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Supercalender Variables (II) The Effect of Supercalender Pressure and Temperature on the Physical Properties of Paper

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SUPERCALENDER VARIABLES (II)
THE EFFECT OF SUPERCALENDER PRESSURE AND TEMPERATURE ON THE PHYSICAL PROPERTIES OF PAPER

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ABSTRACT

This thesis is the second in a series of fundamental investigations of the variables of supercalendering. The variables studied in this thesis are roll temperature and nip pressure. These variables were investigated by testing three types of paper that were supercalendered at various controlled roll pressures and temperatures. Different values of these variables during supercalendering were found to cause noticeable differences in the physical properties of supercalendered paper. It was observed , after studying the physical tests made on each of the three types of paper, that the type of paper being supercalendered, influences, to a varying degree, the effect of the supercalendering action.

The findings of this thesis are, for the most part, in agreement with literature and also the first thesis in this series of investigations.

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LITERATURE SURVEY

Introduction

Calendering and supercalendering have had a large part in the expansion of paper related industries as well as the paper industry itself. The modern, efficient supercalendering machines now in use prepare paper with qualities desirable in many fields including the graphic arts industry. This industry was the chief consumer of supercalendered paper in 1951, when 1,400,000 tons were produced (1).

Some of the properties of paper which may change during supercalendering or rather as a result of supercalendering include:

1.	gloss	6.	smoothness
2.	density	7.	brightness
3.	opacity	8.	porosity
4.	strength	9.	stretch
5.	thickness	10.	oil absorption

Variables seeming to cause the difference between supercalendered and unsupercalendered paper have been divided into two groups by Brecht (2).

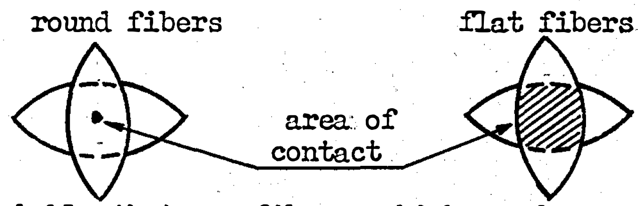
The first of the two groups contains the variables depending on the properties of the paper. The second group is comprised of variables encouraged by the supercalendering machine. E. E. Thomas (1) states that the standard in attainment of results from calendering is a matter of balance between the responsiveness of the paper and coating to the amount of calendering action provided.

GROUP I VARIABLES (related to the paper)

1. Fiber Characteristics

(a) round or flat

In the case of flat fibers the pressure per unit area from a force would obviously be less than in the case of round fibers under an equal force. It also



seems probable that rag fibers, which are known to be flat like ribbons, would resist a much higher pressure without breaking in fiber-to-fiber contact than would round fibers, their intrafiber strength being equal.

(b) individual fiber strength

According to F. T. Carson (3) lack of strength in paper must be attributed to a lack of fiber bonding and not to a deficiency in actual fiber strength. Carson also states that the tensile strength of paper in the direction of its greatest strength ordinarily amounts to less than 10 to 15% of the theoretical tensile strength which would be obtained if individual fibers were held together by forces equal to intrafiber bonds.

(c) degree of beating

Using the Kozeny equation (5), Brown(6) found that the area involved in interfiber bonding is not noticeable in handsheets made from unbeaten sulfite pulp. The same pulp when beaten to a Schopper-Riegler freeness of 610 ml. was found an interfiber bonding of 25 - 30% on the surface of the paper. It was found that the beaten fibers could be bonded together under less pressure than was required for the unbeaten pulp. F. T. Ratliff (7) found while using unbleached kraft that the slope of the bonded area-strength curve falls off in the final stages of beating. Ratliff concluded that the paper failure was due to breaking of intrafiber bonds.

It seems possible that an explaination of the effects of increasing supercalendering pressures may be similiar to that found for beating. E. E. Thomas (1) found that there is a critical point in calendering action after which the quality of the paper is decreased rather than increased.

Higher pressure or More beating → more fiber-to fiber contact area → increased bonding → greater strength

Very high pressure or Very long beating → loss of strength

Beating is therefore a definite function of fiber bonding which must not be neglected where paper strength is being investigated.

2. Degree of fiber bonding

Properly beaten cellulose fibers are capable of a high degree of interfiber bonding, whereas fibers such as artificial silk, glass, asbestos and wool do not form strong paper due to the absence of interfiber bonding. Of all the factors determining paper strength, which include fiber length, fiber surface, fiber size, sheet formation and sheet density, the amount of fiber-to-fiber bonding is most significant (8).

Folding, bursting and tensile strength are some of the physical properties of paper which are most effected by changes in interfiber bonding. Tearing strength is influenced by fiber length as well as interfiber bonding. Cellophane, for example which is a solid sheet of cellulose, has a very low tearing strength once the tear is started regardless of its relatively high bursting strength.

Theories and hypotheses have been proposed in an attempt to explain fiber bonding but none have been substantially proven. A widely used theory is the partial solubility theory. Campbell's version of this theory (13) is based on an early hypothysis by Urquhart (14), proposing that cellulose is water-soluble in certain stages. In this manner the fibers are cemented together during drying by crystallizing of the cellulose

as a result of evaporating the water.

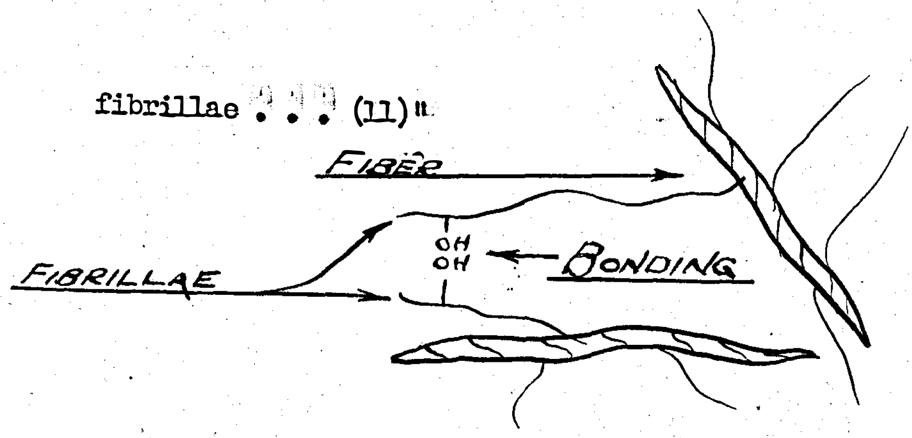
Clark (15) regards the surface of well-beaten fibers as a "two-dimensional colloidal system," the surface fibrillae having two dimensions in the colloidal range, but fastened to the fiber in the third. Clark (16), in defence of his theory, demonstrated that a strong bond can be formed when two sheets of water saturated cellophane are pressed together and dried.

Relating these theories to supercalendering, it seems that the moisture content of the paper when the pressure is applied, as controlled by the temperature of the rolls, would definitely influence the fiber bonding in the paper if this theory is assumed factual.

According to Casey (11) there are four types of forces which might conceivably be involved in fiber bonding. Of the ten factors which Casey (12) lists as affecting fiber bonding one interesting factor was the effect of springwood and summerwood fibers. These two forms of wood fibers seem to justly fit into the discussion of round and flat fibers on page 2 of this research paper, and perhaps behave as such under the calender rolls.

At the present time it is believed that the predominating force in interfiber bonding is one of secondary valence or molecular cohesion between hydroxyl groups of adjacent

fibrillae . . . (11)"



3. Type of filler

J. Strachan (17) found that crystallinity of fillers like talc and clay make a high finish possible. Adjuvants like starch and aluminum stearate used in the furnish help to produce a high finish. They are much more effective when applied to the paper during drying and before calendering.

It seems that if the particle size of the filler were relitively large in comparison to the fibers, cutting would be likely to occure.

4. Moisture content of the paper

Cellulose fibers in paper become more plastic and stronger as the moisture content increases (18). There is a critical moisture content of about 4% for most pulps where blackening occures. At controlled higher percent moisture, the same finish may be obtained at low pressures as was attained at high pressures.

The acting surface tension of the water in paper is so important in relationship to fiber bonding that the presence of even small amounts of reagents which reduce surface tension will lower the compacting force and result in a sheet of low density and low strength properties(19).

5. Hardness of the reels of paper

6. Condition of paper resulting from treatment in machine calender

Thomas (1) states that excessive work done on the paper by the machine calender will restrict the desirable qualities obtainable from the paper after final supercalendering.

GROUP II VARIABLES (related to the supercalender)

1. Speed of operation

2. Working Width of the paper in the supercalender

Unless the paper is worked the full width of the supercalender stack or nearly so, the edges of the paper will receive more pressure than the center of the width.

The working width also determines the pressure, expressed in pounds per linear inch, that is exerted on the paper.

3. Pressure

The area of contact of the paper with the supercalender is the nip width times the working width. The working pressure is therefore: $\frac{\text{force on calender rolls}}{\text{nip width X working width}}$ The proceedure for

measuring the nip of a calender will be explained later.

In 1953 K. L. Maves (10) investigated the effects of supercalender pressure on the physical chacteristics of paper. Maves conducted his investigations using a three-roll laboratory supercalender. The paper used was :

1. Thirty-two pound 50% rag ledger
2. Seventy-three pound coated folder

A comparison of his literature findings with his experimental results is below.

	literature	experimental
1. smoothness	increased	increased
2. gloss	increased	increased
3. opacity	decreased	decreased
4. brightness	decreased	decreased
5. caliper	decreased	decreased
6. tensile	increased	same
7. tear	decreased	decreased
8. burst	decreased	increased

The only deviation from literature that amounted to anything was a 15% increase in Mullen found at 5,000 p.s.i. when the 50% rag ledger was supercalendered. It seems that this increase in bursting strength might be due to an increase in bonding. According to data gathered by Mackin, Keller and Baird (9) bursting

strength is not greatly influenced by calendering. It was found folding endurance decreased up to 20% in the case of bond papers and up to 40% in the case of kraft wrappings. Brecht (2), on the other hand, found a slight rise in folding endurance.

4. Type of filled rolls

The amount of resiliency or "give" which the filled roll exhibits while in contact with the paper determines to some degree the amount of damage done to the fiber during supercalendering.

5. Temperature of the rolls

Going into the first nip the paper is at the moisture content allowed by the temperature and humidity of the finishing room. After the first nip, however, the paper is in intimate contact with each consecutively hot supercalender roll. The temperature usually is around 85°C. The moisture content and resultant plasticity of the paper in the supercalender is therefore dependent on the temperature of the rolls.

A uniform temperature across the width of the supercalender roll will help avoid hard and soft spots which cause uneven finishing of the paper. Control of the temperature may be accomplished by blowing cold air unto the heated spots or warming the cold spots by increasing the friction there (20).

Measurement of supercalender roll temperature will be discussed in an experimental outline.

6. Hardness of the filled rolls

The hardness determines how much roll surface will be working on the paper during supercalendering.

7. Diameter of the supercalender rolls

A possible cause for the sheet caliper varying across the paper is that the diameter of the rolls is too small compared to the pressure applied (20).

Summary of literature survey

A decrease or increase in strength properties will depend largely on the initial characteristics of the paper being supercalendered.

A decrease after supercalendering, of burst, tensile and fold, might be due to:

1. a brittle condition of the fiber from loss of moisture caused by intimate contact with hot supercalender rolls
2. disruption of interfiber bonds caused by loss of moisture
3. breaking of intrafiber bonds (fiber is internally weakened) caused by crushing pressures

An increase of burst, tensile and fold may indicate:

1. because of the properties of the individual fibers, the paper successfully resisted high temperature and pressure

LITERATURE CITED

1. Thomas, E. E., "Machinery for Paper Coating," TAPPI Monograph Series - No. 8, page 44, New York, N. Y., Technical Association of the Pulp and Paper Industry, 1950.
2. Brecht, Walter, Paper-Maker 97, no. 4:TS 41-52 (April 1, 1939).
3. Carson, F. T., Paper Trade J. 78, No. 12: 113-118 (March 20, 1924).
4. Dobrow, Morris C., Paper Trade J. 134, no. 8:102 (Feb. 22, 1952).
5. Campbell, W. B., TAPPI 32, No. 6:265-271 (June, 1949).
6. Brown, J. C., TAPPI 33, No. 3: 130-137 (March, 1950).
7. Ratliff, F. T., TAPPI 32, No. 8:357-367 (Augest, 1949).
8. Casey, J. P., "Pulp and Paper," 1st ed., vol. I, page 371,New York, N. Y., Interscience Publishers, Inc., 1952.
9. Mackin, G. E., Keller, E. L., and Baird, P. K., Paper Trade J. 113, no. 5:31-39 (July 31, 1941).
10. Maves, K. L., "Supercalendering Variables I," undergraduate thesis, Western Michigan College, Kalamazoo, Michigan, personally published, (June, 1953).
11. Casey, J. P., "Pulp and Paper," 1st ed., vol. I, page 372, New York, N. Y., Interscience Publishers, Inc., 1952.
12. Casey, J. P., "Pulp and Paper," 1st ed., vol. I, pages 377-401, New York, N. Y., Interscience Publishers, Inc., 1952.
13. Campbell, W. B., and Pidgeon, L. M., Pulp Paper Mag. Canada 29, No.6: 185-190 (Feb. 6, 1930).
14. Urquhart, A. R., J. TEXTILE Inst. 20, T 125-132 (1929).

LITERATURE CITED (continued)

15. Clark, J. d'A., Paper Ind. No. 5: 507-510 (Aug., 1943).

16. Clark, J. d'A., Paper Trade J. 97, No. 26: 25-31 (Dec. 28, 1933).

17. Strachan, J., Paper Maker 91, No. 5:TS 65-66 (May 1, 1936).

18. Mackin, G. E., Keller, E. L., and Baird, P. K., Paper Trade J. 113, No. 5:53-61 (July 31, 1941).

19. Jayne, J. E., Tongren, J. C., and Jackson, D. T., TAPPI 33, No. 1: 32-35 (Jan., 1950).

20. Briefkasten, Wochbl. Papier-Fabr. 69, No. 2:35 (Jan. 8, 1938).

EXPERIMENTAL OUTLINE

1. Method and atmosphere of supercalendering

(a) A three-roll laboratory sheet supercalender will be used for all supercalendering. It is located in the constant temperature-humidity room of the Pulp and Paper Department. (See Fig. I)

(b) Three kinds of paper will be selected for supercalendering at 5 different pressures and at 2 temperatures. P_1, P_2, P_3, P_4, and P_5, will designate the 5 pressures. T_1 and T_2 will signify the two temperatures; T_1, being the temperature of the rolls at room or standard conditions, and T_2 being an approximation of mill roll temperature. (about 180°F.)

