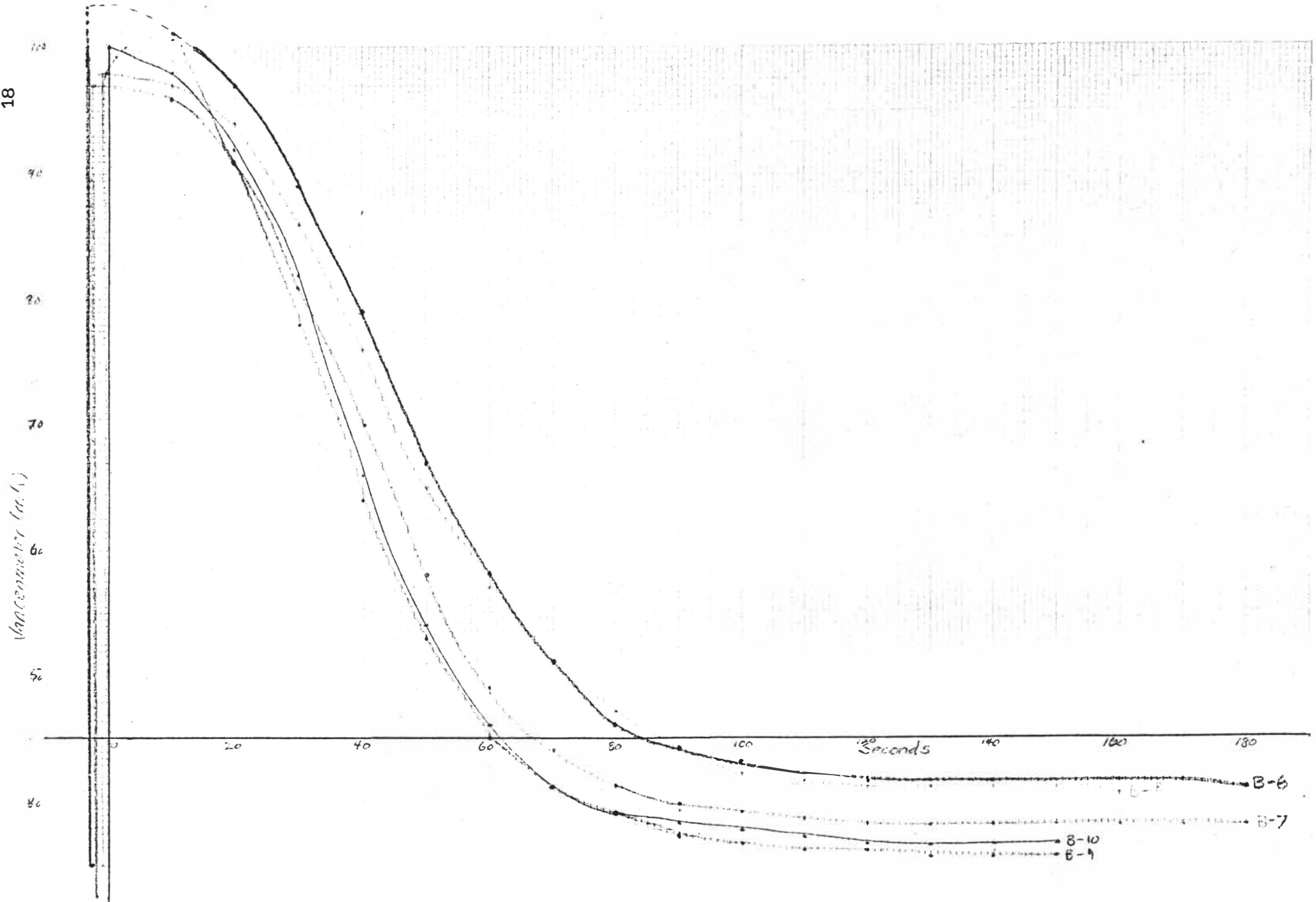


Figure 4

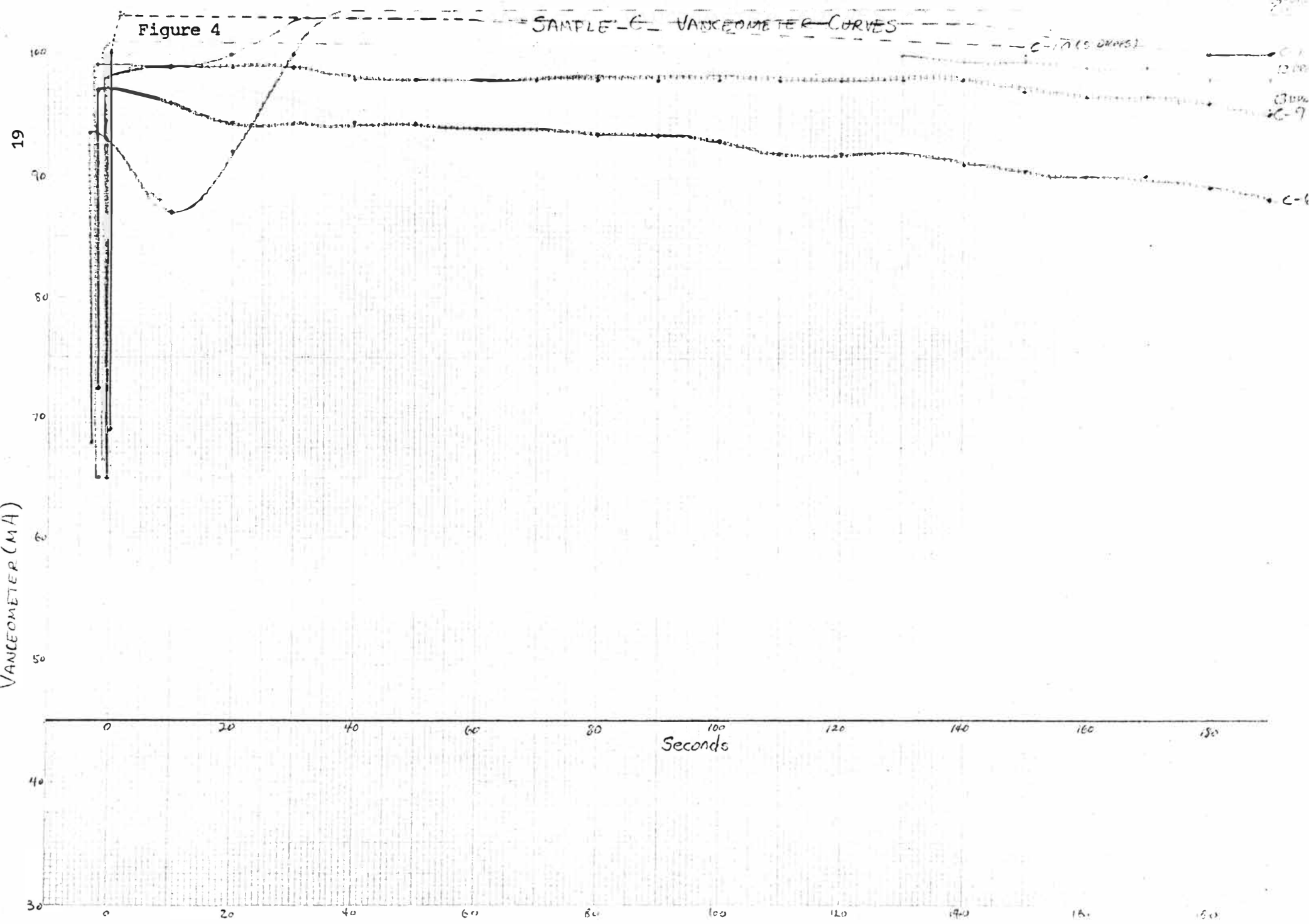

SAMPLE C VANEOMETER CURVES
C-7 (3 DROPS)
C-6
VANEOMETER (MA)
100
90
80
70
60
50
40
30
0
20
40
60
80
100
120
140
160
180
Seconds

