# A STUDY OF THE RETENTION OF DYESTUFFS ON PAPER MAKING FIBERS UNDER VARIOUS CONDITIONS

A thesis submitted by

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# CHAPTER I

## INTRODUCTION

Paper dyeing has increased considerably in the past decade, primarily because of the large growth in the speciality business. This growth, coupled with increased technical knowledge, has induced the dye manufacturers to continually increase their facilities for serving the paper maker. Due to the fact that it has long been recognized that this can be accomplished only when a technical viewpoint is taken, the use of dyes has been put on a greater scientific basis. In the relentless search for new and better colors, the dye companies have built up a wealth of technical knowledge which can not be overestimated. Out of this have come many new refinements of which the determinations of optimum physical and chemical conditions for the dyeing reaction are good examples.

Besides the dye manufacturers, other institutions have studied the dyeing reaction. The most notable probably are the textile research laboratories, and it should be pointed out that a great deal of knowledge in paper dyeing has been taken from these sources.

However, even though a great deal of work has been carried out in the paper dyeing field, there is an apparent scarcity of quantitative data concerning the retention of dyes. Work, for the most part, has been aimed in a direct way at the economics of the problem. This has been done by actually matching whatever was to be dyed using all possible dye formulas, within the limits of the shade, and then calculating the most economical one by taking into consideration the cost of each individual dye. If, however, the quantitative retentions of the various dyes available were known for the particular conditions of the problem, these data, along with their costs, would facilitate the elimination of some dyestuffs immediately in working out a color formula from an economic standpoint. In addition, and even more important in so far as this work is concerned, quantitative retention data obtained under well selected conditions should throw some light upon the trends to be expected in commercial practice. Also it is hoped that this work will be a stepping stone in the right direction for more complete understanding of the dyeing mechanism.

The study of the retention of dyestuffs on paper making fibers under various conditions has been undertaken with the following objectives:

1. To develop a method for determining the retention of dye on paper making fibers.
2. To study the effect of variables on the retention of dye, such as type of dye and its concentration; temperature, pH, and consistency of the pulp; time of reaction; type of fiber, its chemical constants, and method of preparation; and type of acid used.
3. To point out the applicability of the retention data to theoretical equations.

# CHAPTER II

## METHOD OF ATTACK

Paper is ordinarily dyed by the addition of dye to the beater during the processing of the pulp. The pulp dyed at this stage is later formed into a sheet on the paper machine, at which time a considerable amount of water, commonly called white water, carrying with it fiber and dye, is removed from the pulp. The retention of the dye is the amount of dye left in the sheet. The problem may be attacked by two different methods. The first method consists in determining the amount of dye in the sheet after its manufacture, while the second method is to determine the amount of dye left in the white water. In the latter method, the amount of dye in the sheet may be calculated by subtracting the amount found in the white water from the amount added to the beater.

At first, no suitable way could be found for directly determining the amount of dye in the sheet. A colorimetric method for determining dye concentration in white waters using Nessler tubes was considered, but, due to its subjective nature, was discarded. An accurate objective method which would show small differences in retention was necessary if reliable results were to be obtained. A spectrophotometric method, using "Beer's Law" as its fundamental principle for determining the amount of dye in the white water was then developed and found to be satisfactory.

When paper making fibers are dyed, the retention results obtained are dependent upon the conditions used during the dyeing operation. The most important of these conditions are type of fiber, its chemical constants, and method of preparation; type of dye and its concentration; temperature, pH, and consistency of the pulp; time of reaction; and type of acid used. With these conditions in mind, a systematic study was made in which one variable was considered at a time, within the limits that are ordinarily found in commercial practice. In order to have a base line for the results, standard conditions were set up and maintained, except for the variable under consideration, throughout the entire investigation. These standard conditions were 10 minutes reaction time, 20 degrees Centigrade temperature, 0.6 per cent consistency, unprocessed unbleached sulphite pulp, and 4.9 pH obtained by the use of sulphuric acid.

In connection with the retention of dyes under the conditions outlined above, it was thought desirable to study the applicability of the Kubelka and Monk equations, which involve an absorption coefficient, and the Freundlich adsorption equation to these data.

By the above method of attack it was hoped that retention results would be obtained which would facilitate the working out of scientific color formulas as well as throw some light upon the retention trends to be expected in commercial practice. It was also hoped that the results would be applicable to theoretical absorption and adsorption equations which, no doubt, in time to come, will help to solve more completely the dyeing mechanism.

Terms and phrases used in this investigation which might have several meanings are defined at this point.

## DEFINITIONS

<u>Natural White Water</u>: White water obtained when no dye has been used in the sheet making process.

<u>Natural Sheet</u>: Sheet obtained when no dye has been used in the sheet making operation.

Transmission: The process of transmitting rays of light, considered as a function of wavelength (in the range 400 to 700 millimicrons). Example: transmission curve of distilled water.

Transmittance: The relative capacity of a dye solution to pass rays of light of a specified wavelength. The wavelength used for any given dye is at the point where the transmittance is at its maximum deviation from the transmission curve of distilled water.

Reflection: The process of throwing back rays of incident light, considered as a function of wavelength (in the range 400 to 700 millimicrons). Example: the reflection curve of a natural sheet.

Reflectivity: The relative capacity of a sheet of paper of infinite thickness to throw back rays of incident light of a specified wavelength. The wavelength used for any given dye is at the point where the reflectivity is at its maximum deviation from the reflection curve of a natural sheet.

Scattering: The process of deflecting light energy from its original direction.

Absorption: The process of disappearance of light upon passing through a medium.

# CHAPTER III

## MATERIALS, EQUIPMENT, AND PROCEDURES

In carrying out the work outlined in the method of attack the following materials, equipment, and procedures were used.

A. Materials.

The unbleached sulphite pulp used was a hard commercial pulp made from hemlock and as a result was on the red side in color. Bleached sulphite in five different grades was produced from this unbleached pulp by using 3, 6, 10, 20, and 30 per cent bleach (based on 35 per cent available chlorine) in a single stage, high density (12 per cent consistency, calcium hypochlorite treatment. In each case the pulp was well washed after complete exhaustion of the bleach liquors.

The unbleached kraft pulp used was an extremely hard grade of commercial jack pine kraft. This pulp was bleached to four different degrees using 5, 15, 30, and 40 per cent bleach (based on 35 per cent available chlorine) with calcium hypochlorite. The bleach using 5 per cent was carried out in a single stage at 12 per cent consistency; the 15 and 30 per cent bleaches were carried out in two stages, both at 12 per cent consistency, by adding two-thirds of the bleach in the first stage and one-third in the second; the 40 per cent bleach was carried out exactly the same as the 30 per cent bleach except that an additional 10 per cent of bleach was added in a third stage at 12 per cent consistency. In the case of multiple stage bleachings, the second or third stage was never started until after the chlorine from the previous stage was completely exhausted and the bleach residues were washed out.

The dyes used represented Du Pont Company products and are sold under the following trade names: Du Pont Victoria Green Small Crystals; Du Pont Rhodamine B; Du Pont Auramine Concentrated; Du Pont Methylene Blue ZX; Du Pont Basic Brown BR; Du Pont Safranine T Extra; Du Pont Methyl Violet NE; Du Pont Brilliant Crocein FL; Du Pont Anthraquinone Blue B; Du Pont Nigrosine WSB Powder; Du Pont Quinoline Yellow Concentrated; Du Pont Orange II Concentrated; Pontacyl Violet S4B; Pontamine Fast Red 8BL; Du Pont Purpurine 4B Concentrated; Pontamine Yellow SXP; Pontamine Fast Scarlet 4BS; Pontamine Black E; Du Pont Brilliant Paper Yellow Concentrated; and Pontamine Fast Yellow NNL. These dyes were used in 0.3 gram per liter solutions which were freshly prepared each day.

Two types of acid, both of reagent grade, were used, namely, sulphuric acid and alum (aluminum sulphate).

The size used was neutral in a three per cent solution made from "G" gum rosin.

B. Equipment.

The sheet making apparatus, figure 1, consisted of an ordinary 6 inch Buchner funnel connected to a 2 liter suction flask carrying a vacuum of 14 inches of water. Auxiliary equipment used in connection with the sheet making apparatus consisted of a Hamilton Beach malted milk mixer, model 25, a 65 mesh wire to fit the Buchner funnel, drying plates and rings such as are used with the British sheet making apparatus[7], a Jena glass funnel of 1G1 porosity, a good grade of white blotters, and a press capable of holding 7 by 7 inch sheets and exerting a pressure of 100 pounds per square inch.

The pH standards used were the ordinary colorimetric standards put out by the LaMotte Chemical Products Company.

An experimental Valley beater, of one pound capacity, was used for processing the pulp.

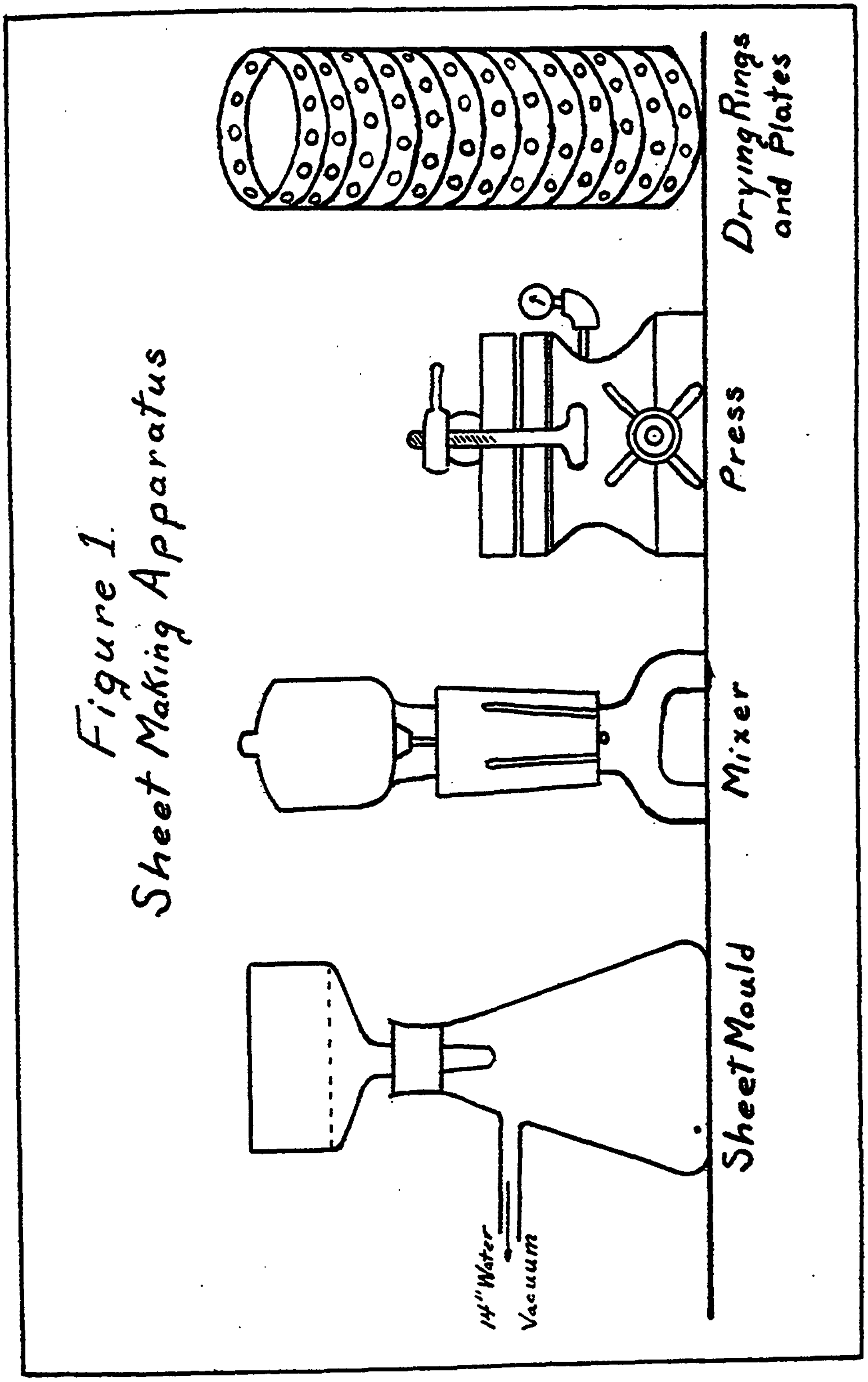



Figure 1.
Sheet Making Apparatus

A General Electric Recording Color Analyzer, developed by Professor A. C. Hardy of the Massachusetts Institute of Technology, was used for the spectrophotometric measurement of transmittance and reflectivity. The operation of this instrument may briefly be described as follows: the light source, a ribbon filament projection lamp, is focused upon the entrance slit of a monochromator which is of the Abbé autocollimating type. The light beam leaving this system, comprising a wavelength band of ten millimicrons width, is split up into two beams. One beam passes to a flicker disk and is reflected one half of the time by the disk to a photoelectric cell, while the other beam passes through a small glass cell containing the liquid to be analyzed, is reflected off the surface of a block of magnesium carbonate, and is caught by the photoelectric cell when it is not viewing the previously mentioned beam. When the instrument is to be used for analyzing color in papers, the glass cell is removed and the paper is inserted in place of the magnesium carbonate. The current from the photoelectric cell is amplified by a three stage resistance coupled amplifier, the output of which feeds the grids of two thyratrons; the plates of these tubes are in series with the field coils of a small motor, the armature of which is supplied from an independent source of the same frequency. With this arrangement the armature rotates in one direction when the beam from the specimen is the more intense and in the opposite direction when the beam that is reflected from the flicker disk is the more intense. When the intensities are equal, the field currents are equal and opposite thus stopping the motor. By causing the motor to control a sector diaphragm which varies the intensity incident upon the flicker disk, the two beams are automatically balanced. A pen operating on a rotating drum covered with a sheet of graph paper records the position of this diaphragm on the ordinate of the graph while the rotation of the drum, which is synchronized with the optical system, changes the wavelength of the spectral band admitted to the photo-electric cell and is recorded on the abscissa of the graph. When the instrument is to be used for analyzing the color of liquids for their transmittance, the result obtained is relative to the transmittance of the glass cell when filled with distilled water. On the other hand, when analyzing papers for their reflectance, the result obtained at any given wavelength with a freshly prepared magnesium carbonate block is arbitrarily chosen as 100 per cent reflectivity.

C. Experimental Procedures.

The following experimental procedures were used in carrying out the work of this investigation.

1. Method of Dyeing.

The dyeing procedure is carried out under well controlled conditions as follows: Exactly 3.0000 grams of pulp, calculated on the bone dry basis, are weighed out on an analytical balance. Sufficient distilled water of the correct temperature is placed upon the pulp so that when the dye and acid are added the mixture will be of the correct consistency. The pulp mixture is then placed in a malted milk mixer, the correct amount of dye run in from a burette, a stop watch started, and the acid used for setting the dye added. At the moment the reaction time is up, the dyed pulp is removed from the stirrer and immediately made into a sheet on the sheet making apparatus. The sheet formed in this way is removed by couching off on a smooth surfaced metal plate (British sheet mould drying plate), pressed between clean blotters at a pressure of 100 pounds per square inch for exactly one minute, air dried under tension (by the use of

British sheet mould drying rings), and stored in the dark for later spectrophotometric examination. The white water caught in the flask of the sheet making apparatus is filtered through a Jena filter to remove any fiber draining through from the sheet and set aside for later spectrophotometric examination.

2. Method of Determining Dye Retention by the Use of Beer's Law[2].

The determination of dye retention for any given dye is carried out in nine steps as follows:

a. Dye standards of known concentration are prepared by adding a known amount of dye to a known volume of distilled water. These standards are used for comparing the unknown dye solutions (white waters) and are adjusted to a corresponding pH. Solutions, in a range from no dye to one containing more dye than is expected in the white waters being examined, are prepared for each dye so that the amount in the unknown white water will fall within the range of the standards.

b. Transmission curves of the standard dye solutions for the dye in question along with the transmission curve of distilled water are obtained by the use of the color analyzer.

c. A point on the wavelength scale of the transmission curves is picked where maximum deviation occurs for the dye solution relative to distilled water. When the transmittance of a solution is stated, it is hereafter understood to be at this point.

d. The logarithms of the transmittances of the standard dye solutions are plotted against their concentrations (Beer's law[2] is satisfied if the curves are straight lines).

e. Transmission curves of the white water in question and a natural white water, i.e. no dye, are obtained by the use of the color analyzer.

f. The transmittances of the white water and the natural white water are determined at the wavelength of maximum deviation. This point remains the same for any given dye.

g. The transmittance of the white water, corrected for turbidity, is obtained by dividing the product of the transmittance of the white water and the transmittance of the distilled water by the transmittance of the natural white water.

h. The logarithm of the corrected white water transmittance is determined and the concentration of the dye solution corresponding to this value is read from the standard graph as developed in (d) above.

i. From the concentration of the dye in the white water the per cent retention of the dye is determined.

3. Method of Determining Dye Retention by the Use of Kubelka and Monk Equations[6].

The determination of dye retention for any given dye is carried out in eight steps as follows:

a. The reflection curves of the series of papers under consideration using the same furnish and dyed with the same dye in varying concentrations, as well as a natural sheet (i.e. no dye), are obtained with the help of the color analyzer.

b. The retention of dye for one of the papers is determined by the method using Beer's law.

From this, the weight of dye in the sheet is determined.

c. A point on the wavelength scale of the reflection curve is picked where maximum deviation is obtained for the dyed paper relative to the natural sheet. When the reflectance of the paper is stated it is always considered to be at this point.

d. The K/S values for all the papers are determined by the use of the equation, $K/S = (R_\infty - 1)^2 / 2R_\infty$, where $R_\infty$ is the reflectivity of the paper (Kubelka and Monk equation).

e. The K/S value for the natural sheet is subtracted from the K/S value for each of the other papers in order to get the K/S value due to the dye in each paper. It is assumed that the S values are not affected by the dyeing.

f. The weight of dye left in the sheet as determined by the method using Beer's law, see (b.) above, is set equal to the product of the corresponding K/S value and a constant. From this equation the value of the constant is determined.

g. The product of the constant, as determined in (f.) above, and the K/S value for a given sheet is equal to the weight of dye in that sheet.

h. From the weight of dye in the sheet the per cent retention is calculated.

4. Methods of Determining Chemical Constants for Pulps.

The methods used in determining the chemical constants of the pulps are as follows:

a. Lignin is determined by the Modified Forest Products Laboratory Method[4] (Institute Standard Method 13).

b. Alpha cellulose is determined by the T. A. P. P. I. Method T 203m[10] (Institute Standard Method 421).

c. The permanganate number is determined by a method published by R.H. Wiles[9] (Institute Standard Method 409).

d. The methoxyl content is determined according to the Viebock and Schwappach Method as published by E.P. Clark[1].

e. Total sulphur is determined by a micro chemical method as follows: The sample (3 grams) is placed in a large test tube, covered with concentrated nitric acid and heated gently until brown nitric acid fumes are evolved freely. Until the pulp is hydrolyzed, the reaction generates enough heat to maintain the rate of reaction. When the violent reaction subsides, heat is applied to complete the oxidation and boil off the excess acid. Small amounts of potassium chlorate are added occasionally to aid in the oxidation and furnish an alkali cation to combine with the sulphates formed by the oxidation. The test tube is boiled just to dryness to drive off all the nitric acid; the residue is then taken up in hydrochloric acid and analyzed for sulphates in the ordinary way using a micro chemical technique. This method is outlined by Holzer[3] and differs only in the weight of sample taken.

f. Inorganic sulphur is determined microchemically by analyzing the ash for sulphates in the usual way.

g. Organic sulfur is calculated by subtracting the inorganic from the total sulphur.

# CHAPTER IV

## DISCUSSION OF EXPERIMENTAL PROCEDURE

As has already been pointed out, Beer's law[2] has been used as the fundamental principle in the determination of the retention of dyes. The use of this method is dependent upon dye standards, solutions of known concentration for each dye, and a method of accurately comparing dyed white waters with the standard solutions. Beer's law requires that the logarithm of the transmittance vary linearly with the concentration. With graphs of this type it has been possible to determine the dye concentration in white waters from their corrected transmittance data, hence the retention may be calculated.

### A. Beer's Law.

In materials such as dye solutions which are homogeneous, the absorption of light by them depends upon the thickness in accordance with Bouger's law. Bouger set forth this law in 1729. It was further developed by Lambert and consequently is frequently called Lambert's law of absorption. Suppose that a layer of unit thickness transmits a fraction t of the light incident upon it. This layer will absorb a fraction (1 - t). Consequently a thickness x of the material will transmit the fraction $t^x$, and the intensity of the light transmitted is

$$I = I_o t^x$$

where $I_o$ is the intensity of the incident light. This expression may be written

$$I = I_o e^{-ax}$$

where a, the absorption coefficient, equals -log t. The absorption coefficient of a solution is in general proportional to the concentration of the solute. The absorption coefficient can therefore be written as

$$a = bc,$$

where c is the concentration and b is the absorption coefficient for unit concentration. With this substitution, the equation becomes

$$I = I_o e^{-bcx},$$

which is known as Beer's law. In the practical application of this law a cell of constant thickness was used to measure the transmittance, $I / I_o$, of a dyed solution. Beer's law can therefore be written as

$$I / I_o = e^{-kc}$$

where k equals bx. This expression may further be written as

$$\log I / I_o = \log e^{-kc} = -kc,$$

where $I / I_0$ is the transmittance by definition, or, in other words, the logarithm of the transmittance is a linear function of the concentration.

Dye standards for the dyes investigated were prepared and the logarithms of their transmittances were plotted against their concentrations for each dye. These results will be found in section B of the appendix. The resulting straight lines show that this law is applicable under the conditions of this investigation.

B. Correction for the Turbidity of White Waters.

The white water obtained from a natural sheet, that is, one to which no dye has been added, has a slightly cloudy appearance in comparison with distilled water even though it has been filtered. This fact shows up conclusively when the transmittance data of the two solutions are examined. For instance, the transmittance of unbleached sulphite white waters at 620 millimicrons is 83.0 per cent while that of distilled water is 97.4 per cent. (See section D of the appendix for natural white water data). A correction has to be made in order to put the white water data on a basis corresponding to that of the distilled water, and thus make the transmittance data of the white waters applicable to the graphical data set up by the known dye standards. In determining the nature of this correction, dye in known amounts was added to a natural white water and its transmittance determined. It was found that the product of the transmittance of a dyed white water and a constant gave a corrected transmittance reading which, when applied to the graphical results obtained with the standard dye solutions, produced a result within one per cent of the amount of dye added. The constant in these calculations is obtained for any given pulp by dividing the transmittance of distilled water by the transmittance of the natural white water at the same wavelength used in determining the transmittance of the dyed white water. Experimental results in this connection are shown in table 1.

TABLE 1.

ACTUAL AND CALCULATED DYE CONCENTRATION IN WHITE WATERS

| Dye Added Grams per Liter | Transmittance | Corrected Transmittance | Logarithm Corrected Transmittance | Dye Calculate Grams per Liter |
|---|---|---|---|---|
| 0 | 83.0 | 98.3* | 1.993 | 0 |
| 0.00375 | 64.0 | 75.9 | 1.880 | 0.00375 |
| 0.00750 | 49.7 | 58.9 | 1.770 | 0.00745 |

Note *. The corrected transmittance for 0 grams dye added is the transmittance of distilled water.

The turbidity of white waters for any given pulp is very nearly constant due to the fact that the white waters are put through a Jena filter of 1G1 porosity immediately after their separation from the pulp. Any deviation from the natural white water would throw the determination off because of an increase or a decrease in the scattering of light.

It has been noticed from transmittance data on dye standards that every dye solution has a transmittance equal to the transmittance of distilled water at some point in the visible wavelength band. For instance, it was noticed that a solution of Du Pont Victoria Green SC has exactly the same transmittance at 480 millimicrons as distilled water. Both Du Pont Brilliant Crocein FL and Pontamine Fast Red 8BL have transmittances equal to distilled water at 620 millimicrons. From this it may be postulated that a white water containing Du Pont Victoria Green SC should have the same transmittance at 480 millimicrons as its natural white water, that a white water containing Du Pont Brilliant Crocein FL should have the same transmittance at 620 millimicrons as its natural white water, etc. This has been found to be true with few exceptions. Exceptions, however, can be attributed only to a variation in turbidity because a white water is made up of only three things, distilled water, dye, and the so-called turbidity or light scattering material. If the deviations were in the dye or water, deviations would be seen in the dye standards at this point. These deviations may be corrected for without much loss in accuracy if the results do not show a greater variation than a few tenths of one per cent. For example, if the transmittance of a white water solution containing Du Pont Victoria Green SC is 0.2 per cent low at 480 millimicrons where it should coincide with the transmittance of the natural white water, then 0.2 per cent is added to the transmittance of this solution at 620 millimicrons which is the point used in calculating dye retentions for that particular dye. If, however, the transmittance is 0.2 per cent too high at the coinciding point, then 0.2 per cent is subtracted from the transmittance of the dye at 620 millimicrons, etc. Proof that small corrections of this nature do not impare the accuracy of the results was obtained by studying white waters with varying amounts of turbidity. The white water from a natural sheet of unbleached sulphite was divided into three equal parts. The first part was undiluted, the second part was diluted by one half of its volume with distilled water, while the third part was diluted by twice its volume. These solutions then contained amounts of turbidity per unit volume in the ratios of one, two thirds, and one third. The transmittances of these solutions, along with distilled water, were then determined at 500 and 600 millimicrons. The results are tabulated in table 2. It is

TABLE 2.

TRANSMITTANCE OF WHITE WATER WITH VARYING AMOUNTS OF TURBIDITY

| Turbidity Ratio | 0 | 1/3 | 2/3 | 1 |
|---|---|---|---|---|
| Transmittance at 500 millimicrons | 94.0 | 86.6 | 80.5 | 75.1 |
| Transmittance at 600 millimicrons | 97.4 | 91.8 | 87.2 | 83.0 |

apparent from table 2 that the difference in transmittance between the ratios of one and two thirds turbidity per unit volume is not the same at 500 and 600 millimicrons being 5.4 and 4.2 per cent respectively. If these differences had been equal, corrections of any magnitude could be made. However, in this case, a maximum correction of only 0.3 per cent can be made without reducing the accuracy of the method. A correction of 0.3 per cent amounts roughly to a 2 per cent change in the amount of turbidity present in the standard, and the assumption can be made for the purpose of a rough calculation that the turbidity changes as a linear function of the transmittance. Then (0.3)(0.33)(100)/5.4 or 1.85 per cent change in turbidity is equal to a 0.3 per cent change in the transmittance. Now if a 0.3 per cent error was noticed at the coincidence point, 500 millimicrons for example, and corrected for at 600 millimicrons by adding to or subtracting from the transmittance at that point, an error would be introduced. Instead of a 0.3 per cent correction only (0.3)(4.2)/5.4 or 0.233 per cent correction should have been made. However, if a correction no larger than 0.3 per cent is used, the accuracy of the method will not be impaired. The points, 500 and 600 millimicrons, were arbitrarily chosen and the results obtained therefrom are typical of the results that would be obtained with any dye.

Due to the fact that the turbidity in white water settles out with time, it was found necessary to vigorously agitate the white water solution and to make the transmittance determination at a definite time after this agitation. Actual settling rates for the turbidity produced in an unbleached sulphite white water are shown in table 3 at wavelengths of 500 and 600 millimicrons.

TABLE 3

SETTLING RATES FOR TURBIDITY IN AN UNBLEACHED SULPHITE WHITE WATER

| Time of settling Minutes | 0 | 3 | 6 | 9 | 12 |
|---|---|---|---|---|---|
| Transmittance at 500 millimicrons | 75.1 | 76.1 | 76.7 | 77.1 | 77.4 |
| Transmittance at 600 millimicrons | 83.0 | 84.0 | 84.5 | 84.9 | 85.2 |

C. Method of Determining Dye Retention by the Use of Beer's Law.

The determination of dye retention by the use of Beer's law has already been given. In addition, a discussion of the method will be given at this point in order to furnish a clear understanding of the way in which the retention calculations were handled. For the most part, dyeings were made at 0.6 per cent consistency by adding 3.0000 grams of pulp to 500 cubic centimeters of water. At other consistencies, the weight of pulp was varied, but the volume of water was always kept constant. The volume of white water obtained when these conditions were used amounted to 470 cubic centimeters.

The transmittance of the dyed white water was determined and corrected in the manner which has already been discussed. Dye concentration corresponding to the corrected transmittance was then obtained from the plotted standard dye solution data. The concentration obtained in this way was converted into weight of dye present by multiplying by 470 (the volume of the white water in cubic centimeters) and dividing by 1000. The per cent retention of dye was determined by subtracting the amount in the white water from the amount originally used, dividing the result by the amount originally used, and multiplying by 100. Sample calculations, starting with the corrected transmission, are given in table 4 for Du Pont Victoria Green SC on unbleached sulphite. Complete calculations for all the work carried out in this investigation are tabulated in section A of the appendix.

TABLE 4

SAMPLE CALCULATIONS FOR THE DETERMINATION OF PER CENT DYE RETENTION BY THE METHOD USING BEER'S LAW

| Corrected Transmittance | Log Corrected Transmittance | Conc. of White Water | Gms. of Dye in White Water | Gms. of Dye Used | Gms. of Dye in Sheet | Per Cent Retention |
|---|---|---|---|---|---|---|
| 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| 92.5 | 1.966 | .000895 | .000420 | .0090 | .00858 | 95.3 |

D. Limits of Error in the Retention Method Using Beer's Law.

In examining the errors inherent in the retention method using Beer's law for determining dye retentions, it was found that dyed white water solutions could be produced under identical conditions which would not vary more than one tenth per cent in transmittance. It was also found that the color analyzer would reproduce results within one tenth per cent. With this in mind, the error in retention was determined when the transmittance was purposely changed by one tenth per cent for the $\frac{1}{2}$, 1, and 3 pound dyeings of Du Pont Victoria Green SC, Du Pont Brilliant Crocein FL, and Pontamine Fast Red 8BL on unbleached sulphite. These three dyes are representative of the three common classes of dyestuffs and give a general idea of the errors to be expected for any dye.

It was found in carrying out this calculation that as the transmittance of a given dye solution for a given weight dyeing was varied, the per cent retention varied as a linear function of the transmittance. In the light of this fact a change in the transmittance could be arbitrarily made to correspond to a possible error, the per cent retention determined, and then the change due to 0.1 per cent change in transmittance calculated. Accuracy was conserved in this way. The calculations for Du Pont Victoria Green SC are shown in table 5. A sample calculation will be shown for a one half pound dyeing of this dye. The transmittance changes 14.0 per cent as the retention changes 79.0 per cent. Due to the fact that per cent retention is a linear function of transmittance as is shown graphically in figures 2, 3, and 4, the per cent change in retention due to one tenth per cent change in transmittance can be calculated by dividing 79.0 by 140. The result is 0.564 per cent. Calculations for Du Pont Brilliant Crocein FL and Pontamine Fast Red 8BL are shown in tables 6 and 7 while a summary of all the data concerning errors to be expected with the dyes studied is shown in table 8.

TABLE 5

RETENTION OF DU PONT VICTORIA GREEN SC AS TRANSMITTANCE IS PURPOSELY VARIED

| POUNDS DYE PER 1000 POUNDS PULP | TRANS-MITTANCE | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GMS. DYE IN WHITE WATER | GMS. DYE USED | GMS. DYE IN SHEET | PER CENT RETENTION |
|---|---|---|---|---|---|---|---|---|
| ½ | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 80.0 | 93.6 | 1.971 | .000710 | .000335 | .0015 | .001166 | 77.8 |
| | 70.0 | 82.0 | 1.914 | .002620 | .001185 | .0015 | .000313 | 21.0 |
| 1 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 80.0 | 93.6 | 1.971 | .000710 | .000335 | .0030 | .002665 | 88.7 |
| | 70.0 | 82.0 | 1.914 | .002620 | .001185 | .0030 | .001815 | 60.4 |
| 3 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 80.0 | 93.6 | 1.971 | .000710 | .000335 | .0090 | .008665 | 96.3 |
| | 70.0 | 82.0 | 1.914 | .002620 | .001185 | .0090 | .007815 | 86.8 |

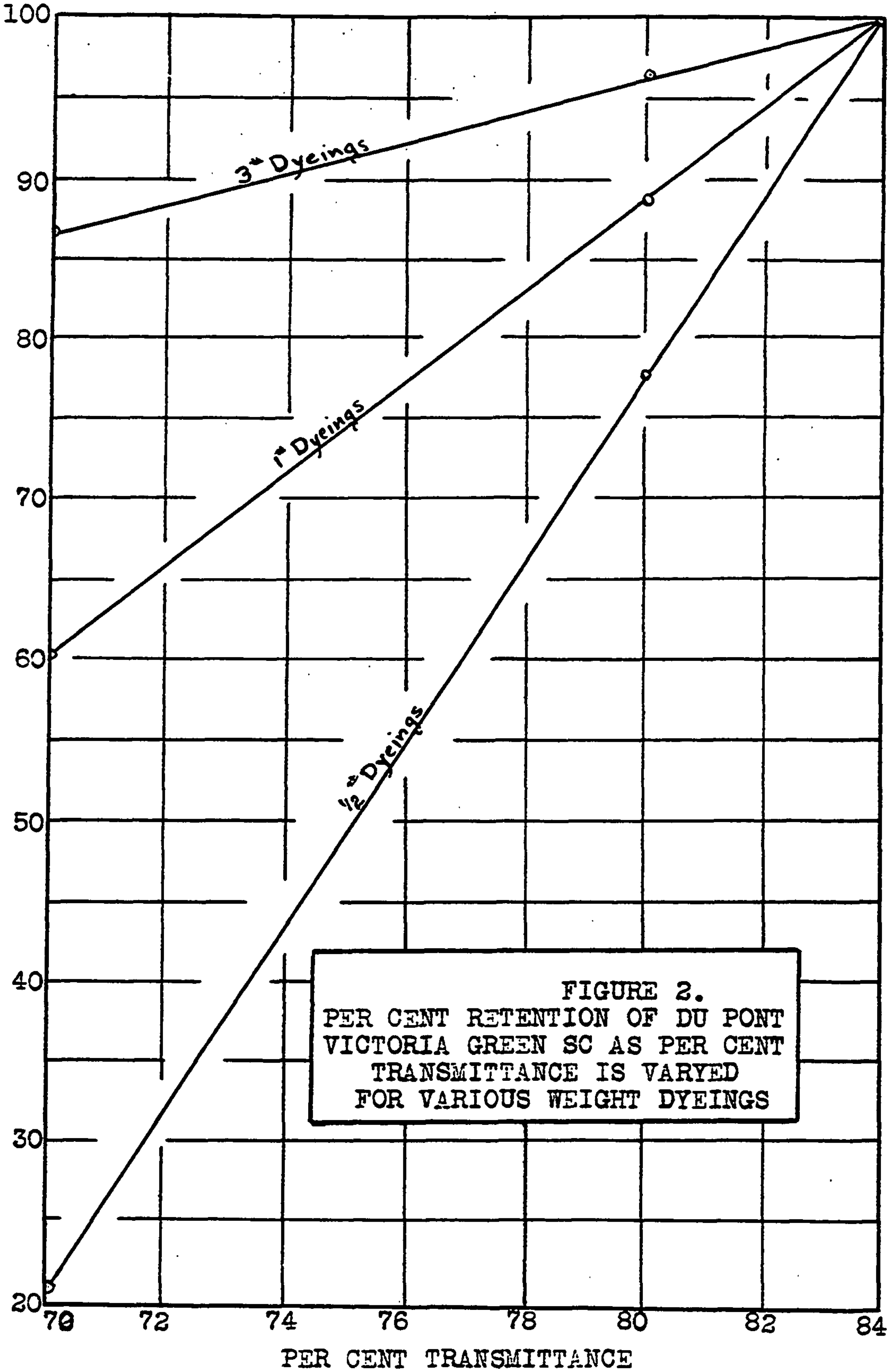



FIGURE 2.
PER CENT RETENTION OF DU PONT VICTORIA GREEN SC AS PER CENT TRANSMITTANCE IS VARYED FOR VARIOUS WEIGHT DYEINGS

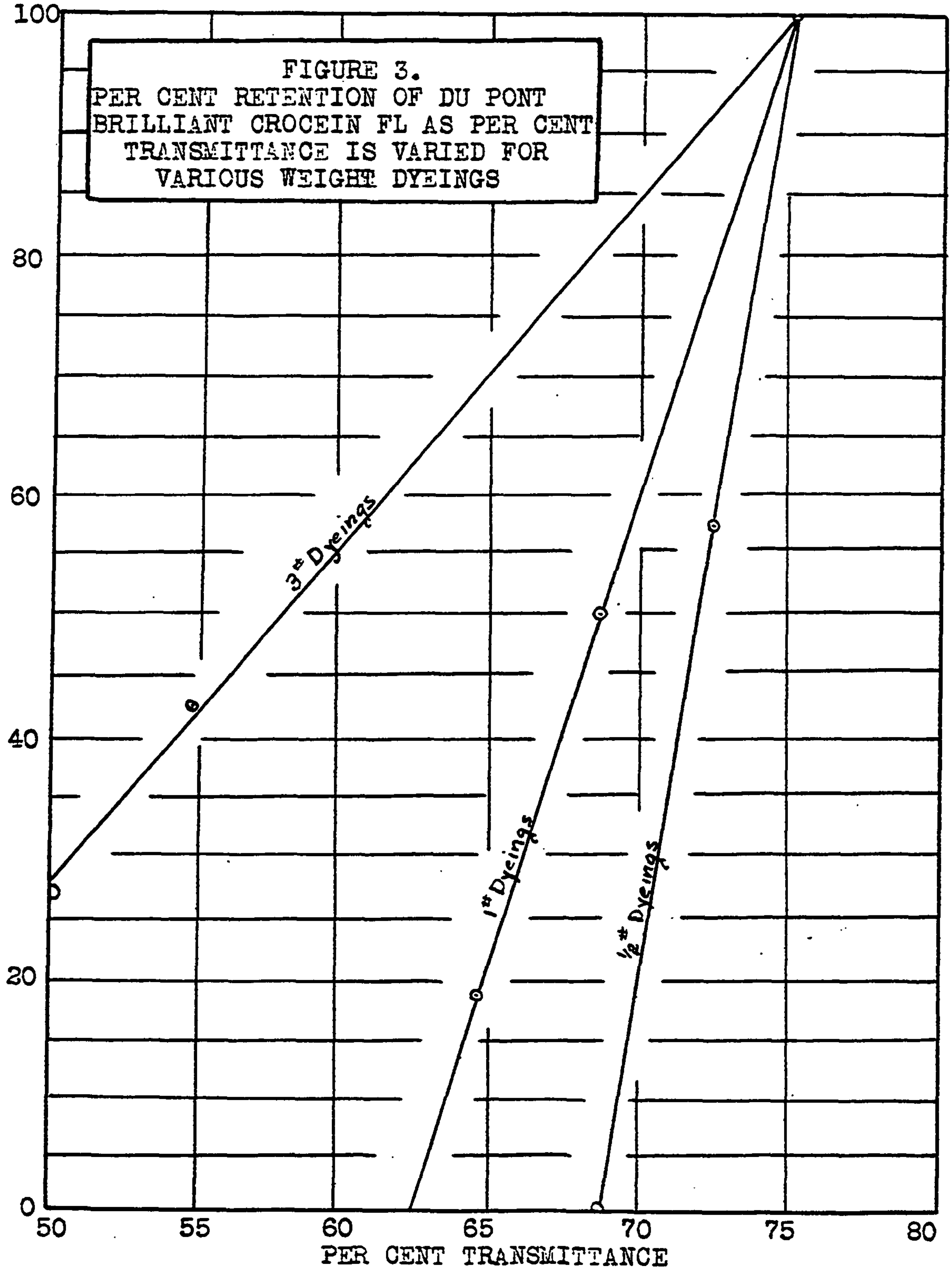



FIGURE 3.
PER CENT RETENTION OF DU PONT BRILLIANT CROCEIN FL AS PER CENT TRANSMITTANCE IS VARIED FOR VARIOUS WEIGHT DYEINGS