(c) Tests will be run to determine the effect of each supercalendering condition on the the 3 kinds of paper. Tests to be run are:

1. caliper	5. tensile
2. tear	6. smoothness (Bekk)
3. opacity	7. Fold (M.I.T.)
4. brightness (Photovolt)	8. Burst (Mullen)

2. Types of paper to be used and why

(a) paper with coating on each side
43 lb. raw stock with 27 lb. of coating   25 x 38 - 500
RAW STOCK: 45% West Coast Sulphite
10% West Coast Bleached Kraft
45% Bleached old paper stock
4.5% clay filler
3.0% Alum
0.6 lb. fortified Rosin size per 2000 lb. beater

COATING: High grade clay plus calcium carbonate
adhesive. . . . . casein and latex

(a) con't. Practically all coated paper is supercalendered to give it the smooth surface which is advantageous for good printing. Paper of this type was chosen for experiments because of the sound, practical value of the data which is to be obtained.

(b) The second kind of paper to be supercalendered will be the raw stock of the coated paper which was just described. This paper was chosen for theoretical reasons. Although raw stock, as such without the coating, may never find its way to the supercalenders, it will show, when compared to supercalendered coated raw stock, the effect of the coating during supercalendering.

(c) The third paper is a high rag content uncoated bond. This type of paper was chosen largely because of the author's interest in how rag fibers react to supercalendering pressures and temperatures, as compared to other fibers.

PAPER CONTENT: 24 lb. 22 x 17 - 500
(61 lb. 25 x 38 - 500)

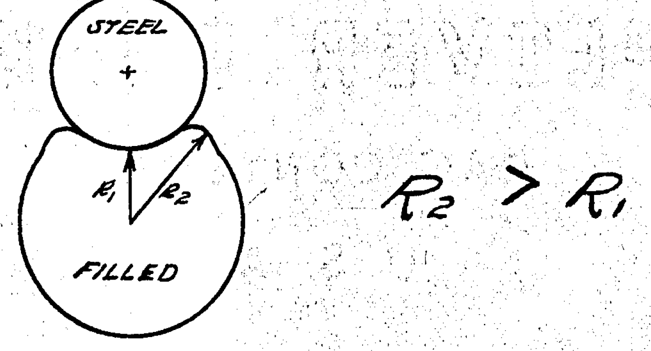
75% rag
25% bleached sulphite
3% TiO_2 retained
starch tub sized

LABORATORY SUPERCALENDER

The supercalendering in this thesis was carried out on a three-roll laboratory sheet supercalender located in a room maintained at a constant temperature of 72°F. and a humidity of 50 %. The supercalender is explained in further detail in Fig. 1.

As the top roll is pressed harder and harder against the cotton roll, an area of contact is formed between the steel roll and the cotton roll. Obviously , it is while the paper is passing through this area in the nip that the paper is affected by the pressure of the supercalender. Various theories have been presented as to what happens in this nip area. At a lecture on May 25, 1954, at Western Michigan College, W. O. Wheeler, president of Wheeler Roll Co. of Kalamazoo, Michigan, described his theory of what happensiin the supercalender nip. Fundamentally, Mr. Wheeler's discussion was as follows.

The filled roll is indented by the steel roll, thus giving the surface of the filled roll a maximum and a minimum distance from the center of the filled roll. A point on the surface of the filled ro ll farthest



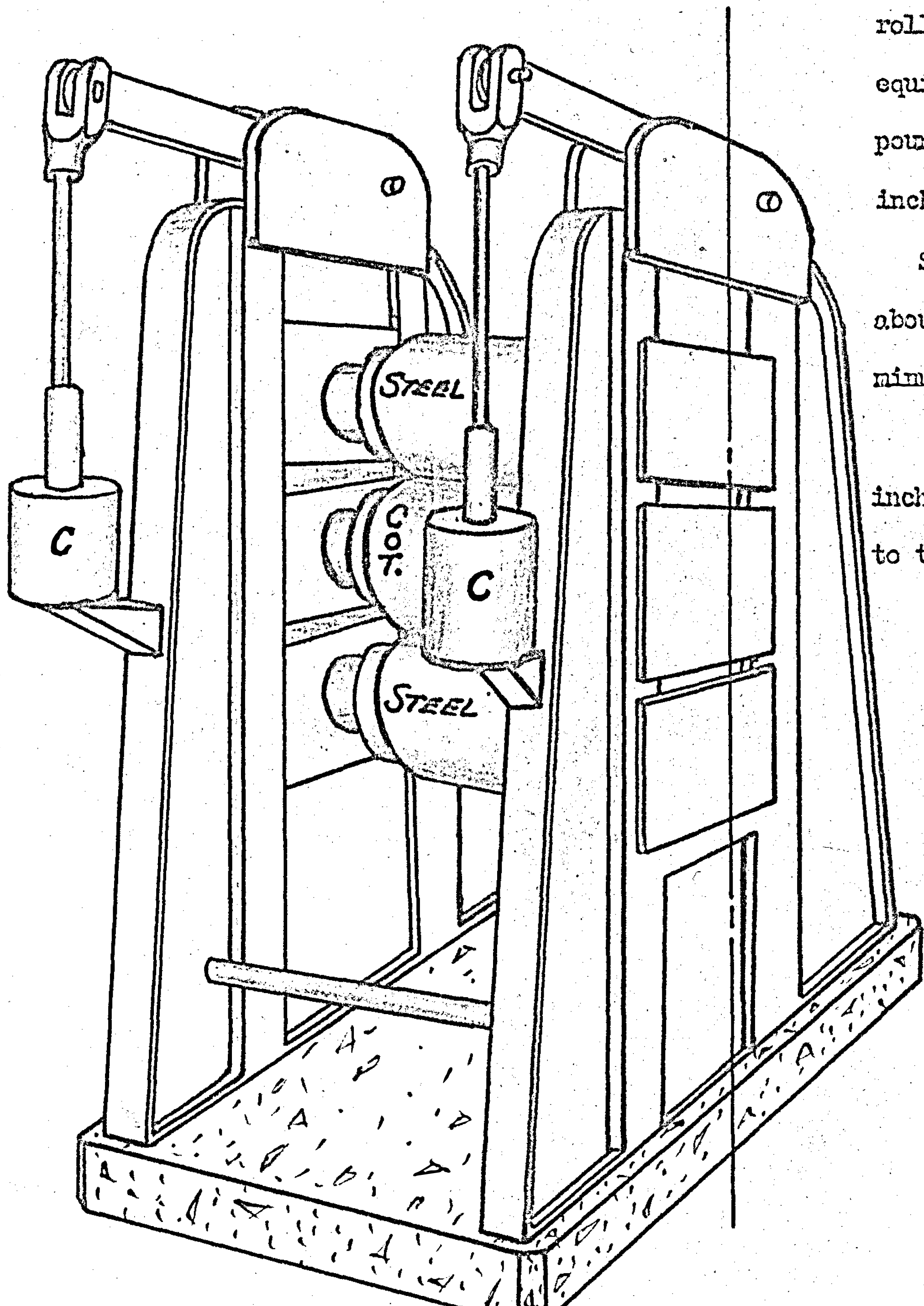
LABORATORY SUPERCALENDER Fig. I

This three roll laboratory supercalender is located at Western Michigan College in the constant temperature-humidity room of the Pulp and Paper Department.

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 applied to the two cylinders, C, cause forces up to 33,000 pounds on the top roll. This is equivalent to 2,430 pounds per lineal inch at the nip.

Speed equals about 36 feet per minute.

Height is 69 inches from the floor to the top.

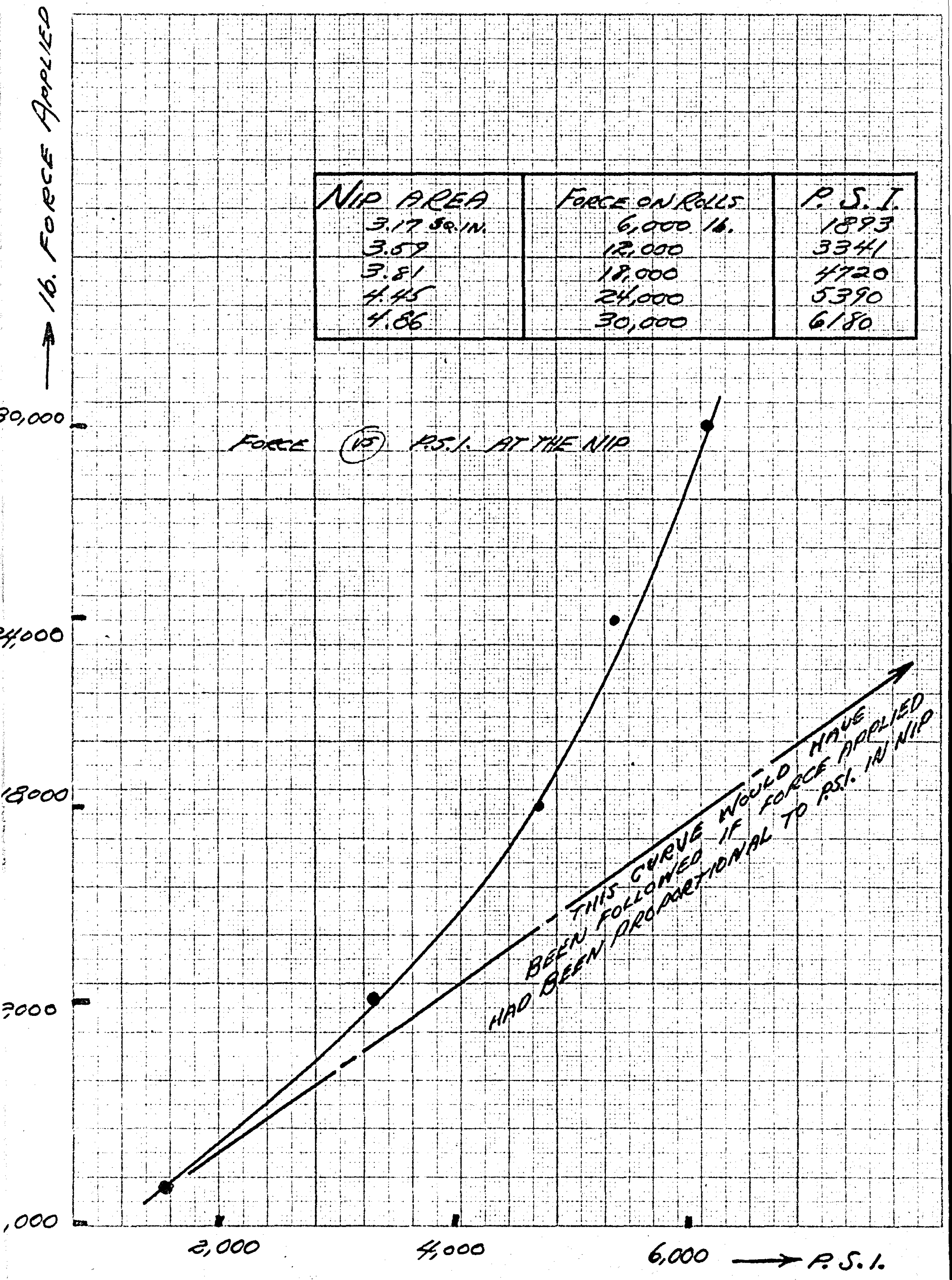


from its center will have a greater peripheral speed than will a point on the surface at the roll's minimum diameter. The surface speed goes from a maximum to a mimimum and back to a maximum as progression is made through the contact area at the nip. The paper going through the nip is gripped by the surface of the filled roll. As this surface slows down, going into the nip, the steel roll slips over the surface of the paper with a polishing action. A polishing action is also transmitted to the surface of the paper on the way out of the nip. In this case the sheet of paper is polished as it is accelerated over the steel roll by the accelerating surface of the filled roll. In both cases the paper is more greatly polished on the surface that was in contact with the steel roll.

As the force on the top roll is increased, the nip gradually widens. Consequently, supercalendering pressure is best reported as p.s.i. of pressure in the nip, rather than force on the top roll. A study of the relationship between the force applied on the top roll and p.s.i. of nip pressure is given in Fig. II. We can see from this graph that an increase in force does not result in a proportional increase in p.s.i. in the nip. In other words, the nip gets wider slower at increased forces.

The nip width, necessary in nip p.s.i. calculations, was measured by putting a crumpled sheet of aluminum foil (0.0004 in. thick) between the seperated steel and filled rolls, and then bringing the steel roll down on the sheet of foil at the pressure I was using. After raising the steel roll, an exact, smooth imprint of the nip area was found on the aluminum foil. This method of finding the area of contact at the nip was also used at each

Fig. II



NIP AREA	FORCE ON ROLLS	P.S.I.
3.17 SQ. IN.	6,000 lb.	1893
3.59	12,000	3341
3.81	18,000	4720
4.45	24,000	5390
4.86	30,000	6180

of the five dirrerent pressures used before any supercalendering was done, to make sure the applied pressure was the same from one side of the roll to the other.

The laboratory supercalender used is located in a constant temperature - humidity room. Heating the supercalender throws off the equilibrium of the air in the room. For this reason, the supercalender is more conveniently used at room temperature. Since, however, mill supercalendering is done with roll temperatures as high as 190°F. or higher, it seemed worthwhile to find out how much difference there is between supercalendering at high and low temperatures.

The supercalender was heated by placing an electric coil heater under the bottom steel roll, and jacketing the entire supercalender with corrugated cardboard to prevent convection air currents from cooling the rolls. After continuous running of the supercalender for about 12 hours, a temperature of 185°F. was reached. However, a roll temperature of 165°F. was the highest maintainable during supercalendering. The roll temperature was measured with a special surface pyrometer.