Figure 5

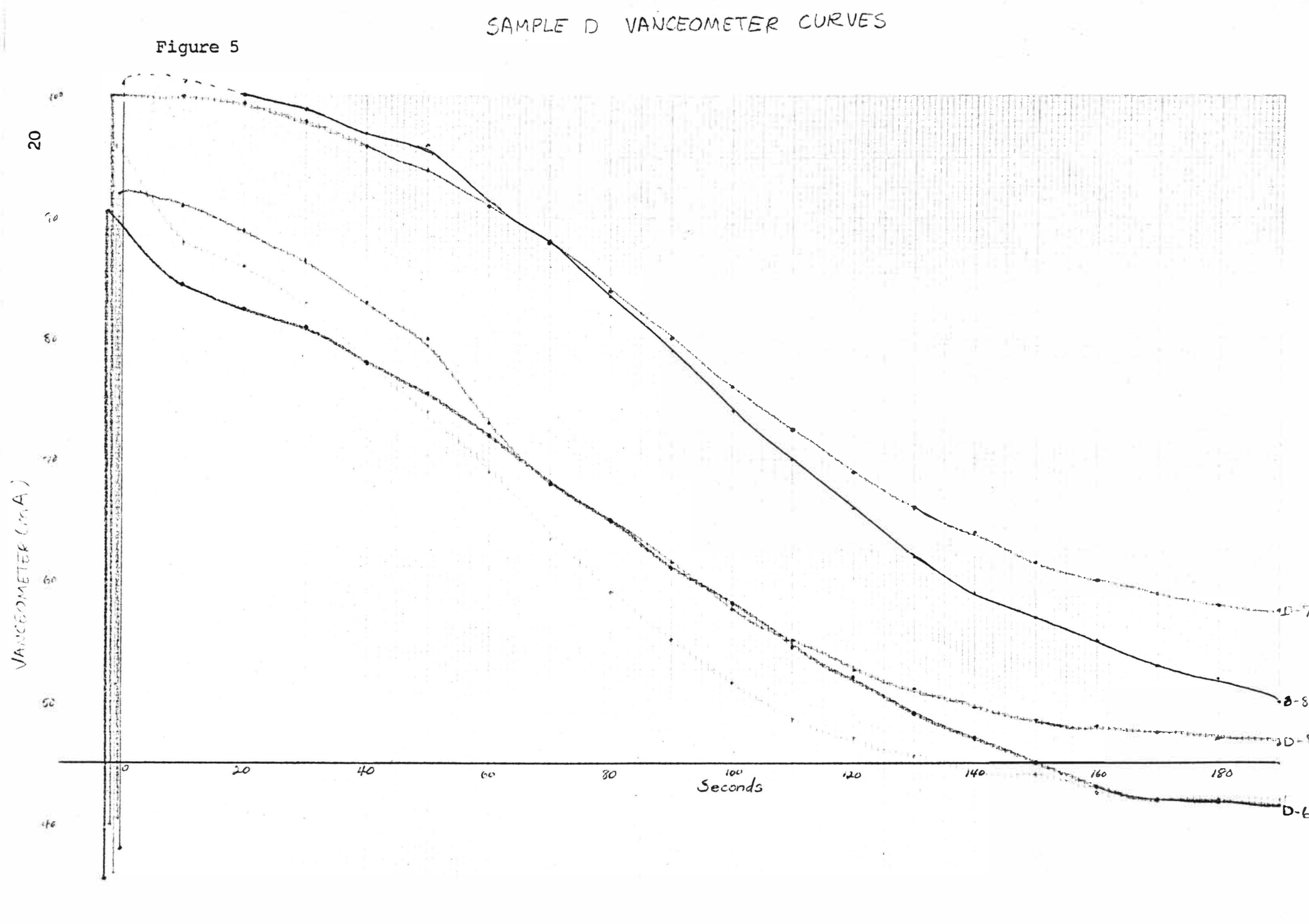

SAMPLE D VANCEOMETER CURVES
20
VANCEOMETER (mA)
Seconds
0
20
40