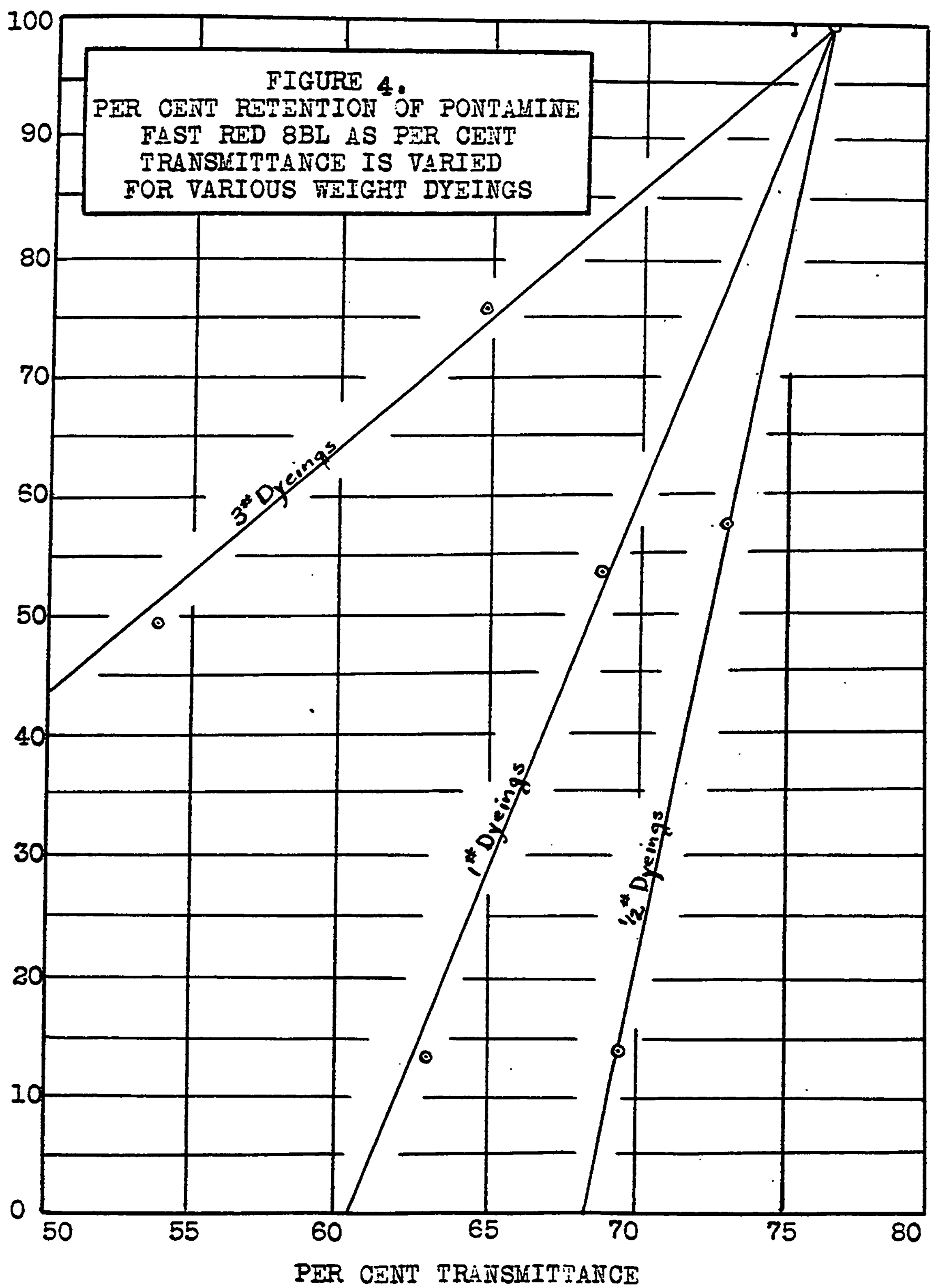


FIGURE 4.
PER CENT RETENTION OF PONTAMINE
FAST RED 8BL AS PER CENT
TRANSMITTANCE IS VARIED
FOR VARIOUS WEIGHT DYEINGS
100
90
80
70
60
50
40
30
20
10
0
50
55
60
65
70
75
80
3# Dyeings
1# Dyeings
1/2# Dyeings
PER CENT TRANSMITTANCE

TABLE 6

RETENTION OF DU PONT BRILLIANT CROCEIN FL AS TRANSMITTANCE IS PURPOSELY VARIED

| POUNDS DYE PER 1000 POUNDS PULP | TRANS- MITTANCE | COR- RECTED TRANS- MISSION | LOG COR- RECTED TRANS- MISSION | CONCEN- TRATION OF WHITE WATER | GMS. DYE IN WHITE WATER | GMS. DYE USED | GMS. DYE IN SHEET | PER CENT RETENTION |
|---|---|---|---|---|---|---|---|---|
| ½ | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 72.2 | 90.4 | 1.956 | .001350 | .000635 | .0015 | .000865 | 57.7 |
| | 68.5 | 85.7 | 1.933 | .003190 | .001500 | .0015 | 0 | 0 |
| 1 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 68.5 | 85.7 | 1.933 | .003190 | .001500 | .0030 | .001500 | 50.0 |
| | 64.5 | 80.7 | 1.907 | .005200 | .002440 | .0030 | .000560 | 18.7 |
| 3 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 54.4 | 68.1 | 1.833 | .011100 | .005240 | .0090 | .003760 | 41.8 |
| | 50.0 | 62.6 | 1.797 | .014000 | .006580 | .0090 | .002420 | 26.9 |

TABLE 7

RETENTION OF PONTAMINE FAST RED 8BL AS TRANSMITTANCE IS PURPOSELY VARIED

| POUNDS DYE PER 1000 POUNDS PULP | TRANS-MITTANCE | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GMS. DYE IN WHITE WATER | GMS. DYE USED | GMS. DYE IN SHEET | PER CENT RETENTION |
|---|---|---|---|---|---|---|---|---|
| ½ | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 72.9 | 89.9 | 1.954 | .001340 | .000630 | .0015 | .000870 | 58.0 |
| | 69.5 | 58.6 | 1.932 | .002750 | .001290 | .0015 | .000210 | 14.0 |
| 1 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 68.8 | 84.9 | 1.929 | .002940 | .001380 | .0030 | .001620 | 54.0 |
| | 62.8 | 77.4 | 1.889 | .005520 | .002595 | .0030 | .000405 | 13.5 |
| 3 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 64.8 | 80.0 | 1.903 | .004570 | .002150 | .0090 | .006850 | 76.1 |
| | 53.8 | 66.4 | 1.822 | .009750 | .004580 | .0090 | .004420 | 49.1 |

TABLE 8.

SUMMARY OF ERRORS TO BE EXPECTED WHEN TRANSMITTANCE VARIES 0.1 PER CENT

| Pounds Dye per 1000 Pounds Pulp | ½ | 1 | 3 |
|---|---|---|---|
| Du Pont Victoria Green SC | | | |
| Difference in Transmittance (%) | 14.0 | 14.0 | 14.0 |
| Difference in Retention (%) | 79.0 | 39.6 | 13.2 |
| Error in Retention Due to 0.1% Change in Transmittance (%) | 0.564 | 0.282 | 0.094 |
| Du Pont Brilliant Crocein FL | | | |
| Difference in Transmittance (%) | 6.6 | 10.6 | 25.1 |
| Difference in Retention (%) | 100.0 | 81.3 | 73.1 |
| Error in Retention Due to 0.1% Change in Transmittance (%) | 1.516 | 0.767 | 0.291 |
| Pontamine Fast Red 8BL | | | |
| Difference in Transmittance (%) | 7.2 | 13.9 | 22.9 |
| Difference in Retention (%) | 86.0 | 86.5 | 50.9 |
| Error in Retention Due to 0.1% Change in Transmittance | 1.190 | 0.622 | 0.222 |

E. Results.

The results of this investigation may be divided up into ten sections, each section of which takes into consideration one of the variables that is important in the dyeing reaction while all the rest of the variables are held constant. In this way it has been possible to study the retention of the various dyes on various stocks under various conditions. The standard conditions used in this work were 0.6 per cent consistency, 4.9 pH obtained by the use of sulphuric acid, a temperature of 20°C., 10 minutes reaction time, and, unless otherwise stated, these conditions were held constant in each determination. Dyes, Du Pont Victoria Green SC, Du Pont Brilliant Croċein FL, and Pontamine Fast Red 8BL, which are basic, acid, and direct, respectively, were used as typical examples throughout the investigation. Sulphuric acid was used in most of the work because alum produced a flock in the white water which was undesirable. Results in part 10 of this section justify this use of sulphuric acid.

Before discussing these results in detail, one general conclusion, which is true in every part of this investigation, can be made, namely, that for any given dye under identical conditions of time, temperature, consistency, etc., the one half pound dyeings are retained by a given pulp to a greater extent than those using more dye.

1. Retention on Sulphite Pulp Bleached to Various Degrees.

Unbleached sulphite pulp was bleached to five different degrees and dyed, in addition to the unbleached pulp, with the three typical dyestuffs in four different strengths ($\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings). The retention data are tabulated in table 9 and are shown graphically in figures 5, 6, and 7. The chemical constants of these pulps are tabulated in table 10. Du Pont Victoria Green SC was retained better than either Du Pont Brilliant Crocein FL or Pontamine Fast Red 8BL with the acid dye being retained the least. The basic dyestuff is retained to the extent of 97.9 per cent for a one half pound dyeing on unbleached sulphite, while the acid and direct dyes were retained 57.7 and 58.0 per cent respectively.

It has been believed that basic dyestuffs attach themselves to lignified fibers much better than dyes of other classes. In addition, it has

TABLE 9.

PER CENT RETENTION ON SULPHITE PULP BLEACHED

TO VARIOUS DEGREES.

| Per Cent Bleach | Pounds Dye per 1000 Pounds Pulp | Du Pont Victoria Green SC Per Cent | Du Pont Brilliant Crocein FL Per Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| 0 | ½ | 97.9 | 57.7 | 58.0 |
| | 1 | 96.5 | 50.0 | 54.0 |
| | 1½ | 96.0 | 45.7 | 52.2 |
| | 3 | 95.3 | 41.8 | 49.1 |
| 3 | ½ | 98.9 | 54.0 | 48.4 |
| | 1 | 98.2 | 44.9 | 44.3 |
| | 1½ | 97.6 | 40.1 | 42.3 |
| | 3 | 96.7 | 35.0 | 39.1 |
| 6 | ½ | 98.2 | 54.9 | 51.8 |
| | 1 | 97.0 | 46.0 | 48.5 |
| | 1½ | 96.4 | 41.2 | 46.5 |
| | 3 | 95.7 | 37.1 | 43.2 |
| 10 | ½ | 97.3 | 56.4 | 56.8 |
| | 1 | 96.0 | 47.1 | 52.6 |
| | 1½ | 95.1 | 42.8 | 50.9 |
| | 3 | 94.2 | 39.1 | 48.4 |
| 20 | ½ | 93.0 | 60.0 | 59.9 |
| | 1 | 91.2 | 52.0 | 56.7 |
| | 1½ | 90.2 | 47.6 | 54.9 |
| | 3 | 89.1 | 42.4 | 51.8 |
| 30 | ½ | 87.9 | 62.0 | 64.0 |
| | 1 | 86.4 | 53.8 | 61.0 |
| | 1½ | 85.8 | 49.0 | 59.1 |
| | 3 | 85.0 | 43.3 | 56.2 |

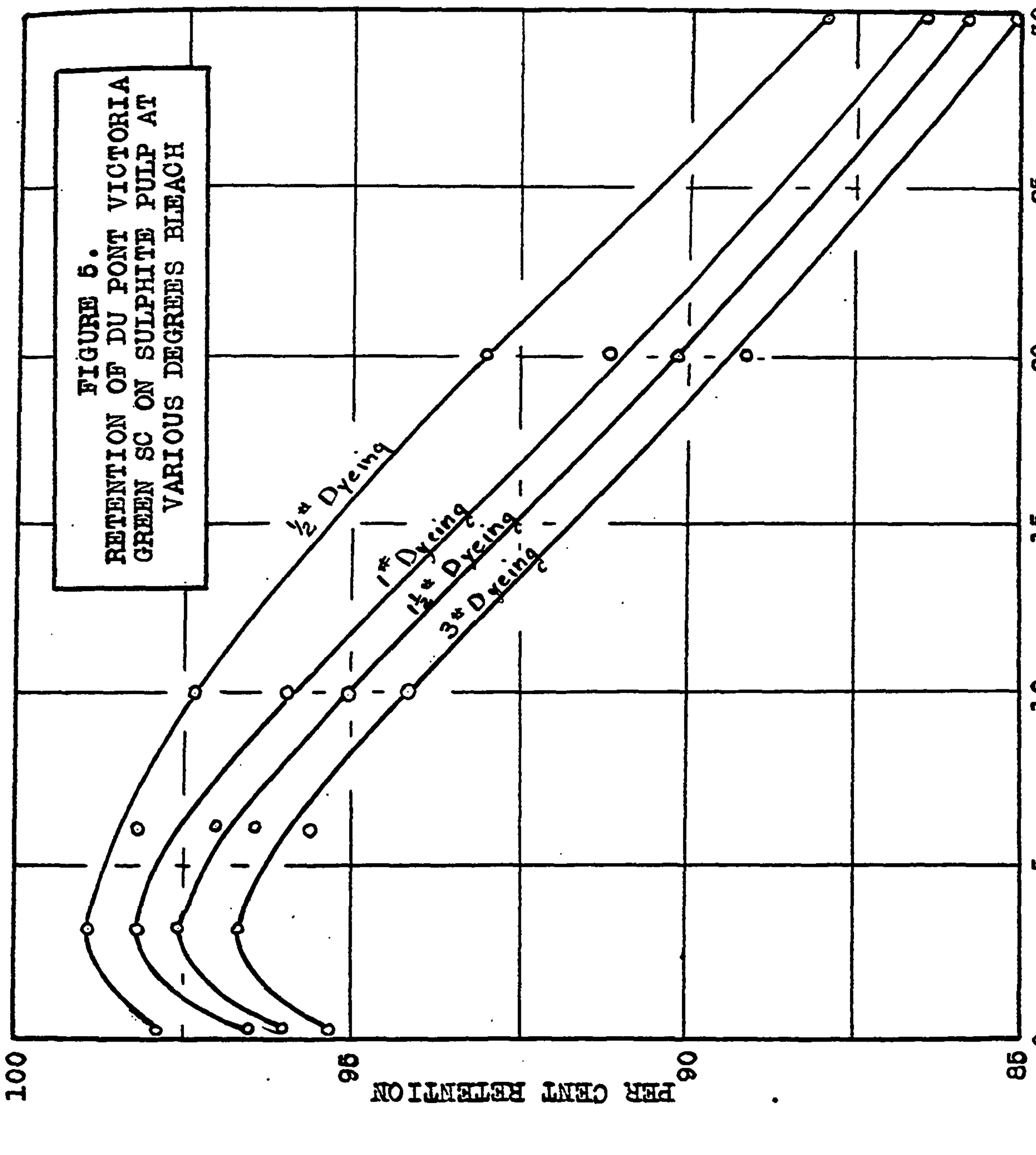



FIGURE 5.
RETENTION OF DU PONT VICTORIA GREEN SC ON SULPHITE PULP AT VARIOUS DEGREES BLEACH

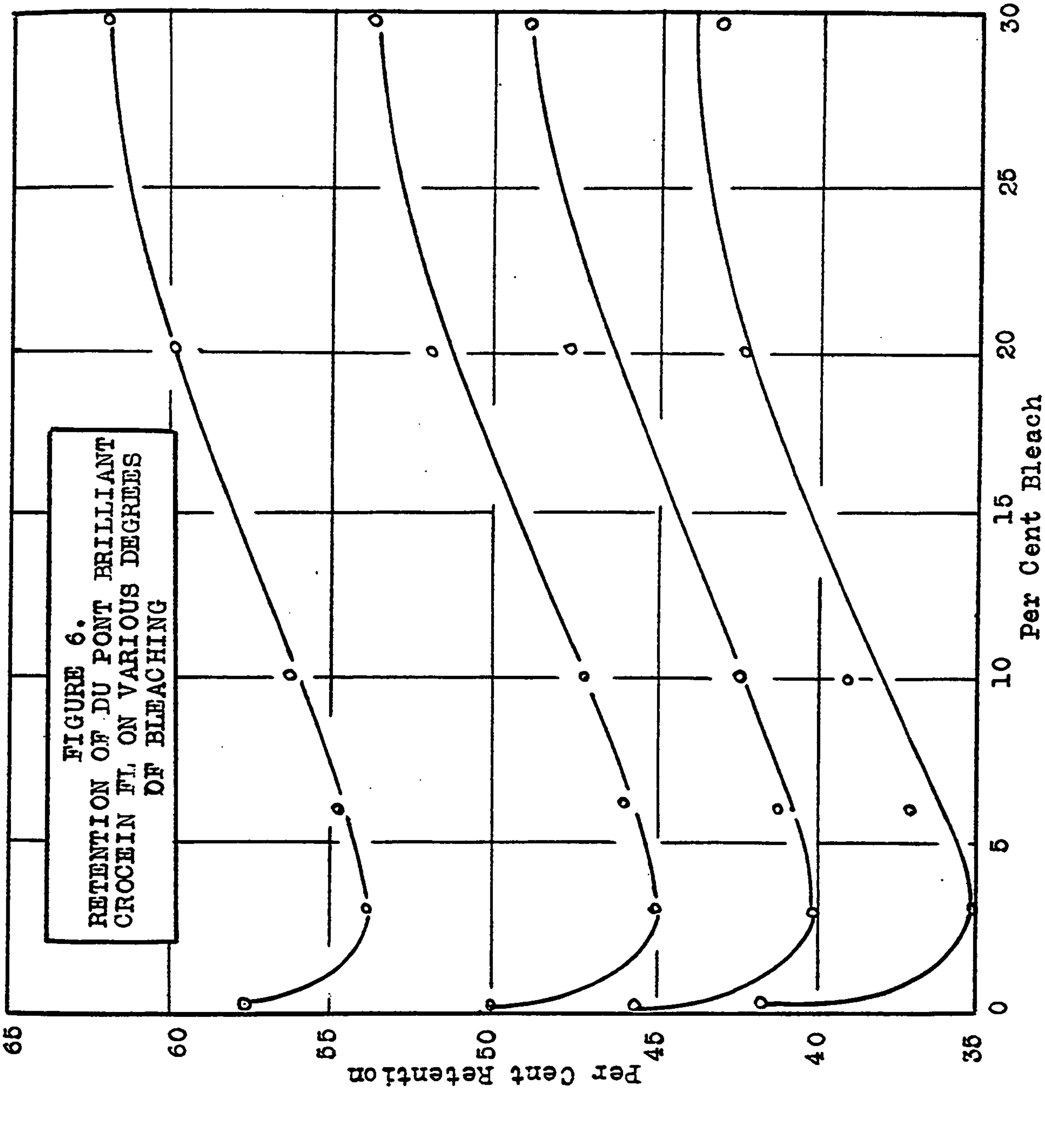



FIGURE 6.
RETENTION OF DU PONT BRILLIANT CROCEIN FL ON VARIOUS DEGREES OF BLEACHING

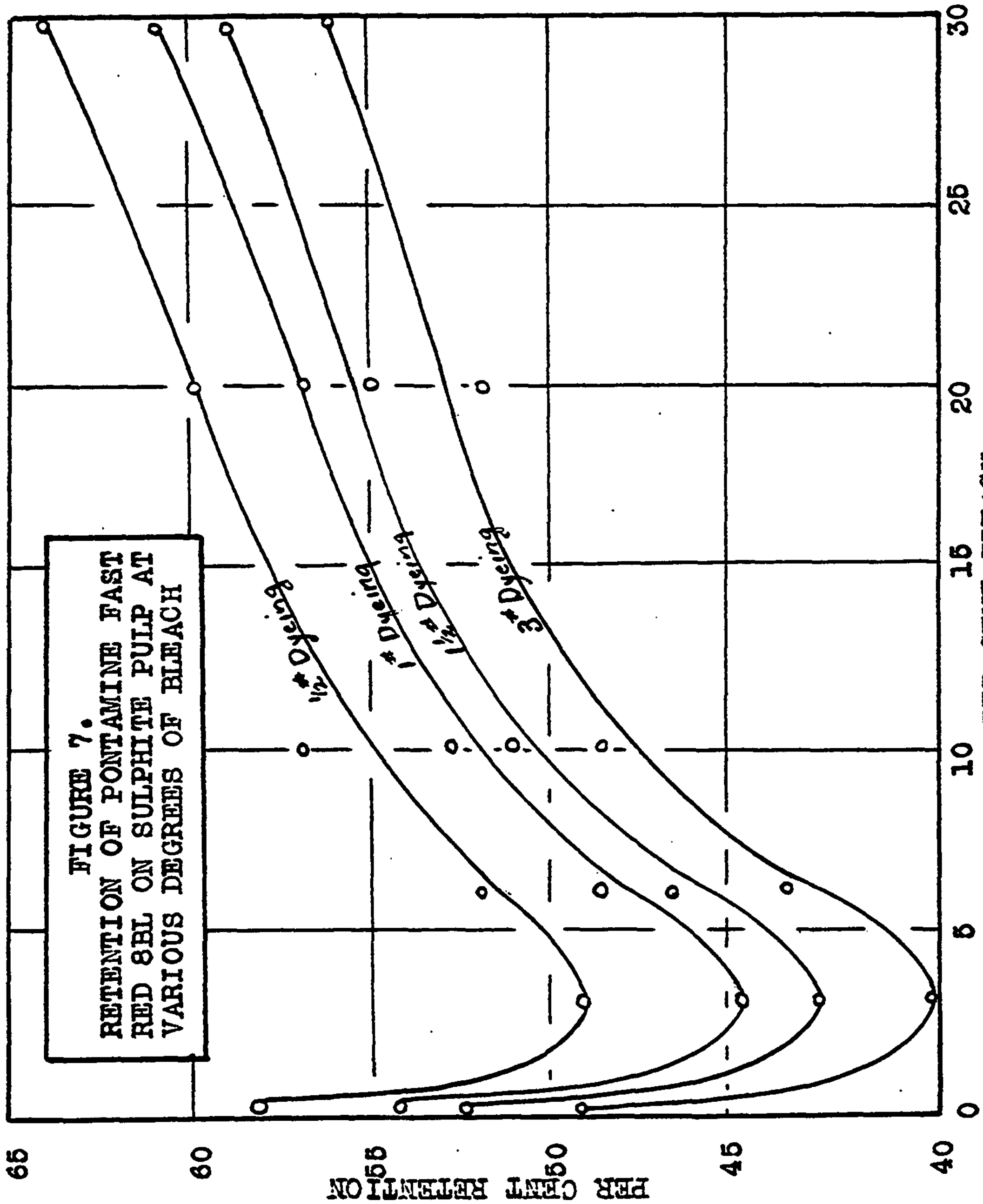



FIGURE 7.
RETENTION OF PONTAMINE FAST RED 8BL ON SULPHITE PULP AT VARIOUS DEGREES OF BLEACH

TABLE 10.

CHEMICAL CONSTANTS OF SULPHITE PULPS BLEACHED TO VARIOUS DEGREES

| Per Cent Bleach | 0 | 3 | 6 | 10 | 20 | 30 |
|---|---|---|---|---|---|---|
| Per Cent Lignin | 2.45 | 1.83 | 0.88 | 0.42 | 0.35 | 0.26 |
| Per Cent Methoxyl | 1.34 | 1.15 | 0.86 | 0.62 | 0.54 | 0.45 |
| Permanganate Number | 17.4 | 15.7 | 13.2 | 11.8 | 6.3 | 4.7 |
| Per Cent Alpha Cellulose | 82.9 | 82.7 | 82.4 | 81.7 | 81.0 | 80.7 |
| Per Cent Total Sulphur | 1.96 | 1.66 | 1.41 | 1.10 | 0.54 | 0.21 |
| Per Cent Inorganic Sulphur | 0.20 | 0.17 | 0.12 | 0.04 | 0.03 | 0.02 |
| Per Cent Organic Sulphur | 1.76 | 1.49 | 1.29 | 1.06 | 0.51 | 0.19 |

further been accepted that the more lignin present, the better the dye retention. This, however, is not always the case as can be seen from figure 6. (5) Du Pont Victoria Green SC is retained better on a lignified fiber which has been slightly bleached. It will be noticed that the retention increases from 97.9 per cent for the unbleached sulphite to 98.9 per cent for the same fiber bleached with three per cent bleach. Also it is noticed from table 2 that the lignin content of the slightly bleached fiber was only 1.83 per cent while the unbleached fiber had a 2.45 per cent lignin content. The most plausible explanation for this result is that the lignin present in the slightly bleached pulp has been chlorinated and, in this condition, has a greater affinity for the basic dye. It must also be taken into account that the unbleached pulp was extremely hard, having a lignin content of 2.45 per cent, a permanganate number of 17.4, and a bleach consumption of 32 per cent. Rys[5] has pointed out that more chlorination takes place during hypochlorite bleaching in hard pulps than in soft pulps. Another point which is evidence that the lignin in the slightly bleached pulp has been chlorinated is its brightness. The slightly bleached pulp has a lower brightness than the unbleached pulp even though its lignin content is lower. The brightness of the unbleached pulp as measured by the General Electric Reflection Meter, filter number 1, is 54.2 per cent while that of the slightly bleached pulp is only 50.8 per cent. As the brightness of the pulp is increased by the use of more bleach, a decided drop in retention is observed. In the light of these facts then, it can be said that basic dyes are attracted by lignin but in different amounts depending upon the physical and chemical properties of the pulp.

In the case of Du Pont Brilliant Crocein FL and Pontamine Fast Red 8BL, exactly the opposite results are obtained. From figures 7 and 8 it can be seen that, when unbleached sulphite is bleached slightly, a decrease in the retentions are obtained with these dyestuffs. However, with further bleaching, the dyes are retained ever increasingly.

From these results then, it might be concluded that the amount of the lignin, as well as it's character, plays an important role in so far as dye retention on sulphite pulp is concerned.

2. Retention on Kraft Pulp Bleached to Various Degrees.

In studying the retention of dyes on kraft pulp bleached to various degrees, unbleached kraft pulp was bleached to four different degrees and dyed, in addition to the unbleached pulp, with the three typical dyestuffs in four different strengths ($\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings). The retention data are tabulated in table 11 and are shown graphically in figures 8, 9, and 10. The chemical constants of these pulps are tabulated in table 12.

TABLE 11.

RETENTION ON KRAFT PULP BLEACHED TO VARIOUS DEGREES

| Per Cent Bleach | Pounds Dye per 1000 Pounds Pulp | Du Pont Victoria Green SC Per Cent | Du Pont Brilliant Crocein FL Per Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| 0 | ½ | 98.3 | 54.5 | 50.0 |
| | 1 | 97.2 | 46.3 | 47.6 |
| | 1½ | 96.6 | 42.6 | 46.6 |
| | 3 | 95.5 | 39.4 | 45.0 |
| 5 Single Stage | ½ | 97.3 | 44.0 | 54.5 |
| | 1 | 95.7 | 37.0 | 51.9 |
| | 1½ | 94.8 | 34.2 | 50.4 |
| | 3 | 93.4 | 31.1 | 48.4 |
| 15 Double Stage | ½ | 94.2 | 46.4 | 56.8 |
| | 1 | 92.6 | 39.8 | 54.2 |
| | 1½ | 91.6 | 37.0 | 52.8 |
| | 3 | 90.7 | 34.0 | 50.7 |
| 30 Double Stage | ½ | 91.4 | 48.0 | 58.8 |
| | 1 | 89.8 | 40.8 | 56.3 |
| | 1½ | 88.8 | 37.9 | 54.9 |
| | 3 | 87.6 | 34.9 | 53.0 |
| 40 Triple Stage | ½ | 88.5 | 49.9 | 60.0 |
| | 1 | 87.1 | 42.6 | 57.4 |
| | 1½ | 86.5 | 39.5 | 56.2 |
| | 3 | 85.7 | 36.5 | 54.1 |

On kraft pulp the basic dye was retained better than any other class of dyes. For one half pound dyeings, the retention of Du Pont Victoria Green SC varied between 88.5 per cent for highly bleached pulp and 98.3 per cent for the unbleached, figure 8. As the lignin decreases in the pulp,

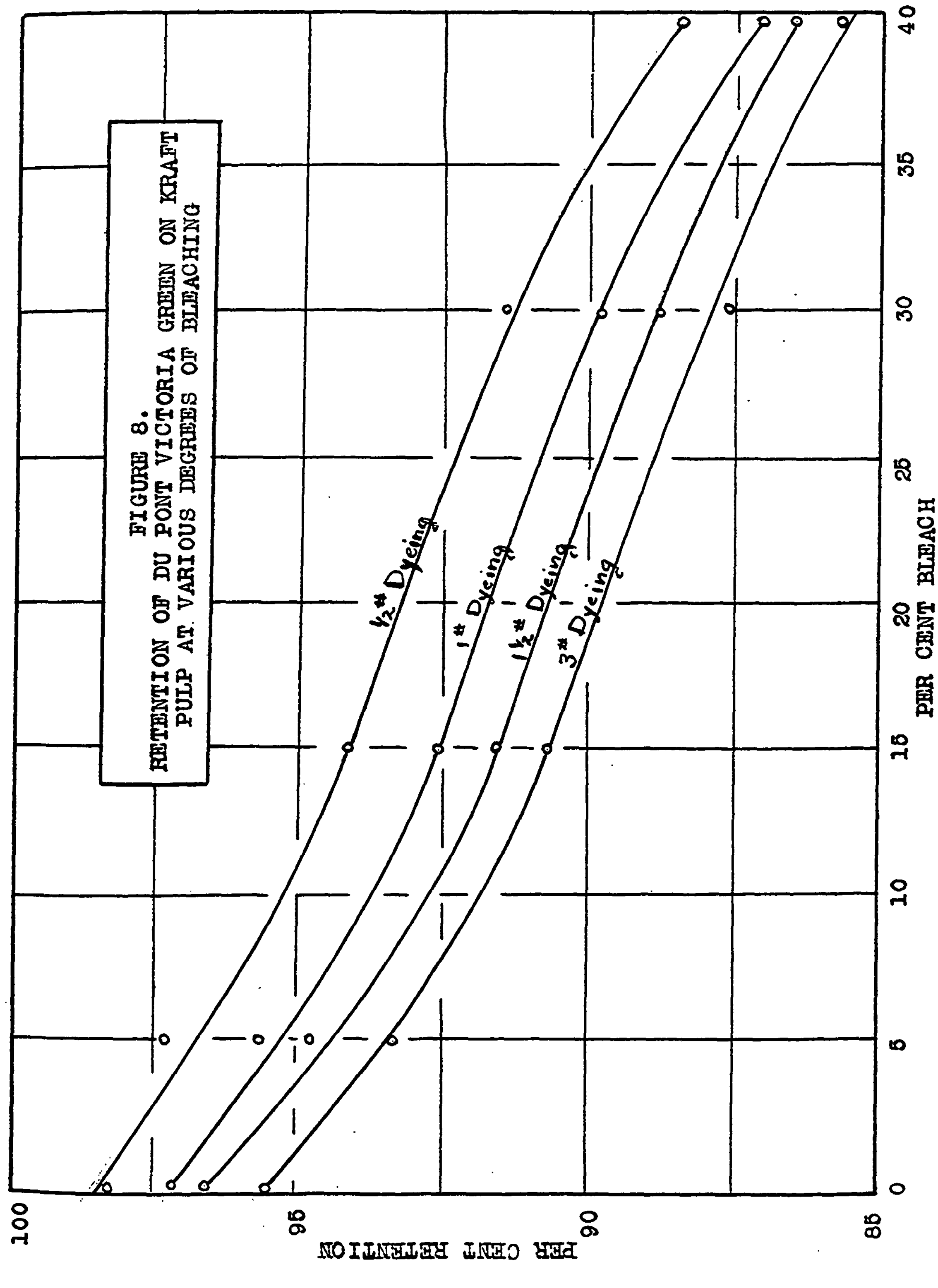



FIGURE 8.
RETENTION OF DU PONT VICTORIA GREEN ON KRAFT PULP AT VARIOUS DEGREES OF BLEACHING

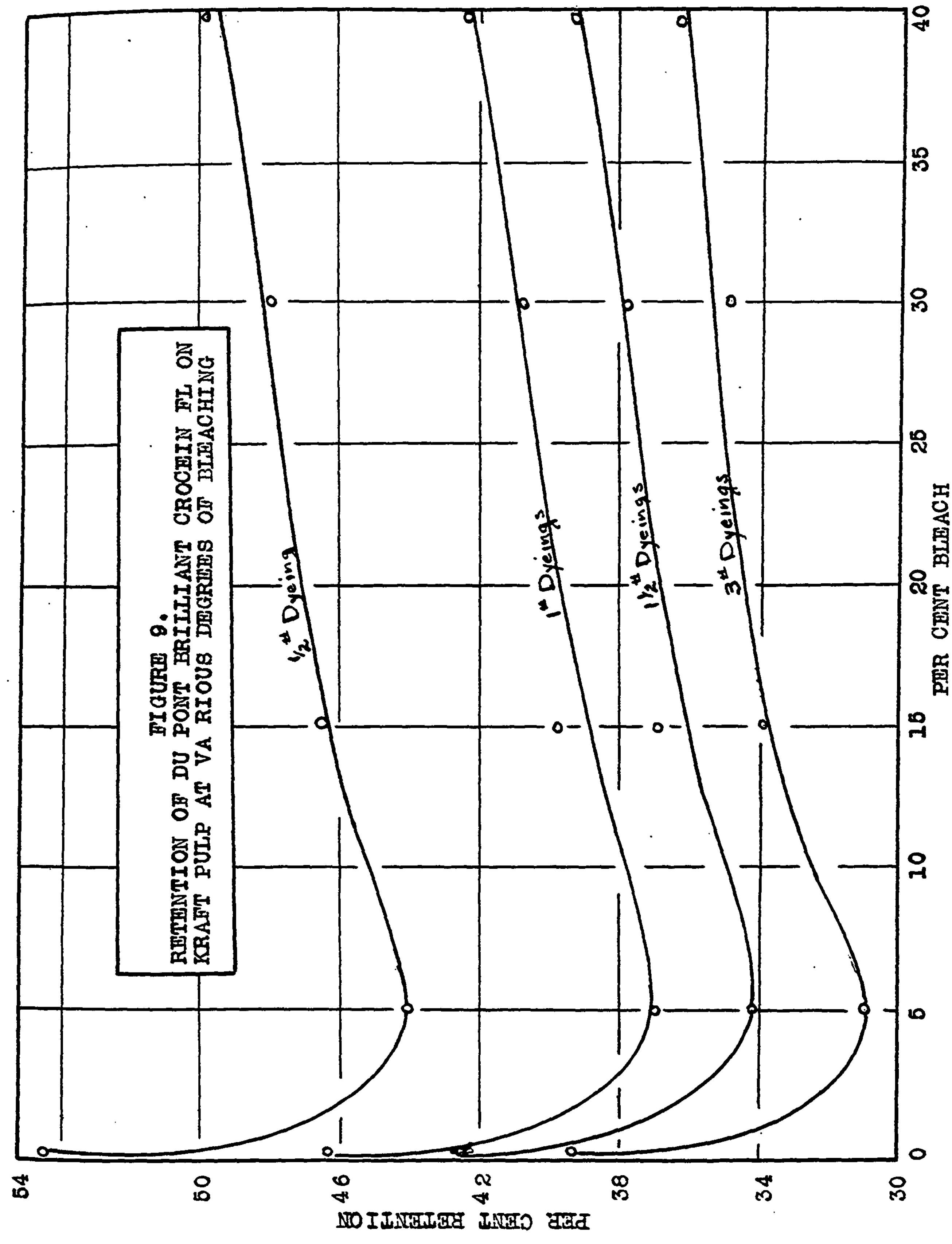



FIGURE 9.
RETENTION OF DU PONT BRILLIANT CROCEIN FL ON KRAFT PULP AT VA RIOUS DEGREES OF BLEACHING

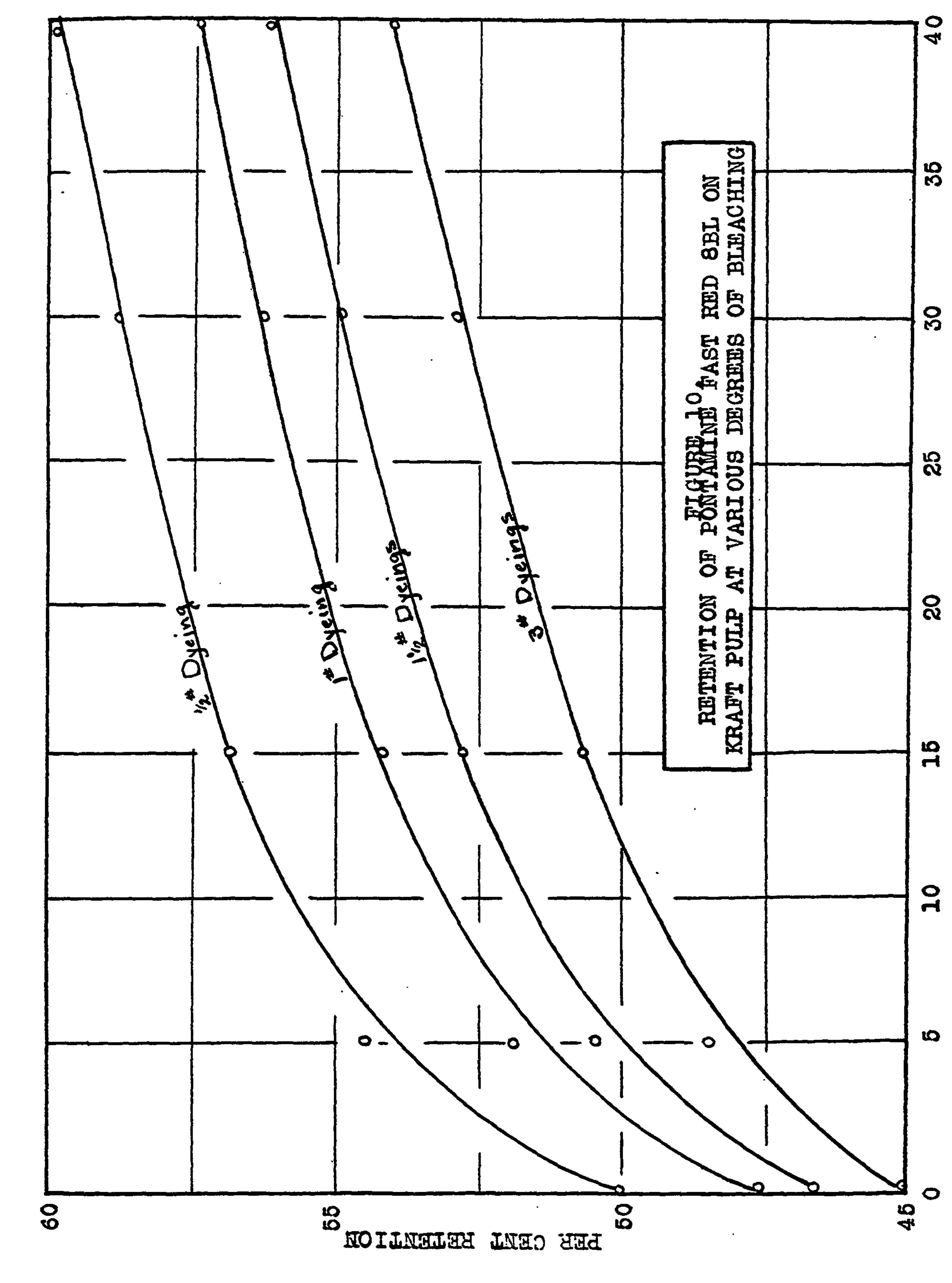



FIGURE 10.
RETENTION OF PONTAMINE FAST RED 8BL ON
KRAFT PULP AT VARIOUS DEGREES OF BLEACHING

TABLE 12.