EXPERIMENTAL PROCEDURE

Three kinds of paper were supercalendered according to the following schedule.

roll pressure and temperatures

P_1 or	1890	p.s.i. in the nip	Each pressure at temperature:	
P_2	3340	"	T_1 or	79°F.
P_3	4720	"	T_2	165°F.
P_4	5390	"		
P_5	6180	"		

The three kinds of paper used were:

1. paper with coating on each side
   43 lb. raw stock with 27 lb. of coating 25 x 38 - 500 basis

   RAW STOCK: 45% West Coast Sulphite
   10% West Coast Bleached Kraft
   45% bleached old paper stock
   4.5% clay filler
   3.0% alum
   0.6 lb. of fortified rosin size per 2000 lb. beater

   COATING: body. . . . . . high grade clay plus calcium carbonate
   adhesive. . . . casein and latex

2. the plain uncoated raw stock of paper No. 1

3. rag bond uncoated tub sized
   24 lb. 22 x 17 - 500
   (61 lb. 25 x 38 - 500)

   75% rag
   25% bleached sulphite
   3% TiO_2 retained

Twelve sheets of each kind of paper were supercalendered at each combination of pressure and temperature that was used. Each sheet was supercalendered through seven nips. The paper surface contacting the steel roll was changed after each pass through the nip.

The supercalendered paper was then tested according to TAPPI standards for the following tests:

1. caliper
2. tear (Elmendorf)
3. opacity
4. brightness (Photovolt)
5. tensile
6. smoothness (Bekk)
7. fold (M. I. T.)
8. burst (Mullen)

Graphs were constructed with the individual test units as the ordinate, and the nip pressure in p.s.i. ploted as the abscissa.

DATA FROM EXPERIMENTAL SUPERCALENDERING

Caliper

Figures III and IV are graphs of caliper measurements recorded from paper supercalendered at temperatures, T_1 and T_2 respectively. The numerical coordinates of each point that was plotted may be found in Table 1.

TABLE 1
(caliper is in 10,000 ths of an inch)

Nip press. cal.	T_1-rag	T_2-rag	T_1-C2S	T_2-C2S	T_1-RS	T_2-RS
P 0	45	45	46	46	33	33
P 1	39	37	37	36	29	29
P 2	36	37	34	35	27	27
P 3	34	37	34	34	27	27
P 4	35	36	33	33	27	25
P 5	34	35	32	33	25	25

Note: C2S, means The paper having coating on two sides.
RS, means the uncoated raw stock.

A mill supercalendered sheet of C2S had a caliper of 0.0034 inches.

Tear

Data from the tearing resistance of the different supercalendered papers have been plotted on Graphs V and VI. Table 2 is a numerical representation of this data.

TABLE 2 - A (temperature T_1 only)
(tear is in grams per 16 sheets)

Nip press.	T_1-rag		T_1-C2S		T_1-RS	
	AM	MD	AM	MD	AM	MD
P 0	104	86	60	50	42	37
P 1	98	85	49	40	42	35
P 2	95	82	50	36	37	30
P 3	91	78	46	37	40	29
P 4	86	77	45	35	34	33
P 5	92	76	42	35	35	29

Fig. III

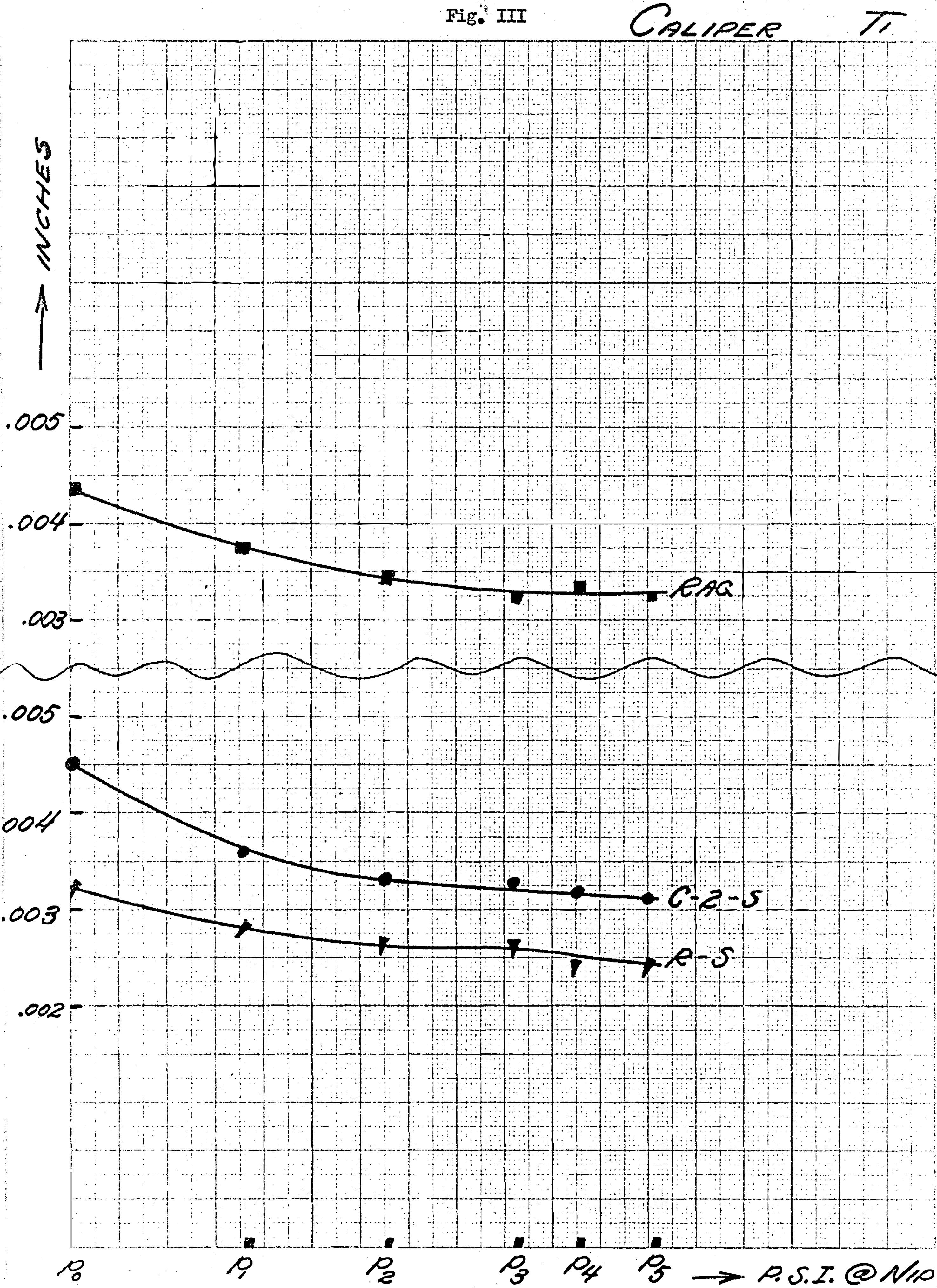
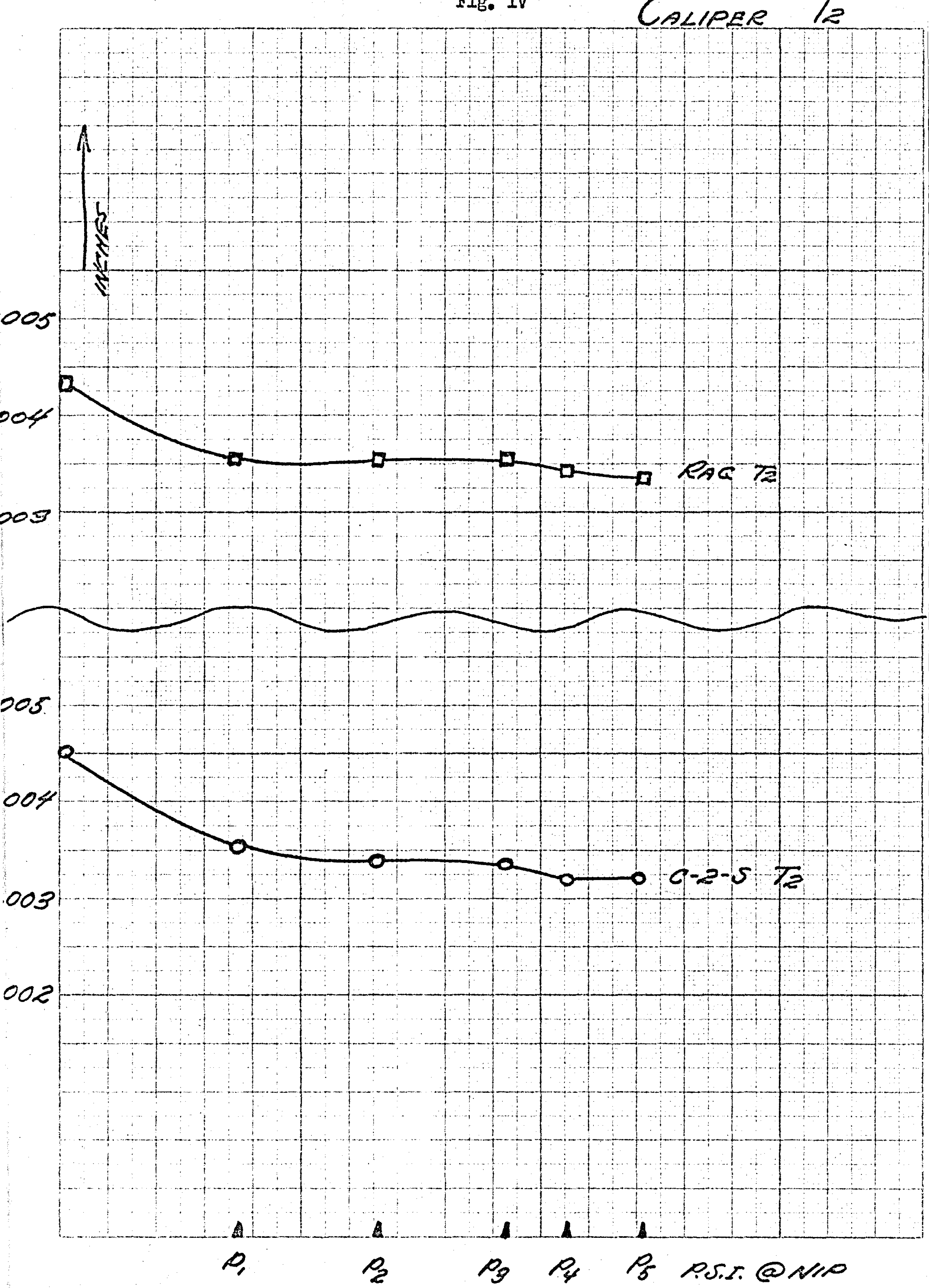

CALIPER
T1
INCHES
.005
.004
.003
.005
.004
.003
.002
RAG
C-2-S
R-S
P0
P1
P2
P3
P4
P5
P.S.I. @ NIP

Fig. IV


CALIPER T2
INCHES
.005
.004
.003
RAG T2
.005
.004
.003
.002
C-2-S T2
P1
P2
P3
P4
P5
P.S.I. @ NIP

Tear (con't.)

TABLE 2 - B (temperature T_2 only)
(tear is in grams per 16 sheets)

Nip press.	T_2-rag AM	T_2-rag MD	T_2-C2S AM	T_2-C2S MD	T_2-RS AM	T_2-RS MD
P 0	104	86	60	50	42	37
P 1	96	81	46	38	42	31
P 2	90	74	44	36	36	32
P 3	92	77	44	35	35	25
P 4	88	75	43	34	35	25
P 5	88	74	44	36	38	28

Opacity

The opacity of each type of paper was measured after supercalendering with a Bausch and Lomb opacimeter and recorded in Table 3. A graphical representation of this data may be found in Figs. VII and VIII.

TABLE 3

Nip press.	rag T_1	rag T_2	C2S T_1	C2S T_2	RS T_1	RS T_2
P 0	94	94	98	98	86	86
P 1	94	93	96	98	84	84
P 2	94	92	96	96	84	82
P 3	92	92	96	95	84	81
P 4	92	92	95	95	80	79
P 5	92	92	94	95	83	82

Brightness

Photovolt brightness measurements of the supercalendered paper were plotted against the nip pressure in p.s.i. and are shown in Figs. IX and X. Table 4, below, contains the coordinates of the plotted points.

Table 4

Nip press.	rag T_1	rag T	C2S T_1	C2S T_2	RS T_1	RS T_2
P 0	79	79	80	80	73	73
P 1	78	78	80	77	71	72
P 2	78	77	79	77	71	72
P 3	78	77	78	76	71	72
P 4	77	77	77	76	71	69
P 5	77	76	77	76	71	68