60
80
100
120
140
160
180
D-6

Figure 6

SAMPLE E VANCEOMETER CURVES

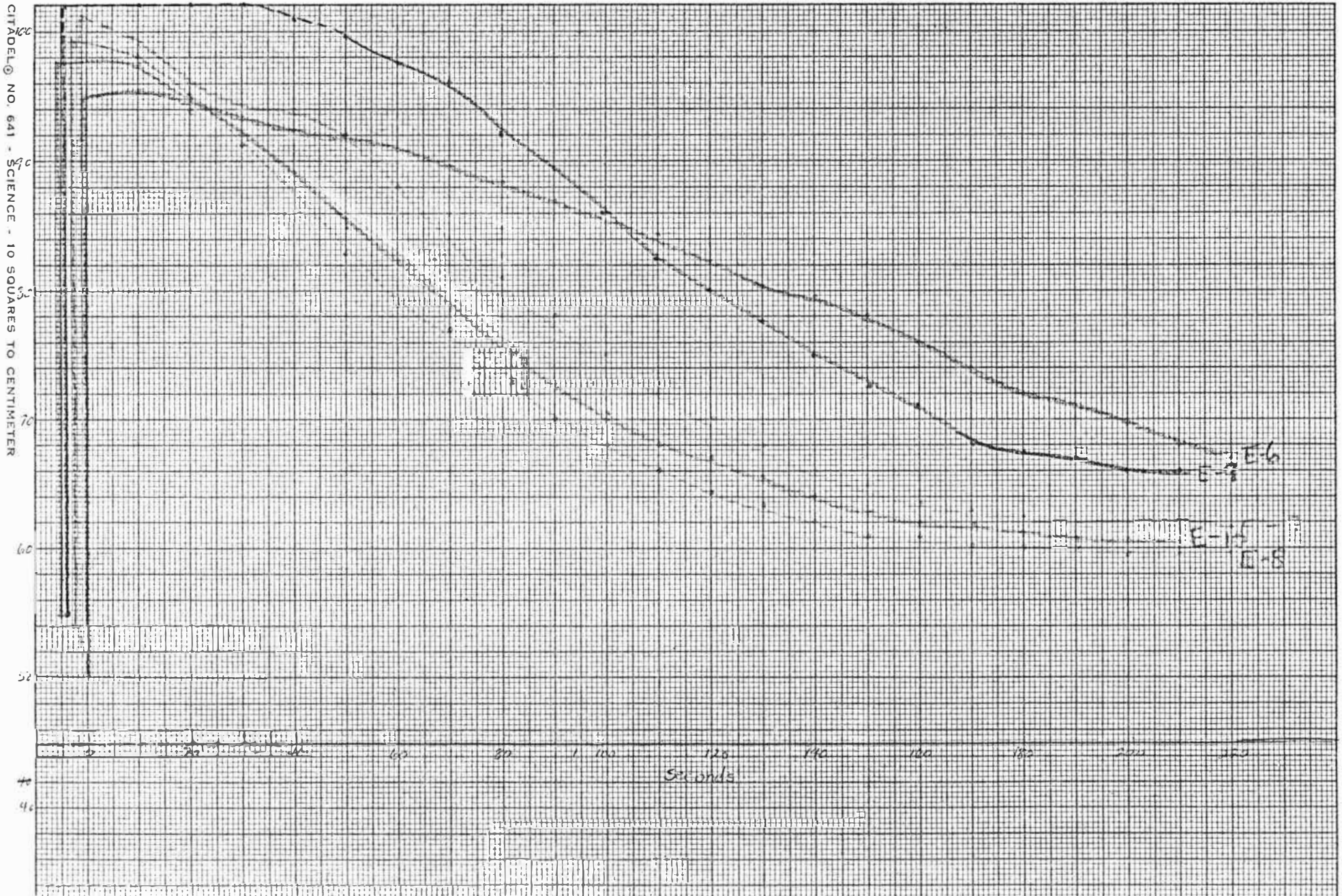