CHEMICAL CONSTANTS OF KRAFT PULPS BLEACHED TO VARIOUS DEGREES

| Per Cent Bleach | 0 | 5 | 15 | 30 | 40 |
|---|---|---|---|---|---|
| Per Cent Lignin | 8.7 | 5.7 | 4.2 | 2.7 | 2.0 |
| Per Cent Methoxyl | 1.885 | 1.450 | 1.120 | 0.750 | 0.416 |
| Permanganate Number | 26.0 | 22.4 | 17.9 | 8.1 | 5.0 |
| Per Cent Alpha Cellulose | 88.3 | 87.3 | 85.1 | 80.1 | 78.5 |
| Per Cent Total Sulphur | 0.0708 | 0.0670 | 0.0595 | 0.0414 | 0.0367 |
| Per Cent Inorganic Sulphur | 0.0316 | 0.0300 | 0.0262 | 0.0173 | 0.0149 |
| Per Cent Organic Sulphur | 0.0398 | 0.0370 | 0.0333 | 0.0241 | 0.0218 |

the per cent retention of basic dyes decreases and in a uniform manner. If the character of the lignin had been changed by bleaching (which was apparently the case with sulphite pulp), slight bleaching of the kraft pulp did not produce a sufficient change in the lignin to cause better retention of the basic dye.

Du Pont Brilliant Crocein FL on kraft pulp bleached to various degrees, however, acted much differently than was expected in view of the previous results. This dye is retained best on unbleached or highly bleached pulp and is retained the least on slightly bleached pulp as can be seen in figure 9. Sulphite pulp when treated in this same manner acted similarly except that its retention rose more rapidly upon bleaching. In order to explain why unbleached kraft pulp retained more dye than highly bleached pulps several details will have to be taken into consideration. From the experiments carried out on the various sulphite pulps it was concluded that both the character and the amount of lignin present were governing factors in dye retention. In the preceding part of this section it was shown that the character of the lignin in kraft pulp could not have been changed much, if any, because the basic dye used was retained to a greater extent by the lignified fibers. This would tend to show that the character of the lignin was about the same at various degrees of bleaching. In the light of this, then, it would be expected that acid and direct dyes would be retained less on the more lignified fibers. In actual results this was not the case for the acid dye. From the chemical constants tabulated in table 12 no clue could be found which would lead to an explanation of the results. In addition to the considerations already made, the well known fact must be recalled that basic dyes have the greatest affinity, while acid dyes have the least affinity, for paper making fibers. One plausible explanation of these results is that the character of the lignin in kraft pulp is changed slightly by bleaching. Due to the fact that Du Pont Victoria Green SC is strongly attracted by the pulp, it is retained increasingly with increased lignin content without regard to the slightly changed character of the lignin, and produced results in agreement with those expected. However, in the case of the acid dye, Du Pont Brilliant Crocein FL, which has only a slight affinity for pulps, the lignin was able to attract and hold the dye producing the results that have been shown in figure 9. It should be pointed out, however, that the lignin in kraft pulp was not changed in character nearly so much as it was in the sulphite pulp during bleaching. In the case of sulphite pulp all three of the dyes were affected in an ununiform manner when dyed on slightly bleached pulp.

Pontamine Fast Red 8BL is apparently a strong enough dye to increase the retention upon bleaching. Bleached kraft pulps retain more of this dye than unbleached pulps as is shown in figure 10. For one half pound dyeings, the unbleached pulp retains 50.0 per cent of the direct dye while the bleached pulp retains 60.0 per cent.

From these results then, it may be concluded that the character of the lignin present in the kraft pulp, when only slightly changed by bleaching, has very little effect on the retention of dyes other than that which would be expected by its presence with the exception of acid dyes such as Du Pont Brilliant Crocein FL. The retention of Du Pont Brilliant Crocein FL is decreased in this case because it has only a slight affinity for paper making fibers. Du Pont Victoria Green SC is retained better on kraft pulp than Pontamine Fast Red 8BL, while Du Pont Brilliant Crocein FL is retained the least.

3. Retention on Bleached and Unbleached Sulphite and Kraft, Bleached Soda, Groundwood, and Rag Pulps.

The pulps most generally used in paper making operations, bleached and unbleached sulphite and kraft, bleached soda, groundwood, and rag, were chosen for the pulp variable in this investigation. The various pulps were dyed with the three typical dyestuffs in four different strengths ($\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings). The retention results are tabulated in table 13 and shown graphically in figures 11, 12, and 13. The chemical constants of the pulps are tabulated in table 14 except for sulphite and kraft which have already been given above in tables 2 and 4 respectively. The retentions of the sulphite and kraft pulps have been given in sections 1 and 2 above, but will be given here again for comparison with the other pulps. The bleached sulphite is the same pulp used in section 1 which was obtained by bleaching unbleached sulphite with thirty per cent bleach while the bleached kraft is the same pulp used in section 2 which was obtained by bleaching unbleached kraft with forty per cent bleach.

Du Pont Victoria Green SC, figure 11, shows that for one half pound dyeings, unbleached kraft retains the dye slightly better than unbleached sulphite, their retentions being 98.3 and 97.9 per cent respectively. Groundwood, unexpectedly, is next with a retention of 95.2 per cent. The

TABLE 13.

RETENTION ON VARIOUS PULPS

| Pulp | Pounds Dye per 1000 Pounds Pulp | Du Pont Victoria Green SC Per Cent | Du Pont Brilliant Crocein FL Per Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| Unbleached Sulphite | ½ | 97.9 | 57.7 | 58.0 |
| | 1 | 96.5 | 50.0 | 54.0 |
| | 1½ | 96.0 | 45.7 | 52.2 |
| | 3 | 95.3 | 41.8 | 49.1 |
| Bleached Sulphite | ½ | 87.9 | 62.0 | 64.0 |
| | 1 | 86.4 | 53.8 | 61.0 |
| | 1½ | 85.8 | 49.0 | 59.1 |
| | 3 | 85.0 | 43.3 | 56.2 |
| Unbleached Kraft | ½ | 98.3 | 54.5 | 50.0 |
| | 1 | 97.2 | 46.3 | 47.6 |
| | 1½ | 96.6 | 42.6 | 46.6 |
| | 3 | 95.5 | 39.4 | 45.0 |
| Bleached Kraft | ½ | 88.5 | 49.9 | 60.0 |
| | 1 | 87.1 | 42.6 | 57.4 |
| | 1½ | 86.5 | 39.5 | 56.2 |
| | 3 | 85.7 | 36.5 | 54.1 |
| Bleached Soda | ½ | 80.7 | 60.0 | 55.0 |
| | 1 | 79.0 | 54.0 | 52.0 |
| | 1½ | 78.9 | 49.5 | 50.1 |
| | 3 | 78.0 | 42.0 | 45.5 |
| Rag | ½ | 74.7 | 66.0 | 63.8 |
| | 1 | 73.3 | 59.5 | 60.0 |
| | 1½ | 72.6 | 55.0 | 58.0 |
| | 3 | 71.0 | 47.2 | 55.3 |
| Ground-wood | ½ | 95.2 | 25.0 | 33.0 |
| | 1 | 94.0 | 23.8 | 30.0 |
| | 1½ | 93.6 | 23.0 | 28.6 |
| | 3 | 92.8 | 22.9 | 25.6 |

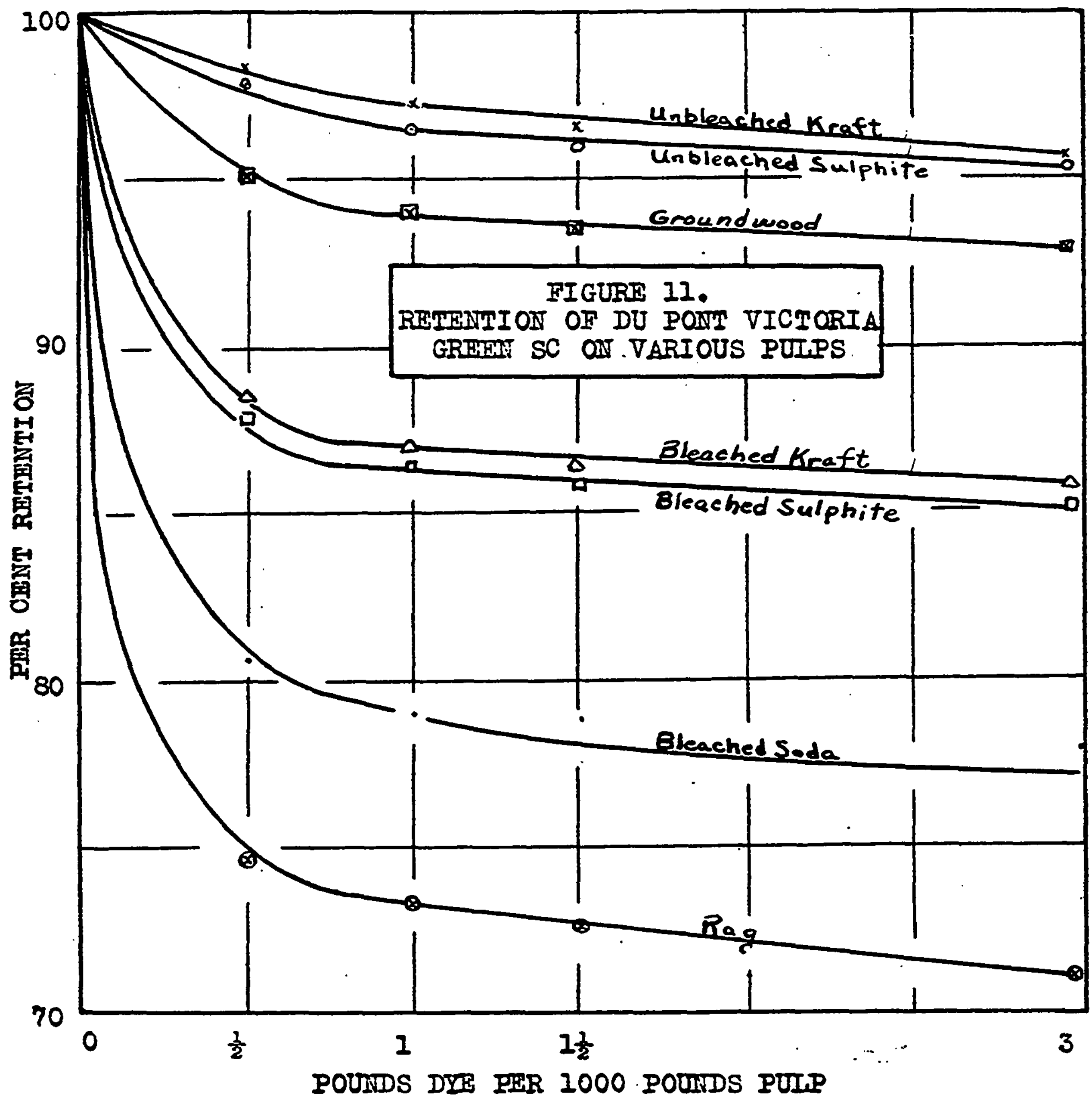



FIGURE 11.
RETENTION OF DU PONT VICTORIA GREEN SC ON VARIOUS PULPS

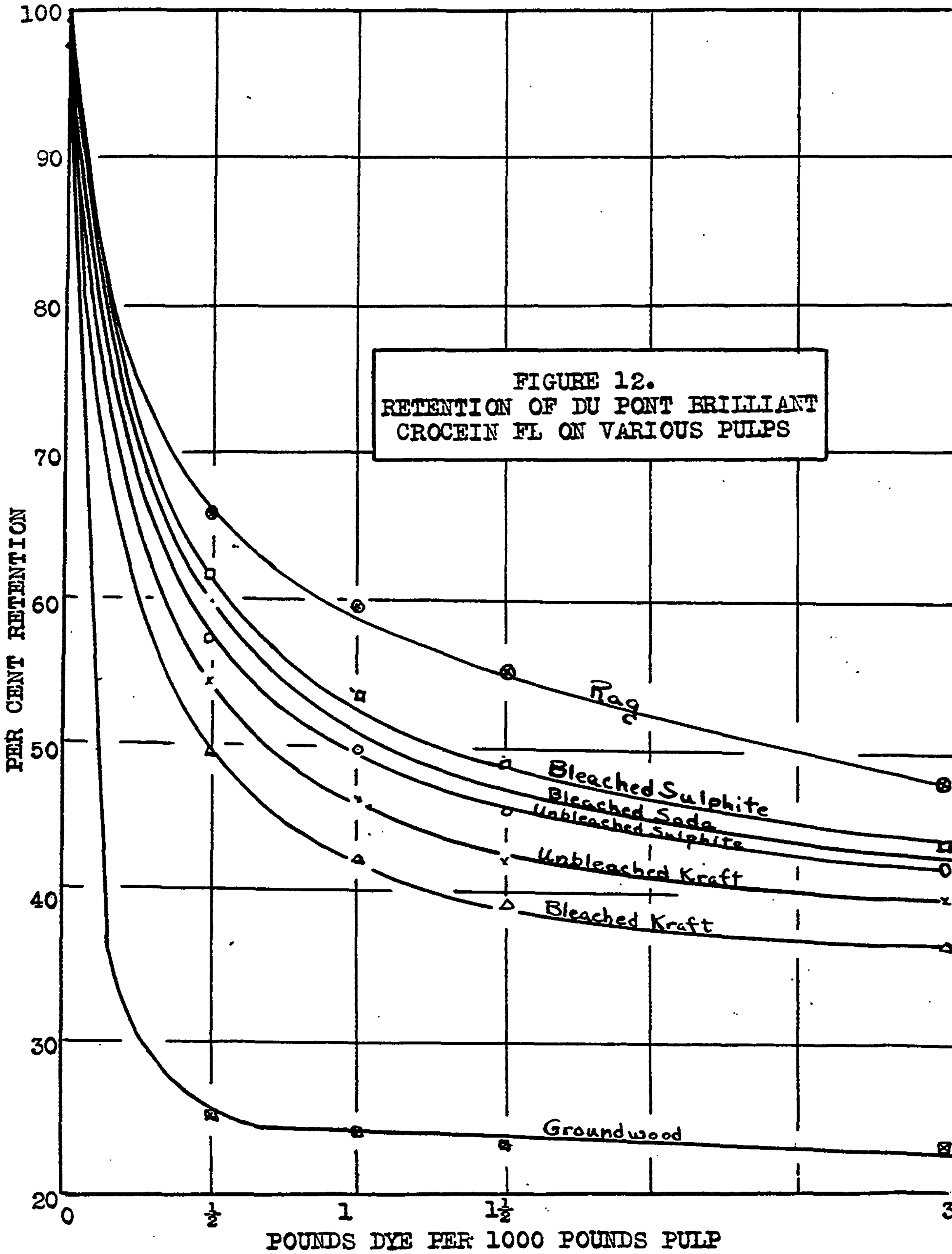


FIGURE 12.
RETENTION OF DU PONT BRILLIANT
CROCEIN FL ON VARIOUS PULPS
PER CENT RETENTION
100
90
80
70
60
50
40
30
20
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
Rag
Bleached Sulphite
Bleached Soda
Unbleached Sulphite
Unbleached Kraft
Bleached Kraft
Groundwood

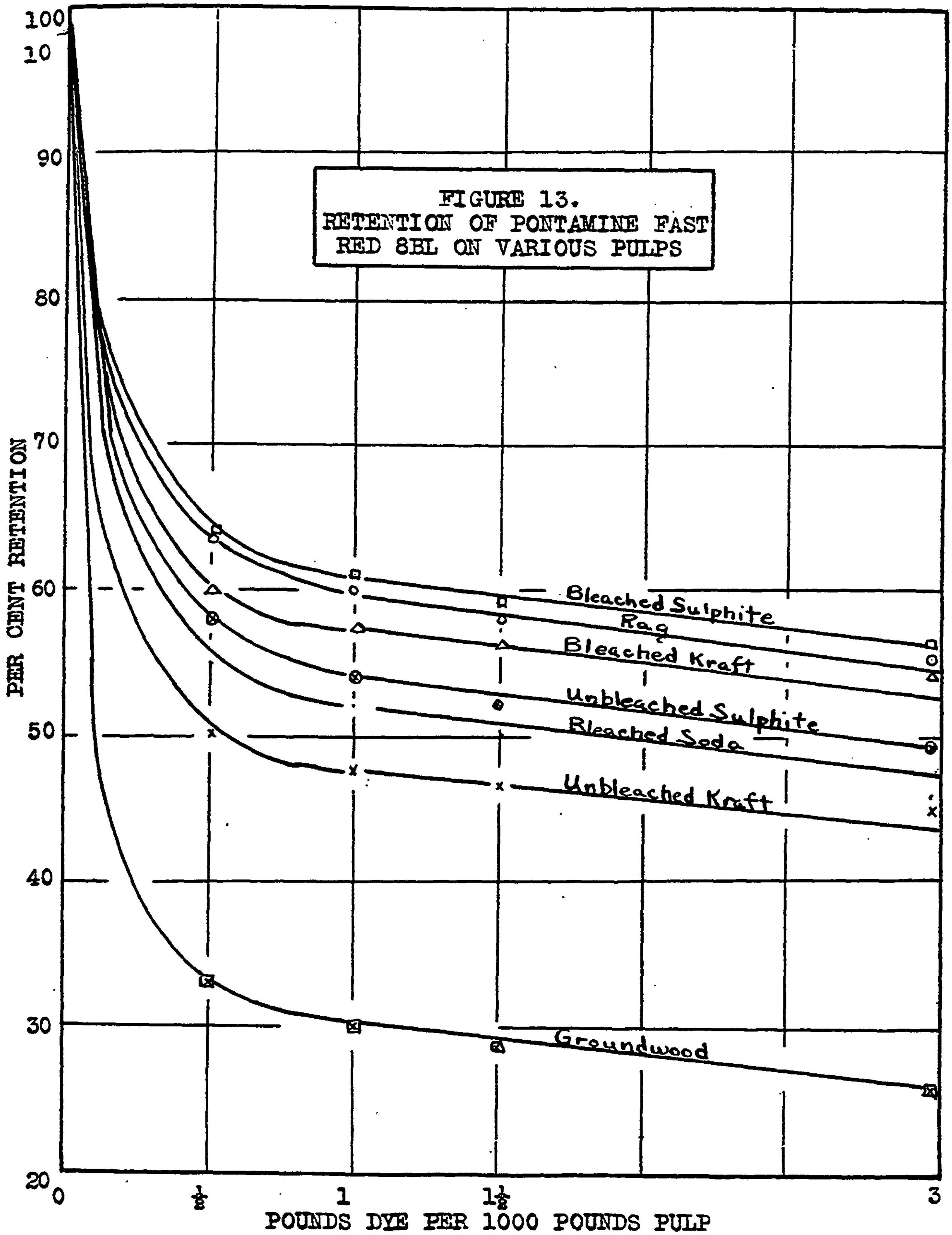


FIGURE 13.
RETENTION OF PONTAMINE FAST RED 8BL ON VARIOUS PULPS
PER CENT RETENTION
100
10
90
80
70
60
50
40
30
20
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
Bleached Sulphite
Rag
Bleached Kraft
Unbleached Sulphite
Bleached Soda
Unbleached Kraft
Groundwood

TABLE 14.

CHEMICAL CONSTANTS OF BLEACHED SODA, RAG, AND GROUNDWOOD

| Pulp | Bleached Soda | Rag | Groundwood |
|---|---|---|---|
| Per Cent Lignin | 0.4 | 0 | 27.1 |
| Per Cent Methoxyl | 0.085 | 0.012 | 5.420 |
| Per Cent Alpha Cellulose | 63.05 | 97.03 | - |

lignin content of groundwood is 27.1 per cent but can not be considered in a relative way with the other lignified pulps because of its entirely different character. Bleached kraft and sulphite are next having retentions respectively of 88.5 and 87.9 per cent. Bleached soda and rag are last with retentions of 80.7 and 74.7 per cent respectively.

From these results it is evident that the various types of pulps have widely varying affinities for Du Pont Victoria Green SC, but, generally speaking, the amount and character of lignin present has a considerable influence in holding this dye to the fiber. In the case of groundwood, however, which is a mechanical pulp and not comparable with chemical pulps, it should be noticed that it is well up in the list in its affinity for basic dyes.

Du Pont Brilliant Crocein FL, figure 12, shows that for one half pound dyeings, for example, rag pulp has the best retention which is 66.0 per cent. Bleached sulphite and soda are next best with retentions of 57.7 and 54.5 per cent respectively. Then comes bleached kraft with a retention of 49.9 per cent. Here again we have this same acid dye on bleached kraft pulp which shows an unexpected result. As has already been explained in section 2, the lignin in this particular case has been changed in some way, even though it is present only to the extent of 2.04 per cent, so that it repels the acid dye. Then the highly lignified mechanical pulp was last with the extremely low retention of 25.0 per cent.

From these results it can be concluded that acid dyes show only a small attraction for these pulps, the best of which are those containing the highest amounts of alpha cellulose and the least lignin.

In the case of Pontamine Fast Red 8BL, figure 13, the one half pound dyeings were also retained better than those using greater quantities of dye.

Bleached sulphite, rag, and bleached kraft pulps retain this dye better than the other pulps. Bleached sulphite has a retention of 64.0, rag 63.6, and bleached kraft 60.0 per cent. Unbleached sulphite, bleached soda, and unbleached kraft are next in line with retentions of 58.0, 55.0, and 50.0 per cent respectively. The bleached soda was expected to be higher in the list but when its alpha cellulose content of only 63.0 per cent is taken into consideration it can be justified. Groundwood with this dye is also last with only 33.0 per cent retention.

These results indicate that the retention of this dye, even though better than that of Du Pont Brilliant Crocein FL, is much less than the retentions obtained with Du Pont Victoria Green SC. In addition, highly purified pulps show dye retentions which are considerably better than those of the more lignified pulps.

4. Retention on Unbleached and Bleached Sulphite and Kraft at Various pH's.

Sulphite and kraft pulps are the most important types of furnishes from a tonnage standpoint that are dyed so they alone were considered regarding the effect of pH on dye retention.

These pulps, both bleached and unbleached, were dyed at three pH's, 3.9, 4.9, and 5.9, with the three typical dyes in four different strengths ($\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings). The results are tabulated in table 15 for the sulphite and in table 16 for the kraft pulp. These same results are plotted graphically in figures 14 to 19 inclusive for the sulphite and 20 to 25 inclusive for the kraft pulp.

Du Pont Victoria Green SC on unbleached sulphite, figure 14, showed retentions, for example, for one half pound dyeings of 96.0, 97.9, and 97.7 per cent for 3.9, 4.9, and 5.9 pH's respectively. From these data it is apparent that the optimum pH to use with Du Pont Victoria Green SC in obtaining a maximum dye retention on unbleached sulphite pulp is somewhere near 4.9. The effect of higher pH's lowers the retention but not to any where near the extent that lower pH's do.

Du Pont Brilliant Crocein FL on unbleached sulphite, figure 15, showed no differences in retention for pH's of 3.9 and 4.9. Above that point, 5.9 for instance, the retention showed a large drop. For one half pound dyeings the retentions 57.7 per cent for pH's of 3.9 and 4.9 and 50.1

TABLE 15.

RETENTION OF DYES ON UNBLEACHED AND BLEACHED SULPHITE PULP AT VARIOUS pH'S

| Hydrogen Ion Concentration and Pulp | Pounds Dye per 1000 Pounds Pulp | Du Pont Victoria Green SC Per Cent | Du Pont Brilliant Crocein FL Per Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| Unbleached Sulphite 3.9 | ½ | 96.0 | 57.7 | 58.2 |
| | 1 | 94.5 | 50.1 | 54.1 |
| | 1½ | 94.1 | 45.6 | 52.2 |
| | 3 | 93.8 | 41.9 | 49.1 |
| Unbleached Sulphite 4.9 | ½ | 97.9 | 57.7 | 58.0 |
| | 1 | 96.5 | 50.0 | 54.0 |
| | 1½ | 96.0 | 45.7 | 52.2 |
| | 3 | 95.3 | 41.8 | 49.1 |
| Unbleached Sulphite 5.9 | ½ | 97.7 | 50.1 | 56.1 |
| | 1 | 96.2 | 42.2 | 52.4 |
| | 1½ | 95.9 | 38.1 | 50.4 |
| | 3 | 94.9 | 34.1 | 47.3 |
| Bleached Sulphite 3.9 | ½ | 85.8 | 62.0 | 64.4 |
| | 1 | 84.8 | 53.5 | 61.5 |
| | 1½ | 84.2 | 48.9 | 59.4 |
| | 3 | 83.2 | 43.1 | 56.8 |
| Bleached Sulphite 4.9 | ½ | 87.9 | 62.0 | 64.0 |
| | 1 | 86.4 | 53.8 | 61.0 |
| | 1½ | 85.8 | 49.0 | 59.1 |
| | 3 | 85.0 | 43.3 | 56.2 |
| Bleached Sulphite 5.9 | ½ | 87.8 | 54.0 | 62.1 |
| | 1 | 86.3 | 44.7 | 58.9 |
| | 1½ | 85.6 | 40.5 | 57.3 |
| | 3 | 85.1 | 36.1 | 54.3 |

TABLE 16.

RETENTION OF DYES ON UNBLEACHED AND BLEACHED KRAFT PULP AT VARIOUS pH'S

| Hydrogen Ion Concentration and Pulp | Pounds Dye per 1000 Pounds Pulp | Du Pont Victoria Green Per Cent | Du Pont Brilliant Crocein FL Per Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| Unbleached Kraft 3.9 | ½ | 97.5 | 54.8 | 50.1 |
| | 1 | 96.5 | 46.6 | 47.6 |
| | 1½ | 96.0 | 42.9 | 46.8 |
| | 3 | 94.9 | 40.0 | 45.0 |
| Unbleached Kraft 4.9 | ½ | 98.3 | 54.5 | 50.0 |
| | 1 | 97.2 | 46.3 | 47.6 |
| | 1½ | 96.6 | 42.6 | 46.6 |
| | 3 | 95.5 | 39.4 | 45.0 |
| Unbleached Kraft 5.9 | ½ | 98.2 | 50.0 | 48.3 |
| | 1 | 97.1 | 42.6 | 45.9 |
| | 1½ | 96.4 | 38.1 | 44.3 |
| | 3 | 95.4 | 35.1 | 43.1 |
| Bleached Kraft 3.9 | ½ | 88.2 | 50.2 | 60.1 |
| | 1 | 87.1 | 43.0 | 57.8 |
| | 1½ | 86.4 | 40.0 | 56.8 |
| | 3 | 85.4 | 36.9 | 54.7 |
| Bleached Kraft 4.9 | ½ | 88.5 | 49.9 | 60.0 |
| | 1 | 87.1 | 42.6 | 57.4 |
| | 1½ | 86.5 | 39.5 | 56.2 |
| | 3 | 85.7 | 36.5 | 54.1 |
| Bleached Kraft 5.9 | ½ | 88.5 | 44.6 | 57.8 |
| | 1 | 87.0 | 37.8 | 55.0 |
| | 1½ | 86.5 | 34.4 | 53.9 |
| | 3 | 85.5 | 32.1 | 51.9 |

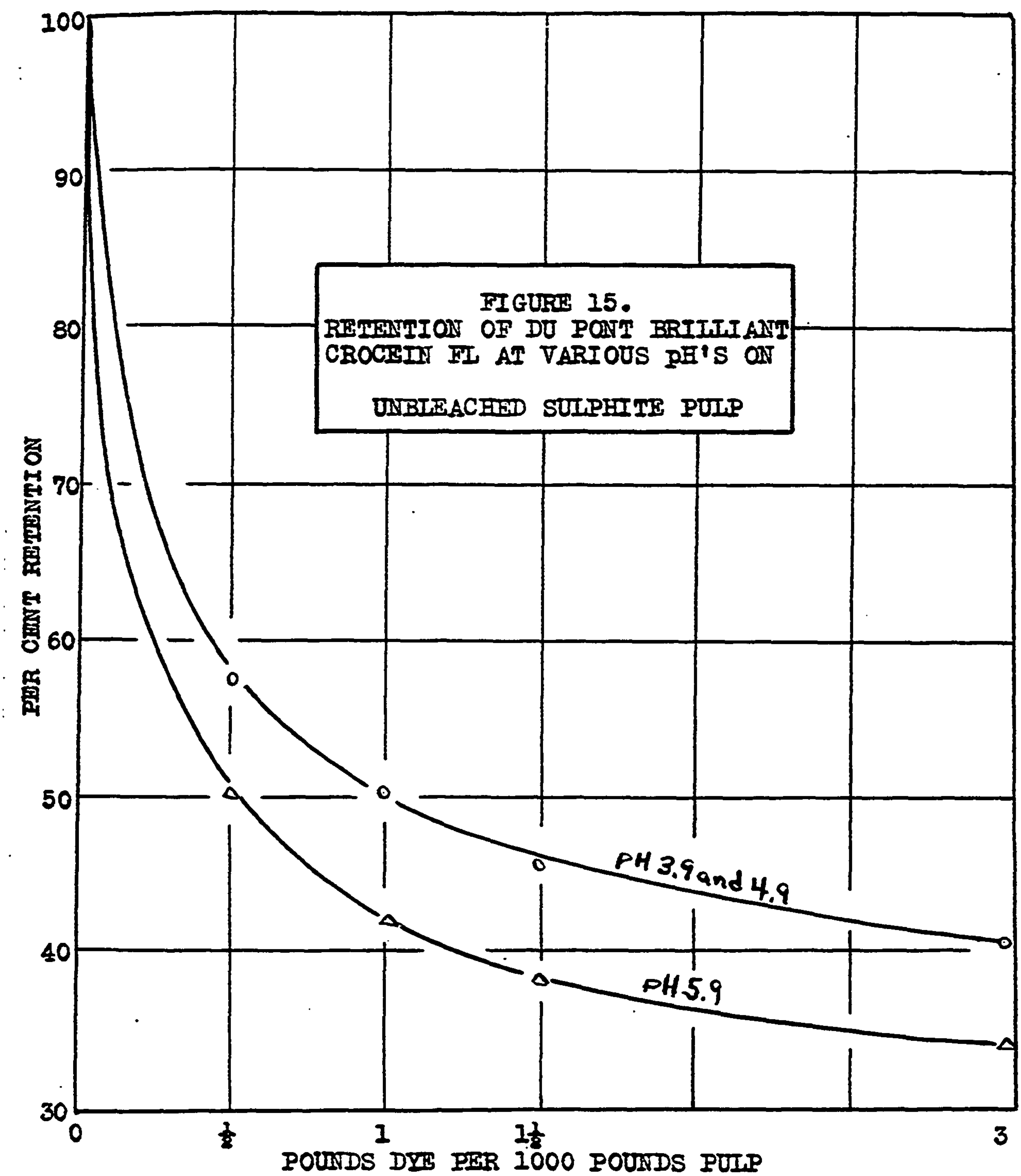


FIGURE 15.
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS pH'S ON
UNBLEACHED SULPHITE PULP
PER CENT RETENTION
100
90
80
70
60
50
40
30
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
pH 3.9 and 4.9
pH 5.9

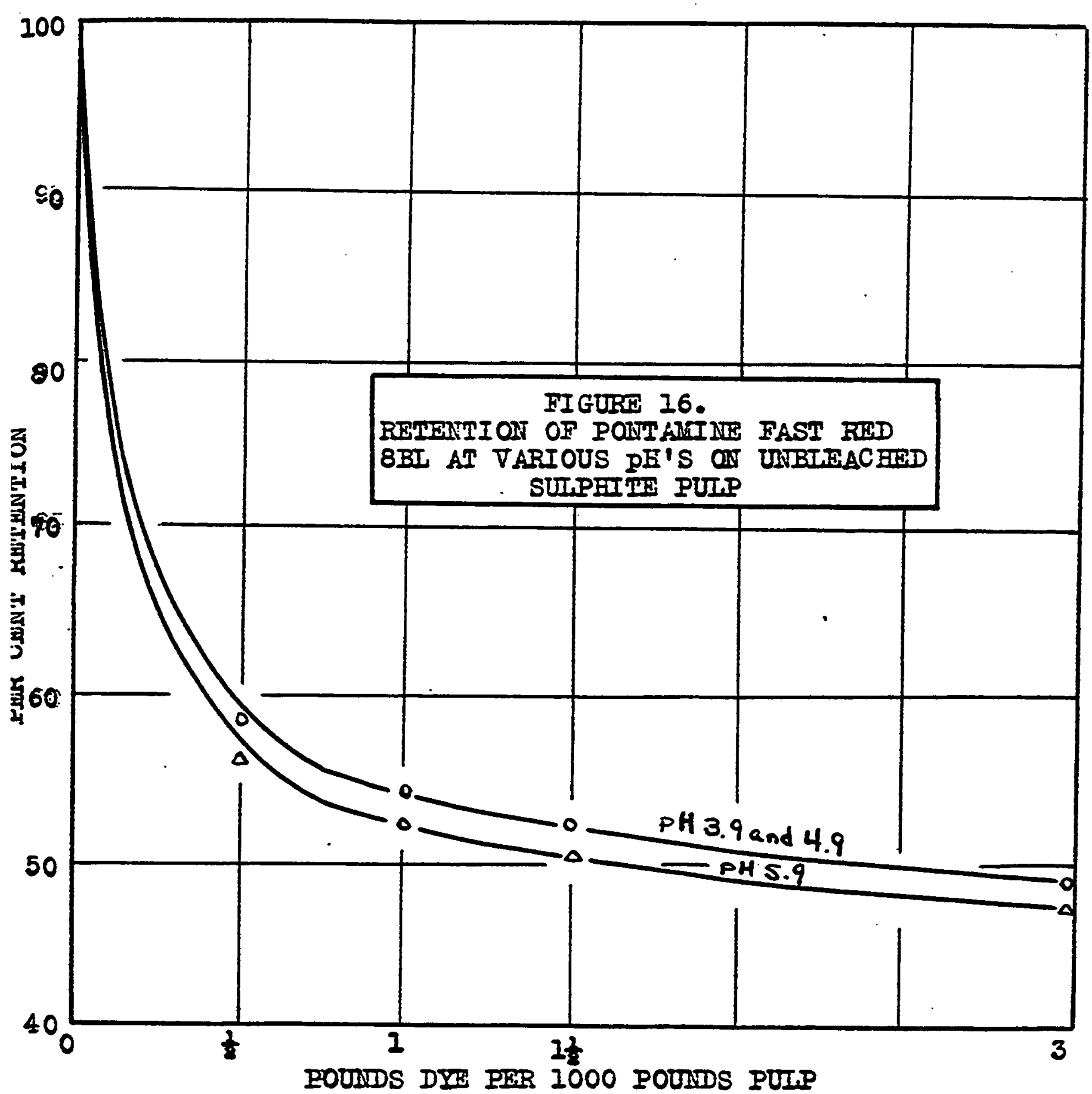


FIGURE 16.
RETENTION OF PONTAMINE FAST RED 8BL AT VARIOUS pH'S ON UNBLEACHED SULPHITE PULP
PER CENT RETENTION
100
90
80
70
60
50
40
0
½
1
1½
3
pH 3.9 and 4.9
pH 5.9
POUNDS DYE PER 1000 POUNDS PULP

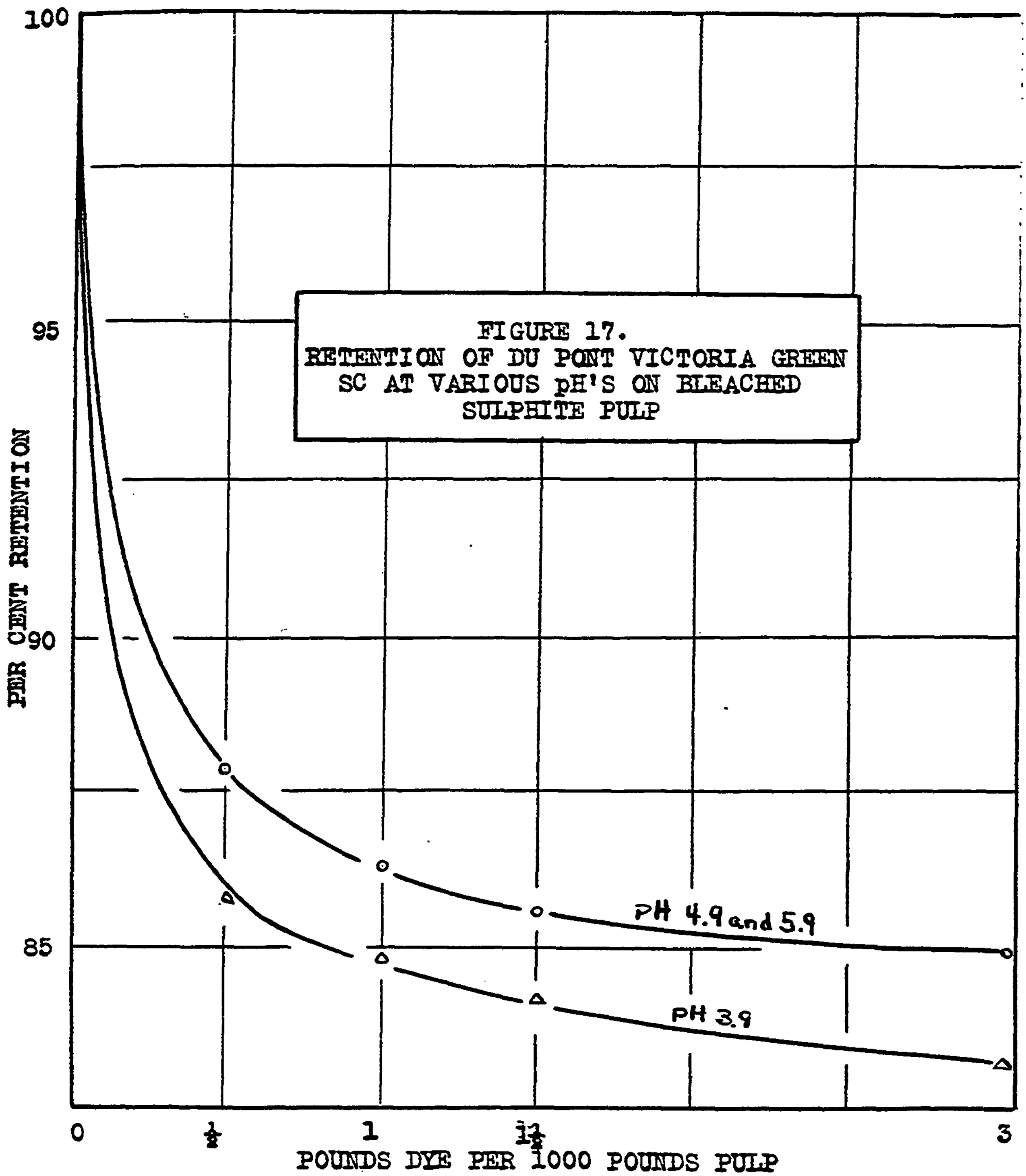


FIGURE 17.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS pH'S ON BLEACHED SULPHITE PULP
100
95
90
85
PER CENT RETENTION
PH 4.9 and 5.9
PH 3.9
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP

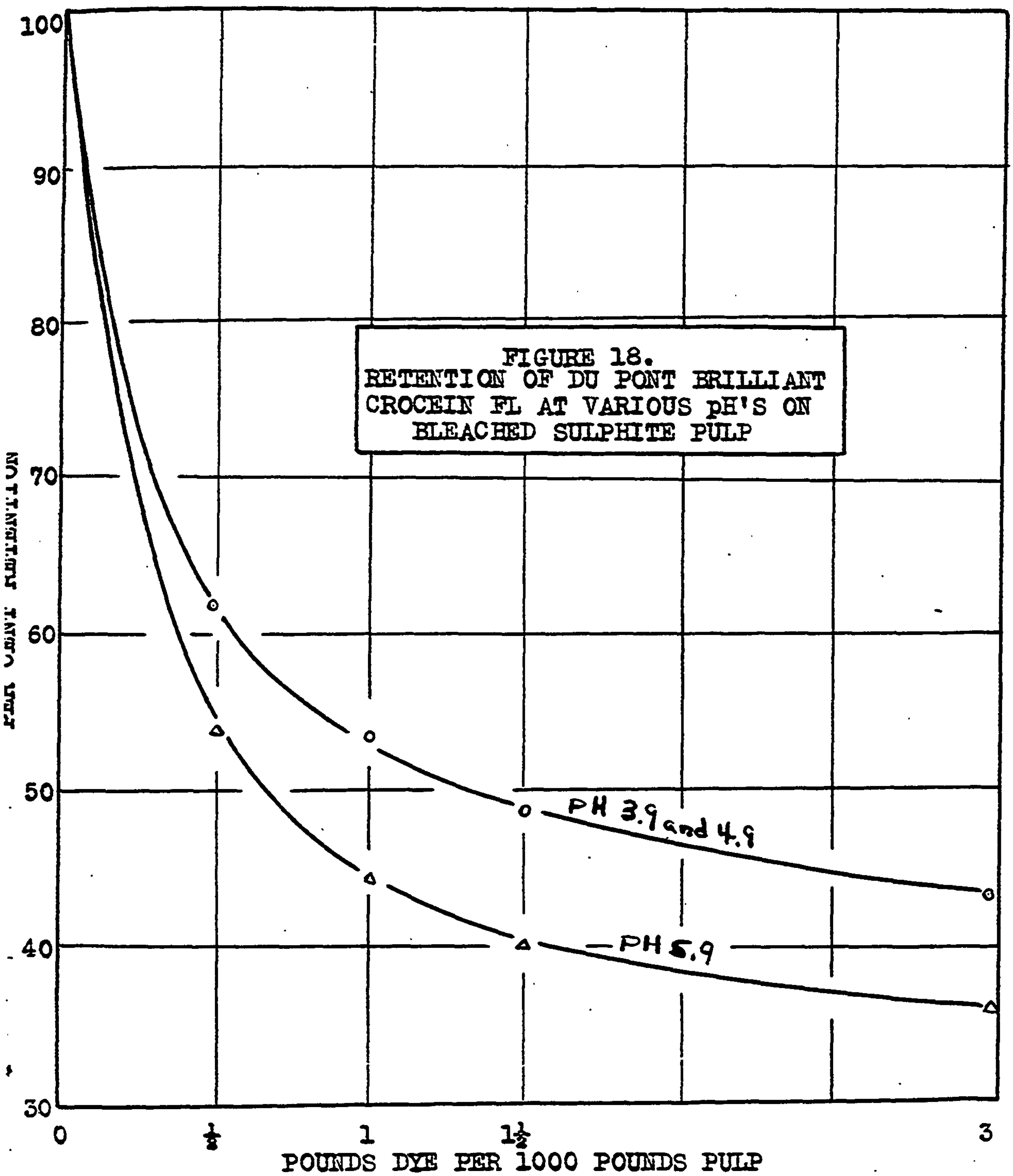



FIGURE 18.
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS pH'S ON BLEACHED SULPHITE PULP

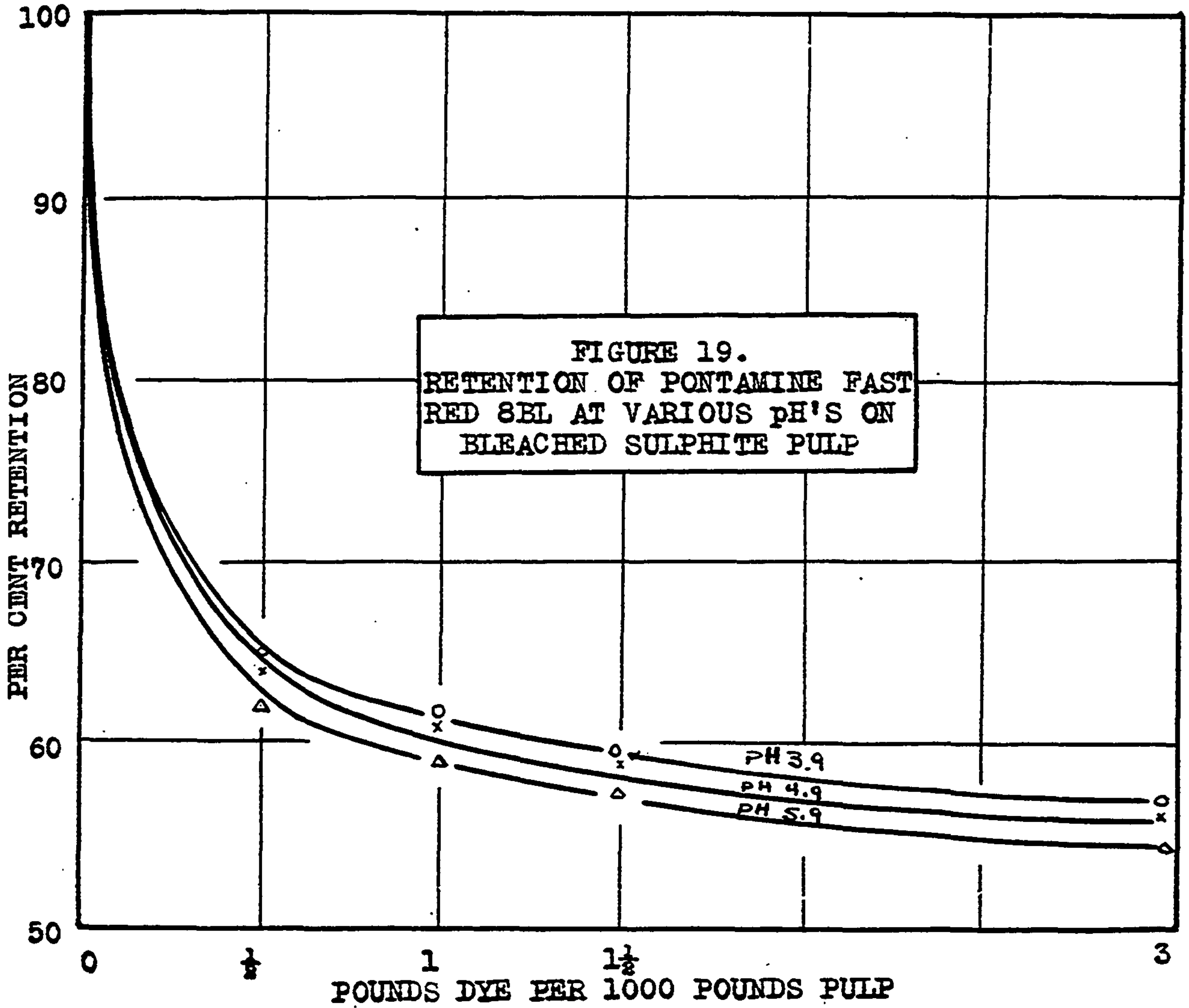


FIGURE 19.
RETENTION OF PONTAMINE FAST RED 8BL AT VARIOUS pH'S ON BLEACHED SULPHITE PULP
PER CENT RETENTION
100
90
80
70
60
50
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
PH 3.9
PH 4.9
PH 5.9

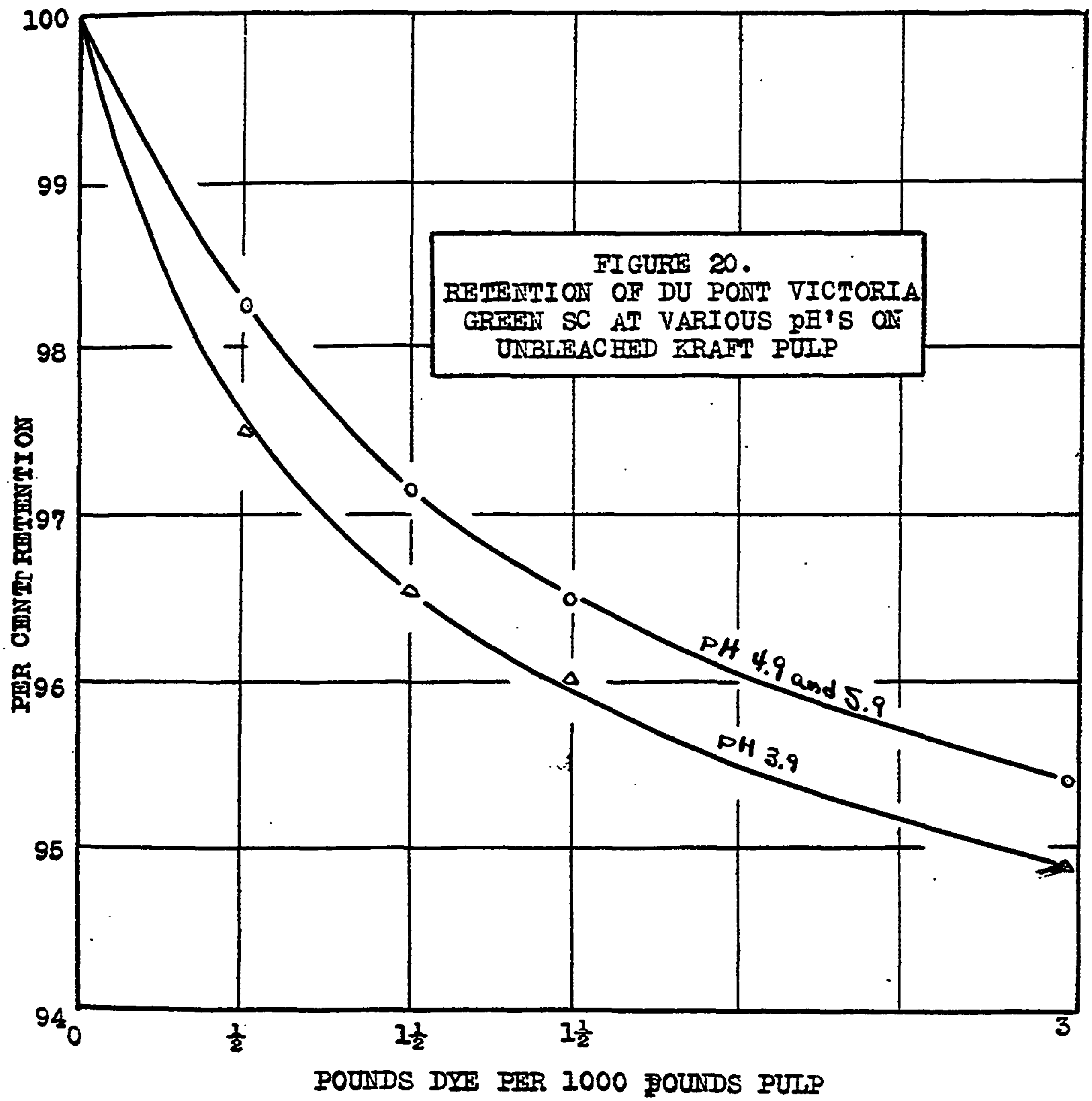


FIGURE 20.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS pH'S ON UNBLEACHED KRAFT PULP
100
99
98
97
96
95
94
PER CENT RETENTION
0
½
1½
1½
3
POUNDS DYE PER 1000 POUNDS PULP
PH 4.9 and 5.9
PH 3.9

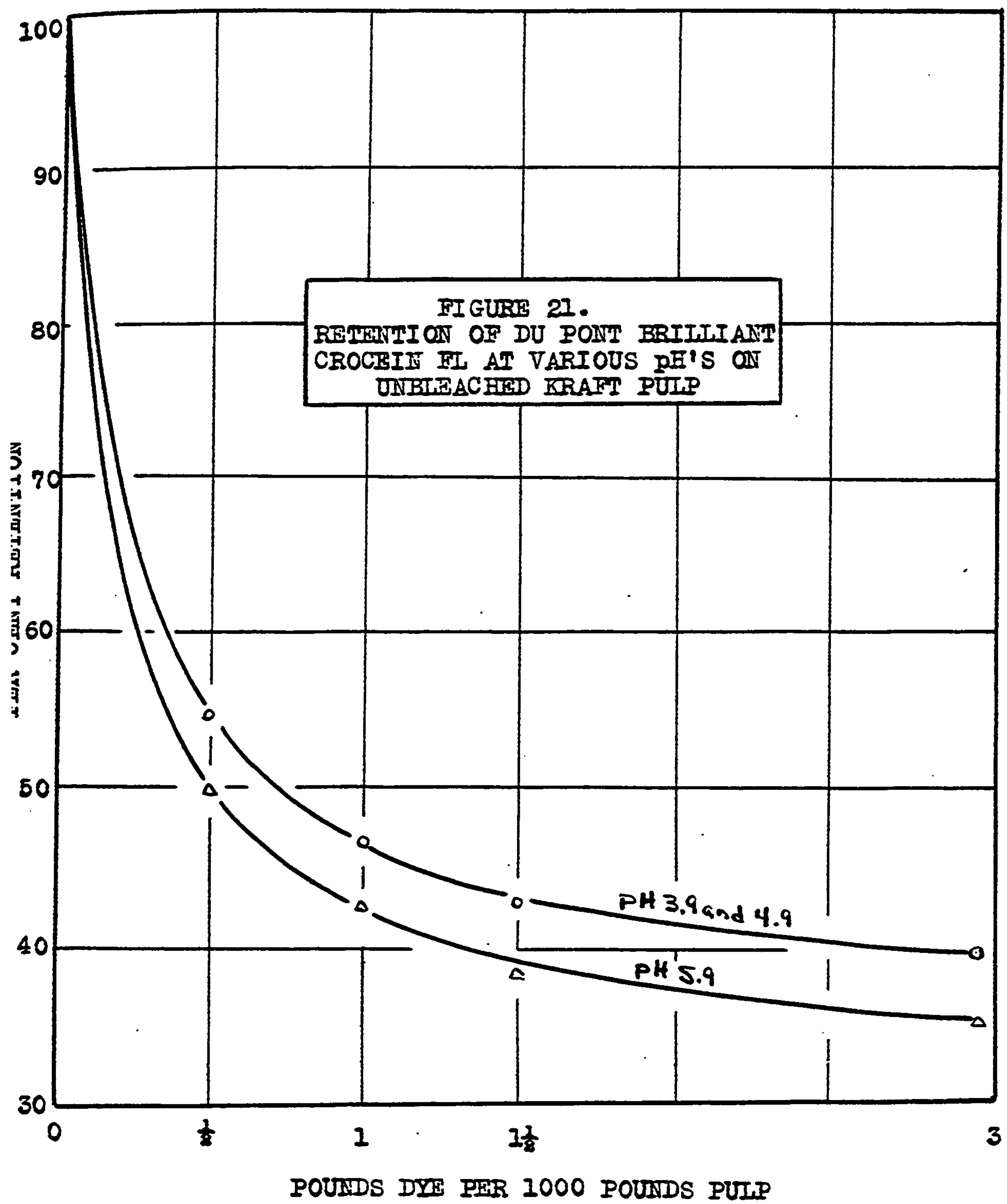



FIGURE 21.
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS pH'S ON UNBLEACHED KRAFT PULP

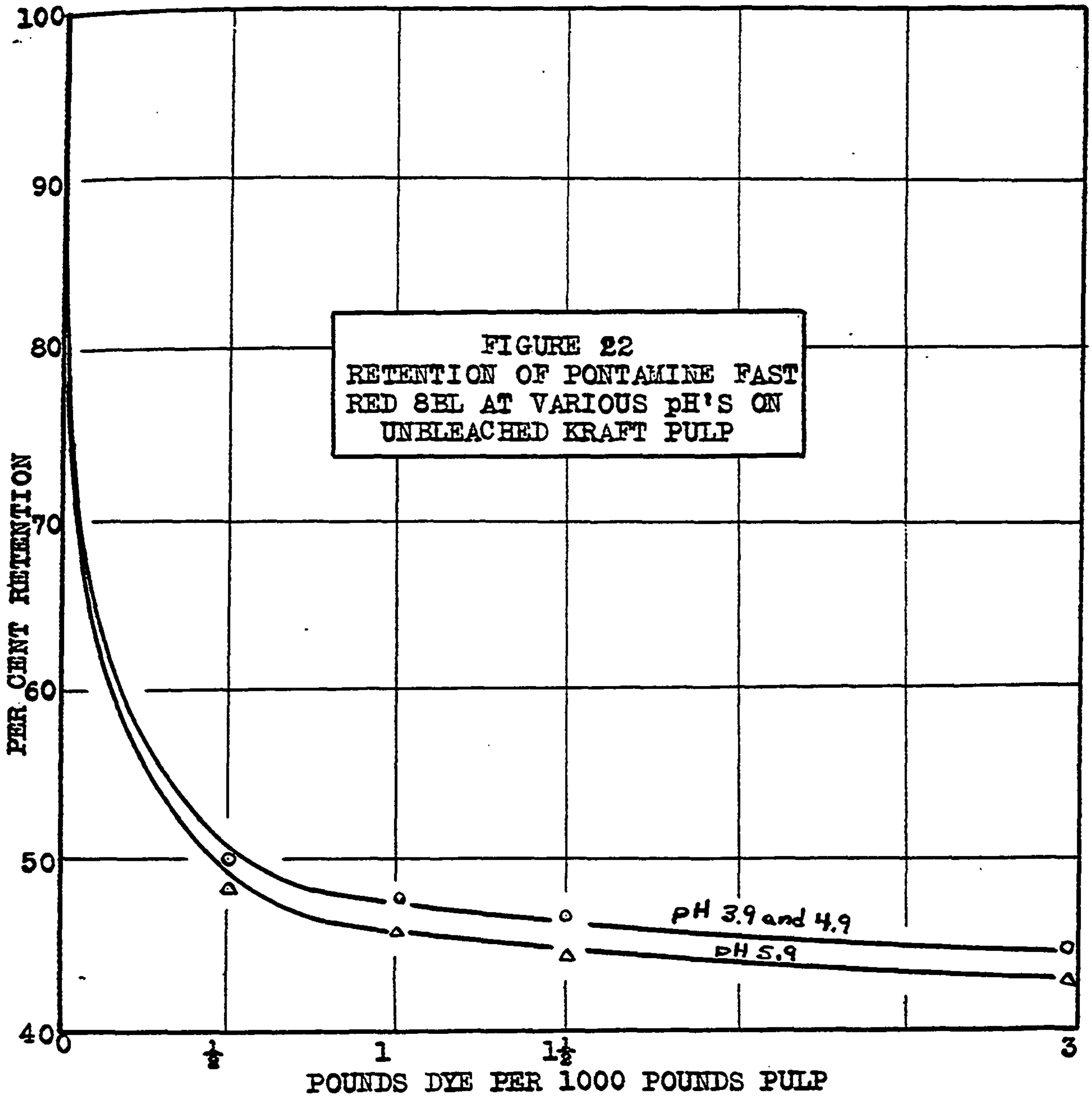


FIGURE 22
RETENTION OF PONTAMINE FAST
RED 8BL AT VARIOUS pH'S ON
UNBLEACHED KRAFT PULP
PER CENT RETENTION
100
90
80
70
60
50
40
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
pH 3.9 and 4.9
pH 5.9

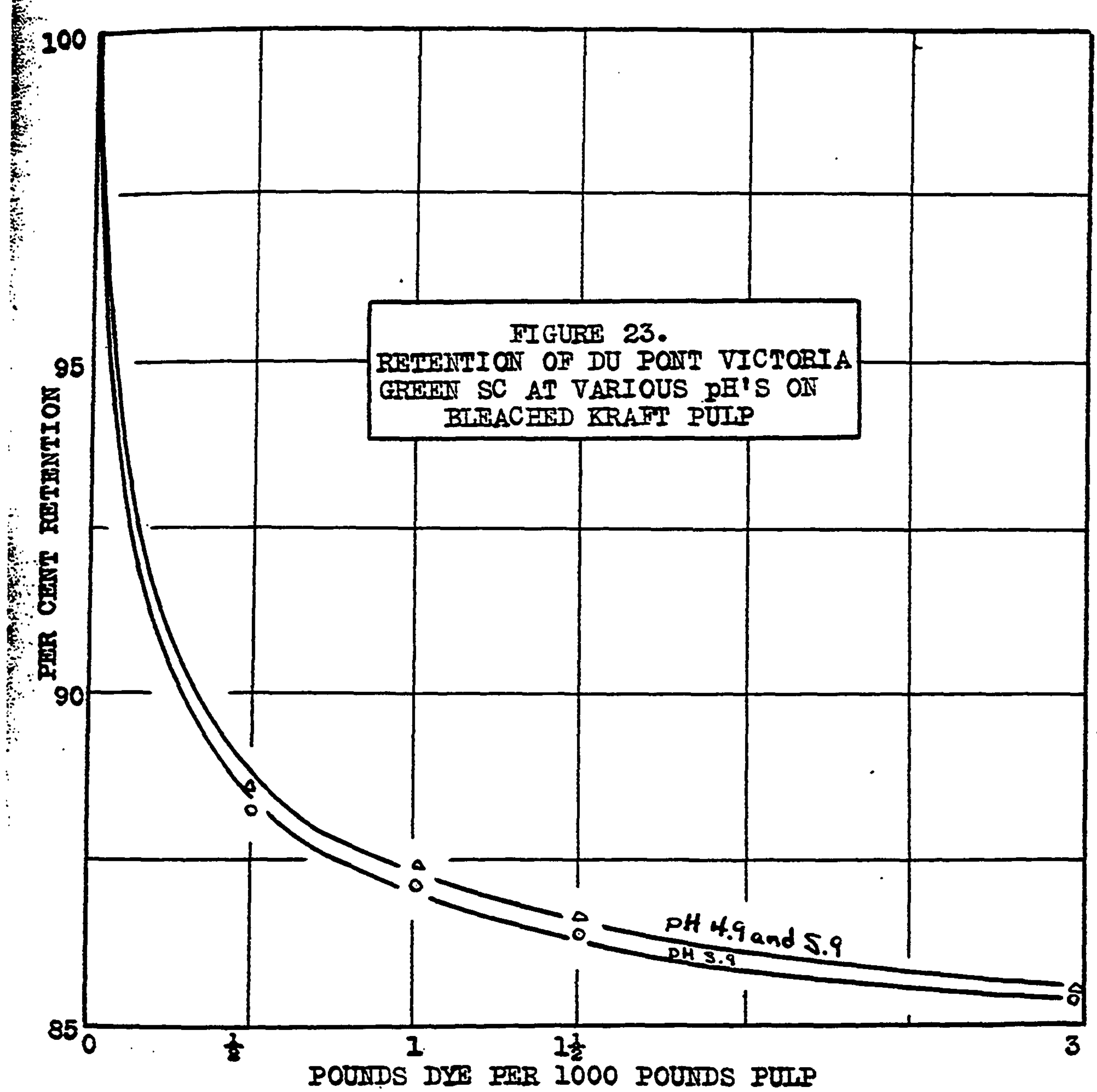



FIGURE 23.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS pH'S ON BLEACHED KRAFT PULP

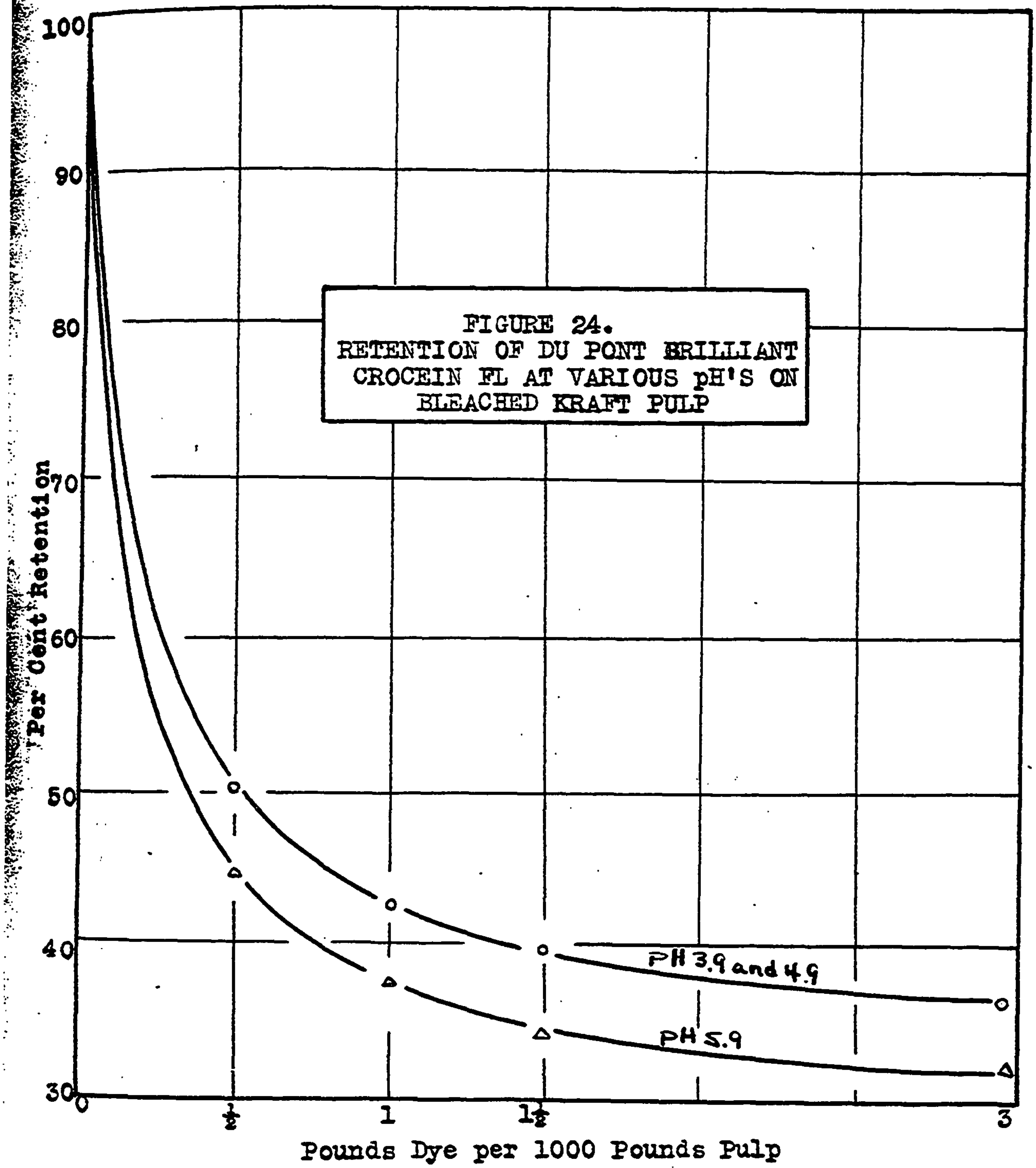


FIGURE 24.
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS pH'S ON BLEACHED KRAFT PULP
Per Cent Retention
100
90
80
70
60
50
40
30
0
½
1
1½
3
pH 3.9 and 4.9
pH 5.9
Pounds Dye per 1000 Pounds Pulp

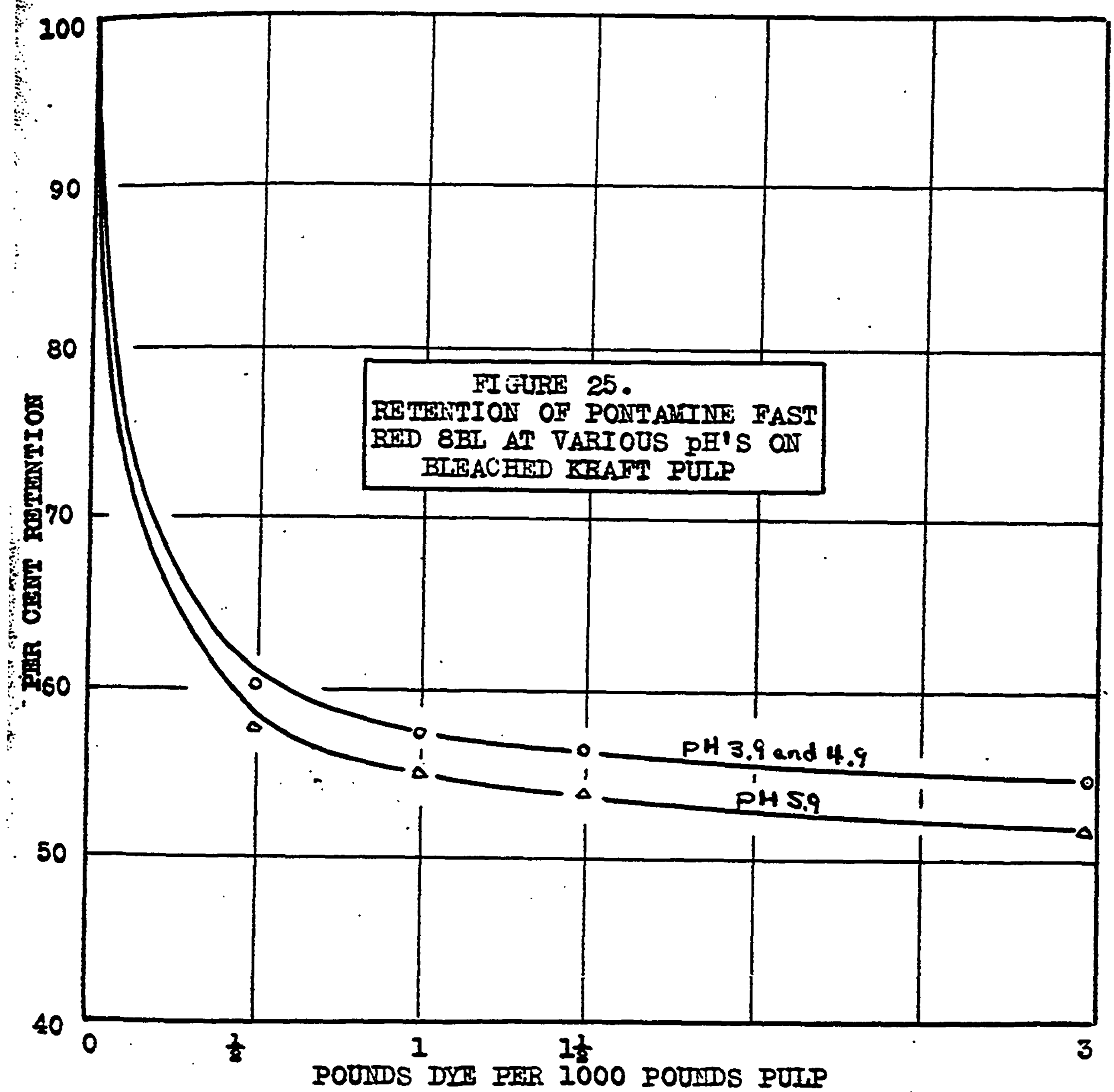


FIGURE 25.
RETENTION OF PONTAMINE FAST RED 8BL AT VARIOUS pH'S ON BLEACHED KRAFT PULP
PER CENT RETENTION
100
90
80
70
60
50
40
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
PH 3.9 and 4.9
PH 5.9

per cent for a pH of 5.9. It is apparent from these data that acid dyes require sufficient acid to set their color groups. From a pH of about 5.0 on down, however, more acid does not help.

Pontamine Fast Red 8BL on unbleached sulphite, figure 16, has approximately the same pH characteristics as Du Pont Brilliant Crocein FL on unbleached sulphite. No difference in retentions were shown for pH's of 3.9 and 4.9. At 5.9, however, the retention dropped a bit, but not nearly to the extent that it did with the acid dye. For one half pound dyeings, for example, the retentions were 58.2, 58.0, and 56.1 per cent for the pH's of 3.9, 4.9, and 5.9 respectively.

Du Pont Victoria Green SC, figure 17, showed a considerable drop in retention on bleached sulphite in relation to this same dye on unbleached sulphite. Retentions for pH's of 4.9 and 5.9 were for all practical purposes the same, but those for the pH of 3.9 were lower. For one half pound dyeings the retentions were 85.8, 87.9, and 87.8 per cent for pH's of 3.9, 4.9, and 5.9 respectively.

Du Pont Brilliant Crocein FL on bleached sulphite pulp, figure 18, showed the same general type of curves as for the the same dye on unbleached sulphite. The pH's of 3.9 and 4.9 showed the same retention while a pH of 5.9 showed a considerable lowering in the retention. Retentions obtained on the unbleached stock were somewhat lower than those obtained on the bleached. For one half pound dyeings the retentions were 62.0 per cent for pH's of 3.9 and 4.9 and 54.0 per cent for a pH of 5.9.

Pontamine Fast Red 8BL on bleached sulphite pulp, figure 19, has a slightly higher retention for a pH of 3.9 than for a pH of 4.9. At a pH of 5.9 the retention is a bit lower. For example, for one half pound dyeings, the retentions are 64.4, 64.0, and 62.1 per cent for pH's of 3.9, 4.9, and 5.9 respectively. From these results it is apparent that the pH has very little effect on the retention of this dye.

Du Pont Victoria Green SC on unbleached kraft, figure 20, shows that practically the same retentions are obtained with pH's of 4.9 and 5.9. A lower pH, 3.9, produces lower retentions. For one half pound dyeings the retentions are 97.5, 98.3, and 98.2 per cent for pH's of 3.9, 4.9, and 5.9 respectively.

Du Pont Brilliant Crocein FL on unbleached kraft, figure 21, shows that for pH's of 3.9 and 4.9 the retentions are practically the same being 54.8 and 54.5 per cent respectively. At the pH of 5.9 the retention is less, being 50.0 per cent.

Pontamine Fast Red 8BL on unbleached kraft, figure 22, shows practically no difference for pH's of 3.9 and 4.9 with only a small difference for a pH of 5.9. For example, with one half pound dyeings, the retentions are 50.1, 50.0 and 48.3 per cent for pH's of 3.9, 4.9, and 5.9 and in that order. The retention drop at 5.9 with this dye did not amount to any where near the drop experienced with the acid dye. Apparently, direct dyes are in general the least sensitive to pH.

Du Pont Victoria Green SC on bleached kraft, figure 23, showed a considerable drop in retention in relation to this dye on unbleached kraft. Retentions for pH's of 4.9 and 5.9 were for all practical purposes the same, with those for the pH of 3.9 being a bit lower. For one half pound dyeings the retentions were 88.2 per cent for the 3.9 pH and 88.5 per cent for the 4.9 and 5.9 pH's.

Du Pont Brilliant Crocein FL on bleached kraft, figure 24, showed the same type of curves on unbleached kraft. The dye at pH's of 3.9 and 4.9 was retained for all practical purposes in the same amounts for the same weight dyeings while the retention at a pH of 5.9 showed a considerable lowering. For one half pound dyeings the retentions were 50.2, 49.9, and 44.6 per cent for pH's of 3.9, 4.9, and 5.9 respectively.

Pontamine Fast red 8BL on bleached kraft, figure 25, has the same retention for pH's of 3.9 and 4.9. At a pH of 5.9 the retention is a bit lower. For one half pound dyeings the retentions are 60.1, 60.0, and 57.8 per cent for pH's of 3.9, 4.9, and 5.9 respectively.

In summarizing the effect of pH on the retention of the three dyes when dyeing sulphite and kraft pulp it can be said that the acid dyes are by far the most affected by pH changes. Retention decreases rapidly above a pH of 5.0. Direct dyes are the least affected by pH changes while basic dyes, in general, have their optimum pH's near 5.0. In addition to these facts it has been apparent from the start that an unmistakable set of trends are present. For instance, with Pontamine Fast Red 8BL it has been noticed that the characteristics of its pH curves, when per cent retention is plotted against strength of dyeing, are always the same. For different pulps the retentions are different but the shape of the curves are the same. The retentions for the direct dye at pH's of 4.9 and 5.9 are always about the same while the retention at a pH of 5.9 is always a bit lower. Even though these generalizations have been made for Pontamine Fast Red 8BL, the retention of the dye is only affected slightly by pH in comparison with other dyes. The characteristics of the pH curves for Du Pont Brilliant Crocein FL are also similar regardless of the pulp being dyed. In every case the retentions for pH's of 3.9 and 4.9 are practically the same with the retention at a pH of 5.9 being lower. The characteristics of the pH curves for Du Pont Victoria Green SC are likewise similar, with the retentions at a pH of 4.9 and 5.9 in general being the same or with the pH of 4.9 being slightly higher. A dyeing made at a pH of 3.9 shows a lower retention. Only three dyes, one typical of each of the three main classes of dyestuffs, have been investigated and probably different dyes in the same class would act differently. However, in so far as this investigation is concerned, it can definitely be pointed out that for any given dye, the characteristics of its pH curves, when per cent retention is plotted against strength of dye, are always very nearly the same for all kinds of pulps.

5. Retention on Unbleached and Bleached Sulphite at Various Consistencies.

In the light of the facts brought out in section 4 above, it was decided that the use of unbleached and bleached sulphite alone would be sufficient to bring out the the trends in dye retention due to any of the variables in the dyeing reaction. In order to study the effect of consistency on the dyeing reaction, unbleached and bleached sulphite were dyed at three consistencies, 0.3, 0.6, and 1.0 per cent with the three typical dyes in four different strengths ($\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings). The retentions are tabulated in table 17 and are shown graphically in figures 26 to 31 inclusive. As was expected, the stock dyed at one per cent consistency showed the highest retention because it had the greatest amount of dye present per unit volume of stock. Due to the fact that the dye was not being taken up by so much water, it naturally had a better chance of being absorbed by the fiber under the conditions of the experiment. The 0.6 per cent stock showed the next best retention for a given pulp and strength of dye, while that of the 0.3 per cent stock gave the poorest retention. In each case the one half pound dyeings gave higher retentions than those

TABLE 17.