Fig. V

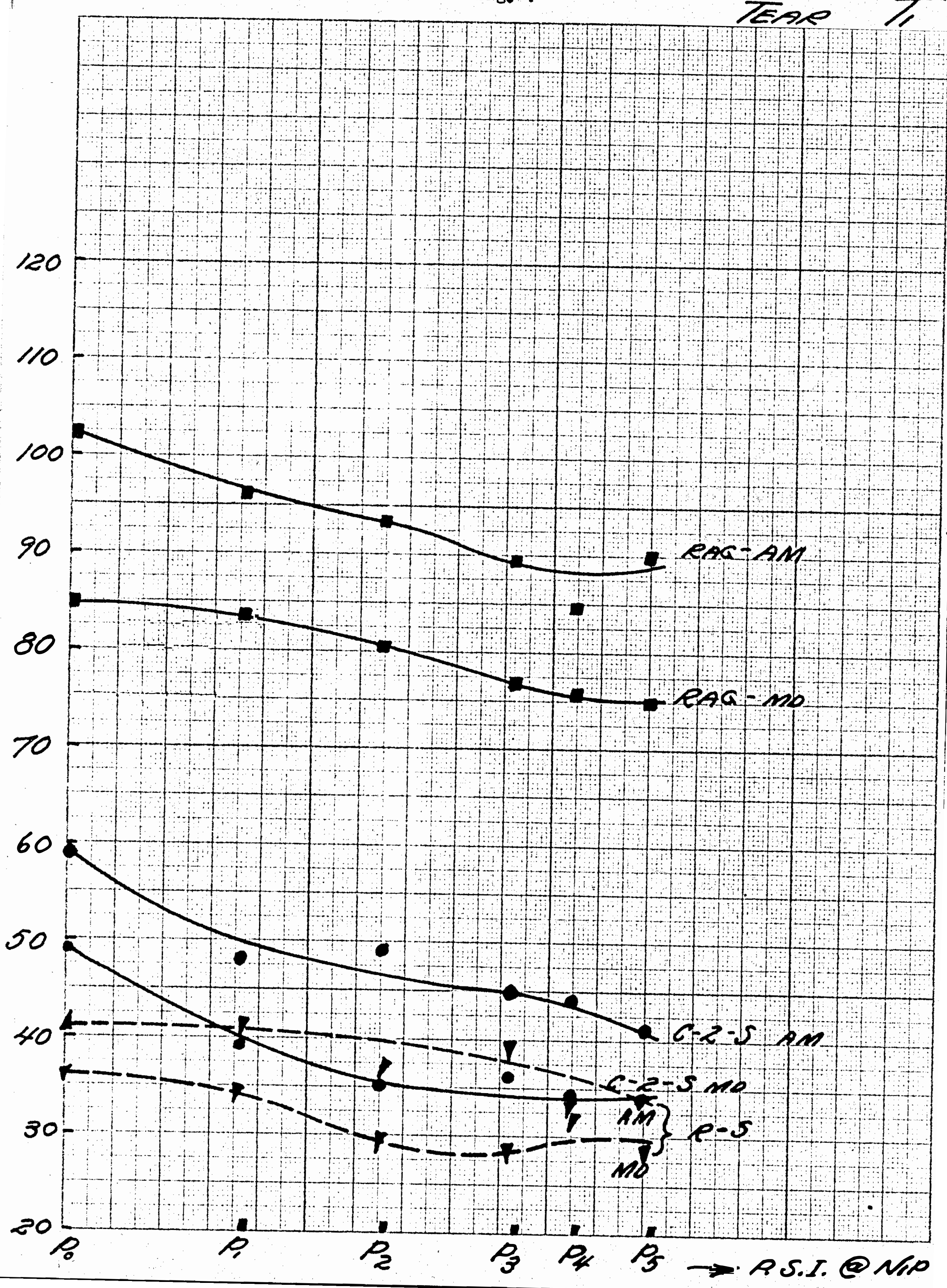

TEAR T1
120
110
100
90
80
70
60
50
40
30
20
RAG-AM
RAG-MD
C-2-S AM
C-2-S MD
AM
R-S
MD
P0
P1
P2
P3
P4
P5
→ R.S.I. @ NIP

Fig. VI

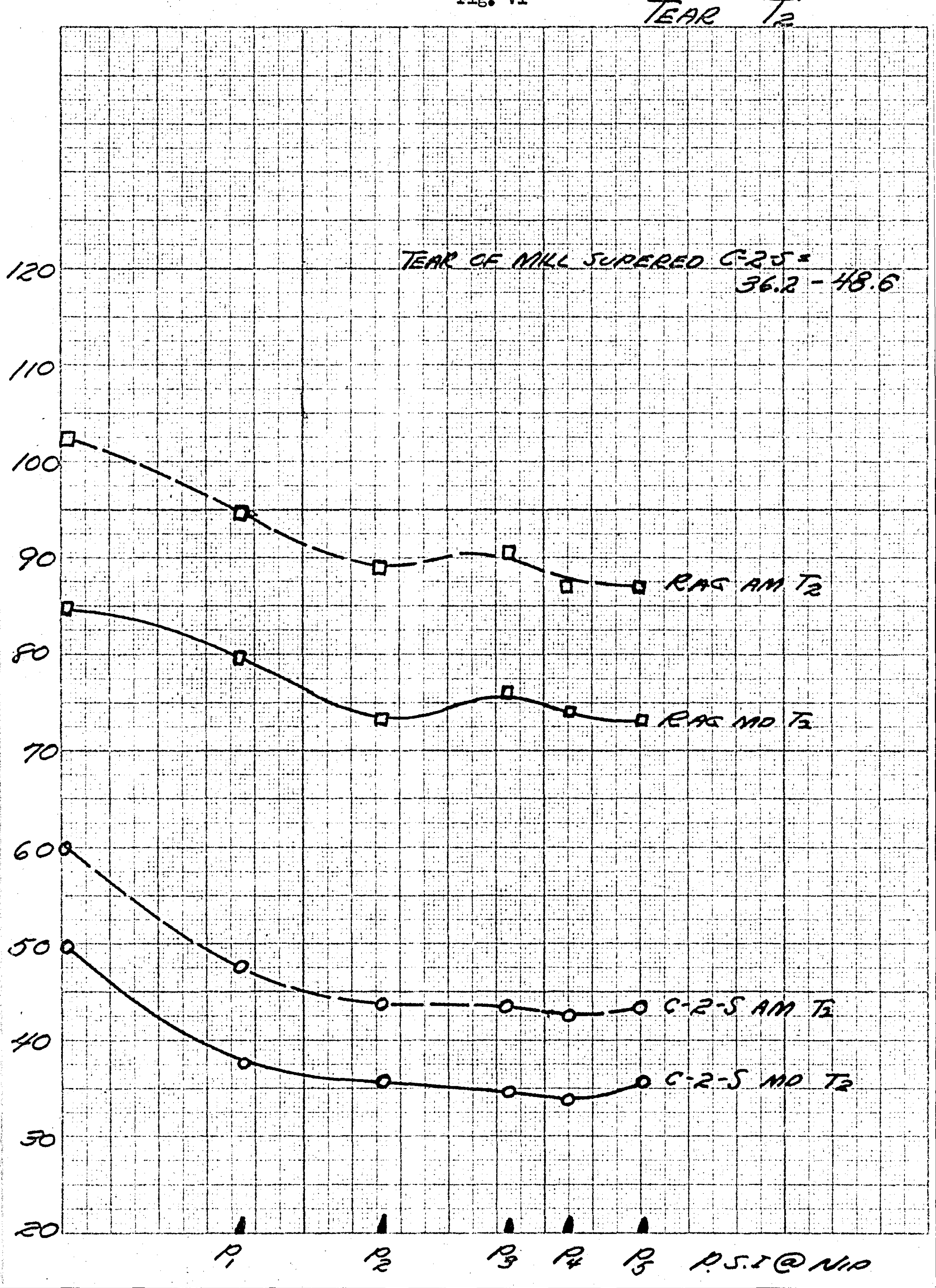

TEAR T2
TEAR OF MILL SUPERED C-2-S = 36.2 - 48.6
120
110
100
90
80
70
60
50
40
30
20
RAG AM T2
RAG MD T2
C-2-S AM T2
C-2-S MD T2
P1
P2
P3
P4
P5
P.S.I @ NIP

Fig. VII

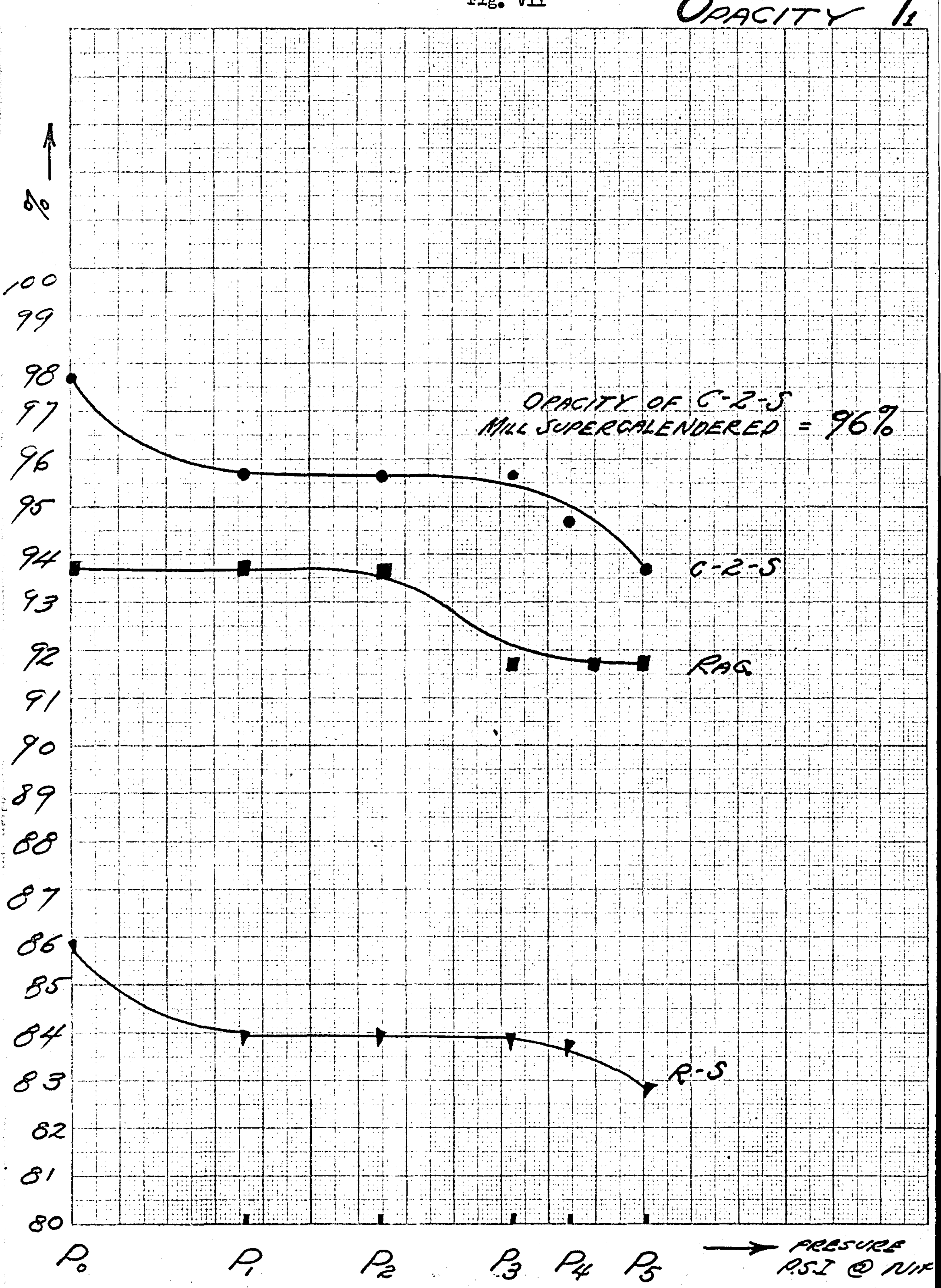

OPACITY T1
%
100
99
98
97
96
95
94
93
92
91
90
89
88
87
86
85
84
83
82
81
80
OPACITY OF C-2-S
MILL SUPERCALENDERED = 96%
C-2-S
RAG
R-S
P0
P1
P2
P3
P4
P5
PRESURE
P.S.I @ NIP