Figure 7 SAMPLE F VANEOMETER CURVES

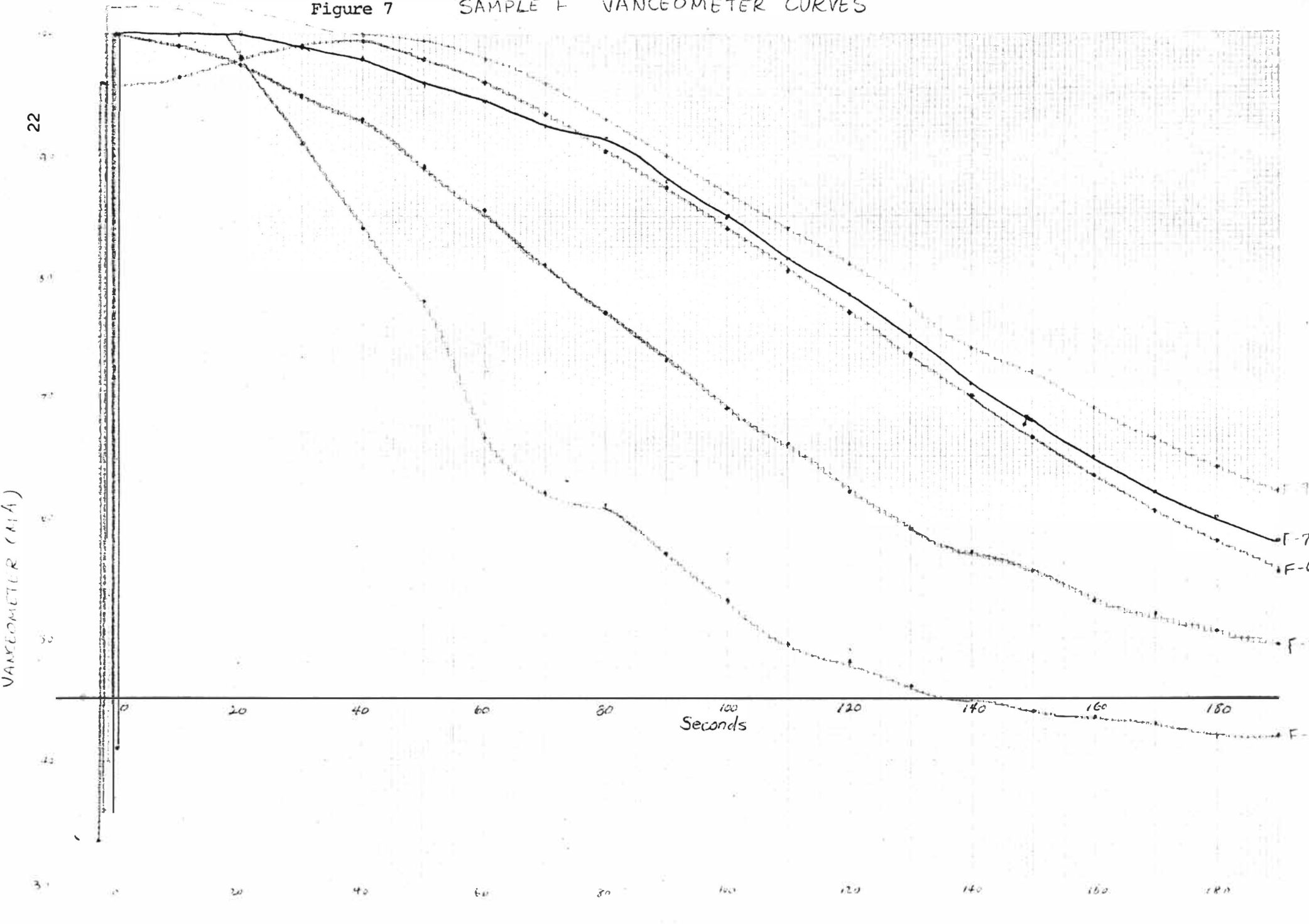
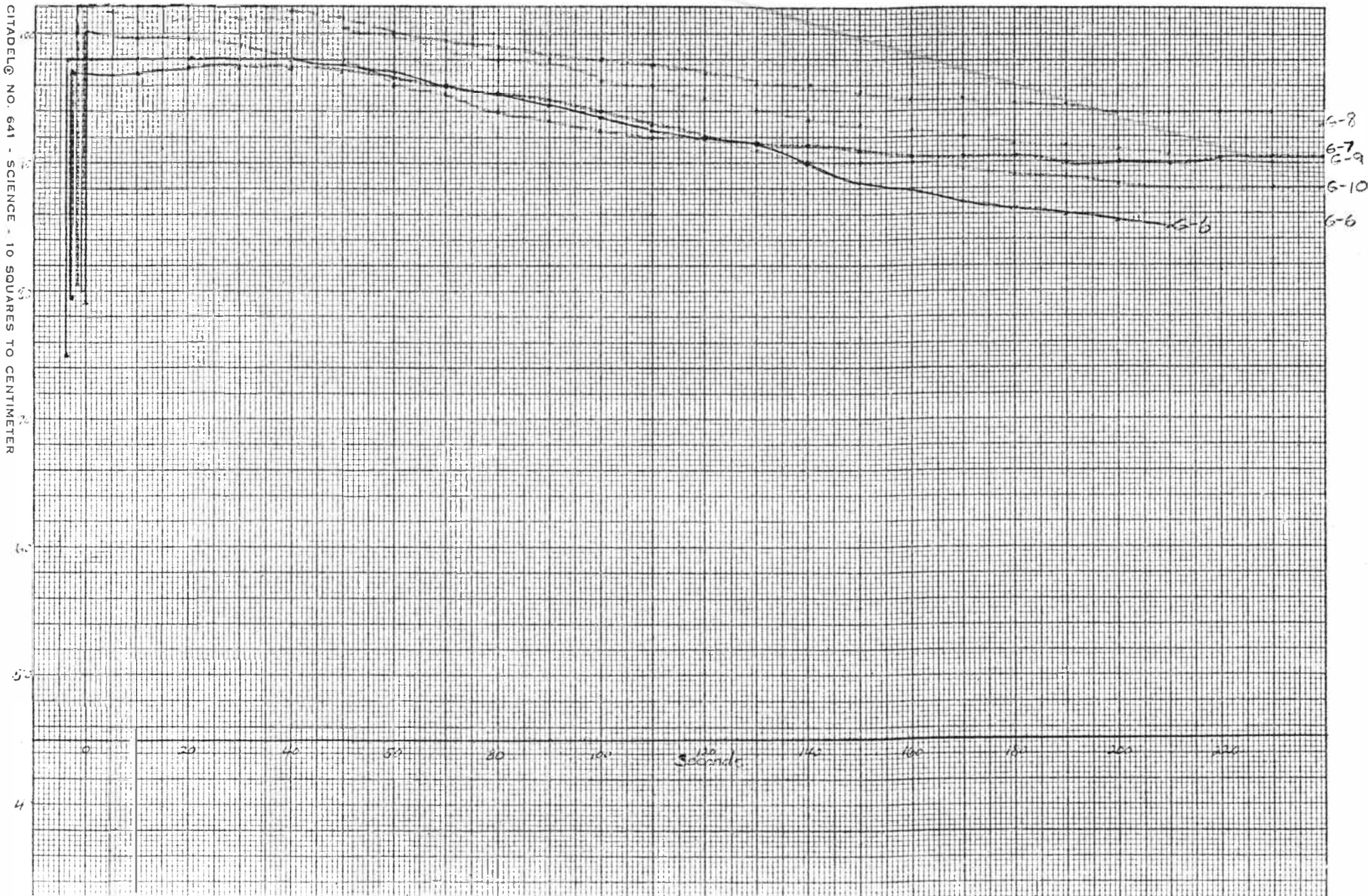