RETENTION OF DYES ON UNBLEACHED AND BLEACHED SULPHITE PULP AT VARIOUS CONSISTENCIES

| Per Cent Consistency | Pounds Dye per 1000 Pounds Pulp | Du Pont Victoria Green SC Per Cent | Du Pont Brilliant Crocein FL Pef Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| Unbleached Sulphite 0.3 | ½ | 96.3 | 53.3 | 46.4 |
| | 1 | 95.4 | 46.0 | 42.8 |
| | 1½ | 94.9 | 43.0 | 41.8 |
| | 3 | 94.0 | 39.6 | 37.8 |
| Unbleached Sulphite 0.6 | ½ | 97.9 | 57.7 | 58.0 |
| | 1 | 96.5 | 50.0 | 54.0 |
| | 1½ | 96.0 | 45.7 | 52.2 |
| | 3 | 95.3 | 41.8 | 49.1 |
| Unbleached Sulphite 1.0 | ½ | 98.6 | 76.3 | 78.7 |
| | 1 | 97.8 | 68.1 | 73.1 |
| | 1½ | 97.3 | 64.0 | 70.0 |
| | 3 | 96.3 | 58.0 | 64.7 |
| Bleached Sulphite 0.3 | ½ | 86.1 | 58.8 | 52.4 |
| | 1 | 85.1 | 50.8 | 47.2 |
| | 1½ | 84.6 | 46.8 | 45.7 |
| | 3 | 83.9 | 42.0 | 41.7 |
| Bleached Sulphite 0.6 | ½ | 87.9 | 62.0 | 64.0 |
| | 1 | 86.4 | 53.8 | 61.0 |
| | 1½ | 85.8 | 49.0 | 59.1 |
| | 3 | 85.0 | 43.3 | 56.2 |
| Bleached Sulphite 1.0 | ½ | 88.4 | 81.3 | 91.0 |
| | 1 | 87.6 | 73.1 | 84.9 |
| | 1½ | 87.0 | 68.2 | 81.1 |
| | 3 | 86.1 | 61.3 | 75.8 |

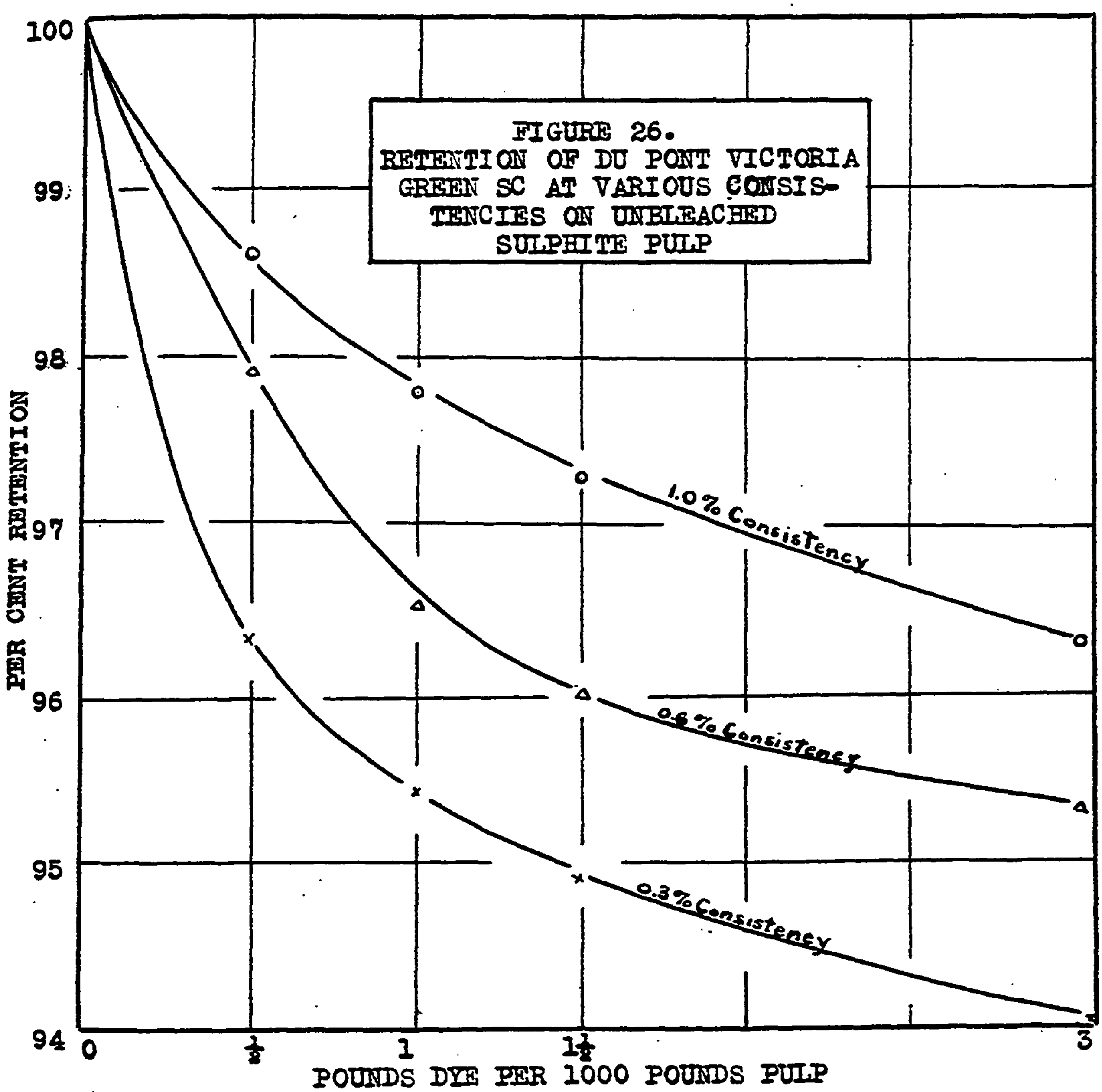


FIGURE 26.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS CONSISTENCIES ON UNBLEACHED SULPHITE PULP
100
99
98
97
96
95
94
PER CENT RETENTION
1.0 % Consistency
0.6 % Consistency
0.3 % Consistency
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP

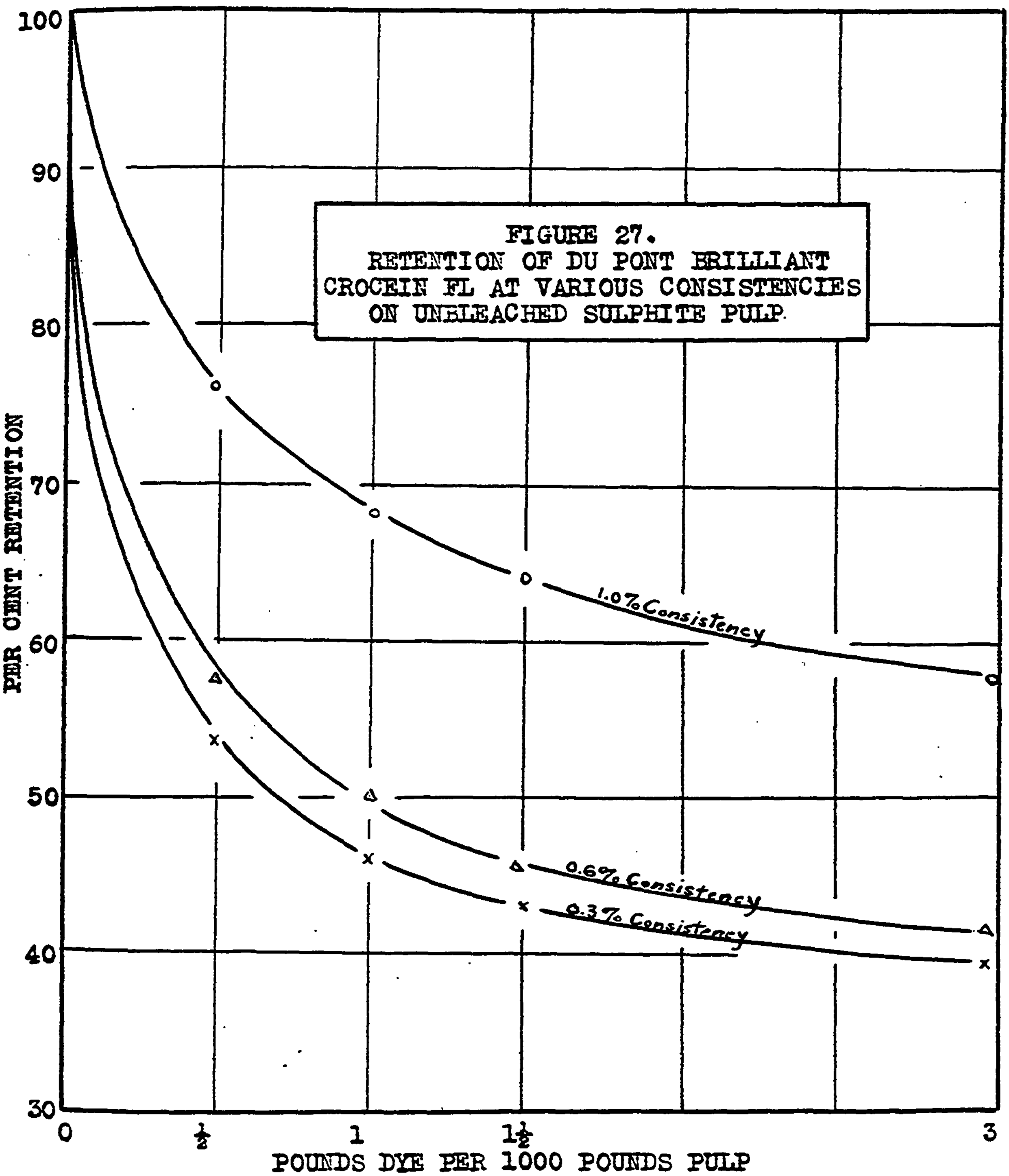


FIGURE 27.
RETENTION OF DU PONT BRILLIANT
CROCEIN FL AT VARIOUS CONSISTENCIES
ON UNBLEACHED SULPHITE PULP
PER CENT RETENTION
100
90
80
70
60
50
40
30
1.0% Consistency
0.6% Consistency
0.3% Consistency
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP

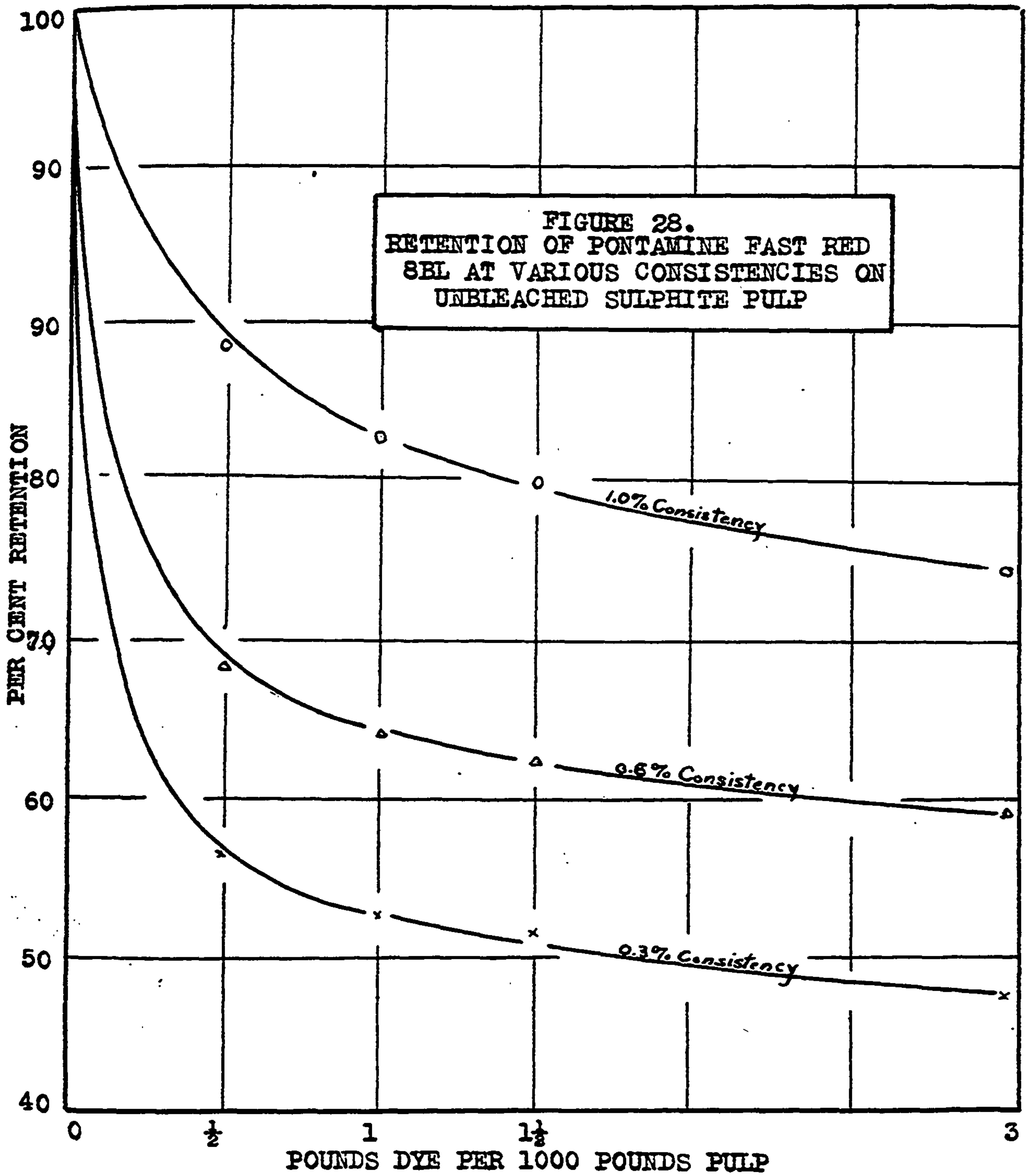


FIGURE 28.
RETENTION OF PONTAMINE FAST RED 8BL AT VARIOUS CONSISTENCIES ON UNBLEACHED SULPHITE PULP
100
90
90
80
70
60
50
40
PER CENT RETENTION
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
1.0% Consistency
0.6% Consistency
0.3% Consistency

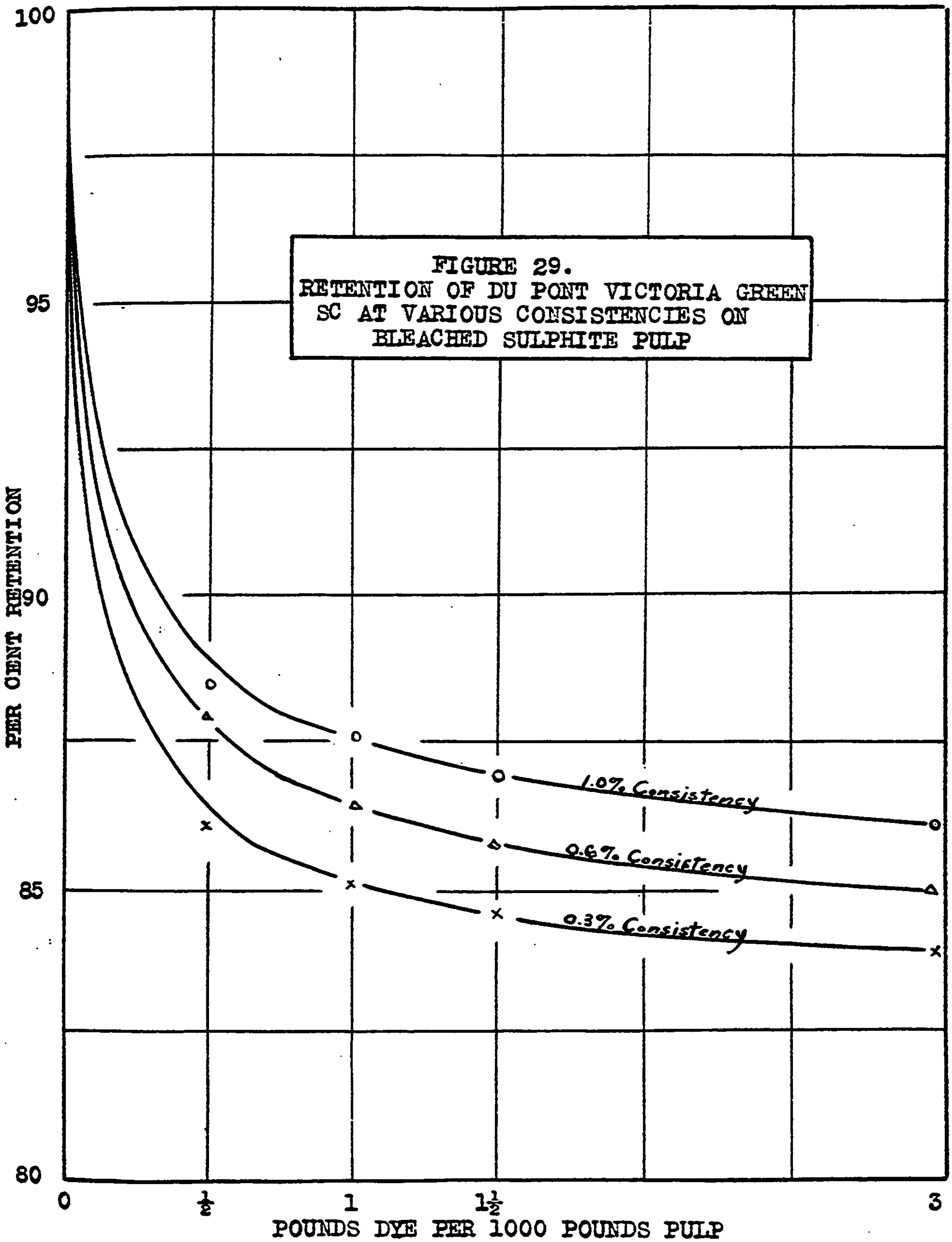


FIGURE 29.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS CONSISTENCIES ON BLEACHED SULPHITE PULP
100
95
90
85
80
PER CENT RETENTION
1.0% Consistency
0.6% Consistency
0.3% Consistency
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP

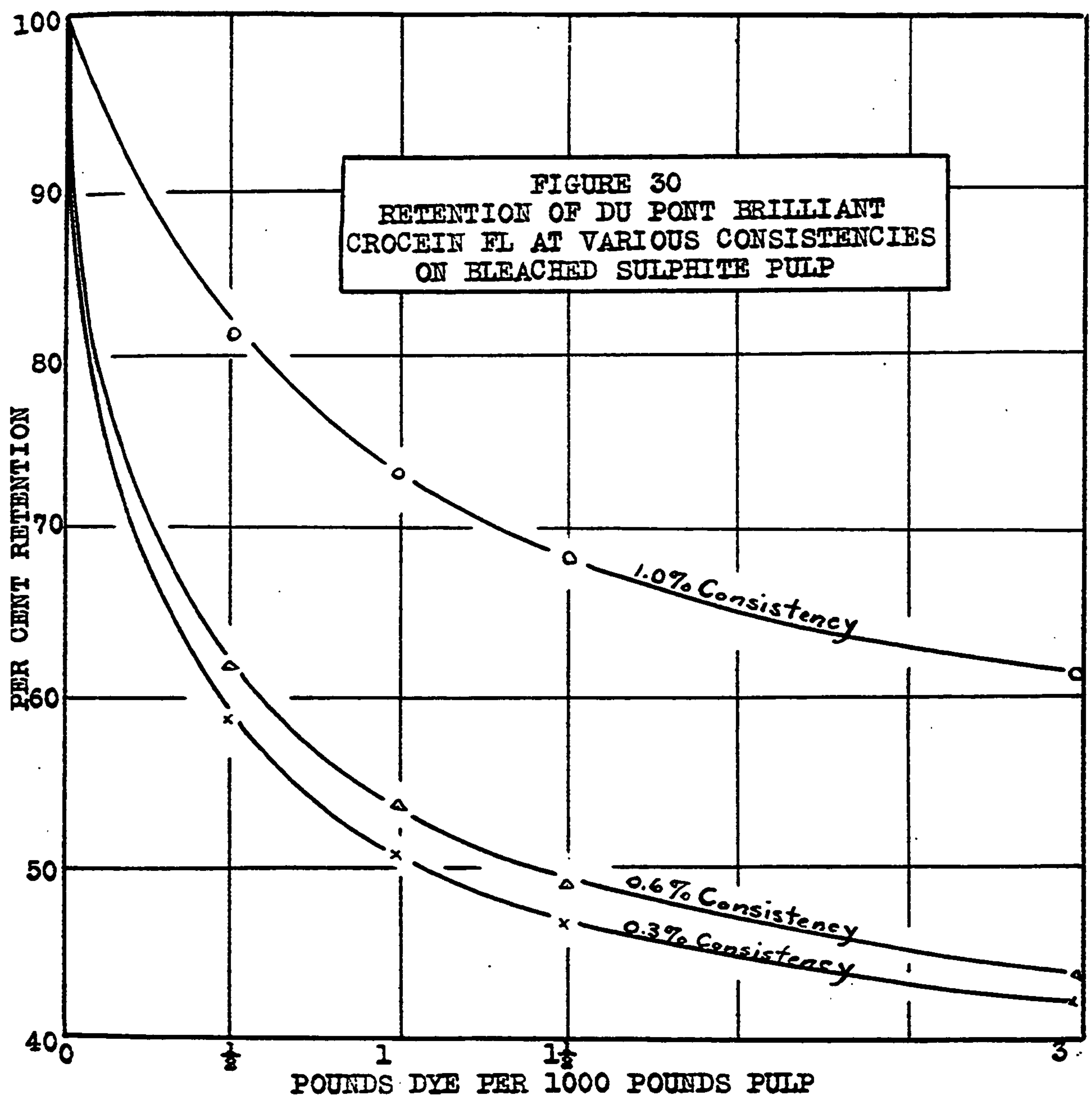


FIGURE 30
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS CONSISTENCIES ON BLEACHED SULPHITE PULP
100
90
80
70
60
50
40
0
½
1
1½
3
PER CENT RETENTION
POUNDS DYE PER 1000 POUNDS PULP
1.0% Consistency
0.6% Consistency
0.3% Consistency

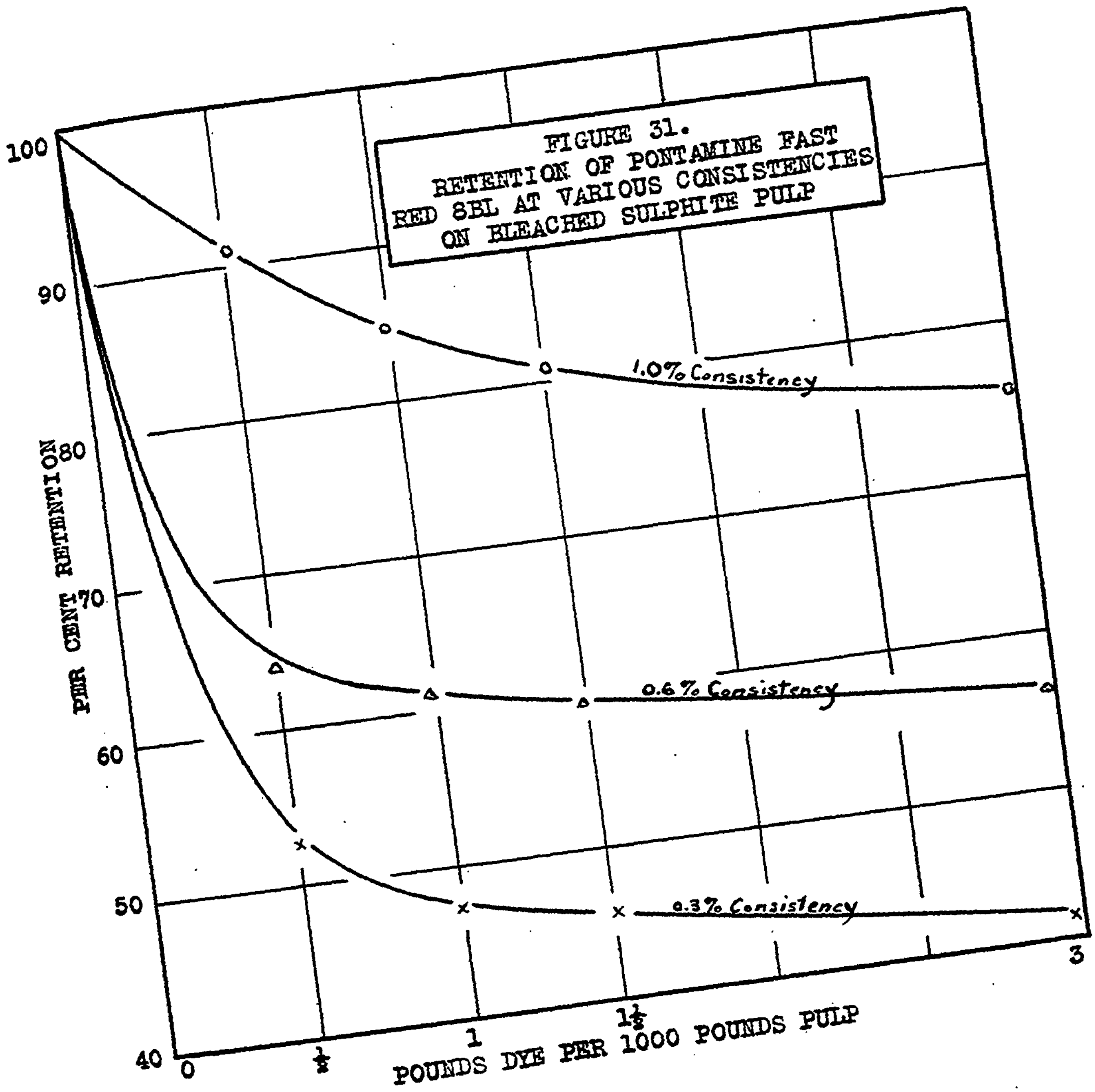


FIGURE 31.
RETENTION OF PONTAMINE FAST
RED 8BL AT VARIOUS CONSISTENCIES
ON BLEACHED SULPHITE PULP
1.0% Consistency
0.6% Consistency
0.3% Consistency
PER CENT RETENTION
100
90
80
70
60
50
40
POUNDS DYE PER 1000 POUNDS PULP
0
½
1
1½
3

dyeings which contained greater amounts of dye.

Du Pont Victoria Green SC on unbleached sulphite, figure 26, showed retentions for one half pound dyeings, for example, of 96.3, 97.9, and 98.6 per cent for 0.3, 0.6, and 1.0 per cent consistencies respectively. It was noticed that the drop from the 0.6 per cent consistency standard to the 0.3 per cent consistency was quite appreciable and the rise to 1.0 per cent consistency was worth while.

Du Pont Brilliant Crocein FL on unbleached sulphite, figure 27, shows considerably larger differences in retention due to the consistency changes. For one half pound dyeings, the retentions were 53.3, 57.7, and 76.3 per cent for the 0.3, 0.6, and 1.0 per cent consistency stocks and in that order. It might be pointed out that as the consistency is raised from 0.3 per cent the changes are not exceptionally large until after 0.6 per cent is reached. After this point, however, large gains are noticed. From these results it can be seen that consistency is an important variable in regard to the retention of acid dyestuffs.

Pontamine Fast Red 8BL on unbleached sulphite, figure 28, shows that differences due to consistence changes are on the same order as those obtained with Du Pont Brilliant Crocein FL. For one half pound dyeings, the retentions are 46.4, 58.0, and 78.7 per cent for pulp of 0.3, 0.6, and 1.0 per cent consistency. The raise from 0.3 to 1.0 per cent consistency is more uniform in this case than it is with the acid dye.

Du Pont Victoria Green SC on bleached sulphite, figure 29, is comparable with the results found for this dye on unbleached stock except that considerably less retention was obtained. For one half pound dyeings only 86.1, 87.9, and 88.4 per cent retentions were obtained for the 3 consistencies, 0.3, 0.6, and 1.0 per cent respectively in comparison with 96.3, 97.9, and 98.6 per cent obtained with the unbleached pulp.

Du Pont Brilliant Crocein FL on bleached sulphite, figure 30, is likewise comparable with the results obtained with the same dye on the unbleached pulp. The increase in retention does not increase rapidly from 0.3 to 0.6 per cent consistency, but large changes were noticed when the consistency advanced to 1.0 per cent. For one half pound dyeings the retentions were 58.8, 62.0, and 81.3 per cent for 0.3, 0.6, and 1.0 per cent consistency respectively. As will be noticed these results are slightly higher than the results obtained with the unbleached stock which is in accord with the findings in section three above.

Pontamine Fast Red 8BL on bleached sulphite, figure 31, shows results which are comparable with those obtained with the same dye on unbleached sulphite except that they are higher. For one half pound dyeings a much higher rate of increase in retention is noticed for the 1.0 per cent over the 0.6 per cent consistency dyeing than in the three pound dyeings for the same consistencies. The reason for this is that the low concentration of dye when put into the higher pulp consistency is taken up rapidly, but when the higher concentration of dye is put into stock of higher consistency, the resulting dye concentration is lowered with a decrease in retention. Retentions obtained for one half pound dyeings were 52.4, 64.0, and 91.0 per cent for 0.3, 0.6, and 1.0 per cent consistencies respectively.

6. Retention on Unbleached and Bleached Sulphite at Various Temperatures.

In studying the retention of dyes on pulps at various temperatures, unbleached and bleached sulphite were chosen to bring out the trends in the dye retention due to this variable. These pulps were dyed at three temperatures, 20, 40, and 60° C., with three typical dyes in four different strengths ($\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings). The retentions obtained are tabulated in table 18 and are shown graphically in figures 32 to 37 inclusive.

Du Pont Victoria Green SC on unbleached sulphite pulp, figure 32, shows that the retention of this basic dye at the temperatures studied does not vary much. It is not known why the retention shown by the 20 degree curve in figure 32 is between the 40 and 60 degree curves unless it is due to the limits of error in the procedure. For all practical purposes, the retentions of Du Pont Victoria Green SC on unbleached sulphite are constant in the range 20° to 60° C. For example, the retentions found for $1\frac{1}{2}$ pound dyeings are 96.0 per cent for temperatures at 20° and 60° C. and 95.9 per cent for a temperature of 40° C.

Du Pont Brilliant Crocein FL on unbleached sulphite, figure 33, shows that the higher the temperature of the dyeing reaction the higher the retention. For one half pound dyeings the retentions were 57.7, 58.6, and 60.0 per cent for 20°, 40°, and 60° C. temperatures respectively.

Pontamine Fast Red 8BL on unbleached sulphite, figure 34, also shows that increased temperature in

TABLE 18.

RETENTION OF DYES ON UNBLEACHED AND BLEACHED SULPHITE PULP AT VARIOUS TEMPERATURES

| Temperature and Pulp | Pounds Dye per 1000 Pounds Pulp | Du Pont Victoria Green SC Per Cent | Du Pont Brilliant Crocein FL Per Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| Unbleached Sulphite 20° | ½ | 97.9 | 57.7 | 58.0 |
| | 1 | 96.5 | 50.0 | 54.0 |
| | 1½ | 96.0 | 45.7 | 52.2 |
| | 3 | 95.3 | 41.8 | 49.1 |
| Unbleached Sulphite 40° | ½ | 97.2 | 58.6 | 59.8 |
| | 1 | 96.4 | 50.5 | 55.5 |
| | 1½ | 95.9 | 46.0 | 53.4 |
| | 3 | 95.0 | 42.1 | 49.8 |
| Unbleached Sulphite 60° | ½ | 98.0 | 60.0 | 61.8 |
| | 1 | 97.0 | 51.9 | 57.1 |
| | 1½ | 96.0 | 47.5 | 54.3 |
| | 3 | 95.3 | 43.9 | 50.7 |
| Bleached Sulphite 20° | ½ | 87.9 | 62.0 | 64.0 |
| | 1 | 86.4 | 53.8 | 61.0 |
| | 1½ | 85.8 | 49.0 | 59.1 |
| | 3 | 85.0 | 43.3 | 56.2 |
| Bleached Sulphite 40° | ½ | 87.8 | 62.3 | 65.8 |
| | 1 | 86.5 | 54.1 | 61.8 |
| | 1½ | 85.7 | 49.5 | 60.1 |
| | 3 | 85.0 | 44.0 | 57.0 |
| Bleached Sulphite 60° | ½ | 87.5 | 63.8 | 68.4 |
| | 1 | 86.5 | 55.2 | 64.4 |
| | 1½ | 85.9 | 51.1 | 62.3 |
| | 3 | 85.4 | 45.0 | 59.5 |

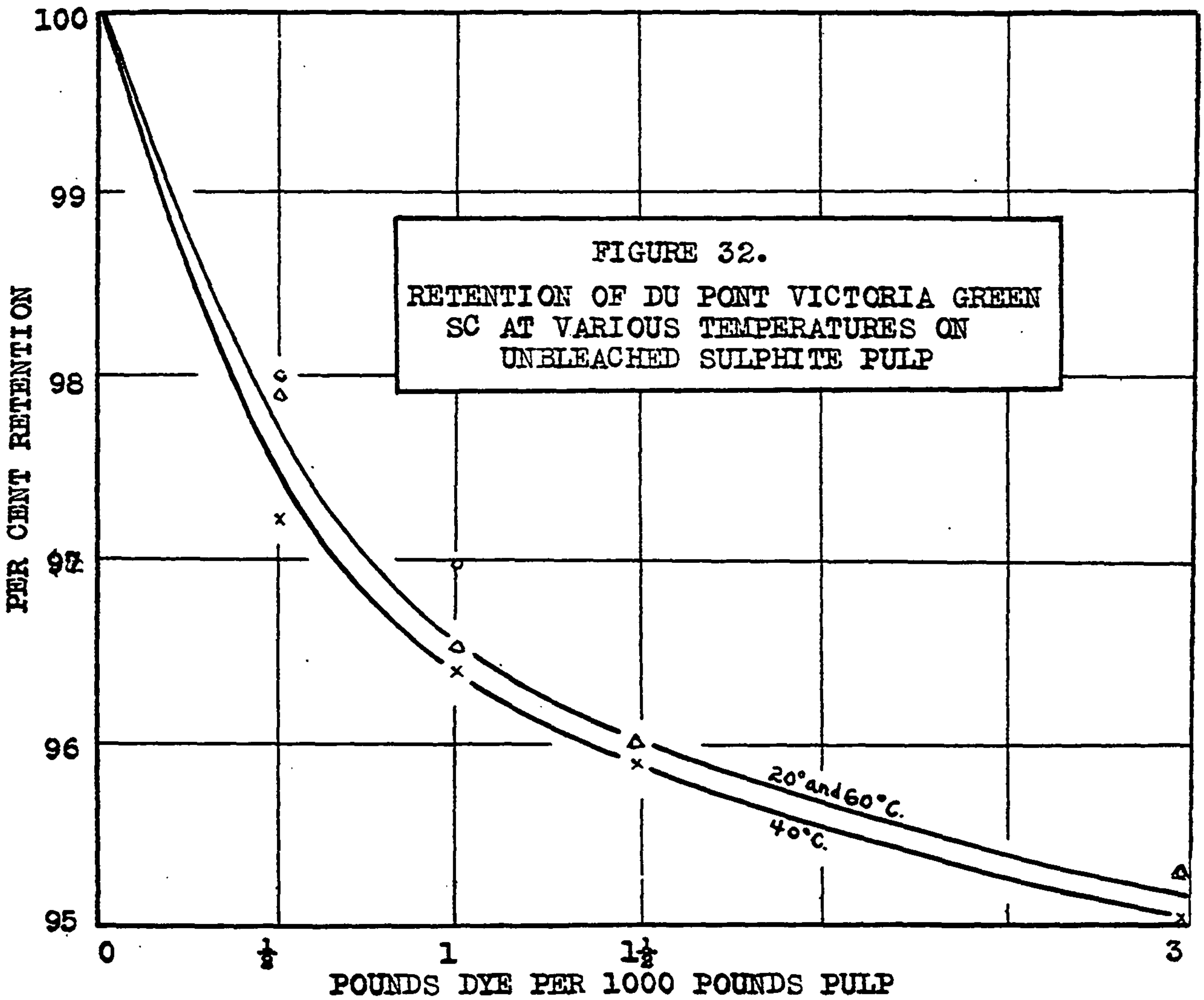


FIGURE 32.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS TEMPERATURES ON UNBLEACHED SULPHITE PULP
PER CENT RETENTION
100
99
98
97
96
95
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
20° and 60° C.
40° C.

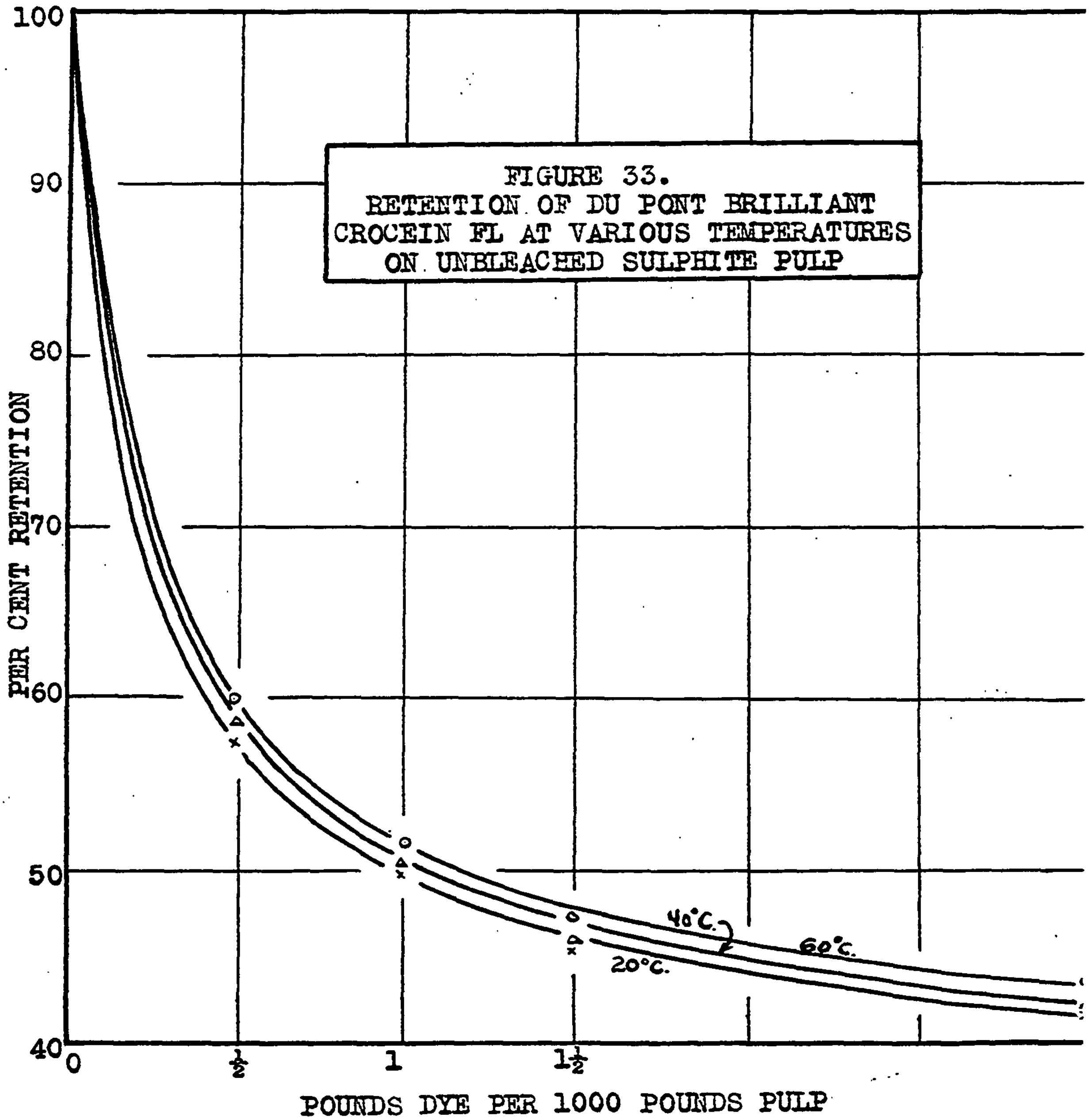


FIGURE 33.
RETENTION OF DU PONT BRILLIANT
CROCEIN FL AT VARIOUS TEMPERATURES
ON UNBLEACHED SULPHITE PULP
100
90
80
70
60
50
40
PER CENT RETENTION
0
½
1
1½
POUNDS DYE PER 1000 POUNDS PULP
40°C.
60°C.
20°C.