Fig. VIII

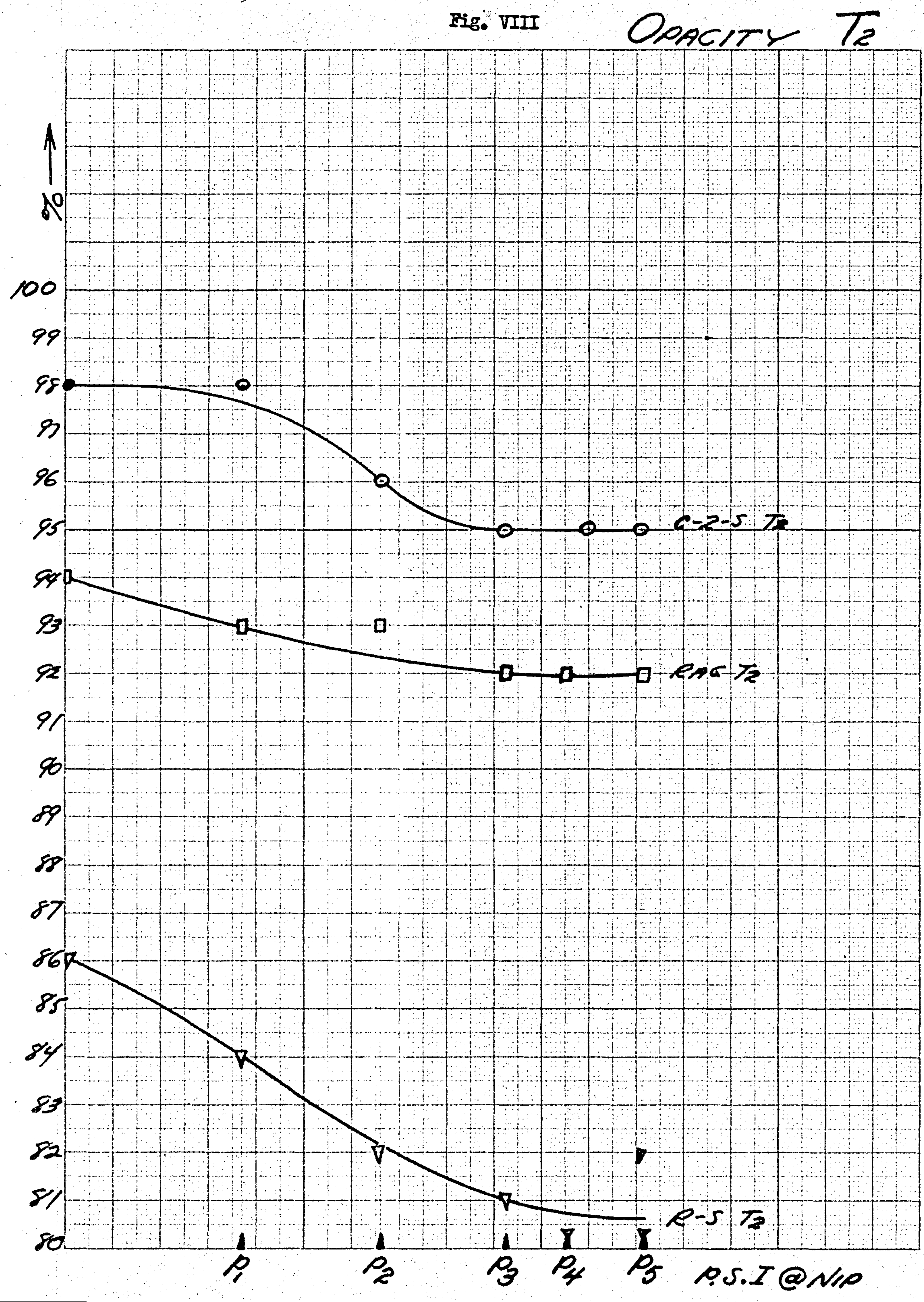
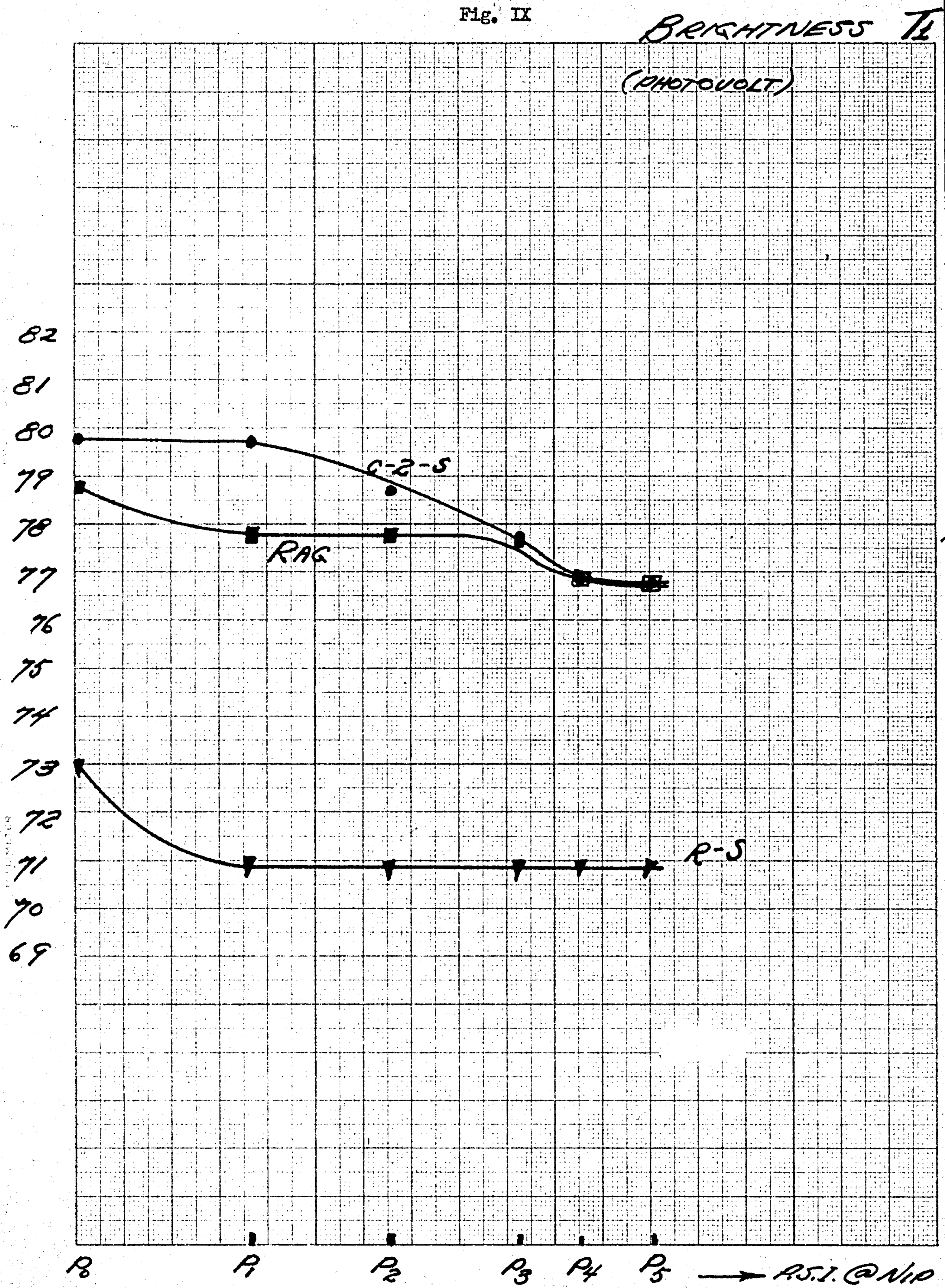
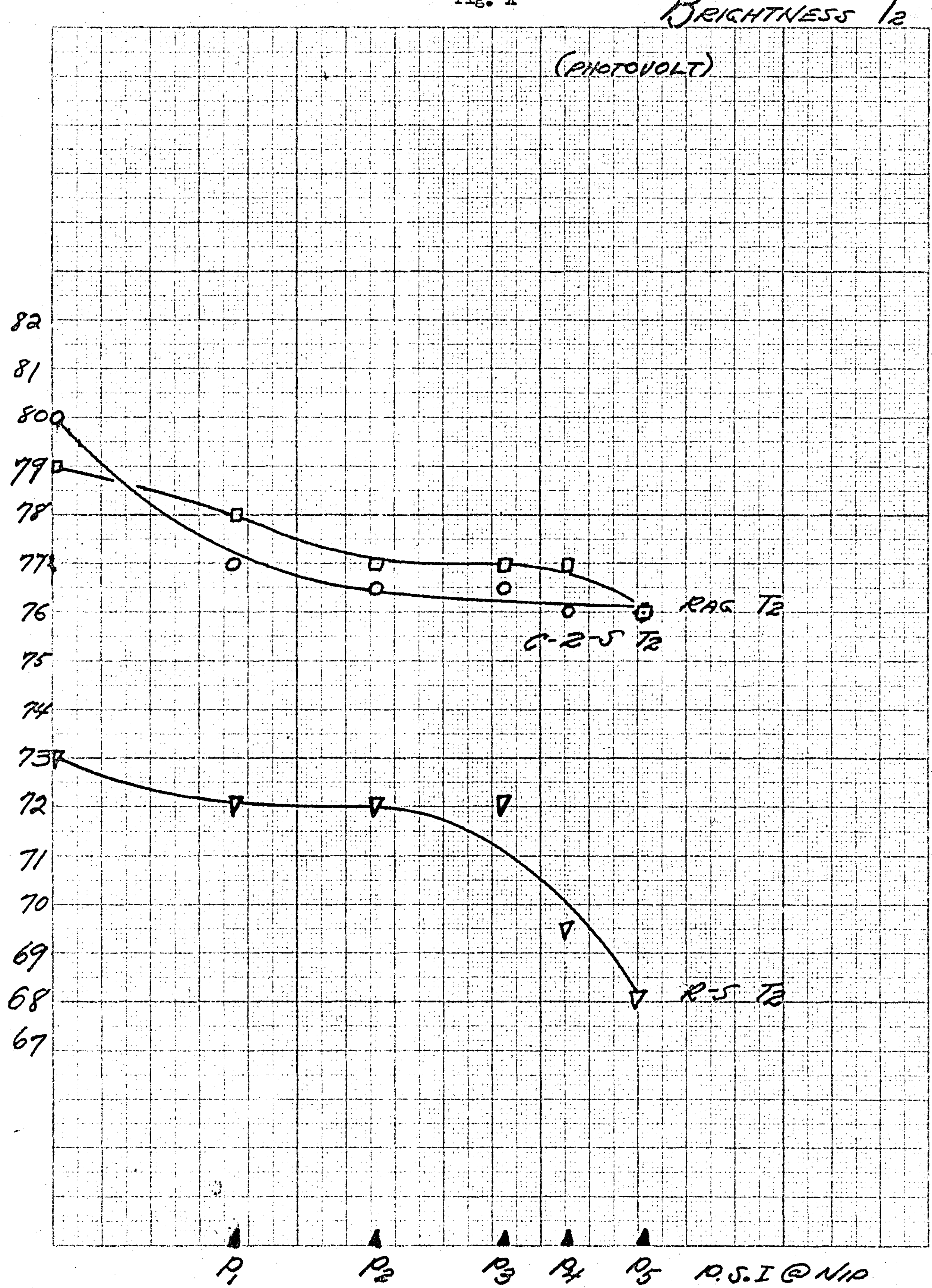

OPACITY T2
%
100
99
98
97
96
95
94
93
92
91
90
89
88
87
86
85
84
83
82
81
80
C-2-S T2
RAG T2
R-S T2
P1
P2
P3
P4
P5
P.S.I @ NIP

Fig. IX



BRIGHTNESS T1
(PHOTOVOLT)
82
81
80
79
78
77
76
75
74
73
72
71
70
69
C-2-S
RAG
R-S
P0
P1
P2
P3
P4
P5
→ A.S.I. @ NIP

Fig. X


BRIGHTNESS T2
(PHOTOVOLT)
82
81
80
79
78
77
76
75
74
73
72
71
70
69
68
67
RAG. T2
C-2-S T2
R-S T2
P1
P2
P3
P4
P5
P.S.I @ NIP

Tensile

Tensile measurements were made with strips of supercalendered paper 15 mm wide and 2.5 inches long. Tensile tests were made with the machine direction (MD) and across the machine direction (AM) of the paper. The observed data, as shown below in table 5, is represented graphically in Fig. XI. Values are in lbs. per 15 mm wide strip.

TABLE 5 - A (AM values only)

Nip press.	rag T_1	rag T_2	C2S T_1	C2S T_2	RS T_1	RS T_2
P 0	10.9	10.9	6.5	6.5	5.9	5.9
P 1	10.3	10.9	7.0	7.3	5.9	6.0
P 2	11.0	10.5	6.7	7.6	5.8	6.0
P 3	10.8	11.9	6.8	7.7	6.1	6.4
P 4	11.4	11.5	7.6	7.5	6.2	6.3
P 5	11.4	11.6	8.0	7.2	6.3	6.4

TABLE 5 - B (MD values only)

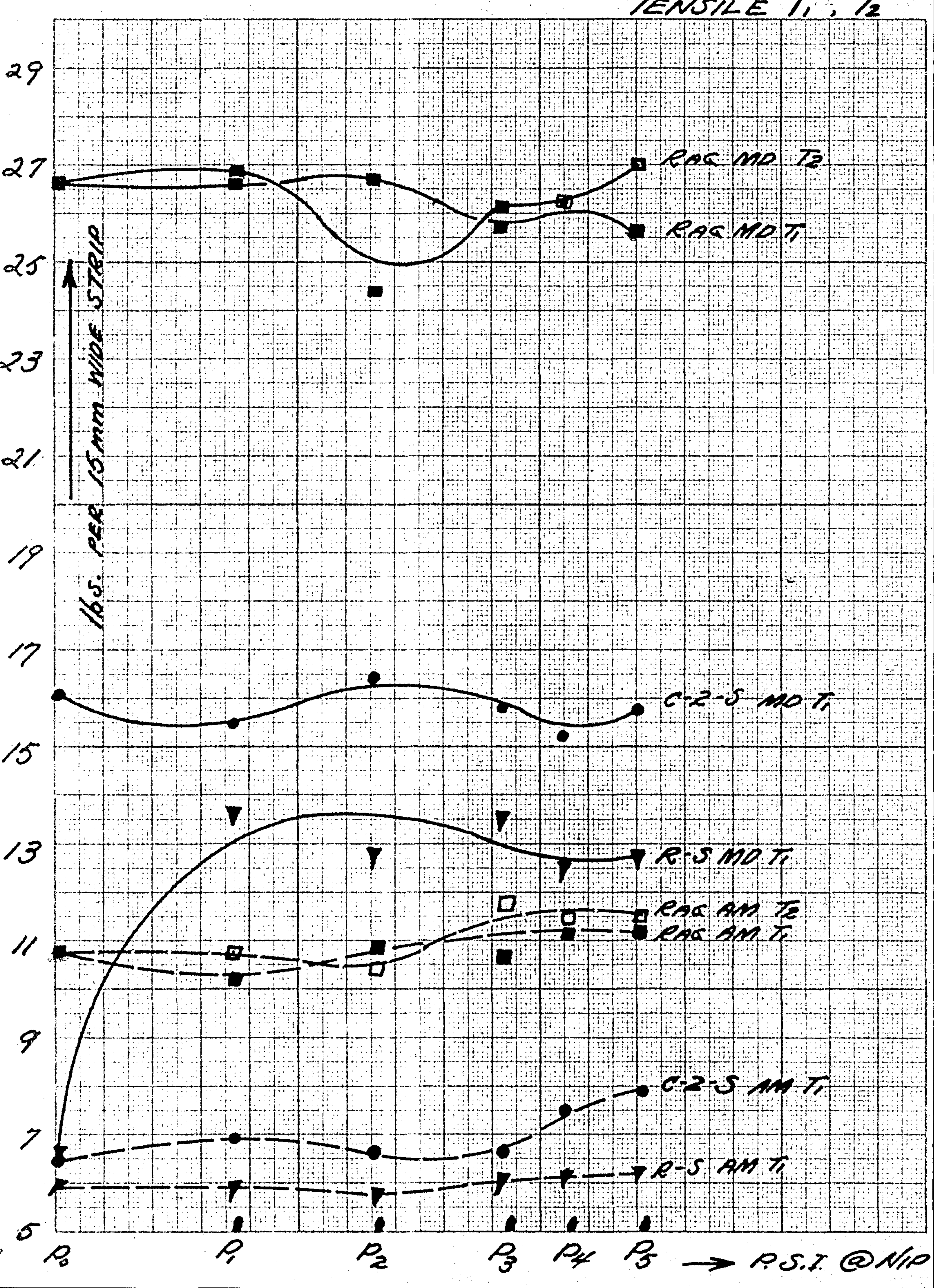
Nip press.	rag T_1	rag T_2	C2S T_1	C2S T_2	RS T_1	RS T_2
P 0	27.0	27.0	16.3	16.3	6.5	6.5
P 1	27.0	27.2	15.7	16.4	13.8	12.5
P 2	27.1	24.7	16.7	16.5	12.9	13.0
P 3	26.1	26.5	16.1	16.7	13.7	13.8
P 4	26.7	26.6	15.4	16.2	12.6	13.2
P 5	26.0	27.4	16.0	15.9	12.8	12.9

Smoothness

The results of the Bekk smoothness measurements made on the supercalendered paper are shown numerically below in Table 6, and graphically in Fig. XII.

TABLE 6 (cont. on next page)

Fig. XI


TENSILE T1, T2
lbs. PER 15 mm WIDE STRIP
29
27
25
23
21
19
17
15
13
11
9
7
5
RAG MD T2
RAG MD T1
C-2-S MD T1
R-S MD T1
RAG AM T2
RAG AM T1
C-2-S AM T1
R-S AM T1
P0
P1
P2
P3
P4
P5
P.S.I. @ NIP

Smoothness (cont.)

TABLE 6
(Bekk smoothness in sec.)