Figure 8

SAMPLE G VANCEOMETER CURVES



COMPARISON OF BASE GLOSS AND PRINT GLOSS OF #2 TACK INK, VANDERCOOK ABSORPTION
80
70
60
50
40
30
20
PRINT GLOSS
BASE GLOSS
B
F
D
E
A
C
G

Figure 9

DISCUSSION

Samples

The seven paper samples used were obtained from an anonymous paper mill. Samples A and B have the same coating; A with a gloss finish and B a matte finish. Samples C and D have another coating; C with a gloss finish and D a matte finish. Samples E and F have a third coating; E gloss and F matte. Sample G has a gloss finish and yet another coating. Table 2 gives the coating formulations of the four coatings.

Strengths and Weaknesses of the Tests

Through running the tests and observing the data generated it became apparent that each test used has particular strengths and weaknesses.

K&N-- The K&N test best meets the criteria of being rapid and simple. Several samples can be tested in the two minute interval. From the comparison of results of K&N tests run in the WMU lab and in the paper mill lab, the test does not demonstrate reproducability. The samples from the two sets of data (run on the same samples in each lab) were rated in different orders of receptivity. The K&N test also involves human judgment, especially when several samples are run at once. Does the two minutes start when the ink first touches the paper or when the ink is completely smoothed out over the several samples? Does "exactly two minutes" end when the ink is beginning to be scraped off, or when the samples are completely wiped clean, or somewhere in between? The lab person has to make human judgments.