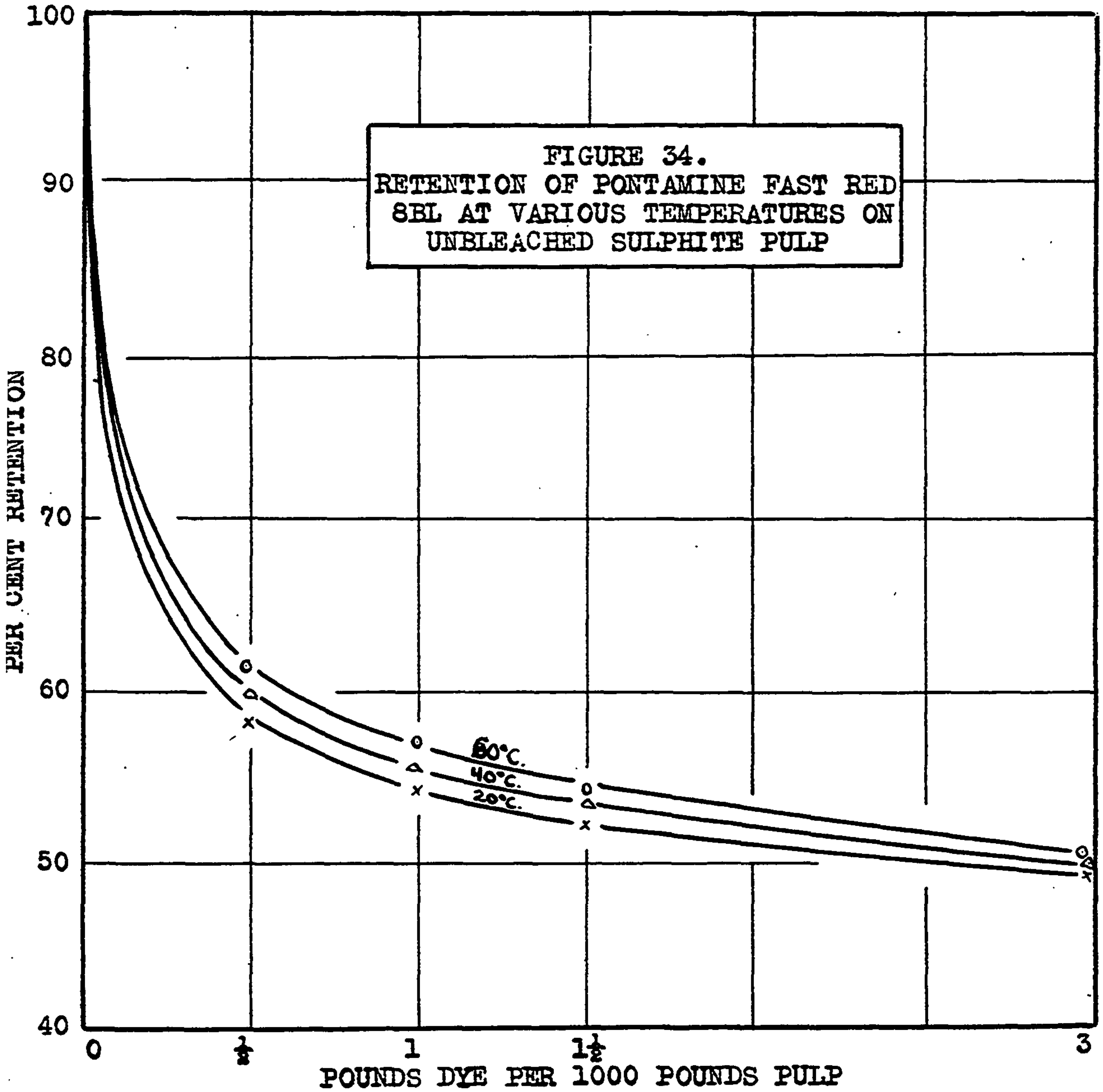


FIGURE 34.
RETENTION OF PONTAMINE FAST RED 8BL AT VARIOUS TEMPERATURES ON UNBLEACHED SULPHITE PULP
PER CENT RETENTION
100
90
80
70
60
50
40
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
60°C.
40°C.
20°C.

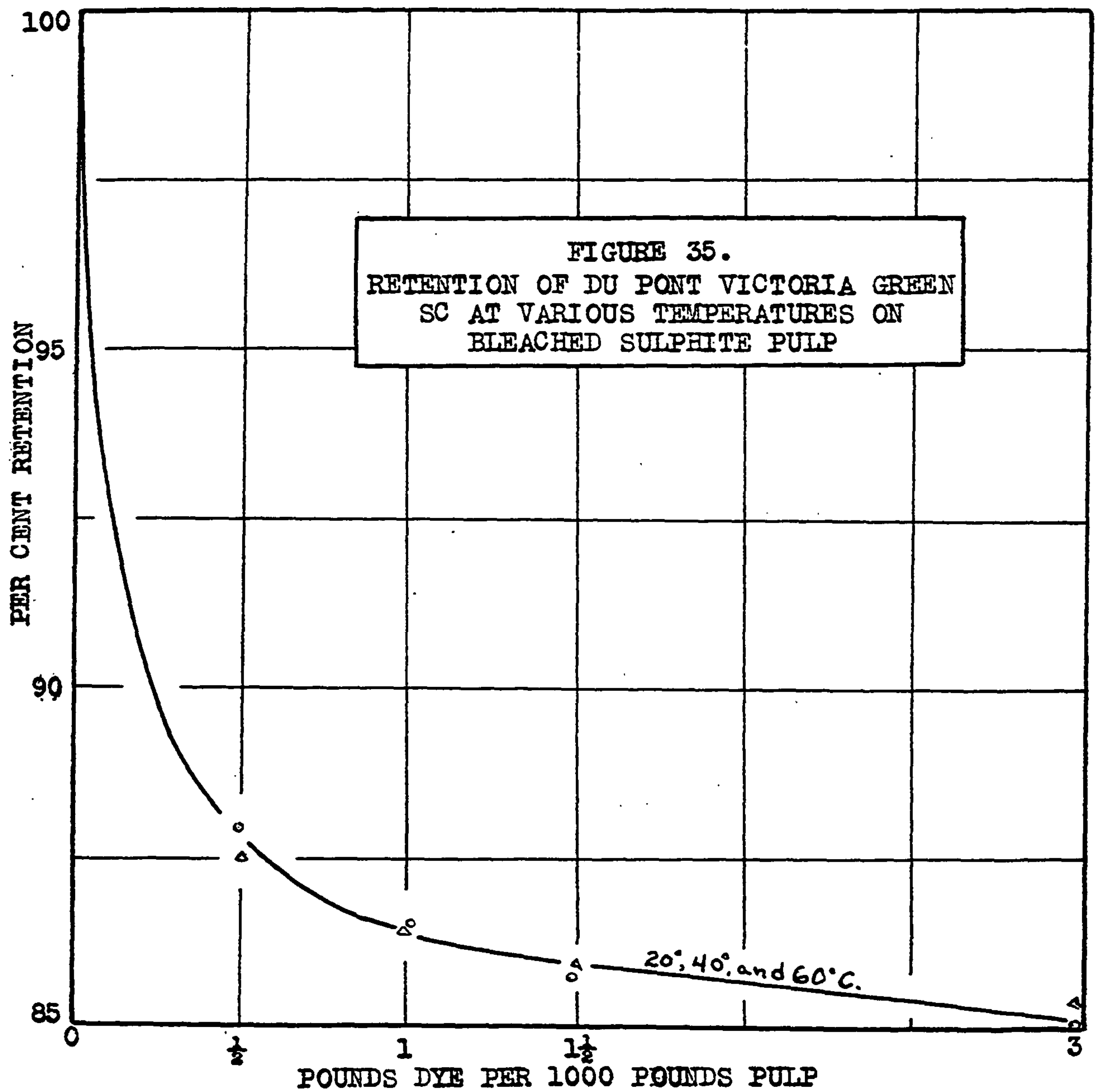


FIGURE 35.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS TEMPERATURES ON BLEACHED SULPHITE PULP
PER CENT RETENTION
100
95
90
85
0
½
1
1½
3
20°, 40°, and 60°C.
POUNDS DYE PER 1000 POUNDS PULP

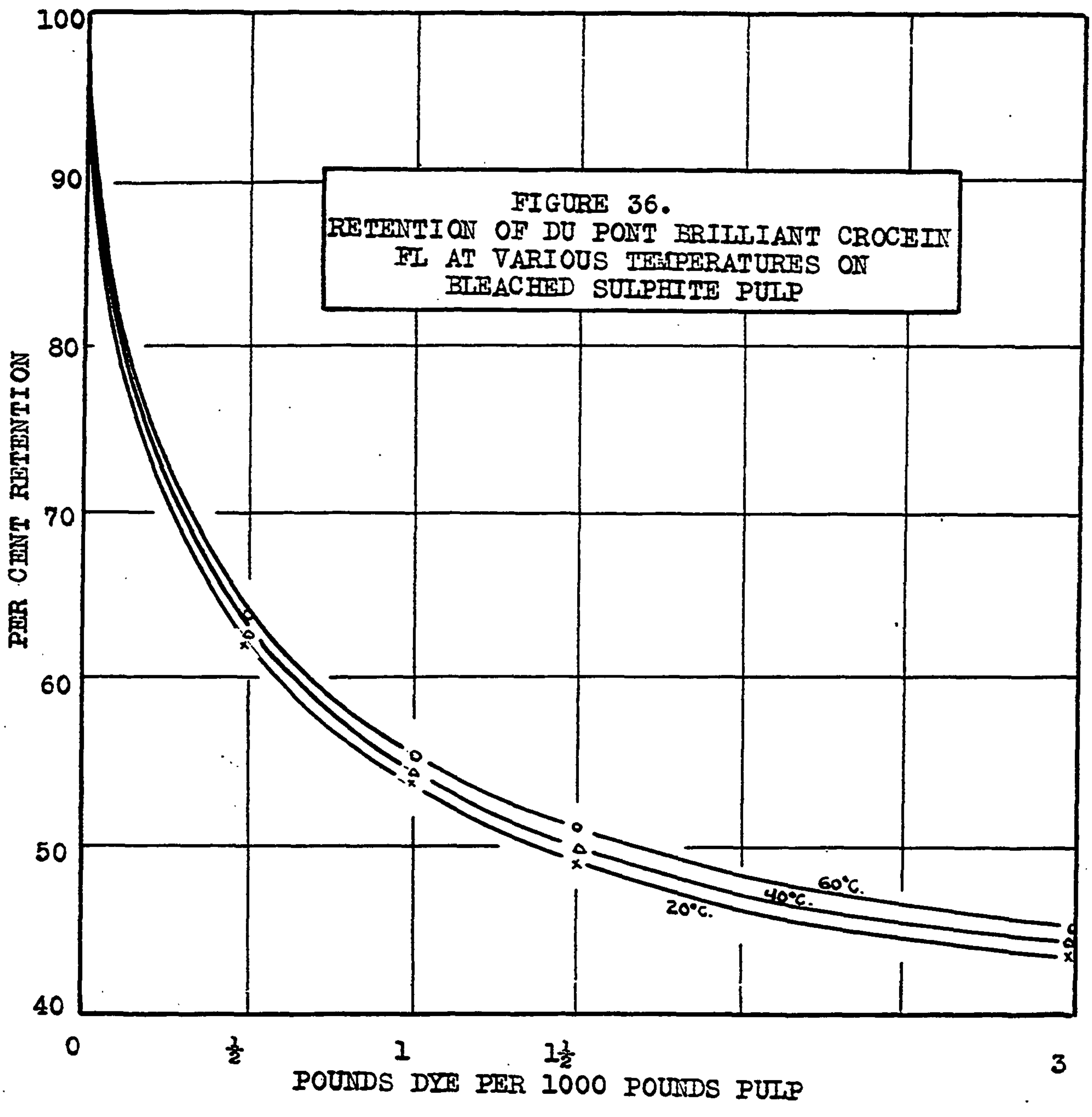


FIGURE 36.
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS TEMPERATURES ON BLEACHED SULPHITE PULP
PER CENT RETENTION
100
90
80
70
60
50
40
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
60°C.
40°C.
20°C.

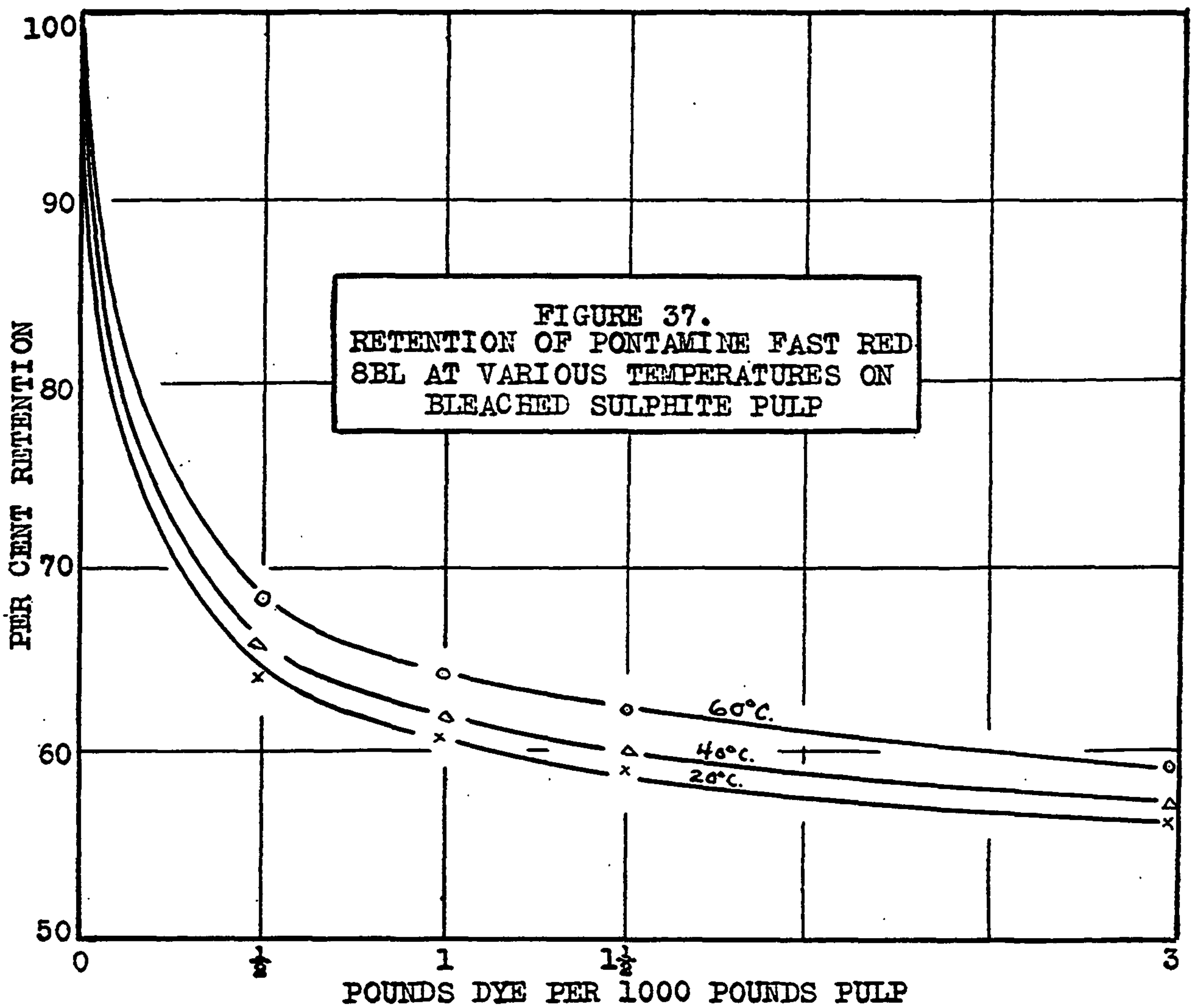


FIGURE 37.
RETENTION OF PONTAMINE FAST RED 8BL AT VARIOUS TEMPERATURES ON BLEACHED SULPHITE PULP
PER CENT RETENTION
100
90
80
70
60
50
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
60°C.
40°C.
20°C.

dyeing produces higher retentions of this dye. This effect was not as great as was expected changing only from 58.0 to 59.8 to 61.8 per cent for one half pound dyeings respectively for 20, 40, and 60° C. reaction temperatures.

Du Pont Victoria Green SC on bleached sulphite, figure 35, shows that, for all practical purposes, these changes in temperature had no affect on the amount of dye retained. For one half pound dyeings the retentions were 87.9, 87.8, and 87.5 per cent respectively for 20°, 40°, and 60° C. dyeing temperatures.

Du Pont Brilliant Crocein FL on bleached sulphite, figure 36, shows that increased temperature produces only slightly higher retention of this dye. For one half pound dyeings the retentions are 62.0, 62.3, and 63.8 per cent for temperatures of 20°, 40°, and 60° C. respectively.

Pontamine Fast Red 8BL on bleached sulphite, figure 37, shows that greater increases in retention than for any of the other dyes studied were obtained when the temperature was raised. For one half pound dyeings the retentions were 64.0, 65.8, and 68.4 per cent respectively for temperatures of 20°, 40°, and 60° C.

Results obtained by varying the temperature show that the retention of basic dyes are not affected from a practical standpoint by temperature; acid dyestuffs are retained very little better by increased temperatures of the dyeing reaction, while direct dyes are retained somewhat better at higher temperatures.

7. Retention on Unbleached and Bleached Sulphite at Various Reaction Times.

In studying the effect of time on the retention of dyes, unbleached and bleached sulphite pulp were dyed at different time periods, 10, 30, and 60 minutes, with the three typical dyes in four different concentrations (½, 1, 1½, and 3 pound dyeings). The results of the retentions under the various conditions are shown in table 19 and are shown graphically in figures 38 to 43 inclusive.

Du Pont Victoria Green SC on unbleached sulphite, figure 38, shows that time has very little effect on the retention of this dye. For one half pound dyeings the retentions were 97.9 per cent for the 10 and 30 minute reaction times and 98.0 per cent for the 60 minute reaction time. For all practical purposes the retention of this dye is the same for all time periods taken into consideration

TABLE 19.

RETENTION OF DYES ON UNBLEACHED AND BLEACHED SULPHITE PULP AT VARIOUS REACTION TIMES

| Time in Minutes and Pulp | Pounds Dye per 1000 Pounds Pulp | Du Pont Victoria Green SC Per Cent | Du Pont Brilliant Crocein Per Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| Unbleached Sulphite 10 | ½ | 97.9 | 57.7 | 58.0 |
| | 1 | 96.5 | 50.0 | 54.0 |
| | 1½ | 96.0 | 45.7 | 52.2 |
| | 3 | 95.3 | 41.8 | 49.1 |
| Unbleached Sulphite 30 | ½ | 97.9 | 59.7 | 68.7 |
| | 1 | 96.4 | 51.5 | 63.3 |
| | 1½ | 96.0 | 47.0 | 60.0 |
| | 3 | 95.4 | 42.3 | 53.9 |
| Unbleached Sulphite 60 | ½ | 98.0 | 64.1 | 77.7 |
| | 1 | 96.5 | 53.5 | 70.1 |
| | 1½ | 96.1 | 48.3 | 65.5 |
| | 3 | 95.4 | 43.0 | 57.0 |
| Bleached Sulphite 10 | ½ | 87.9 | 62.0 | 64.0 |
| | 1 | 86.4 | 53.8 | 61.0 |
| | 1½ | 85.8 | 49.0 | 59.1 |
| | 3 | 85.0 | 43.3 | 56.2 |
| Bleached Sulphite 30 | ½ | 87.0 | 65.0 | 75.8 |
| | 1 | 86.2 | 54.5 | 68.5 |
| | 1½ | 85.8 | 49.8 | 64.7 |
| | 3 | 85.0 | 43.7 | 59.0 |
| Bleached Sulphite 60 | ½ | 87.9 | 67.3 | 86.1 |
| | 1 | 86.4 | 55.2 | 77.4 |
| | 1½ | 86.0 | 50.7 | 71.3 |
| | 3 | 85.3 | 44.0 | 61.1 |

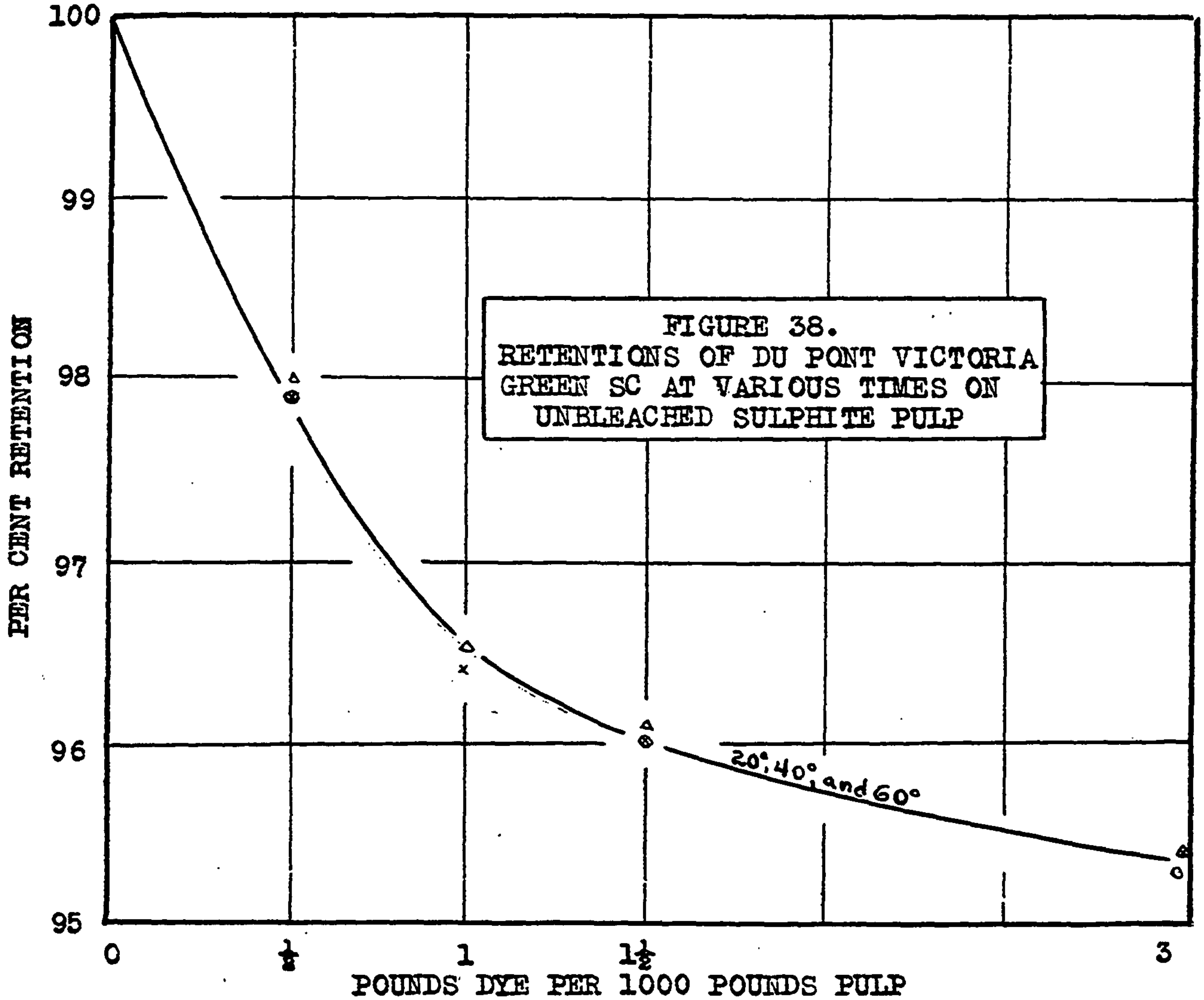



FIGURE 38.
RETENTIONS OF DU PONT VICTORIA GREEN SC AT VARIOUS TIMES ON UNBLEACHED SULPHITE PULP

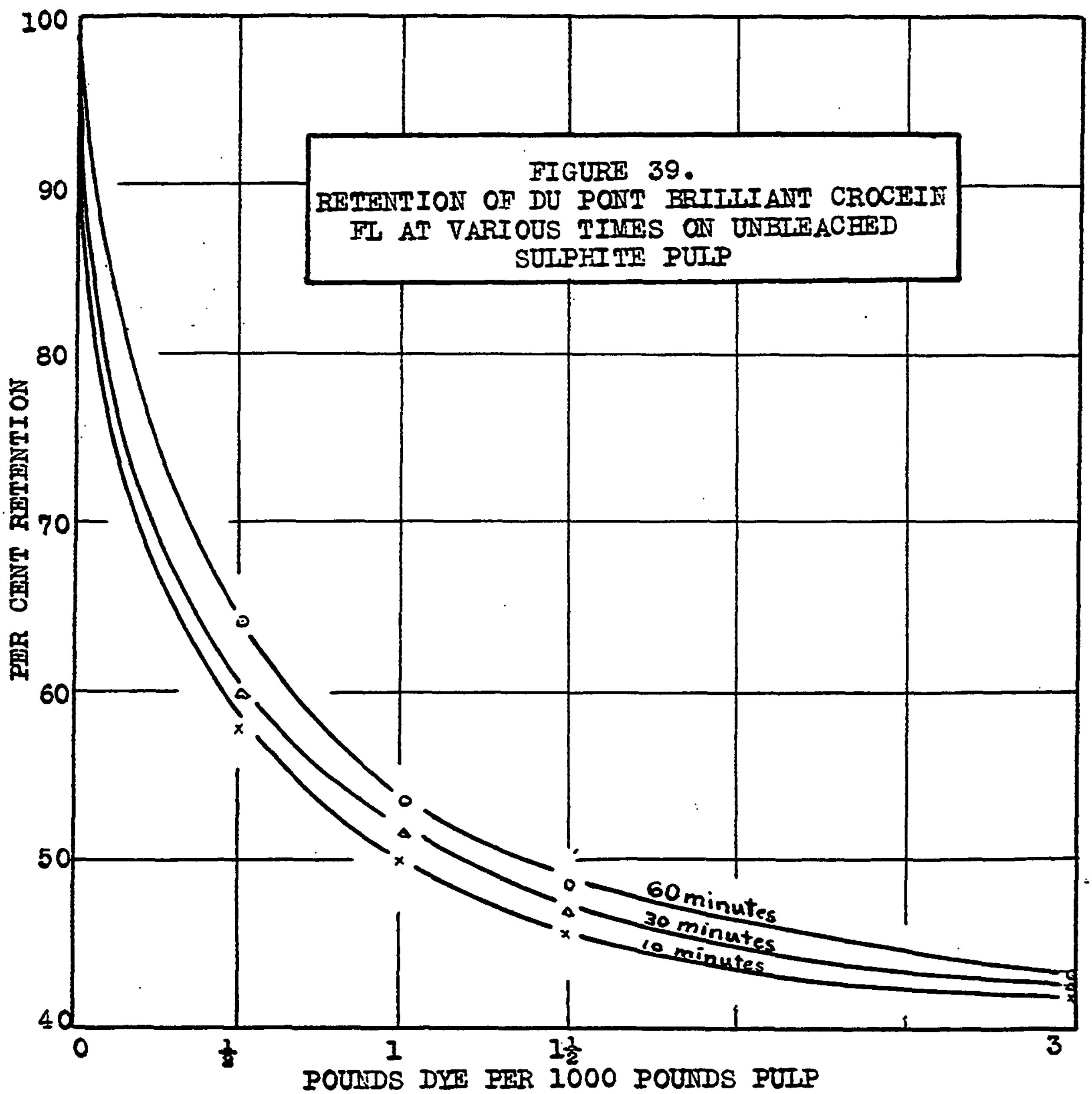


FIGURE 39.
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS TIMES ON UNBLEACHED SULPHITE PULP
100
90
80
70
60
50
40
PER CENT RETENTION
60 minutes
30 minutes
10 minutes
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP

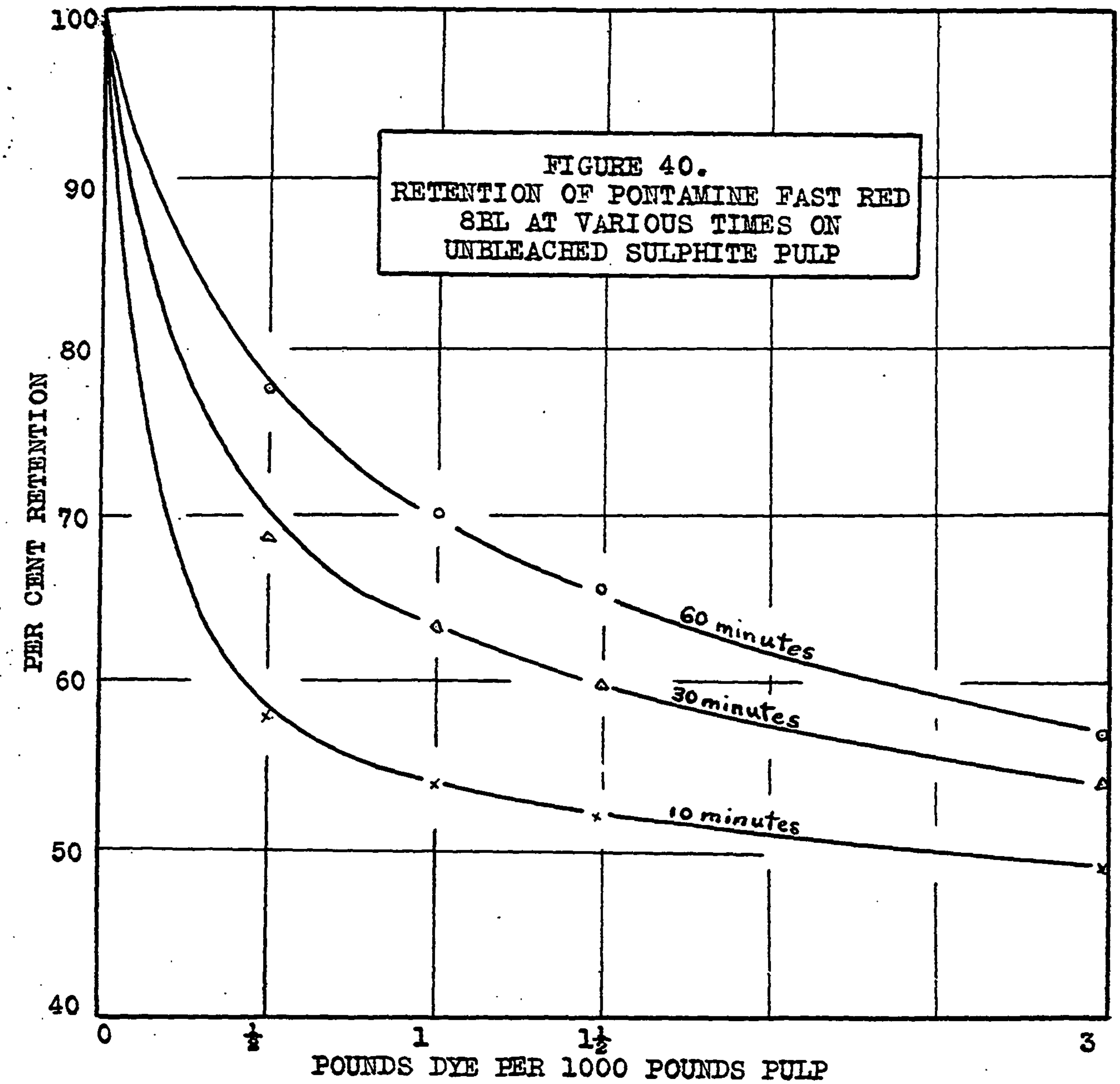


FIGURE 40.
RETENTION OF PONTAMINE FAST RED 8BL AT VARIOUS TIMES ON UNBLEACHED SULPHITE PULP
100
90
80
70
60
50
40
PER CENT RETENTION
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
60 minutes
30 minutes
10 minutes

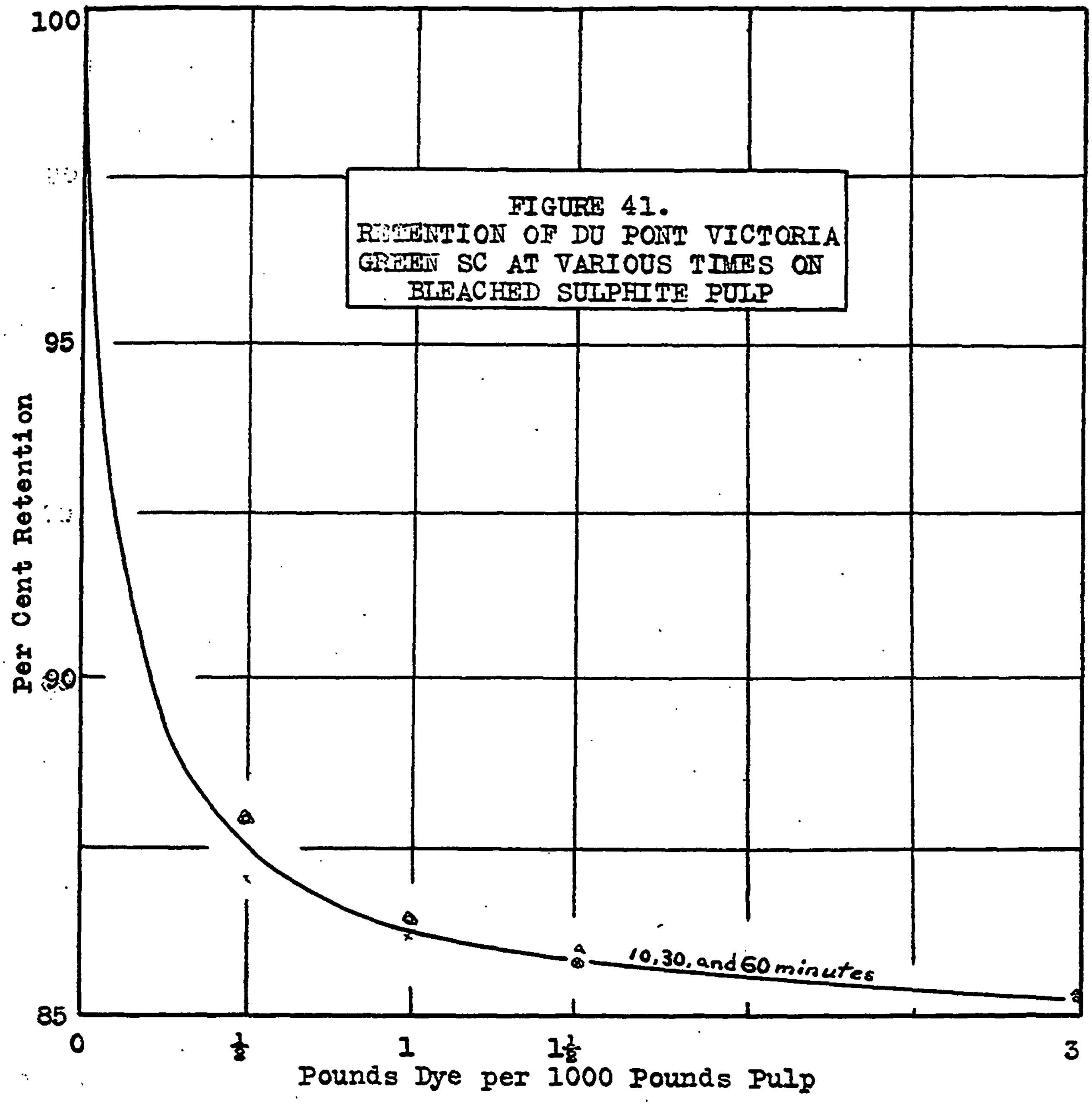



FIGURE 41.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS TIMES ON BLEACHED SULPHITE PULP

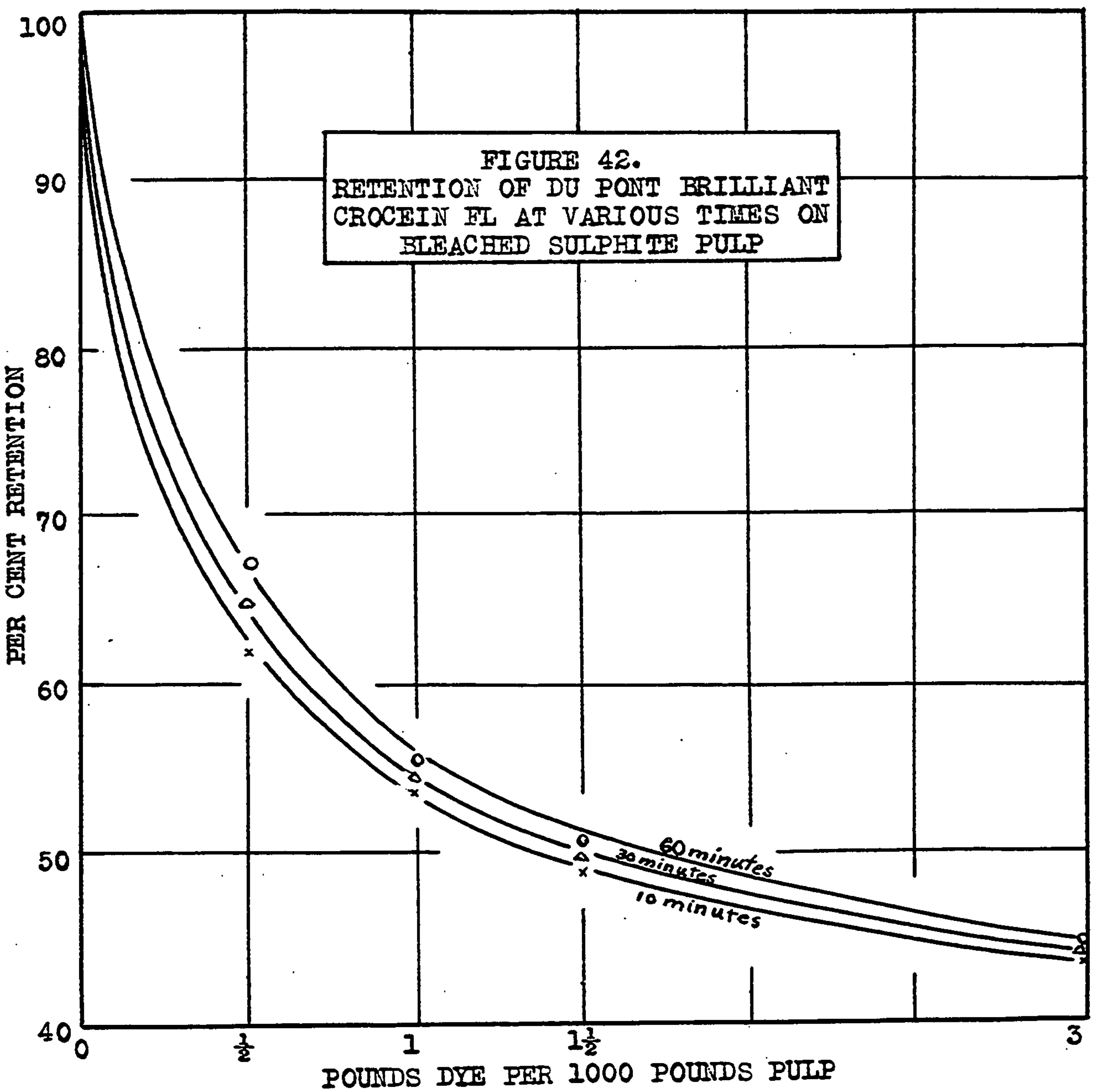


FIGURE 42.
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS TIMES ON BLEACHED SULPHITE PULP
100
90
80
70
60
50
40
PER CENT RETENTION
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
60 minutes
30 minutes
10 minutes

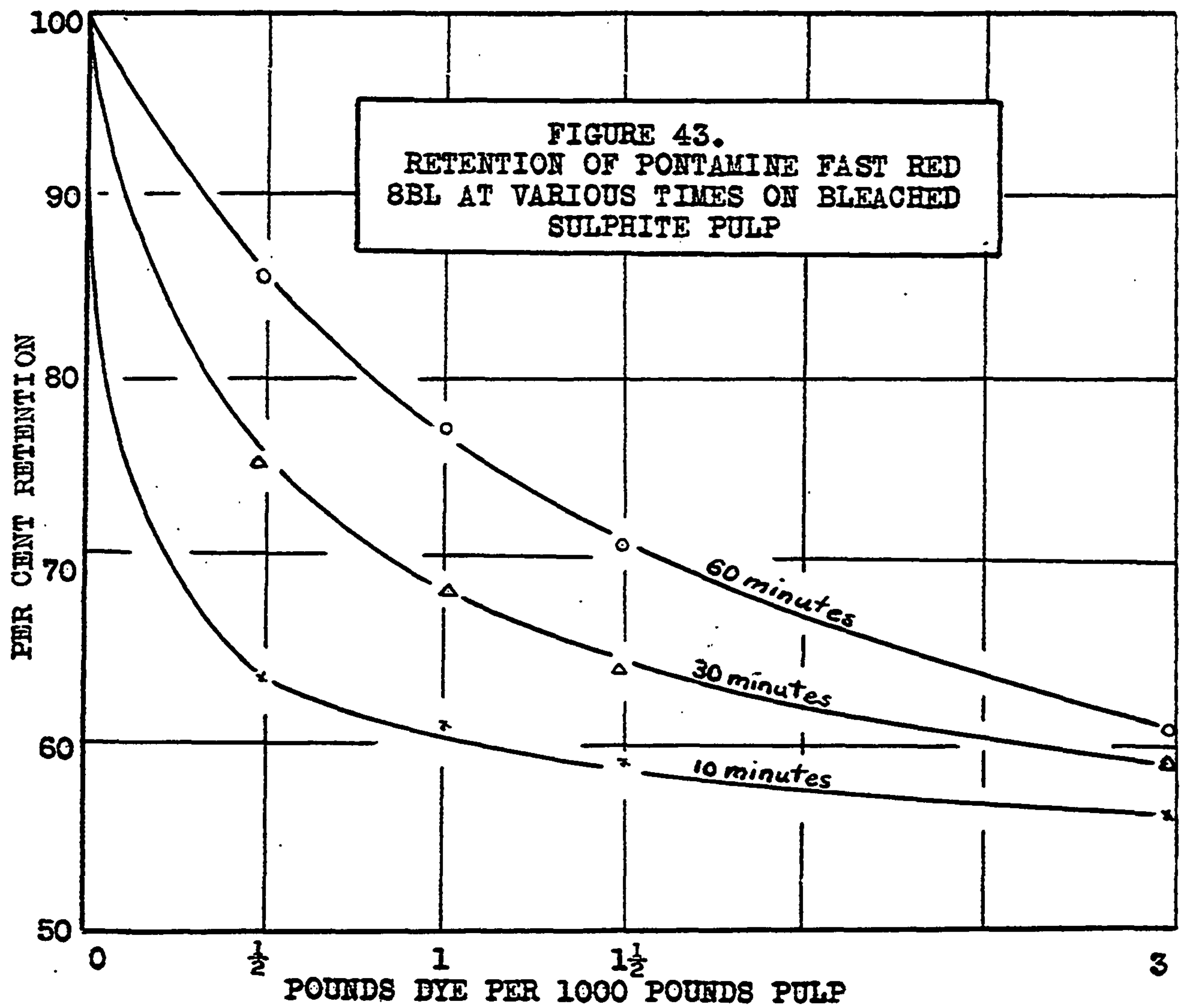


FIGURE 43.
RETENTION OF PONTAMINE FAST RED
8BL AT VARIOUS TIMES ON BLEACHED
SULPHITE PULP
100
90
80
70
60
50
PER CENT RETENTION
0
½
1
1½
3
POUNDS DYE PER 1000 POUNDS PULP
60 minutes
30 minutes
10 minutes

by this investigation.