Nip press.	rag T_1	rag T_2	C2S T_1	C2S T_2	RS T_1	RS T_2
P 0	19	19	29	29	37	37
P 1	93	96	279	300	123	251
P 2	105	101	333	387	159	338
P 3	100	112	331	380	169	358
P 4	90	108	372	407	167	327
P 5	100	113	370	425	148	348

Fold

Each of the three types of paper were tested in both the machine direction and across the machine direction for the number of M.I.T. folds to bring the paper to a tensile of 1 kg. The data shown below in Table 7 has been plotted against p.s.i. at the nip, as shown in Figs. XIII. and XIV.

TABLE 7 - A (AM values only)

Nip press.	rag T_1	rag T_2	C2S T_1	C2S T_2	RS T_1	RS T_2
P 0	116	116	36	36	19	19
P 1	162	169	13	20	20	20
P 2	147	148	16	21	21	20
P 3	191	160	20	19	19	19
P 4	221	224	19	20	21	20
P 5	175	221	21	24	23	24

TABLE 7 - A (MD values only)

Nip Press.	rag T_1	rag T_2	C2S T_1	C2S T_2	RS T_1	RS T_2
P 0	545	545	~~26~~53	~~26~~53	51	51
P 1	565	584	59	39	74	73
P 2	642	647	60	53	83	77
P 3	657	643	78	64	84	80
P 4	592	975	63	60	98	98
P 5	654	748	87	55	125	107

Fig. XII

SMOOTHNESS

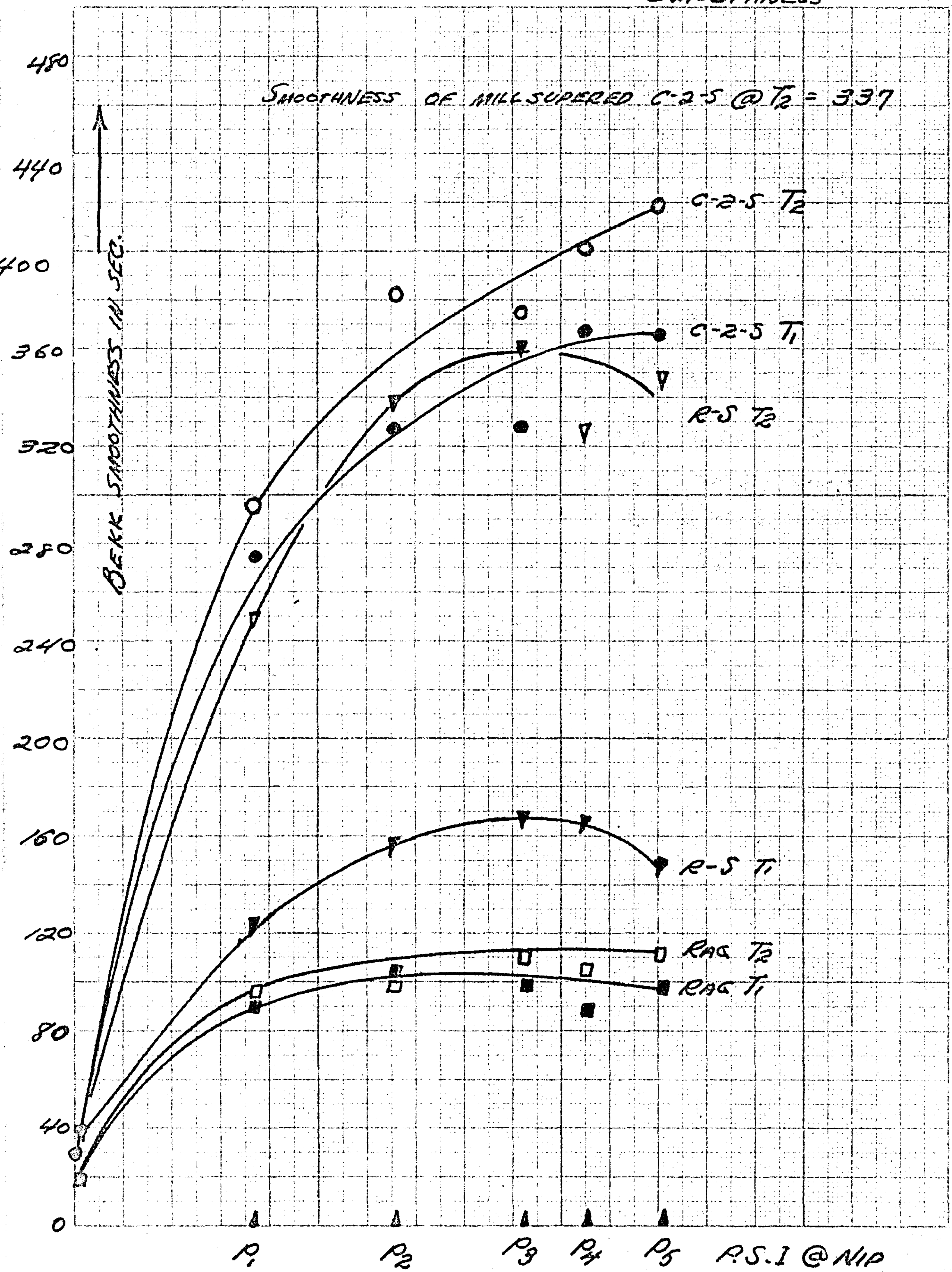


Fig. XIII

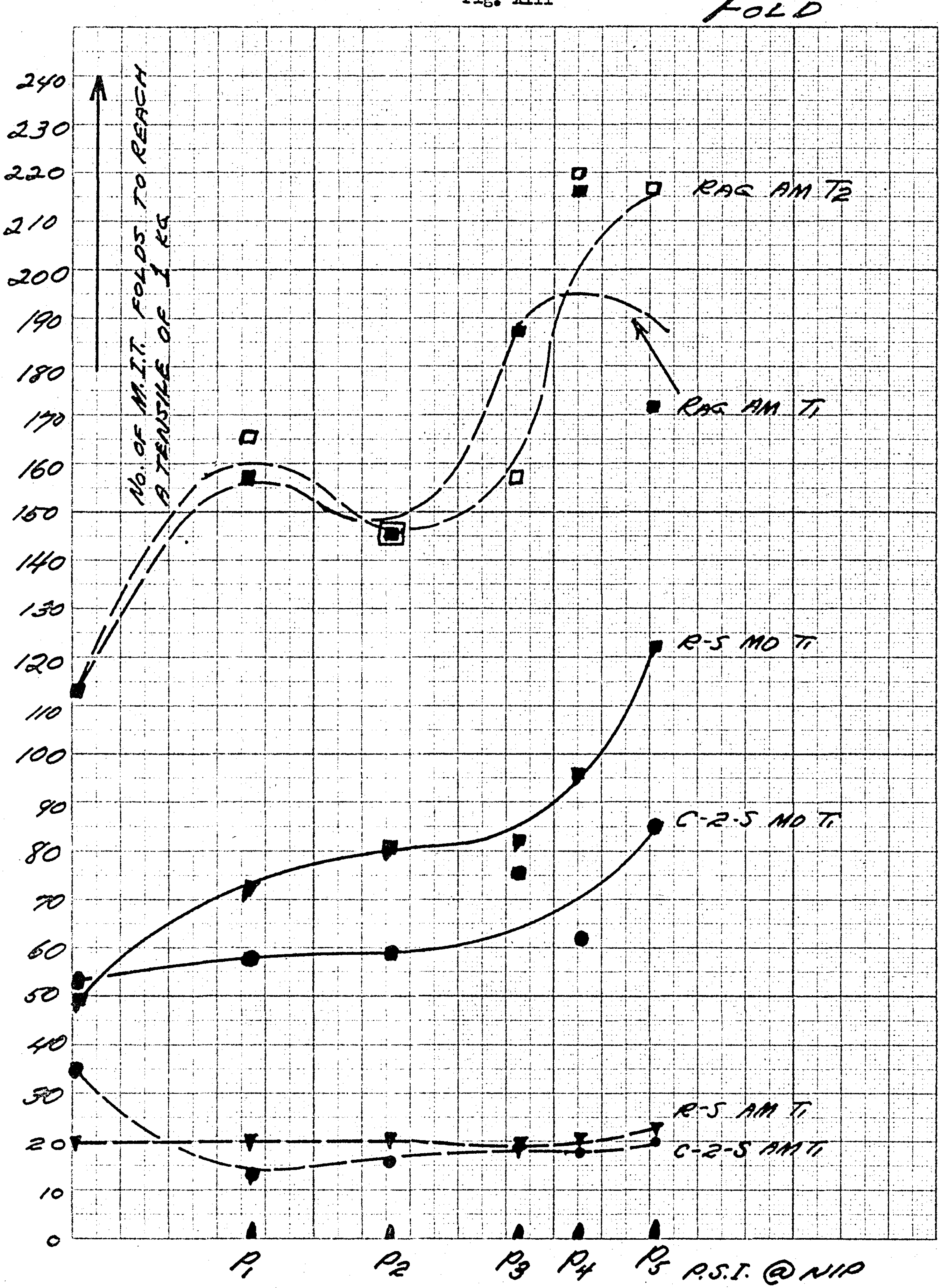
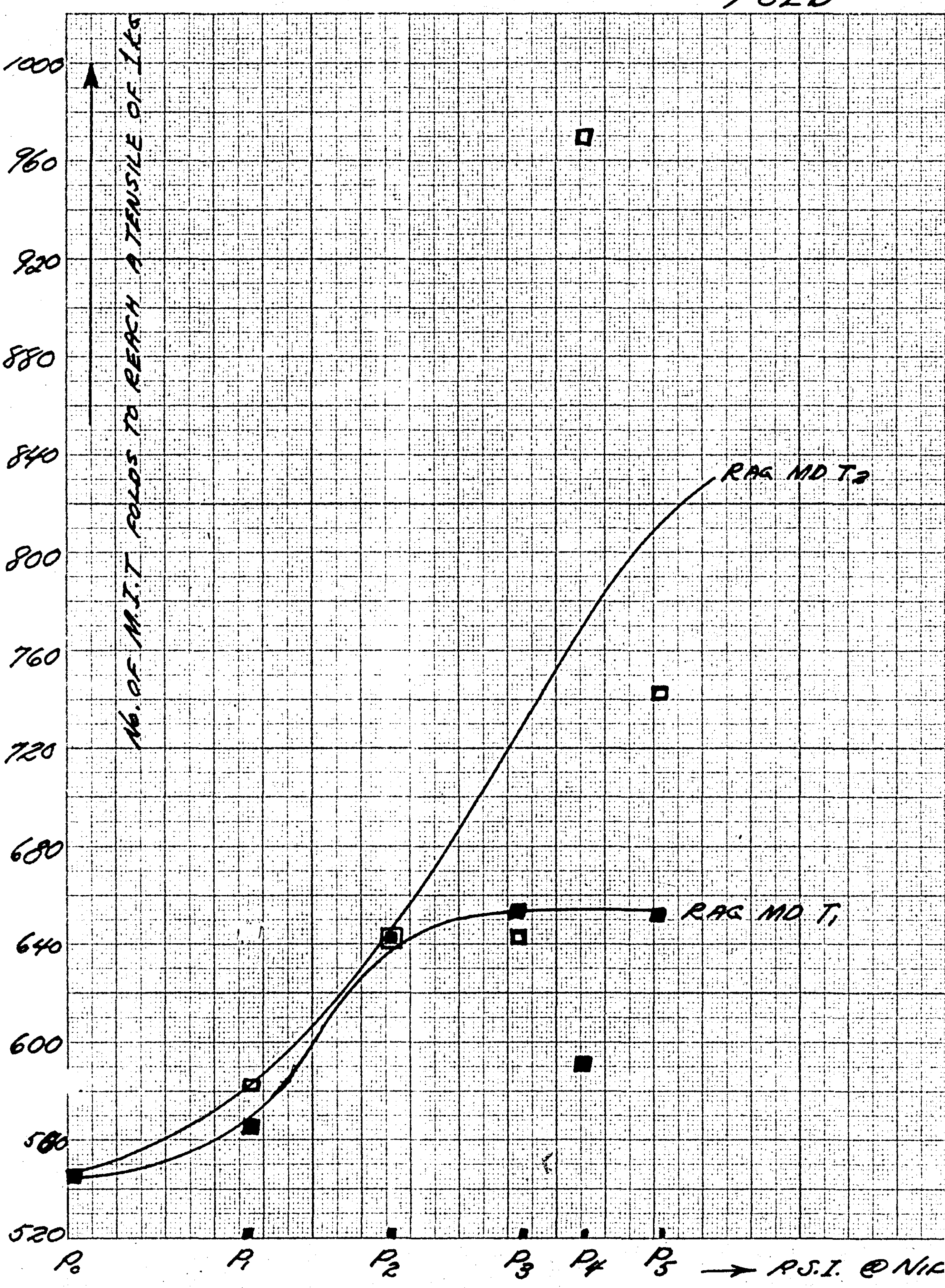

FOLD
No. OF M.I.T. FOLDS TO REACH A TENSILE OF 1 KG
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
RAG AM T2
RAG AM T1
R-S MO T1
C-2-S MO T1
R-S AM T1
C-2-S AM T1
P1
P2
P3
P4
P5
P.S.I. @ NIP

Fig. XIV



FOLD
No. OF M.I.T FOLDS TO REACH A TENSILE OF 1KG
1000
960
920
880
840
800
760
720
680
640
600
560
520
RAG MD T2
RAG MD T1
P0
P1
P2
P3
P4
P5
P.S.I. @ NIP

Burst (Mullen)

After each of the three types of paper had been supercalendered, they were tested for bursting strength. The numbers, found in Table 8 below, represent the force in p.s.i. needed to break through each paper. This data is shown graphically in Figs. XV and XVI.