Vandercook Proof Press-- The strength of this test is the control the experimenter has in holding variables constant. The print speed, ink film thickness, and printing pressure can all be kept constant and uniform from print to print. On thé other hand, the proof press is awkwardly

	Samples A and B	Samples C and D	Samples E and F	Sample G
#2 hi-brightness coating clay	80	100	100	75
precipitated $CaCO_3$	20	--	--	--
enzyme converted starch	--	5	10	--
SBR latex	18	11	8	--
acrylic latex	--	--	--	10
Ca stearate	--	0.3	0.3	--
alginate- low viscosity	1.0	0.2	--	--
calgon	0.12	0.03	0.05	0.05
organic dispersant (polycrylate)	--	0.07	0.10	0.12
TiO_2 (rutile)	--	--	--	25
MF resin	1.2	1.2	1.4	--
CMC- low viscosity	--	--	--	1.3

Table II. Coating formulations of the samples used.

large compared to the apparatus used in the other tests. The major weakness of the proof press however, is the inability to get any gloss reading in the first ten to fifteen seconds after printing (due to the time required to physically remove the sample from the press and transport it to a gloss meter). Use of heat set inks makes it possible to deal with this problem if a method of drying can be found to set the ink in the first few seconds after printing. This would greatly diminish the effects of absorption and more closely approximate the industrial setting. The drying method employed in this experiment of using a space heater took 30 seconds to set the ink. An infared heater would probably be more effective in setting the ink quickly and further reducing the effects of absorption.

IGT Printability Tester-- The IGT procedure finds its strength in the ability to look at various printing pressures. Although the pressure was kept constant in this test it would be a worthwhile study to observe the effects of varied printing pressures on gloss ink holdout. The fact that the proof press involves printing pressures is in itself significant. The largest drawback of the procedure, as used, was the inability to control ink film thickness. The Westvaco method, using two disks instead of one, gives better control of the ink film thickness but is too time consuming to be practical. Running the test is also quite messy.

Vanceometer-- The vanceometer test is the only procedure that produces a set of curves relating absorption rate to time. Unfortunately, absorption rate does not correlate well with gloss ink holdout. The test had two other major drawbacks. The gloss measurement was effected by the base gloss of the sample, since the standard viscosity oil was transparent. The test also produced widely varied results. For any given sample, the resulting curves covered a large range of values at any chosen time. Thus, the test is not reproducable. It is also time consuming to take

readings at ten second intervals for three minutes per sample.

Pressure and Absorption

A comparison of the samples run on the Vandercook Proof Press with heat set ink and tack ink illustrates the relationship between absorbence and drying time. It also indicates that with very short drying times, as with the heat set ink, absorption becomes less important to gloss ink holdout and printing pressure becomes more important. The influence of the absorbence and pressure variables changes so much between the two drying times that the samples are rated in different orders (see table 1).

CONCLUSIONS

The four procedures used are influenced by different factors, which explains the lack of correlation between tests. The vanceometer is influenced mainly by the absorption of the sheet as is the K&N ink smear test. The Vandercook and IGT methods are both dependent on ink film thickness, printing pressure, and drying time, and to a lesser degree on absorption.

Especially with today's use of high speed drying, and heat set inks, the absorption tests alone cannot be expected to give a good representation of the gloss ink holdout capabilities of a sheet. The major variable, printing pressure, must be considered in a valid test of gloss ink holdout. The K&N ink test then, is an inappropriate test for two reasons. First it looks only at absorption, and secondly, it does not give reproducable results from tester to tester. The vanceometer test also falls short since it looks only at absorption and does not give reproducable values within a specific sample.

This leaves us with the vandercook and IGT methods. Of the two, the proof press method comes out on top since the ink film thickness is controlled and can be reproduced from sample to sample. A standard maethod of evaluating the proof press prints remains to be determined.

RECOMMENDATIONS

1. A study with the IGT Printability Tester to study the effects of printing pressure (varied) on gloss ink holdout) with heat set ink.
2. Astudy with the proof press and an infared dryer to reduce drying time to 5 seconds or less.
3. A mathematical study to determine the best mathematical method to report the results comparing base gloss and print gloss.

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