Du Pont Brilliant Crocein FL on unbleached sulphite, figure 39, shows that, as the dyeing time increased, the retention is increased. For example, for one half pound dyeings, the retentions are 57.7, 59.7, and 64.1 per cent for the time periods of 10, 30, and 60 minutes respectively.

Pontamine Fast Red 8BL on unbleached sulphite, figure 40, shows that this dye is considerably affected by the time variable. The increases due to increased time of reaction are sizeable and can not go unnoticed. For one half pound dyeings the retention is increased from 58.0 to 68.7 to 77.7 per cent by changes in the time from 10 to 30 to 60 minutes respectively.

Du Pont Victoria Green SC on bleached sulphite, figure 41, shows the same type of results that were obtained with the unbleached pulp except that the retentions on bleached pulp are in general 10 per cent lower. The retention of this dye apparently is affected very little by time. For example, one half pound dyeings are retained 87.9 per cent for reaction times of 10 and 60 minutes, and 87.0 per cent for a reaction time of 30 minutes. From a practical standpoint the retention is the same in each case.

Du Pont Brilliant Crocein FL on bleached sulphite, figure 42, shows that with increased time of reaction the retention also increases just as was found for this dye with unbleached sulphite. For one half pound dyeings the retention is 62.0, 65.0, and 67.3 per cent respectively for 10, 30, and 60-minute reaction times.

Pontamine Fast Red 8BL on bleached sulphite, figure 43, shows that a sizeable change in retention can be obtained with this dye by allowing sufficient time to permit the dye to react with the fiber. For one half pound dyeings, for example, the retention was raised from 64.0 per cent for a 10-minute reaction time to 86.1 per cent for a 60-minute reaction time.

The results of this retention study, with time as a variable, show that Du Pont Victoria Green SC is not affected to any great extent by time of reaction. Du Pont Brilliant Crocein FL is somewhat affected, giving higher retentions for longer times, while Pontamine Fast Red 8BL produces sizeable increases in retention when the reaction time is lengthened.

8. Retention on Unbleached Sulphite at Various Freenesses.

To study the retention trends as the freeness of the pulp was varied, unbleached sulphite was dyed at six different freenesses with the three typical dyes in just one strength, three pound dyeings. The results of the retentions under these conditions are tabulated in table 20 and are shown graphically in figures 44 to 46 inclusive.

Du Pont Victoria Green SC, figure 44, is retained only slightly better as the freeness of the pulp is decreased. For example, the retention increases from 95.3 to 98.3 per cent when the freeness of the pulp is changed from 860 to 250.

Du Pont Brilliant Crocein FL, figure 45, is retained better at lower freenesses than at high freenesses. The increase is considerable, changing steadily from 41.8 per cent retention at 860 freeness to 68.0 per cent at 250 freeness.

Pontamine Fast Red 8BL, figure 46, relative to the other dyes is retained to a much greater extent as the freeness is lowered. In this particular case the retention was only 49.1 per cent at a freeness of 860, but at a freeness of 250 the retention jumped to 84.5 per cent, all other conditions being equal.

The results of this part of the investigation show that in every case the retention of a dye may be increased by lowering the freeness of the pulp. Direct dyes such as Pontamine Fast Red 8BL are affected the most by freeness changes, acid dyes such as Du Pont Brilliant Crocein FL are next, while basic dyes such as Du Pont Victoria Green SC are affected the least.

TABLE 20.

RETENTION OF DYES ON UNBLEACHED SULPHITE AT VARIOUS FREENESSES

| Time Minutes | Freeness | Du Pont Victoria Green SC Per Cent | Du Pont Brilliant Crocein FL Per Cent | Pontamine Fast Red 8BL Per Cent |
|---|---|---|---|---|
| 0 | 860 | 95.3 | 41.8 | 49.1 |
| 10 | 810 | 95.8 | 47.5 | 53.4 |
| 20 | 705 | 96.7 | 54.0 | 62.5 |
| 30 | 560 | 97.4 | 59.5 | 72.0 |
| 40 | 400 | 97.9 | 63.5 | 79.3 |
| 50 | 250 | 98.3 | 68.0 | 84.5 |

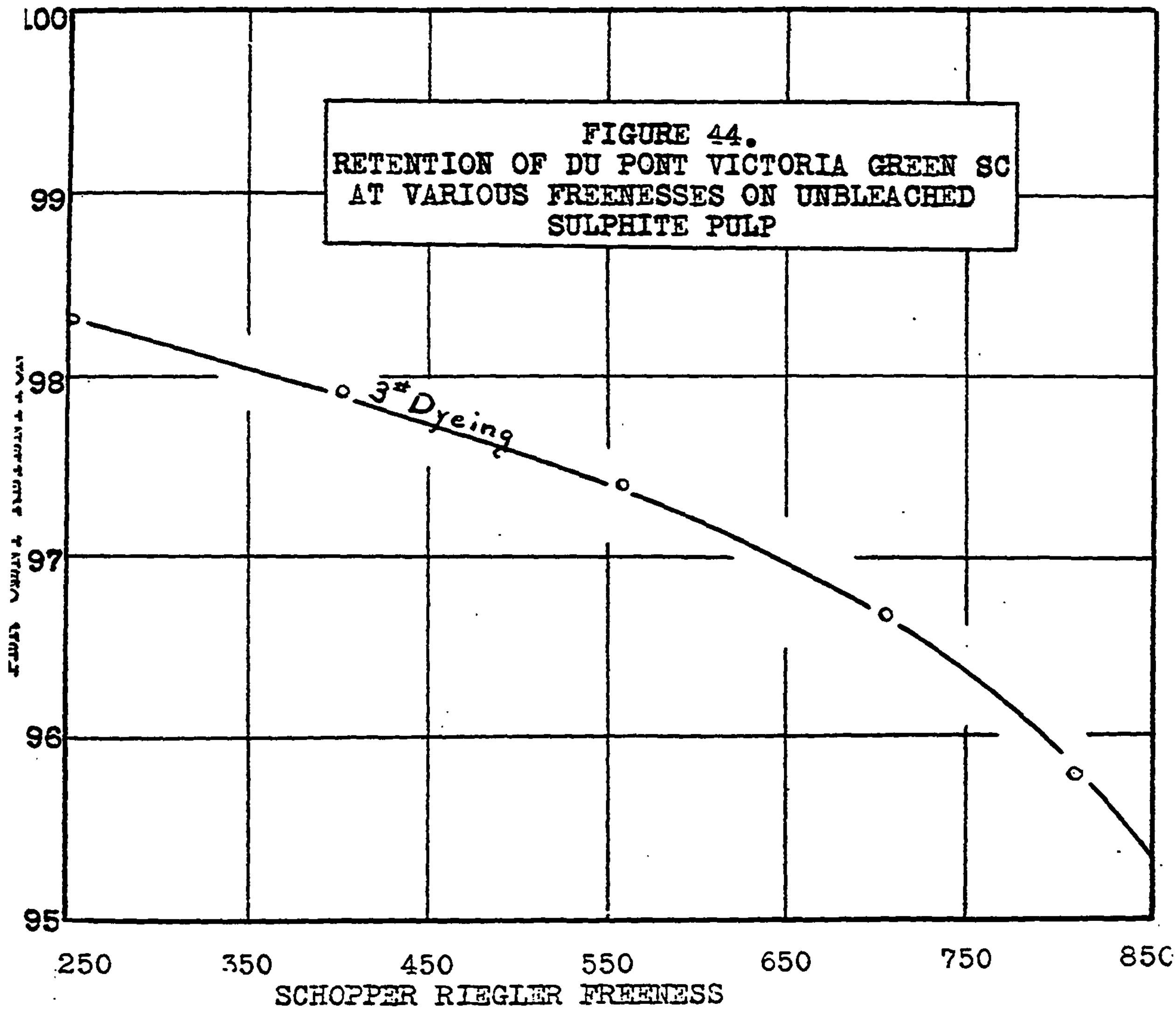



FIGURE 44.
RETENTION OF DU PONT VICTORIA GREEN SC AT VARIOUS FREENESSES ON UNBLEACHED SULPHITE PULP

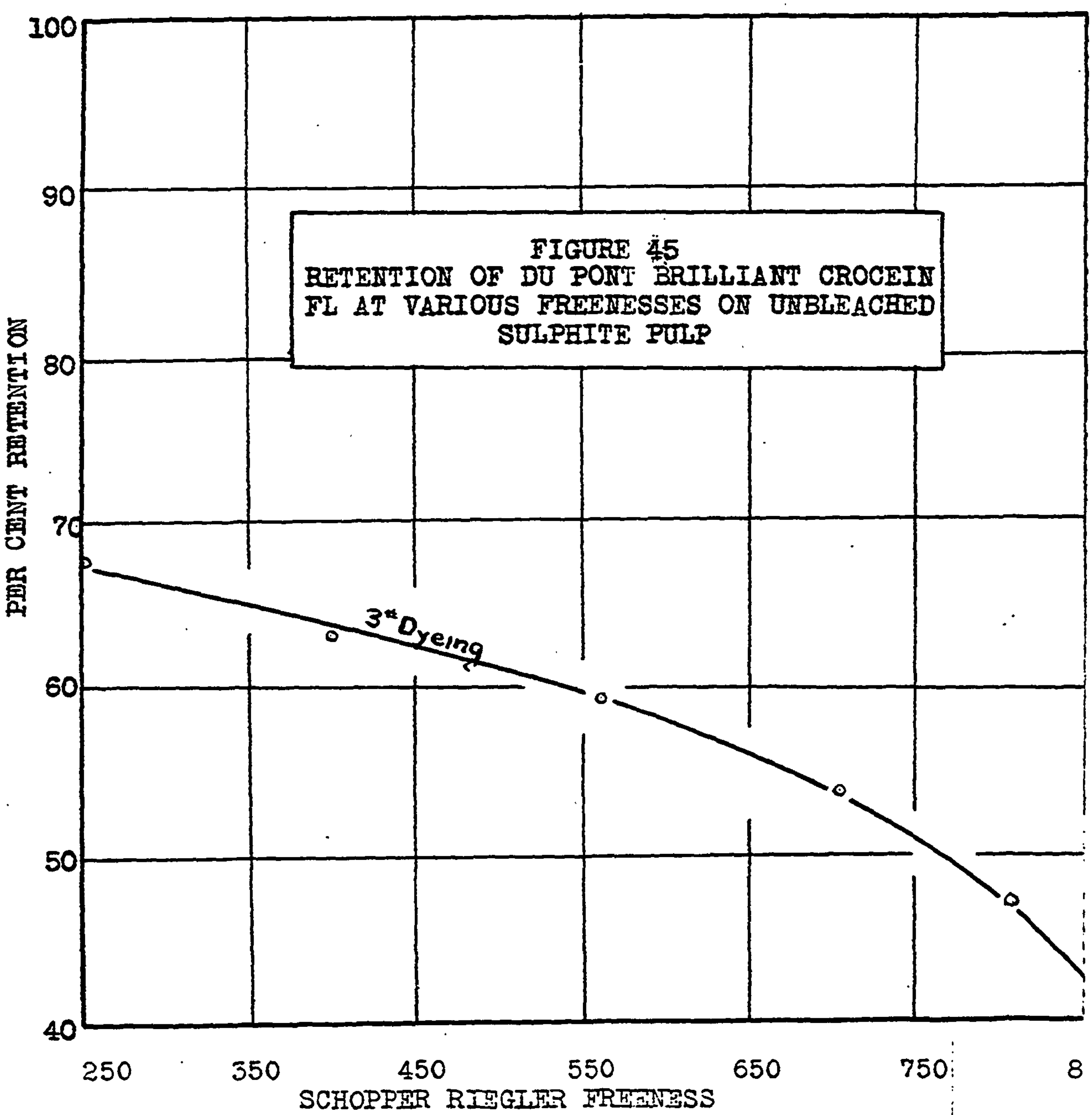


FIGURE 45
RETENTION OF DU PONT BRILLIANT CROCEIN FL AT VARIOUS FREENESSES ON UNBLEACHED SULPHITE PULP
PER CENT RETENTION
100
90
80
70
60
50
40
250
350
450
550
650
750
8
SCHOPPER RIEGLER FREENESS
3rd Dyeing

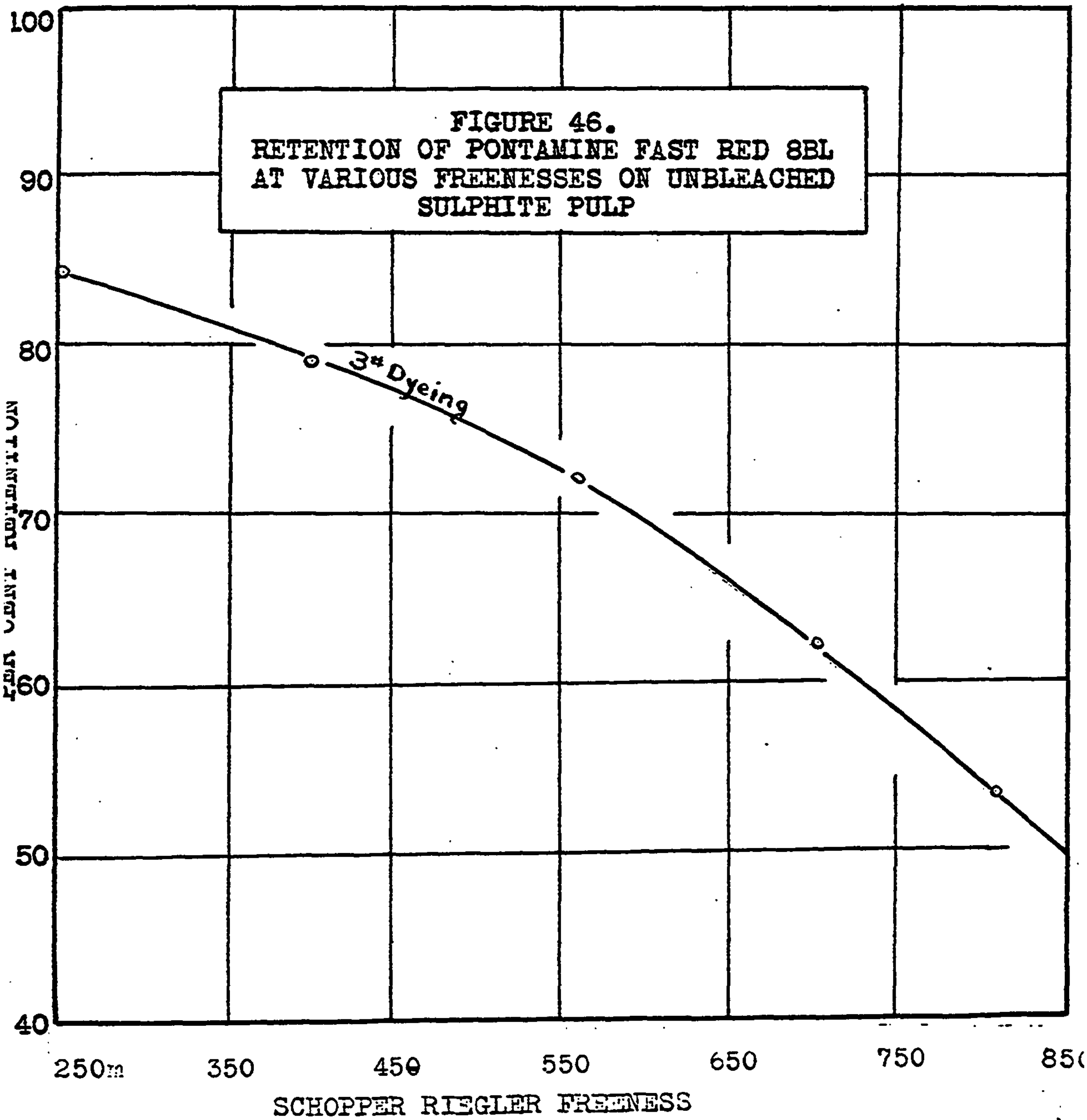


FIGURE 46.
RETENTION OF PONTAMINE FAST RED 8BL
AT VARIOUS FREENESSES ON UNBLEACHED
SULPHITE PULP
3rd Dyeing
100
90
80
70
60
50
40
250m
350
450
550
650
750
85(
SCHOPPER RIEGLER FREENESS

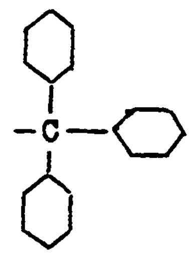
9. Retention of Various Dyes on Unbleached Sulphite.

In studying the retention of various dyes, three pound dyeings on unbleached sulphite were made with twenty different types of dyes obtained from the three main classes of dyestuffs. The results of the retentions are tabulated in table 21.

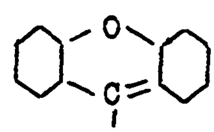
In picking the dyes, one and sometimes two were picked from each of the most important types of dyestuffs in each class as follows:

Basic Dyes

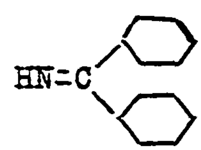
Du Pont Victoria Green SC
Triphenyl Methane Grouping



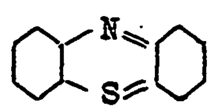

Du Pont Rhodamine B
Xanthene Grouping




Du Pont Auramine Conc.
Ketonamine Grouping




Du Pont Methylene Blue ZX
Thiazine Grouping




Du Pont Basic Brown BR
Disazo Grouping from Diamines

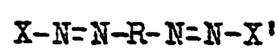


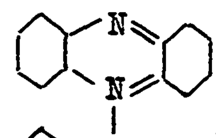
TABLE 21

RETENTION OF VARIOUS DYES ON UNBLEACHED SULPHITE

| Dye | Per Cent Retention |
|---|---|
| Basic Dyes | |
| Du Pont Victoria Green SC | 95.3 |
| Du Pont Rhodamine B | 85.4 |
| Du Pont Auramine Conc. | 94.8 |
| Du Pont Methylene Blue ZX | 96.3 |
| Du Pont Basic Brown BR | 53.8 |
| Du Pont Safranine T Extra | 94.8 |
| Du Pont Methyl Violet NE | 91.8 |
| Acid Dyes | |
| Du Pont Brilliant Crocein FL | 41.8 |
| Du Pont Anthraquinone Blue B | 5.6 |
| Du Pont Nigrosine WSB Powder | 15.9 |
| Du Pont Quinoline Yellow Conc. | 11.7 |
| Du Pont Orange II Conc. | 14.2 |
| Pontacyl Violet S4B | 36.1 |
| Direct Dyes | |
| Pontamine Fast Red 8BL | 49.1 |
| Du Pont Purpurine 4B Conc. | 76.1 |
| Pontamine Fast Scarlet 4BS | 55.7 |
| Pontamine Black E | 39.6 |
| Du Pont Brilliant Paper Yellow Conc. | 30.6 |
| Pontamine Yellow SXP | 25.9 |
| Pontamine Fast Yellow NNL | 58.3 |

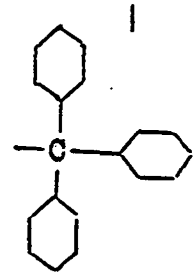
Du Pont Safranine T Extra

Azine Grouping



Du Pont Methyl Violet NE

Triphenyl Methane Grouping



Acid Dyes

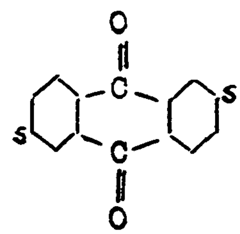
Du Pont Brilliant Crocein FL

Monoazo Grouping

X-N=N-X

Du Pont Anthraquinone Blue B

Anthraquinone Acid Grouping

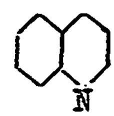


Du Pont Nigrosine WSB Powder

Very Complex Unknown Structure

Du Pont Quinoline Yellow Conc.

Quinoline Grouping



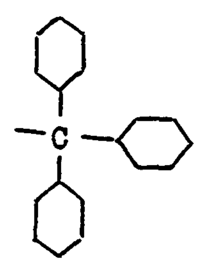
Du Pont Orange II Conc.

Monoazo Grouping

X-N=N-X

Pontacyl Violet 4SB

Triphenyl Methane Grouping



Direct Dyes

Pontamine Fast Red 8BL

Disazo Grouping

X-N=N-R-N=N-X'

Du Pont Purpurine 4B Conc.

Disazo Grouping from Diamines

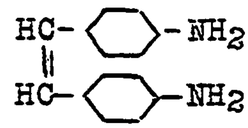
X-N=N-R-N=N-X'

Pontamine Black E

Trisazo Grouping

A-N=N-B-N=N-C-N=N-D

Du Pont Brilliant Paper
Yellow Concentrated
Mono Stilbene Grouping




Pontamine Fast Scarlet 4BS

Disazo Grouping

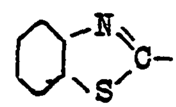
A-N=N-B-N=N-C

Pontamine Yellow SXP

Di Stilbene Grouping

Pontamine Fast Yellow NNL

Thiazole Grouping




Complete structural formulas of these dyes are given in section C of the appendix. These dyes were picked so as to have a dye from each important grouping and at the same time have them overlap enough so as to determine whether or not dyestuffs having the same groupings would have approximately the same retentions.

The results show that dyes having the same groupings do not necessarily have the same retentions. For example, Du Pont Orange II Concentrated and

Du Pont Brilliant Crocein FL both have monoazo groupings but have widely differing retentions, 14.2 and 41.8 per cent respectively. All the basic dyes used in this investigation have retentions above 91.0 per cent except for Du Pont Rhodamine B which had a retention of 85.4 per cent and notably Du Pont Basic Brown which has the exceptionally low retention of 53.8 per cent. The acid dyestuffs have the lowest retentions of any class varying between 5.6 per cent for Du Pont Anthraquinone Blue B and 41.8 per cent for Du Pont Brilliant Crocein FL. The direct dyestuffs as a class are retained better than the acid dyes but not as well as the basic dyes. Du Pont Purpurine 4B Concentrated is exceptionally high with a retention of 76.1 per cent.

10. Retention on Unbleached Sulphite When Various Acids were Used With and Without Size.

In studying the retention of dyes when various acids were used with and without size, three pound dyeings were made with the dyes, Du Pont Victoria Green SC, Du Pont Brilliant Crocein FL, Du Pont Orange II, and Pontamine Fast Red 8BL, on unbleached sulphite. The acids investigated were sulphuric acid and alum (aluminum sulphate). In addition, the increase in retention obtained when size and alum are both used was investigated. The results of the dye retentions obtained in this study are tabulated in table 22.

TABLE 22.

RETENTION OF DYES ON UNBLEACHED SULPHITE WITH VARIOUS ACIDS

| Acid | Du Pont Victoria Green SC | Du Pont Brilliant Crocein FL | Du Pont Orange II | Pontamine Fast Red 8BL |
|---|---|---|---|---|
| Sulphuric Acid | 95.3 | 41.8 | 14.2 | 49.1 |
| Alum | 95.2 | 41.9 | 14.7 | 48.2 |
| Size and Alum | 95.3 | 43.1 | 19.8 | 50.3 |

These results show quite conclusively that the retentions are the same, from a practical standpoint, when either alum or sulphuric acid are used. The use of size in connection with alum increases the retentions of the dyes except in the case of Du Pont Victoria Green SC, which is not affected. In the case of acid dyes, Du Pont Orange II shows a marked increase in its retention, changing from 14.7 per cent without size to 19.8 per cent with size. Du Pont Brilliant Crocein FL shows only a moderate increase, changing from 41.9 to 43.1 per cent retention. Pontamine Fast Red 8BL is also increased slightly by the addition of size to the furnish. Size and alum were investigated in order to determine their effects on retention results. Sulphuric acid was used for the most part of this investigation because it produced results which were similar to those obtained with alum as has been shown above, and in addition, did not produce a flock in the white water. Alum did produce a flock in the white waters which necessitated an exceptionally large correction in the transmittance when examined spectrophotometrically and therefore was objectionable.

In summing up these results it can be said that the retentions obtained, when either sulphuric acid or alum is used, are the same from a practical standpoint. The use of alum and size together, however, produces an increase in the retention, the amount of which depends upon the dye under consideration

F. Applicability of the Kubelka and Monk Equations for Determining Dye Retentions.

In proving the applicability of the Kubelka and Monk equations, it appears that the best approach is to use the equations for determining dye retention. Such a method was developed and the results checked very well with those obtained by the retention method using Beer's law. Since it was not necessary to check all the results obtained by the retention method using Beer's law to prove the applicability of the Kubelka and Monk equations, only $\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings of the three typical dyes on unbleached and bleached sulphite were considered in this part of the investigation. Hand sheets obtained when white waters were produced for these conditions were saved for this determination. The following section will consider in detail the equations, procedure, results, and errors of the method.

1. Kubelka and Monk Equations.

Steele[6] has used the Kubelka and Monk equations to good advantage in studying the optical characteristics of paper. Due to the fact that the amount of dye in a sheet of paper affects the optical properties of the sheet, these equations have been studied in connection with this investigation. When light enters a diffusing medium, such as a sheet of paper, part of it is reflected, part of it is absorbed, and part of it is transmitted. In dealing with the color of paper, the light reflected is of primary importance. This is a function of the scattering and absorption characteristics of the paper together with the thickness of the sheet and the reflecting characteristics of the background. Steele gives the derivation of the Kubelka and Monk equations concerning the reflection of light from diffusing media as follows:

"In a sheet of a translucent diffusing substance, such as paper, of a finite thickness, X, let us consider an element parallel to the surface of thickness dx and at x distance from the bottom. Let $I_O$ be the intensity of illumination on the top, $i_T$ the intensity of illumination on the element dx from the top due to transmission and $i_R$ the intensity on the bottom of dx due to reflection from lower layers. Then in passing through dx,

$i_T$ is decreased by $i_T\ (S + K)dx$ and,

$i_R$ is decreased by $i_R\ (S + K)dx$, by definition,

where S is the scattering coefficient and K is the absorption coefficient.

Similarly,

$i_T$ is increased by $Si_R dx$, and

$i_R$ is increased by $Si_T dx$. Then

$-di_T = -(S + K)i_T dx + Si_R dx$, and

$di_R = -(S + K)i_R dx + Si_T dx$.

Dividing by $i_T$ and $i_R$ respectively, and adding,

$$\frac{di_R}{i_R} - \frac{di_T}{i_T} = d\underline{ln}\frac{i_R}{i_T} = -2(S + K)dx + S\left(\frac{i_T}{i_R} + \frac{i_R}{i_T}\right)dx.$$

When I = intensity of reflected light, let

$\frac{I}{i_o} = R.$ Then

$\frac{i_R}{i_T} = r$, by analogy. Then, since

$$d\underline{ln}r = \frac{dr}{r} ,$$

$$dr = \left(-2(S + K)r + S + Sr^2\right)dx;$$

$$\int_{R'}^{R} \frac{dr}{r^2 - \frac{2(S \quad K)r}{S} + 1} = S \int_{0}^{X} dx$$

which, when integrated between the limits shown gives R, the reflectance of the sheet, in terms of X, the thickness, and R' the reflectance of the background. Substituting

$$\frac{S + K}{S} = 1 + \frac{K}{S} = a,$$

and integrating between limits,

$$\underline{ln}\,\frac{(R - a - \sqrt{a^2 - 1})(R' - a\sqrt{a^2 - 1})}{(R' - a - \sqrt{a^2 - 1})(R \ - a\sqrt{a^2 - 1})} \quad 2SX\sqrt{a^2 - 1}.$$

When $X = \infty$, $R' = R = R_\infty$, and

$$R_\infty = a - \sqrt{a^2 - 1}$$

giving, finally

$$R_{\infty} = 1 + \frac{K}{S} - \sqrt{\frac{K^2}{S^2} + 2\frac{K}{S}}$$ , which is the general equation for reflectance at infinite thickness."

Rearranging and solving for $\frac{K}{S}$ ,

$$\frac{K}{S} = \frac{(R. - 1)^2}{2R}$$ is obtained.

This equation has been the basis of the method using the Kubelka and Monk equations for determining the retention of dyes.

2. Method of Determining Dye Retention by the Use of the Kubelka and Monk Equations.

The reflectance of a sheet of paper is dependent upon the optical properties of the materials present in it. Of all the materials that go into a sheet of paper, dye is one of the most important in this connection. The more dye in a sheet, the less the reflectance and vice-versa. Kubelka and Monk have derived a formula which shows the scattering and absorption coefficients of a sheet to be a function of its reflectance. With the help of this equation, another method of determining the dye retention has been developed. This method has already been given under "Procedures" but will be discussed at this point in order to furnish a clear understanding of the way in which the calculations were made. Kubelka and Monk have used a quantity in their equation which is the absorption coefficient divided by the scattering coefficient for a given wavelength and is given the notation of K/S. This K/S value for a sheet can be calculated from its reflectivity, as derived above, and is dependent upon the material of which the sheet is made. With this in mind, it is assumed that the K/S value for the dye in a sheet may be determined by subtracting the K/S value of a natural sheet from the K/S value of a dyed sheet providing conditions, other than dye, have been kept equal. At this point a result from the method using Beer's law was used in order to obtain a constant. The product of the K/S value for the dye and a constant was set equal to the weight of dye known to be in that sheet as determined by the retention method using Beer's law. The constant is calculated from this equation and may be used for determining the weight of dye in any sheet using the same furnish and dye by simply multiplying it by the K/S value of the sheet in question. In tables 23, 24, and 25 are shown the calculations of the retentions for

Du Pont Victoria Green SC, Du Pont Brilliant Crocein FL, and Pontamine Fast Red 8BL respectively on unbleached and bleached sulphite pulp when $\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings were made. The constant in each case was determined from the results obtained for a one half pound dyeing by the retention method using Beer's law.

In table 26 is shown a summary of data determined by the retention method using the Kubelka and Monk equations along with the corresponding data determined by the retention method using Beer's law.

TABLE 23.

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON UNBLEACHED SULPHITE BY THE METHOD USING THE KUBELKA AND MONK EQUATIONS

| Pounds Dye per 1000 Pounds Pulp | Reflectivity at 620 millimicrons | $\frac{K}{S}$ Value | $\frac{K}{S}$ Due to Dye | Gms. Dye Used | Calc. Gms. Dye in Sheet | Calc. Per Cent Retention |
|---|---|---|---|---|---|---|
| 0 | 71.0 | 0.059 | 0 | 0 | 0 | 100.0 |
| ½ | 22.3 | 1.352 | 1.293 | 0.0015 | 0.001469 | 97.9 |
| 1 | 14.1 | 2.616 | 2.557 | 0.0030 | 0.002900 | 96.7 |
| 1½ | 10.5 | 3.814 | 3.755 | 0.0045 | 0.004250 | 94.7 |
| 3 | 6.0 | 7.363 | 7.304 | 0.0090 | 0.008290 | 92.2 |

TABLE 23A.

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON BLEACHED SULPHITE BY THE METHOD USING THE KUBELKA AND MONK EQUATIONS

| Pounds Dye per 1000 Pounds Pulp | Reflectivity at 620 millimicrons | $\frac{K}{S}$ Value | $\frac{K}{S}$ Due to Dye | Gms. Dye Used | Calc. Gms. Dye in Sheet | Calc. Per Cent Retention |
|---|---|---|---|---|---|---|
| 0 | 83.2 | 0.017 | 0 | 0 | 0 | 100.0 |
| ½ | 24.2 | 1.187 | 1.170 | 0.0015 | 0.001320 | 87.9 |
| 1 | 15.4 | 2.323 | 2.306 | 0.0030 | 0.002600 | 86.6 |
| 1½ | 11.7 | 3.332 | 3.315 | 0.0045 | 0.003740 | 83.1 |
| 3 | 6.6 | 6.609 | 6.592 | 0.0090 | 0.007430 | 82.6 |

TABLE 24.

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON UNBLEACHED SULPHITE BY THE METHOD USING THE KUBELKA AND MONK EQUATIONS

| Pounds Dye per 1000 Pounds Pulp | Reflectivity at 500 millimicrons | $\frac{K}{S}$ Value | $\frac{K}{S}$ Due to Dye | Gms. Dye Used | Calc. Gms. Dye in Sheet | Calc. Per Cent Retention |
|---|---|---|---|---|---|---|
| 0 | 56.5 | 0.168 | 0 | 0 | 0 | 100.0 |
| ½ | 42.1 | 0.398 | 0.230 | 0.0015 | 0.000865 | 57.7 |
| 1 | 36.2 | 0.562 | 0.394 | 0.0030 | 0.001480 | 49.3 |
| 1½ | 32.3 | 0.710 | 0.542 | 0.0045 | 0.002040 | 45.5 |
| 3 | 24.9 | 1.133 | 0.965 | 0.0090 | 0.003630 | 40.4 |

TABLE 24A.

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON BLEACHED SULPHITE BY THE METHOD USING THE KUBELKA AND MONK EQUATIONS

| Pounds Dye per 1000 Pounds Pulp | Reflectivity at 500 millimicrons | $\frac{K}{S}$ Value | $\frac{K}{S}$ Due to Dye | Gms. Dye Used | Calc. Gms. Dye in Sheet | Calc. Per Cent Retention |
|---|---|---|---|---|---|---|
| 0 | 71.0 | 0.059 | 0 | 0 | 0 | 100.0 |
| ½ | 46.1 | 0.315 | 0.256 | 0.0015 | 0.000931 | 62.0 |
| 1 | 38.0 | 0.506 | 0.447 | 0.0030 | 0.001627 | 54.2 |
| 1½ | 33.6 | 0.656 | 0.597 | 0.0045 | 0.002170 | 48.2 |
| 3 | 24.9 | 1.133 | 1.074 | 0.0090 | 0.003812 | 42.4 |

TABLE 25.