TABLE 8

Nip press.	rag T_1	rag T_2	C2S T_1	C2S T_2	RS T_1	RS T_2
P 0	49	49	26	26	20	20
P 1	49	51	25	26	22	20
P 2	52	51	26	25	23	21
P 3	54	52	26	26	22	21
P 4	54	52	25	27	21	21
P 5	53	52	27	26	21	22

DISCUSSION OF TEST RESULTS

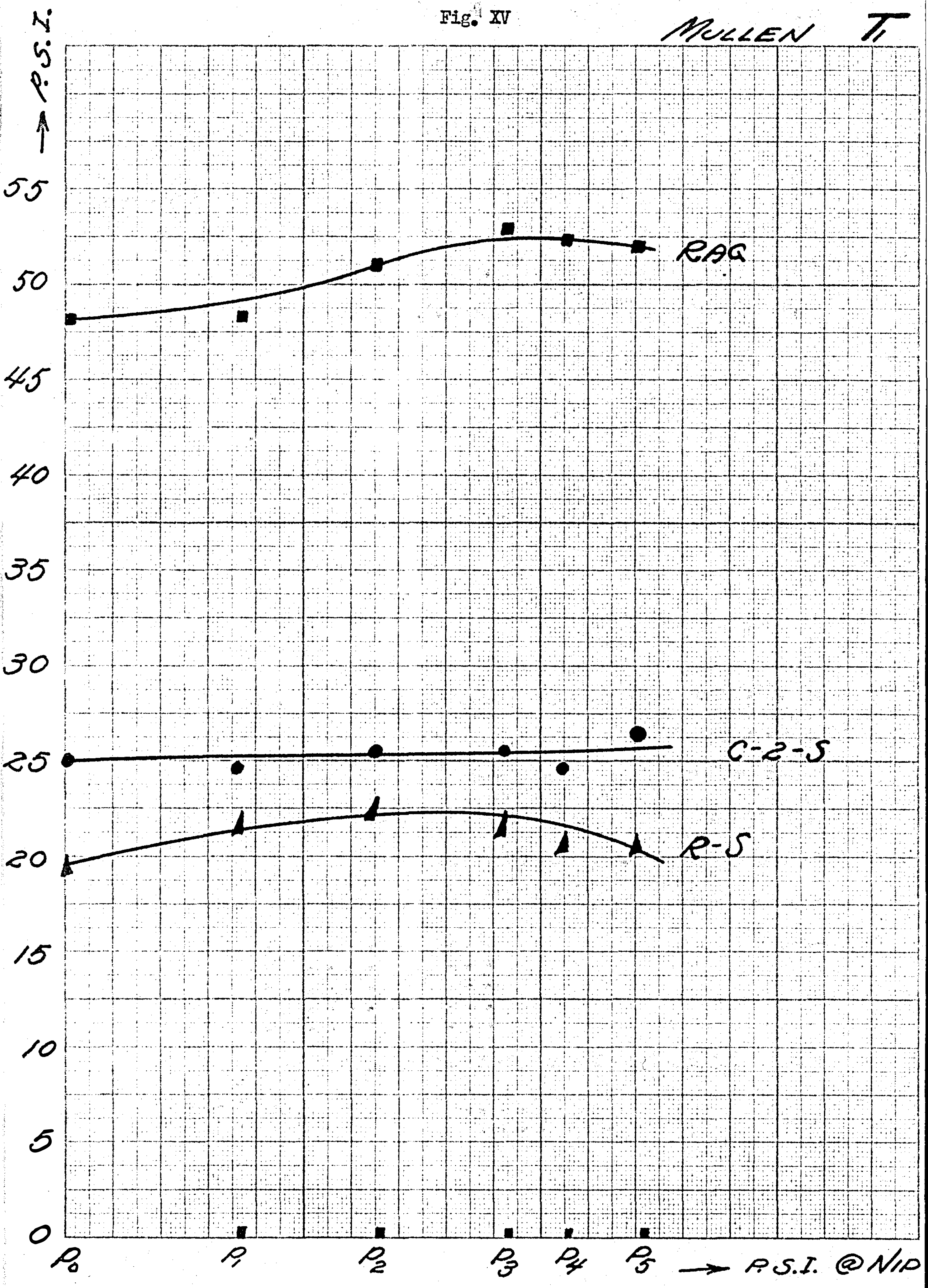
The conditions of experimenting may well be reviewed here. Roll temperature and pressure are the variables of supercalendering under study in this thesis. Three types of paper were chosen for supercalendering at controlled conditions of these variables. Five different pressures were used in cooperation with two different temperatures. The five nip pressures used, denoted as P_1, P_2, P_3, P_4 and P_5, had the following values.

P 1 . . . . . 1890 p.s.i.
P 2 . . . . . 3340 p.s.i.
P 3 . . . . . 4720 p.s.i.
P 4 . . . . . 5390 p.s.i.
P 5 . . . . . 6180 p.s.i.

The two roll temperatures used, denoted as T_1 and T_2, had the following values.

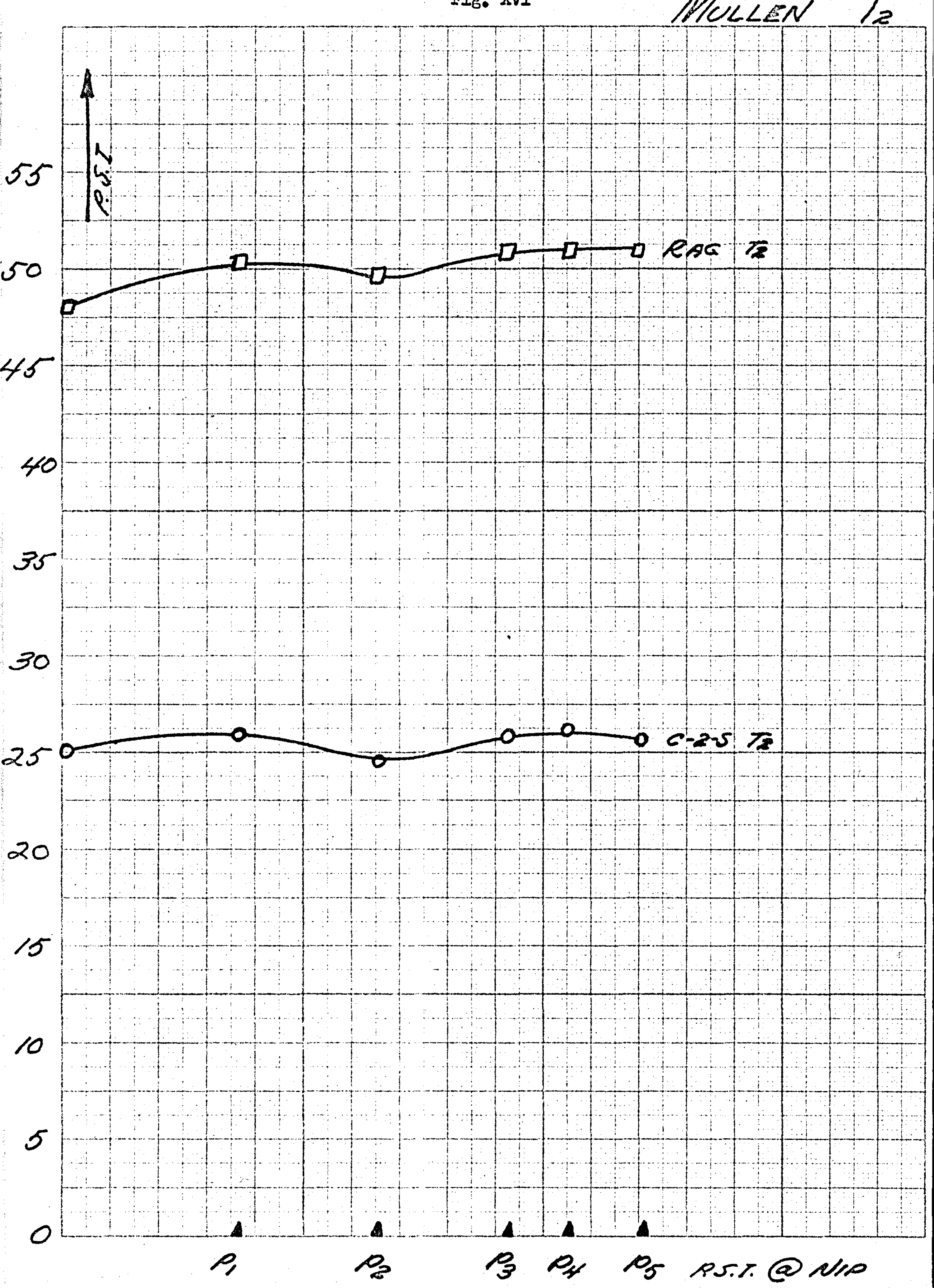
T 1 . . . . . 79° F.
T 2 . . . . .165° F.

Fig. XV



MULLEN T_1
P.S.I.
55
50
45
40
35
30
25
20
15
10
5
0
RAG
C-2-S
R-S
P_0
P_1
P_2
P_3
P_4
P_5
P.S.I. @ NIP

Fig. XVI


MULLEN T_2
P.S.I.
55
50
45
40
35
30
25
20
15
10
5
0
RAG T_2
C-2-S T_2
P_1
P_2
P_3
P_4
P_5
R.S.T. @ NIP

P-2 was the pressure used that most closely resembled common mill pressures.

The three types of paper used were:

1. uncoated 75% rag paper (denoted rag)
2. raw stock coated on both sides (denoted C2S)
3. the same raw stock as No. 2 but uncoated (denoted RS)

All three types of paper were supercalendered at all passible combinations of the five pressures and two temperatures used.

P1 T1	P2 T1	P3 T1	P4 T1	P5 T1
P1 T2	P2 T2	P3 T2	P4 T2	P5 T2

The following tests were made on the supercalendered paper.

1. caliper
2. tear
3. opacity
4. brightness (Photovolt)
5. tensile
6. smoothness (Bekk)
7. fold (M.I.T.)
8. burst (Mullen)

TEST RESULTS ON EACH TYPE OF PAPER

RAG - caliper

T - 1 The caliper decreased 20% between P-0 and P-2 and 5% between P-2 and P-5 for a total decrease of 25% between P-0 and P-5.

T-2 The caliper decreased 18% between P-0 and P-2 and 4% between P-2 and P-5 for a totaldecrease of 22% between P-0 and P-5.

Comments: The larger decrease of the caliper in the case of the paper supercalendered at T-1, as compared to T-2, may be due to the fact that the T-1 paper continues to be more pliable or compressable during supercalendering because of the moisture held in the paper and not driven off by hot supercalender rolls.

<u>RAG</u> - tear - AM

T-1 The AM tear <u>decreased</u> 8.6% between P-0 and P-2 and 2.9% between P-2 and P-5 for a total <u>decrease</u> of 11.5% between P-0 and P-5.

T-2 The AM tear <u>decreased</u> 13.4% between P-0 and P-2 and 1.9% between P-2 and P-5 for a total <u>decrease of</u> 15.3% between P-0 and P-5.

tear - MD

T-1 The MD tear <u>decreased</u> 4.7% between P-0 and P-2 and 7% between P-2 and P-5 for a total <u>decrease</u> of 11.7% between P-0 and P-5.

T-2 The MD tear <u>decreased</u> 13% between P-0 and P-2 and 1.0% between P-2 and P-5 for a total <u>decrease</u> of 14.0% between P-0 and P-5.

Comments:

The T-1 tear continued to decrease during the entire range of pressures used. Likewise, in review of the previous caliper findings, the T-1 caliper continued to decrease during the entire range of pressures used. However, in both the cases of T-2 tear and T-2 caliper, the decrease was only initially substantial. Since the temperature of the rolls controls the moisture content of the paper, the paper supercalendered at T-2 is probably drier than the paper supercalendered at T-1. The drier paper appears to be less pliable and compressable than the more moist paper. It also seems possible that in the case of the more moist paper inter-fiber bonding might occure during supercalendering between fibrillae which had not been in close enough contact before supercalendering.

RAG - opacity

T-1 The opacity decreased 0% between P-0 and P-2 and 2% between P-2 and P-5 for a total decrease of 2% between P-0 and P-5.

T-2 The opacity decreased 2% between P-0 and P-2 and 0% between P-2 and P-5 for a total decrease of 2% between P-0 and P-5.

Comments:

This data supports the idea thusfar supposed that the drier fibers at T-2 do not bond together or otherwise increase the density of the paper after P-2. Such an increase in density would have been seen as an opacity decrease between P-2 and P-5.

RAG - brightness

T-1 The brightness decreased 1.3% between P-0 and P-2 and 1.3% between P-2 and P-5 for a total decrease of 2.6% between P-0 and P-5.

T-2 The brightness decreased 2.5% between P-0 and P-2 and 1.3% between P-2 and P-5 for a total decrease of 3.8 % between P-0 and P-5.

Comments:

The paper supercalendered at T-2 had a larger initial and total decrease in brightness than did the paper at T-1.

RAG - tensile - AM

T-1 The tensile increased 1.0% between P-0 and P-2 and 3.7% between P-2 and P-5 for a total increase of 4.7% between P-0 and P-5.

T-2 The AM tensile had a 0% change between P-0 and P-2 and increased 6.5% between P-2 and P-5 for a total increase of 6.5%.

<u>RAG</u> - tensile- MD

T-1 The MD tensile changed 0% between P-0 and P-2 and <u>decreased</u> 3.8% between P-2 and P-5 for a total <u>decrease</u> of 3.8% between P-0 and P-5.

T-2 The MD tensile <u>decreased</u> 3.8% between P-0 and P-2 and <u>increased</u> back to its original state between P-2 and P-5.

Comments:

This data does not support the idea that interfiber bonding increases with increasing supercalendering pressures. Also since rag fibers are relatively ribbon-like they should withstand high supercalendering pressures without being broken. The author can think of no explaination for the increase in AM tensile and no increase in the MD tensile.

<u>RAG</u> - smoothness

T-1 The smoothness <u>increased</u> 450% between P-0 and P-2 and <u>decreased</u> TO a 426% increase over the original value between P-2 and P-5.

T-2 The smoothness <u>increased</u> 432% between P-0 and P-2 and 63% between P-2 and P-5 for a total <u>increase of</u> 495% between P-2 and P-5.

Comments:

The surface smoothness of paper (in most cases the only reason for supercalendering) will be seen to be very dependent on the type of surface on the paper before supercalendering. Although a smoothness increase is expected during supercalendering, it is interesting to note the downward drop in smoothness at very high pressures.

MAG - fold - AM

T-1 The AM fold increased 30% between P-0 and P-2 and 21% between P-2 and P-5 for a total increase of 51% between P-0 and P-5.

T-2 The AM fold increased 30% between P-0 and P-2 and 60% between P-2 and P-5 for a total increase of 90% between P-0 and P-5.

- fold - MD

T-1 The MD fold increased 18% between P-0 and P-2 and 2% between P-2 and P-5 for a total increase of 20% between P-0 and P-5.

T-2 The MD fold increased 19% between P-0 and P-2 and 18% between P-2 and P-5 for a total increase of 37% between P-0 and P-5.

Comments:

It was found that the fold tests on the AM-T-2 and MD-T2 supercalendered paper increased substantially between P-2 and P-5. However, in both the cases of the AM-T-1 and MD-T-1 supercalendered paper, the increase in fold in the P-2 to P-5 range was only minor. These results contridict the idea that the fibers should increase in interfiber bonding only during T-1 conditions where more moisture is left in the paper than during T-2 supercalendering. An explaination of these results may, however, be found in the assumption that the interfiber bonds, although fewer, are more set and less yeilding in their dry state. It is a known fact that interfiber bonding in a sheet of paper virtually if not actually disappears when the paper is thoroughly wetted with water.

<u>RAG</u> – burst

T-1 The bursting strength <u>increased</u> 6% between P-0 and P-2 and 2% between P-2 and P-5 for a total <u>increase</u> of 8% between P-0 and P-5.

T-2 The bursting strength <u>increased</u> 4% between P-0 and P-2 and 2% between P-2 and P-5 for a total <u>increase</u> of 6% between P-0 and P-5.

Comments:

A larger increase in bursting strength was recorded in the case of T-1 supercalendered paper, as compared to T-2 supercalendered paper. Whether these results mean that bonding occured to a greater degree under T-1 conditions, or that the drier fibers offered less resistance to being pulled past each other during the bursting pressure, or other reasons, requires further study.

C-2-S – caliper

T-1 The caliper <u>decreased</u> 26% between P-0 and P-2 and 4.3% between P-2 and P-5 for a total <u>decrease</u> of 30.3% between P-0 and P-5.

T-2 The caliper <u>decreased</u> 24% between P-0 and P-2 and 4.3% between P-2 and P-5 for a total <u>decrease</u> of 28.3% between P-0 and P-5.

Comments:

These results are similiar to those recorded for supercalendered rag paper, in that the T-1 supercalendered paper has undergone a a greater decrease in caliper than has the T-2 supercalendered paper.

C-2-S tear - AM

T-1 The AM tear <u>decreased</u> 17% between P-0 and P-2 and 14% between P-2 and P-5 for a total <u>decrease</u> of 31% between P-0 and P-5.

T-2 The AM tear <u>decreased</u> 27% between P-0 and P-2 and 0% between P-2 and P-5 for a total <u>decrease</u> of 27% between P-0 and P-5.

tear - MD

T-1 The MD tear <u>decreased</u> 28% between P-0 and P-2 and 2% between P-2 and P-5 for a total <u>decrease</u> of 30% between P-0 and P-5.

T-2 The MD tear <u>decreased</u> 28% between P-0 and P-2 and 0% between P-2 and P-5 for a total decrease of 28% between P-0 and P-5.

Comments:

A larger decrease was recorded for AM T-2 tear than for AM T-1 tear. This may be due to less interfiber bonding survived or resulted from T-2 supercalendering. The machine direction (MD) tear remained nearly the same at both T-1 and T-2 supercalendering. A reason may be that the very nature of MD tear seems less dependent on interfiber bonding than AM tear.

C-2-S - opacity

T-1 The opacity <u>decreased</u> 2% between P-0 and P-2 and 2% between P-2 and P-5 for a total <u>decrease</u> of 4% between P-0 and P-5.

T-2 The opacity <u>decreased</u> 2% between P-0 and P-2 and 1% between P-2 and P-5 for a total decrease of 3% between P-0 and P-5.

Comments:

The greater opacity decrease in the case of T-1 supercalendered

C-2S paper may indicate that more interfiber bonding and thus a denser more opaque sheet results from supercalendering under more moist conditions.

C-2S - brightness

T-1 The brightness decreased 1.3% between P-0 and P-2 and 2.5% between P-2 and P-5 for a total decrease of 3.8%.

T-2 The brightness decreased 3.8% between P-0 and P-2 and 1.3% between P-2 and P-5 for a total decrease of 5.1% between P-0 and P-5.

Comments:

The higher brightness decrease in the case of T-2 supercalendered paper is in good cooperation with the preceding opacity results. A densily bonded paper appears dark in color due to its semi-transparency. (e.g., glassine)

C-2-S - tensile - AM

T-1 The AM tensile increased 3.1% between P-0 and P-2 and 20% between P-2 and P-5 for a total increase of 23.1% between P-0 and P-5.

T-2 The AM tensile increased 17% between P-0 and P-2 and dropped back to an 11% increase between P-2 and P-5 for a final increase of 11%.

- tensile - MD

T-1 The MD tensile increased 1.2% between P-0 and P-2 and decreased 2.5% between P-2 and P-5 for an average decrease of 0.55% between P-0 and P-5.

T-2 The MD tensile increased 1.2% between P-0 and P-2 and decreased 2.5% between P-2 and P-5 for an average decrease of 0.55%.

C-2-S - tensile - cont.

Comments:

The increase in tensile measurements from using moderate supercalender pressures and a final decrease in tensile from using higher supercalender pressures indicates that at a certain point in the pressure range of the rolls, bonding or strength in general is caused to decrease.

C-2-S - smoothness

T-1 The smoothness increased 1050% between P-0 and P-2 and 162% between P-2 and P-5 for a total increase of 1212% between P-0 and P-5.

T-2 The smoothness increased 1240% between P-0 and P-2 and 130% between P-2 and P-5 for a total increase of 1370% between P-0 and P-5.

Comments:

The smoothness increases noted here are substantially higher than those recorded in the case of uncoated rag paper as can be seen by referring to page 27. The surface of the paper has very much to do with the smoothing influence of supercalendering.

C-2-S - fold - AM

T-1 The AM fold decreased 55% between P-0 and P-2 and increased to a final decrease of 42% between P-2 and P-5.

T-2 The AM fold decreased 42% between P-0 and P-2 and during P-2 to P-5 increased until a final decrease of 33 % was reached.

C-2-S - fold - MD

T-1 The MD fold increased 13% between P-0 and P-2 and 51% between P-2 and P-5 for a total increase of 64% between P-0 and P-5.

T-2 The MD fold increased 0% between P-0 and P-2 and 4% between P-2 and P-5 for a total increase of 4% between P-0 and P-5.

C-2-S - burst (Mullen)

T-1 The burst stayed the same between P-0 and P-2 and increased 4% between P-2 and P-5 for a total increase of 4% from P-0 to P-5.

T-2 The burst decreased 4% between P-0 and P-2 and increased enough during P-2 to P-5 to bring the average decrease to 0%.

RS - caliper

T-1 The caliper decreased 18% between P-0 and P-2 and 6% between P-2 and P-5 for a total decrease of 24% between P-0 and P-5.

T-2 The caliper decreased 18% between P-0 and P-2 and 6% between P-2 and P-5 for a total decrease of 24% between P-0 and P-5.

Comments:

It will be noted from page 29 that this raw stock when coated and and supercalendered suffers a greater % dedrease in caliper.

RS RS - tear - AM

T-1 The AM tear decreased 12% between P-0 and P-2 and 48% between P-2 and P-5 for a total decrease of 16.8% between P-0 and P-5.

RS - tear - AM

T-2 The tear decreased 14% between P-0 and P-2 and stayed the same between P-2 and P-5 for a total decrease of 14% between P-0 and P-5.

- tear - MD

T-1 The MD tear decreased 19% between P-0 and P-2 and 3% between P-2 and P-5 for a total decrease of 22% between P-0 and P-5.

T-2 The MD tear decreased 14% between P-0 and P-2 and stayed the same between P-2 and P-5 for a total decrease of 14% between P-0 and P-5.

RS - opacity

T-1 The opacity decreased 2.3% between P-0 and P-2 and 1.2% between P-2 and P-5 for a total decrease of 3.5% between P-0 and P-5.

T-2 The opacity decreased 4.7% between P-0 and P-2 and stayed the same between P-2 and P-5 for a total decrease of 4.7% from P-0 to P-5.

RS - brightness

T-1 The brightness decreased 3.0% between P-0 and P-2 and stayed the same between P-2 and P-5 for a total decrease of 3% from P-0 to P-5.

T-2 The brightness decreased 1.4% between P-0 and P-2 and 5.5% between P-2 and P-5 for a total decrease of 6.9% between P-0 and P-5.

RS - tensile - AM

T-1 The AM tensile stayed the same between P-0 and P-2 and increased 6.8% between P-2 and P-5 for a total increase of 6.8% from P-0 to P-5.

T-2 The AM tensile increased 1.7% between P-0 and P-2 and 6.8% between P-2 and P-5 for a total increase of 8.5% between P-0 and P-5.

RS - tensile - MD

T-1 The MD tensile increased 99% between P-0 and P-2 and stayed the same between P-2 and P-5 for a total increase of 99% between P-0 and P-5.

T-2 The MD tensile increased 100% between P-0 and P-2 and stayed the same between P-2 and P-5 for a total increase of 100% from P-0 to P-5.

RS - smoothness

T-1 The smoothness increased 330% between P-0 and P-2 and stayed approx. the same between P-2 and P-5 for a total increase of 330% to P-5.

T-2 The smoothness increased 820% between P-0 and P-2 and 33% between P-2 and P-5 for a total increase of 853% between P-0 and P-5.

RS - fold - AM

T-1 The AM fold increased 10% between P-0 and P-2 and 10% between P-2 and P-5 for a total increase of 20% between P-0 and P-5.

T-2 The AM fold increased 4% between P-0 and P-2 and 21% between P-2 and P-5 for a total increase of 25% between P-0 and P-5.

- fold - MD

T-1 The MD fold increased 63% between P-0 and P-2 and 82% between P-2 and P-5 for a total increase of 145% between P-0 and P-5.

T-2 The MD fold increased 51% between P-0 and P-2 and 59% between P-2 and P-5 for a total increase of 110% between P-0 and P-5.

RS - burst (Mullen)

T-1 The burst increased 10% between P-0 and P-2 and decreased to such an extent that a final increase of 5% between P-0 and P-5 was recorded.

T-2 The burst increased 5% between P-0 and P-2 and 5% between P-2 and P-5 for a total increase of 10% between P-0 and P-5.

SUMMARY OF TEST RESULTS

This summary of the preceding test results will consist of three parts. Part (A) will summarize the effect of roll pressure during supercalendering on the physical properties of the three types of paper used in the experiments of this thesis. Part (B) will summarize the effect of roll temperature during supercalendering. Part (C) will summarize the results that show how different types of paper react differently during supercalendering. Discussion in this summary will be made from data found in Table 9.

(A) Roll Pressure

- caliper -

Results from the testing of all three types of paper used show that supercalender pressures cause a decrease in caliper.

* tear -

The tear test was found to decrease as a result of supercalender pressures for the three types of paper used.

TABLE 9

D denotes decrease   I denotes increase
All Numbers Are Percentages

	RAG		C-2-S		R-S	
	T-1	T-2	T-1	T-2	T-1	T-2
caliper	25 D	22D	30 D	28 D	24 D	24 D
tear AM	11.5 D	15.3 D	31 D	27 D	17 D	14 D
MD	11.7 D	14 D	30 D	28 D	22 D	14 D
opacity	2 D	2 D	4 D	3 D	4 D	5 D
brightness	2.6 D	3.8 D	3.8 D	5.1 D	3 D	7 D
tensile AM	4.7 I	6.5 I	23.1 I	11 I	7 I	9 I
MD	3.8 D	same	0.6 D	0.6 D	99 I	100 I
smoothness	426 I	495 I	1212 I	1370 I	330 I	853 I
fold AM	51 I	90 I	42 D	33 D	20 I	25 I
MD	20 I	37 I	64 I	4 I	145 I	110 I
burst	8 I	6 I	4 I	0 I	5 I	10 I

- opacity -

The opacity of all three papers was found to <u>decrease</u> as a result of the roll pressure during supercalendering.

- brightness -

The brightness of all three papers used was found to <u>decrease</u> as a result of supercalender pressure.

- tensile -

Uncoated rag paper showed a slight average <u>increase in</u> tensile. The coated paper <u>increased slightly</u>, while the uncoated raw stock <u>increased</u> substantially.

- smoothness -

The smoothness of all three types of paper <u>increased</u> substantially as a result of supercalender pressure.

- fold -

The folding strength of all three types of <u>paper increased</u> in their machine direction. The rag paper and the uncoated raw stock <u>increased</u> in their across machine direction, while the coated paper <u>decreased</u> in the across machine direction.

- burst -

Increases in bursting strength as a result of supercalender pressure were recorded for all three papers supercalendered.

(B) <u>Roll Temperature</u>

(B) Roll Temperature

- caliper -

Results from testing all three types of paper used show that a larger decrease in caliper occured during T-1 (79°F.) supercalendering than during T-2 (165°F.) supercalendering.

- tear -

In the case of the rag paper the T-2 tear was higher than the T-1 tear. Results from testing both the supercalendered coated paper (C-2-S) and raw stock (RS) show the T-1 tear to be higher than the T-2 tear.

- opacity -

The opacity of the rag paper was the same at both temperatures of supercalendering. The coated paper had a higher opacity after T-2 supercalendering, while the uncoated raw stock had a higher opacity after T-1 supercalendering.

- brightness -

The brightnesses of the three types of paper used were found to decrease less as a result of T-1 supercalendering than as a result of T-2 supercalendering.

- tensile -

The tensile tests for both the rag and the uncoated raw stock papers were higher as a result of T-2 supercalendering. The tensile test for the coated paper was higher after T-1 supercalendering.

- smoothness -

Results showed that all of the three papers had greater smoothnesses after T-2 supercalendering.

- fold -

The rag paper had a higher fold test after T-2 supercalendering. The coated paper had a higher fold test after T-1 supercalendering. The average fold test after T-1 and T-2 supercalendering of uncoated raw stock was about the same.

- burst -

The bursting strength of the rag paper and the coated paper was higher as a result of T-1 supercalendering. The raw stock had a greater bursting strength after T-2 supercalendering.

(C) Different Paper Types

The effectsof supercalendering different types of paper are best seen in Table 9. Data may be found in this table that shows the extent or degree of change of a physical test as a result of supercalendering. For example it may be seen that the coated paper increased in smoothness about 1,300%, while the rag paper only increased about 450% over the range of pressures used.

CONCLUSION

The values of the roll temperature and pressure of a supercalender were found to cause paper supercalendered under these conditions to have

individual physical properties different from the properties of the same paper if supercalendered undered under different conditions.

It was observed, from physical tests recorded, that the type of paper being supercalendered, influences, to a varying degree, the effect of the supercalendering action.

END

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