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON UNBLEACHED SULPHITE BY THE METHOD USING THE KUBELKA AND MONK EQUATIONS

| Pounds Dye per 1000 Pounds Pulp | Reflectivity at 520 millimicrons | $\frac{K}{S}$ Value | $\frac{K}{S}$ Due to Dye | Gms. Dye Used | Calc. Gms. Dye in Sheet | Calc. Per Cent Retention |
|---|---|---|---|---|---|---|
| 0 | 57.5 | 0.157 | 0 | 0 | 0 | 100.0 |
| $\frac{1}{2}$ | 35.0 | 0.603 | 0.446 | 0.0015 | 0.000870 | 58.0 |
| 1 | 26.8 | 1.000 | 0.843 | 0.0030 | 0.001645 | 54.8 |
| $1\frac{1}{2}$ | 22.5 | 1.335 | 1.178 | 0.0045 | 0.002300 | 51.2 |
| 3 | 15.0 | 2.408 | 2.251 | 0.0090 | 0.004390 | 48.8 |

TABLE 25A.

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON BLEACHED SULPHITE BY THE METHOD USING THE KUBELKA AND MONK EQUATIONS

| Pounds Dye per 1000 Pounds Pulp | Reflectivity at 520 millimicrons | $\frac{K}{S}$ Value | $\frac{K}{S}$ Due to Dye | Gms. Dye Used | Calc. Gms. Dye in Sheet | Calc. Per Cent Retention |
|---|---|---|---|---|---|---|
| 0 | 73.0 | 0.050 | 0 | 0 | 0 | 100.0 |
| $\frac{1}{2}$ | 38.4 | 0.494 | 0.444 | 0.0015 | 0.000960 | 64.0 |
| 1 | 28.7 | 0.886 | 0.836 | 0.0030 | 0.001808 | 60.2 |
| $1\frac{1}{2}$ | 23.4 | 1.253 | 1.203 | 0.0045 | 0.002600 | 57.8 |
| 3 | 15.5 | 2.303 | 2.253 | 0.0090 | 0.004880 | 54.2 |

TABLE 26.

SUMMARY OF PER CENT RETENTION DATA DETERMINED BY THE METHOD USING BEER'S LAW AND THE CORRESPONDING DATA OBTAINED BY USING THE KUBELKA AND MONK EQUATIONS

| Pounds Dye per 1000 Pounds Pulp | ½ | 1 | 1½ | 3 |
|---|---|---|---|---|
| Victoria Green SC | | | | |
| Unbleached Sulphite | | | | |
| Method Using Beer's Law | 97.9 | 96.5 | 96.0 | 95.3 |
| Method Using K. & M. Eq. | 97.9 | 96.7 | 94.7 | 92.2 |
| Bleached Sulphite | | | | |
| Method Using Beer's Law | 87.9 | 86.4 | 85.8 | 85.0 |
| Method Using K. & M. Eq. | 87.9 | 86.6 | 83.1 | 82.6 |
| Brilliant Crocein FL | | | | |
| Unbleached Sulphite | | | | |
| Method Using Beer's Law | 57.7 | 50.0 | 45.7 | 41.8 |
| Method Using K. & M. Eq. | 57.7 | 49.3 | 45.5 | 40.4 |
| Bleached Sulphite | | | | |
| Method Using Beer's Law | 62.0 | 53.8 | 49.0 | 43.3 |
| Method Using K. & M. Eq. | 62.0 | 54.2 | 48.2 | 42.4 |
| Fast Red 8BL | | | | |
| Unbleached Sulphite | | | | |
| Method Using Beer's Law | 58.0 | 54.0 | 52.2 | 49.1 |
| Method Using K. & M. Eq. | 58.0 | 54.8 | 51.2 | 48.8 |
| Bleached Sulphite | | | | |
| Method Using Beer's Law | 64.0 | 61.0 | 59.1 | 56.2 |
| Method Using K. & M. Eq. | 64.0 | 60.2 | 57.8 | 54.2 |

3. Limits of Error in the Retention Method Using the Kubelka and Monk Equations.

In examining the errors inherent in the method for determining dye retentions by using the Kubelka and Monk Equations, it was found that dyed paper could be produced experimentally under identical conditions which would not vary more than 0.1 per cent in reflectivity if the proper precautions were taken. The results in table 27 bear this point out. Reflectivities were taken at different points on each of five sheets dyed with one pound of Du Pont Brilliant Crocein FL and five sheets dyed with three pounds of the same dye.

TABLE 27

REFLECTANCES OF VARIOUS SHEETS DYED UNDER IDENTICAL CONDITIONS WITH DU PONT BRILLIANT CROCEIN FL

| ight of Dyeing | 1 Pound | | | | | 3 Pound | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| eet Number | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| flectance | 36.3 | 36.3 | 36.1 | 36.2 | 36.3 | 24.9 | 24.9 | 25.0 | 24.7 | 24.9 |
| | 36.2 | 36.2 | 36.2 | 36.2 | 36.2 | 24.9 | 24.8 | 24.9 | 24.8 | 24.9 |
| | 36.2 | 36.3 | 36.2 | 36.2 | 36.2 | 24.8 | 24.8 | 25.0 | 24.8 | 24.9 |
| | 36.2 | 36.3 | 36.2 | 36.2 | 36.2 | 24.8 | 24.8 | 24.9 | 24.8 | 24.9 |
| | 36.2 | 36.2 | 36.2 | 36.2 | 36.2 | 24.8 | 24.9 | 24.9 | 24.8 | 24.9 |
| erage | 1 Pound Dyeings 36.204 | | | | | 3 Pound Dyeings 24.860 | | | | |

It was also found that for any given point on a sheet, the color analyzer would reproduce itself exactly. With the above results in mind, the error in retention was determined when the reflectance was purposely changed by one tenth per cent for $\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings of Du Pont Victoria Green, Du Pont Brilliant Crocein FL, and Pontamine Fast Red 8BL on unbleached and bleached sulphite pulp. These three dyes were picked to be representative of the three common classes of dyestuffs and give a general idea of the errors to be expected with any dye. It was found in carrying out these calculations that the calculated amount of a given dye in a given sheet varied with the reflectance on a smooth curve. This is graphically shown in figures 47, 48, and 49. In the light of this fact, it is apparent that the per cent error at different reflectances will be different. The calculations of these errors and the results are shown in tables 28, 29, and 30 for Du Pont Victoria Green SC, Du Pont Brilliant Crocein FL, and Pontamine Fast Red 8BL respectively. The errors due to a one tenth per cent change in reflectance are, for the most part, less than six tenths per cent in retention with the notable exception of Du Pont Victoria

Green SC. Larger errors in the case of this dye are due to its high retention which necessitates extremely high K/S values and therefore pulls the curve out as shown in figure 50 until a slight change in reflectance indicates a large change in the weight of dye in the sheet.

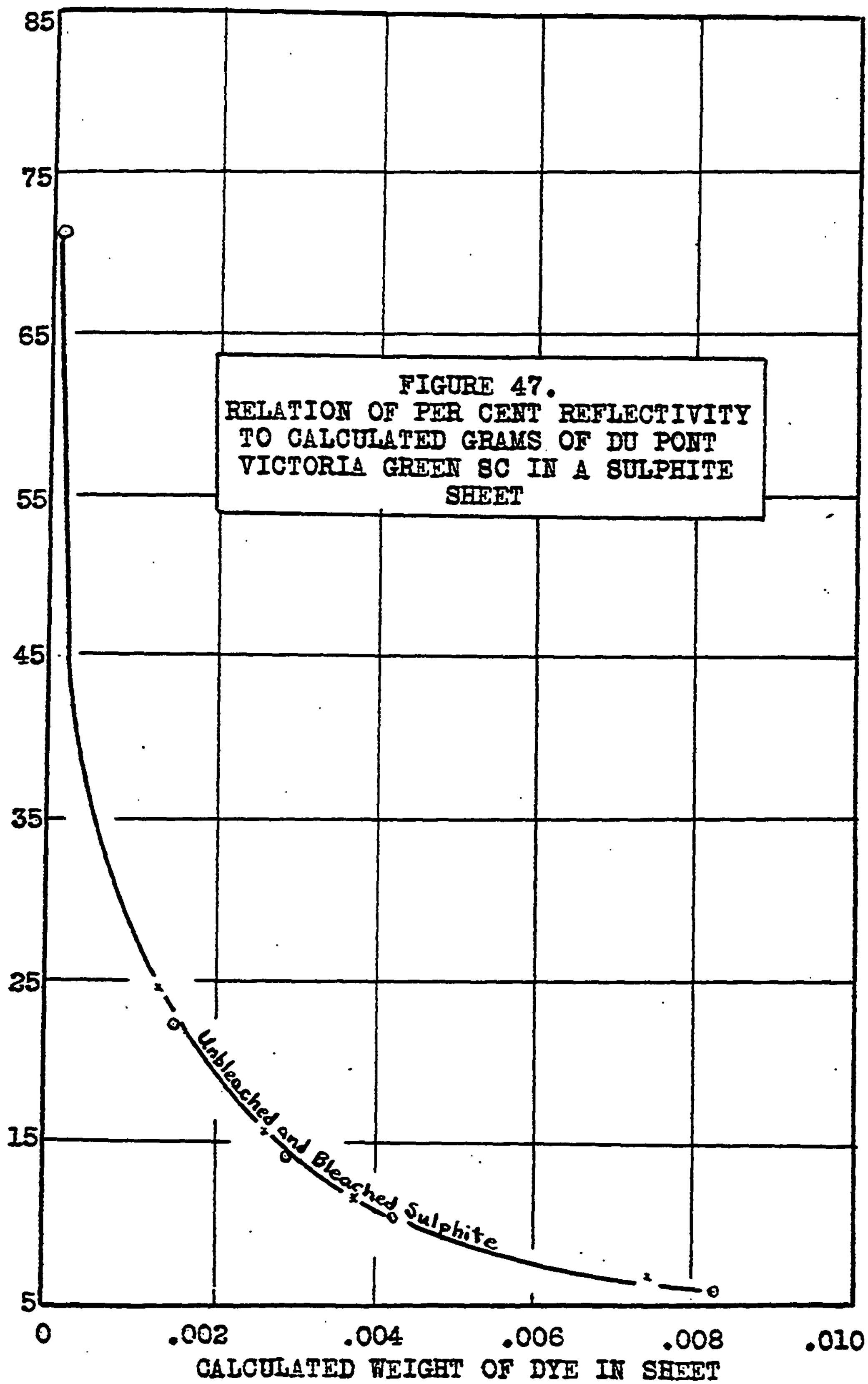



FIGURE 47.
RELATION OF PER CENT REFLECTIVITY TO CALCULATED GRAMS OF DU PONT VICTORIA GREEN SC IN A SULPHITE SHEET

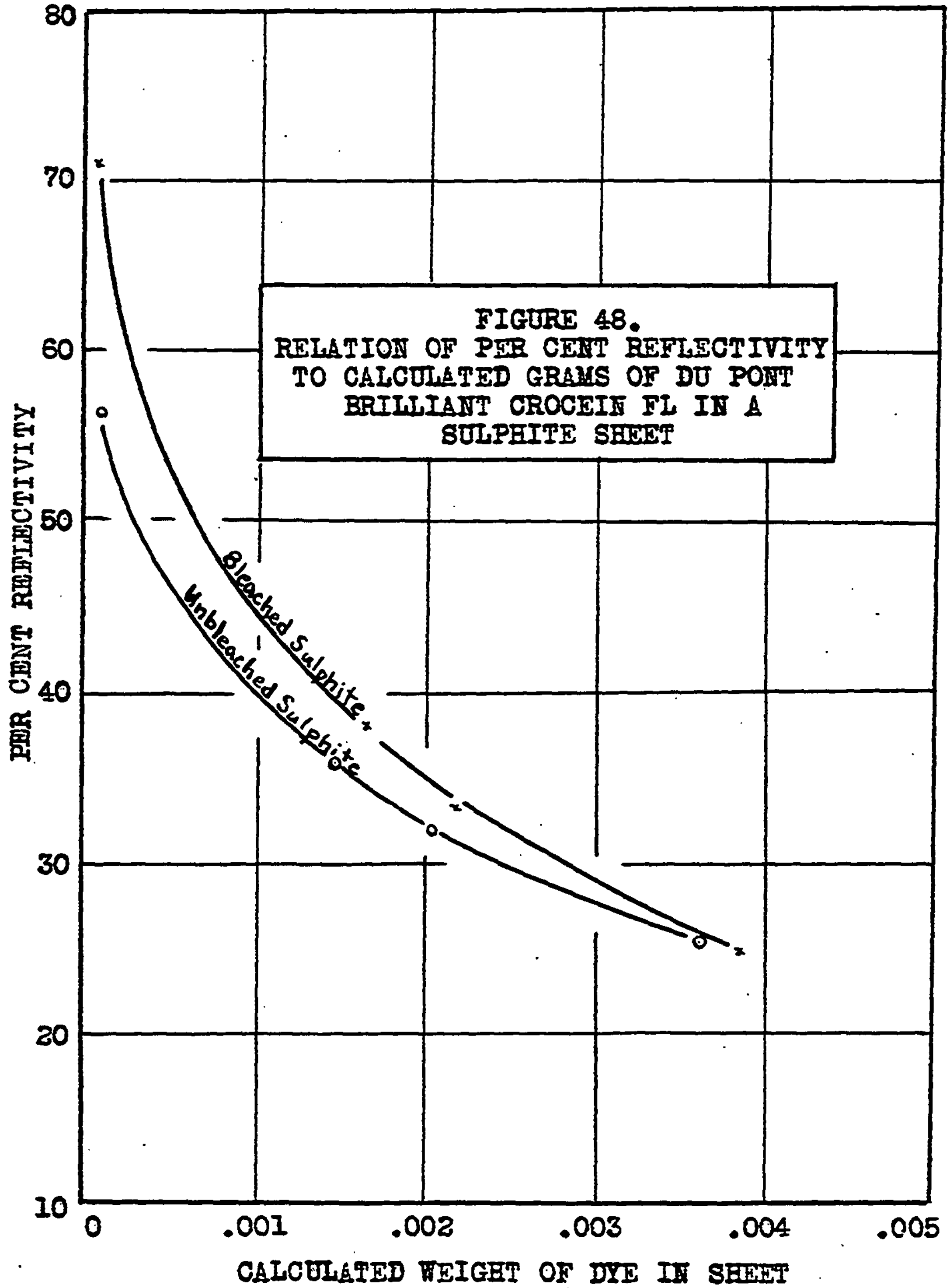



FIGURE 48.
RELATION OF PER CENT REFLECTIVITY TO CALCULATED GRAMS OF DU PONT BRILLIANT CROCEIN FL IN A SULPHITE SHEET

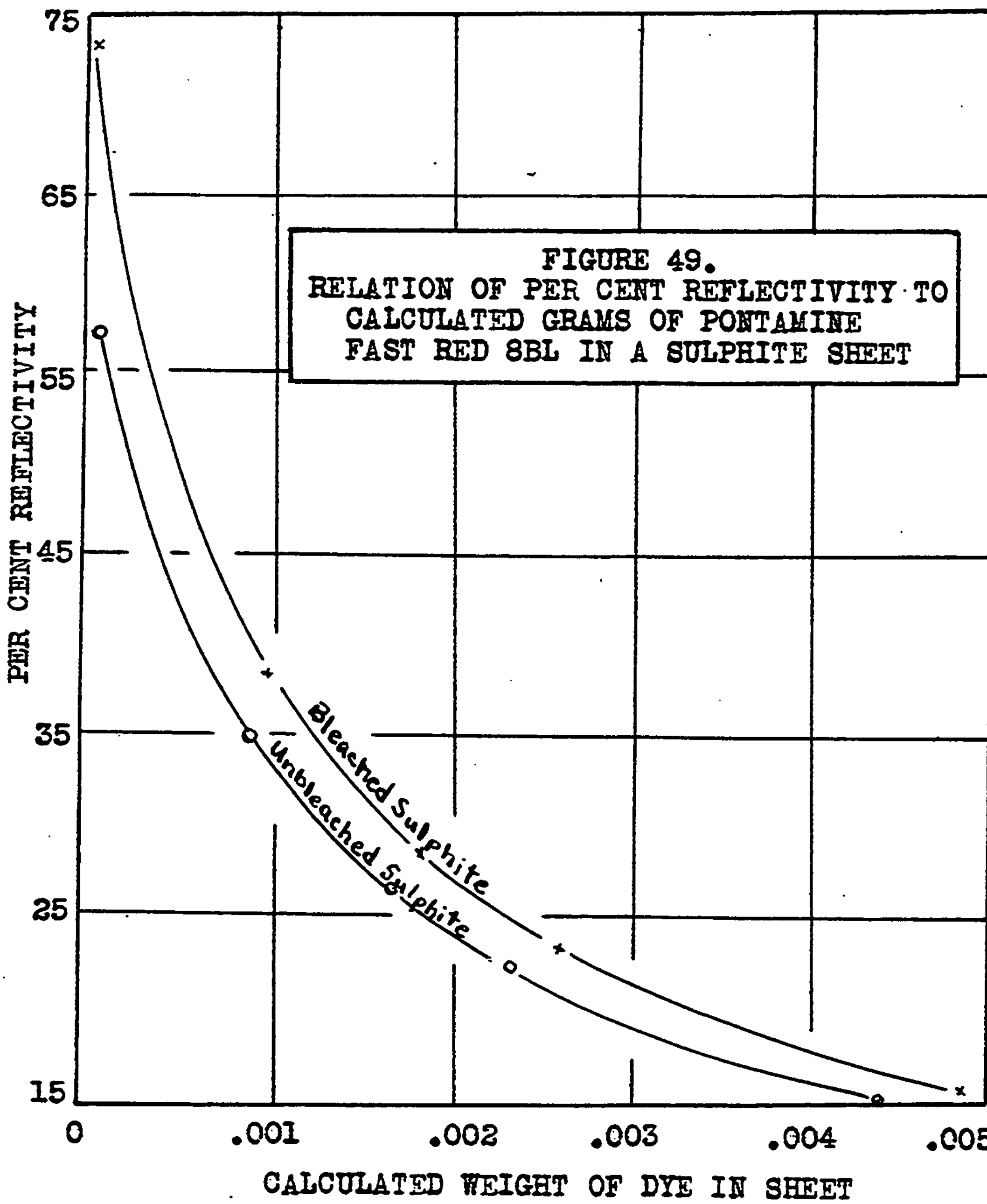


FIGURE 49.
RELATION OF PER CENT REFLECTIVITY TO
CALCULATED GRAMS OF PONTAMINE
FAST RED 8BL IN A SULPHITE SHEET
PER CENT REFLECTIVITY
75
65
55
45
35
25
15
0
.001
.002
.003
.004
.005
CALCULATED WEIGHT OF DYE IN SHEET
Bleached Sulphite
Unbleached Sulphite

TABLE 28.

CALCULATION OF ERROR OF RETENTION OF DU PONT VICTORIA GREEN SC ON UNBLEACHED SULPHITE AS REFLECTIVITY IS VARIED 0.1 PER CENT

| Pounds Dye per 1000 Pounds Pulp | Reflectivity | $\frac{K}{S}$ | $\frac{K}{S}$ Due to Dye | Gms. Dye in Sheet | Per Cent Retention | Error |
|---|---|---|---|---|---|---|
| ½ | 22.3<br>22.4 | 1.352<br>1.342 | 1.293<br>1.283 | 0.001469<br>0.001457 | 97.9<br>97.2 | 0.7 |
| 1 | 14.1<br>14.2 | 2.616<br>2.592 | 2.557<br>2.533 | 0.002900<br>0.002870 | 96.7<br>95.7 | 1.0 |
| 1½ | 10.5<br>10.6 | 3.814<br>3.770 | 3.755<br>3.711 | 0.004260<br>0.004210 | 94.7<br>93.6 | 1.1 |
| 3 | 6.0<br>6.1 | 7.363<br>7.227 | 7.304<br>7.168 | 0.008290<br>0..08140 | 92.2<br>90.5 | 1.70 |

TABLE 28A.

CALCULATION OF ERROR OF RETENTION OF DU PONT VICTORIA GREEN SC ON BLEACHED SULPHITE AS REFLECTIVITY IS VARIES 0.1 PER CENT

| Pounds Dye per 1000 Pounds Pulp | Reflectivity | $\frac{K}{S}$ | $\frac{K}{S}$ Due to Dye | Gms. Dye in Sheet | Per Cent Retention | Error |
|---|---|---|---|---|---|---|
| ½ | 24.2<br>24.3 | 1.187<br>1.179 | 1.170<br>1.162 | 0.001320<br>0.001311 | 87.9<br>87.4 | 0.5 |
| 1 | 15.4<br>15.5 | 2.323<br>2.303 | 2.306<br>2.286 | 0.002600<br>0.002578 | 86.6<br>86.0 | 0.6 |
| 1½ | 11.7<br>11.6 | 3.332<br>3.368 | 3.315<br>3.351 | 0.003740<br>0.003780 | 83.1<br>84.0 | 0.9 |
| 3 | 6.6<br>6.5 | 6.609<br>6.725 | 6.592<br>6.708 | 0.007430<br>0.00756 | 82.6<br>84.0 | 1.4 |

TABLE 29.

CALCULATION OF ERROR OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON UNBLEACHED SULPHITE AS REFLECTIVITY IS VARIED 0.1 PER CENT

| Pounds Dye per 1000 Pounds Pulp | Reflectivity | $\frac{K}{S}$ | $\frac{K}{S}$ Due to Dye | Gms. Dye in Sheet | Per Cent Retention | Error |
|---|---|---|---|---|---|---|
| ½ | 42.1<br>42.0 | 0.398<br>0.401 | 0.230<br>0.233 | 0.000865<br>0.000876 | 57.7<br>58.3 | 0.6 |
| 1 | 36.2<br>36.3 | 0.562<br>0.559 | 0.394<br>0.391 | 0.001480<br>0.001469 | 49.3<br>49.0 | 0.3 |
| 1½ | 32.3<br>32.4 | 0.710<br>0.705 | 0.542<br>0.537 | 0.002040<br>0.002020 | 45.3<br>44.9 | 0.4 |
| 3 | 24.9<br>25.0 | 1.133<br>1.125 | 0.965<br>0.957 | 0.003630<br>0.003600 | 40.4<br>40.0 | 0.4 |

TABLE 29A.

CALCULATION OF ERROR OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON BLEACHED SULPHITE AS REFLECTIVITY IS VARIED 0.1 PER CENT

| Pounds Dye per 1000 Pounds Pulp | Reflectivity | $\frac{K}{S}$ | $\frac{K}{S}$ Due to Dye | Gms. Dye in Sheet | Per Cent Retention | Error |
|---|---|---|---|---|---|---|
| ½ | 46.1<br>46.0 | 0.315<br>0.317 | 0.256<br>0.258 | 0.000931<br>0.000938 | 62.0<br>62.4 | 0.4 |
| 1 | 38.0<br>38.1 | 0.506<br>0.503 | 0.447<br>0.444 | 0.001627<br>0.001616 | 54.2<br>53.8 | 0.4 |
| 1½ | 33.6<br>33.5 | 0.656<br>0.660 | 0.597<br>0.601 | 0.002170<br>0.002190 | 48.2<br>48.6 | 0.4 |
| 3 | 25.0<br>24.9 | 1.125<br>1.133 | 1.066<br>1.074 | 0.003877<br>0.003812 | 43.1<br>42.4 | 0.7 |

| TABLE 30. CALCULATION OF ERROR OF RETENTION OF PONTAMINE FAST RED 8BL ON UNBLEACHED SULPHITE AS REFLECTIVITY IS VARIED 0.1 PER CENT | | | | | | |
|---|---|---|---|---|---|---|
| Pounds Dye per 1000 Pounds Pulp | Reflectivity | $\frac{K}{S}$ | $\frac{K}{S}$ Due to Dye | Gms. Dye in Sheet | Per Cent Retention | Error |
| ½ | 35.0<br>35.1 | 0.603<br>0.600 | 0.446<br>0.443 | 0.000870<br>0.000863 | 58.0<br>57.5 | 0.5 |
| 1 | 26.8<br>26.9 | 1.000<br>0.993 | 0.843<br>0.836 | 0.001645<br>0.001630 | 54.8<br>54.3 | 0.5 |
| 1½ | 22.5<br>22.6 | 1.335<br>1.325 | 1.178<br>1.168 | 0.002300<br>0.002280 | 51.2<br>50.7 | 0.5 |
| 3 | 15.0<br>15.1 | 2.408<br>2.387 | 2.251<br>2.230 | 0.004390<br>0.004350 | 48.8<br>48.3 | 0.5 |

| TABLE 30A. CALCULATION OF ERROR OF RETENTION OF PONTAMINE FAST RED 8BL ON BLEACHED SULPHITE AS REFLECTIVITY IS VARIED 0.1 PER CENT | | | | | | |
|---|---|---|---|---|---|---|
| Pounds Dye per 1000 Pounds Pulp | Reflectivity | $\frac{K}{S}$ | $\frac{K}{S}$ Due to Dye | Gms. Dye in Sheet | Per Cent Retention | Error |
| ½ | 38.4<br>38.5 | 0.494<br>0.491 | 0.444<br>0.441 | 0.000960<br>0.000954 | 64.0<br>63.5 | 0.5 |
| 1 | 28.7<br>28.8 | 0.886<br>0.880 | 0.836<br>0.830 | 0.001808<br>0.001693 | 60.2<br>59.7 | 0.5 |
| 1½ | 23.4<br>23.5 | 1.253<br>1.245 | 1.203<br>1.195 | 0.002600<br>0.002580 | 57.8<br>57.3 | 0.5 |
| 3 | 15.5<br>15.6 | 2.303<br>2.283 | 2.253<br>2.233 | 0.004880<br>0.004830 | 54.2<br>53.7 | 0.5 |

G. Applicability of the Freundlich Adsorption Equation to Dye Retention Results.

The exact mechanism of the adsorption of dye on fiber is still a matter of dispute. Some of the available evidence shows that adsorption is due to chemical combination of the dye with the free valences of atoms on the surface of the fibers, while in other cases, the evidence indicates that adsorption is due to the retention of the dye by capillary action in the exceedingly fine pores of the fiber. No doubt, in some cases, the two phenomena coexist.

Whatever the mechanism of adsorption, the equilibrium between the dye and the adsorbing fiber has been expressed by the Freundlich equation[8],

$$a = xc^{1/n}$$

where a is the amount of dye adsorbed per unit mass of adsorbing material, and c is the amount of dye in the white water which is in equilibrium with the reacting materials; x and n are constants. For convenience in this investigation a and c will be expressed in grams of dye. The value of n determines the firmness of the dye retention and x is proportional to the active surface of the fiber. While it has been claimed that this equation has theoretical basis, it is probably safer to regard it as empirical in character. From the form of the equation, it is obvious that if one plot the logarithm of the weight of dye in a sheet against the logarithm of the weight of dye in the white water, the equation demands that the data follow a straight line, the slope of which is equal to the exponent, 1/n. This offers a ready means of testing the applicability of the Freundlich equation to any given set of data.

The quantitative data obtained in this investigation has given itself very favorably in application to this equation. Straight lines were obtained in every case with the exception of a few very slight deviations. As illustrations, the adsorption isotherms of seven pulps dyed with the three typical dyes in four different strengths ($\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 pound dyeings) have been calculated. The calculated data are tabulated in tables 31, 32, and 33, and are shown graphically in figures 50, 51, and 52.

These results are typical of those which would be obtained under any of the conditions in this investigation and do show that the Freundlich adsorption equation represents the retention data.

TABLE 31.

CALCULATION OF RETENTION DATA FOR DU PONT VICTORIA GREEN SC ON VARIOUS PULPS IN CONNECTION WITH THE FREUNDLICH ADSORPTION EQUATION

| Pulp | Pounds Dye per 1000 Pounds Pulp | Gms. Dye in Sheet(a) | Gms. Dye in White Water(c) | Logarithm 10000(a) | Logarithm 10000(c) |
|---|---|---|---|---|---|
| Soda | ½ | .00121 | .00029 | 1.0828 | 0.4624 |
| | 1 | .00237 | .00063 | 1.3747 | 0.7993 |
| | 1½ | .00355 | .00095 | 1.5502 | 0.9777 |
| | 3 | .00702 | .00192 | 1.8463 | 1.2833 |
| Rag | ½ | .00112 | .00038 | 1.0492 | 0.5798 |
| | 1 | .00220 | .00080 | 1.3424 | 0.9031 |
| | 1½ | .00327 | .00123 | 1.5145 | 1.0899 |
| | 3 | .00639 | .00261 | 1.8055 | 1.4166 |
| Ground-wood | ½ | .00143 | .00007 | 1.1553 | -1.8451 |
| | 1 | .00282 | .00018 | 1.4502 | 0.2553 |
| | 1½ | .00422 | .00028 | 1.6253 | 0.4472 |
| | 3 | .00834 | .00066 | 1.9212 | 0.8195 |
| Unbleached Sulphite | ½ | .00147 | .00003 | 1.1673 | -1.4771 |
| | 1 | .00289 | .00011 | 1.4609 | 0.0414 |
| | 1½ | .00432 | .00018 | 1.6355 | 0.2553 |
| | 3 | .00858 | .00042 | 1.9335 | 0.6232 |
| Bleached Sulphite | ½ | .00132 | .00018 | 1.1206 | 0.2553 |
| | 1 | .00259 | .00041 | 1.4137 | 0.6096 |
| | 1½ | .00386 | .00064 | 1.5866 | 0.8062 |
| | 3 | .00765 | .00135 | 1.8837 | 1.1303 |
| Unbleached Kraft | ½ | .00148 | .00003 | 1.1688 | -1.3979 |
| | 1 | .00292 | .00008 | 1.4654 | -1.9031 |
| | 1½ | .00434 | .00016 | 1.6375 | 0.2041 |
| | 3 | .00859 | .00041 | 1.9340 | 0.6128 |
| Bleached Kraft | ½ | .00133 | .00017 | 1.1212 | 0.2355 |
| | 1 | .00261 | .00039 | 1.4166 | 0.5911 |
| | 1½ | .00389 | .00061 | 1.5899 | 0.7853 |
| | 3 | .00771 | .00129 | 1.8871 | 1.1106 |

TABLE 32.

CALCULATION OF RETENTION DATA FOR DU PONT BRILLIANT CROCEIN FL ON VARIOUS PULPS IN CONNECTION WITH THE FREUNDLICH ADSORPTION EQUATION

| Pulp | Pounds Dye per 1000 Pounds Pulp | Gms. Dye in Sheet(a) | Gms. Dye in White Water(c) | Logarithm 10000(a) | Logarithm 10000(c) |
|---|---|---|---|---|---|
| Soda | ½ | .00090 | .00060 | 0.9542 | 0.7782 |
| | 1 | .00162 | .00138 | 1.2095 | 1.1399 |
| | 1½ | .00223 | .00227 | 1.3485 | 1.3560 |
| | 3 | .00378 | .00522 | 1.5775 | 1.7177 |
| Rag | ½ | .00099 | .00051 | 0.9956 | 0.7076 |
| | 1 | .00179 | .00122 | 1.2516 | 1.0855 |
| | 1½ | .00248 | .00202 | 1.3945 | 1.3054 |
| | 3 | .00424 | .00476 | 1.6274 | 1.6776 |
| Ground-wood | ½ | .00038 | .00112 | 0.5740 | 1.0512 |
| | 1 | .00071 | .00229 | 0.8537 | 1.3588 |
| | 1½ | .00104 | .00346 | 1.0151 | 1.5397 |
| | 3 | .00206 | .00694 | 1.3139 | 1.8414 |
| Unbleached Sulphite | ½ | .00086 | .00064 | 0.9370 | 0.8028 |
| | 1 | .00150 | .00150 | 1.1761 | 1.1761 |
| | 1½ | .00206 | .00244 | 1.3139 | 1.3874 |
| | 3 | .00376 | .00524 | 1.5752 | 1.7193 |
| Bleached Sulphite | ½ | .00093 | .00067 | 0.9685 | 0.8261 |
| | 1 | .00161 | .00139 | 1.2080 | 1.1415 |
| | 1½ | .00221 | .00229 | 1.3444 | 1.3598 |
| | 3 | .00390 | .00510 | 1.5611 | 1.7076 |
| Unbleached Kraft | ½ | .00082 | .00068 | 0.9128 | 0.8338 |
| | 1 | .00139 | .00161 | 1.1430 | 1.2068 |
| | 1½ | .00192 | .00258 | 1.2821 | 1.4123 |
| | 3 | .00355 | .00545 | 1.5502 | 1.7364 |
| Bleached Kraft | ½ | .00075 | .00075 | 0.8750 | 0.8750 |
| | 1 | .00128 | .00172 | 1.1060 | 1.2360 |
| | 1½ | .00178 | .00272 | 1.2504 | 1.4046 |
| | 3 | .00329 | .00571 | 1.5166 | 1.7570 |

TABLE 33

CALCULATION OF RETENTION DATA FOR PONTAMINE FAST RED 8BL ON VARIOUS PULPS IN CONNECTION WITH THE FREUNDLICH ADSORPTION EQUATION

| Pulp | Pounds Dye per 1000 Pounds Pulp | Gms. Dye in Sheet (a) | Gms. Dye in White Water (c) | Logarithm 10000(a) | Logarithm 10000(c) |
|---|---|---|---|---|---|
| Soda | ½ | .00082 | .00068 | 0.9165 | 0.8293 |
| | 1 | .00156 | .00144 | 1.1931 | 1.1584 |
| | 1½ | .00226 | .00224 | 1.3541 | 1.3504 |
| | 3 | .00409 | .00491 | 1.6117 | 1.6911 |
| Rag | ½ | .00096 | .00054 | 0.9814 | 0.7340 |
| | 1 | .00180 | .00120 | 1.2553 | 1.0792 |
| | 1½ | .00261 | .00189 | 1.4166 | 1.2765 |
| | 3 | .00498 | .00402 | 1.6972 | 1.6042 |
| Ground-wood | ½ | .00049 | .00101 | 0.6949 | 1.0022 |
| | 1 | .00090 | .00210 | 0.9542 | 1.3222 |
| | 1½ | .00129 | .00321 | 1.1106 | 1.5065 |
| | 3 | .00230 | .00670 | 1.3617 | 1.8261 |
| Unbleached Sulphite | ½ | .00063 | .00087 | 0.7993 | 0.9395 |
| | 1 | .00138 | .00162 | 1.1399 | 1.2095 |
| | 1½ | .00215 | .00235 | 1.3324 | 1.3711 |
| | 3 | .00458 | .00442 | 1.6609 | 1.6454 |
| Bleached Sulphite | ½ | .00054 | .00096 | 0.7324 | 0.9832 |
| | 1 | .00117 | .00183 | 1.0682 | 1.2625 |
| | 1½ | .00184 | .00266 | 1.2648 | 1.4249 |
| | 3 | .00395 | .00505 | 1.5966 | 1.7033 |
| Unbleached Kraft | ½ | .00075 | .00075 | 0.8751 | 0.8751 |
| | 1 | .00157 | .00143 | 1.1847 | 1.1553 |
| | 1½ | .00241 | .00209 | 1.3820 | 1.3201 |
| | 3 | .00496 | .00404 | 1.6955 | 1.6064 |
| Bleached Kraft | ½ | .00060 | .00090 | 0.7782 | 0.9542 |
| | 1 | .00128 | .00172 | 1.1072 | 1.2355 |
| | 1½ | .00197 | .00253 | 1.2945 | 1.4031 |
| | 3 | .00413 | .00487 | 1.6160 | 1.6875 |

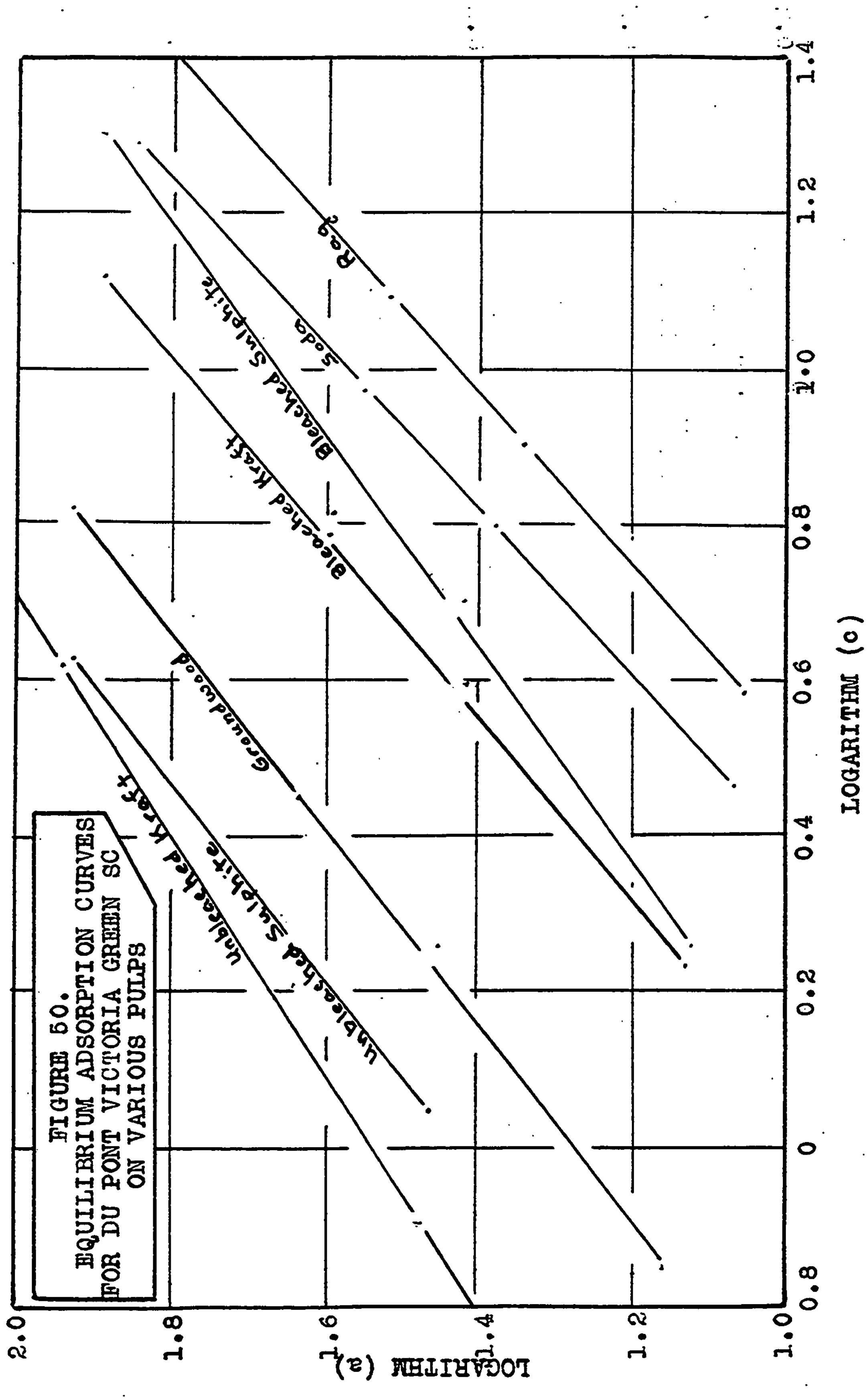



FIGURE 50.
EQUILIBRIUM ADSORPTION CURVES
FOR DU PONT VICTORIA GREEN SC
ON VARIOUS PULPS

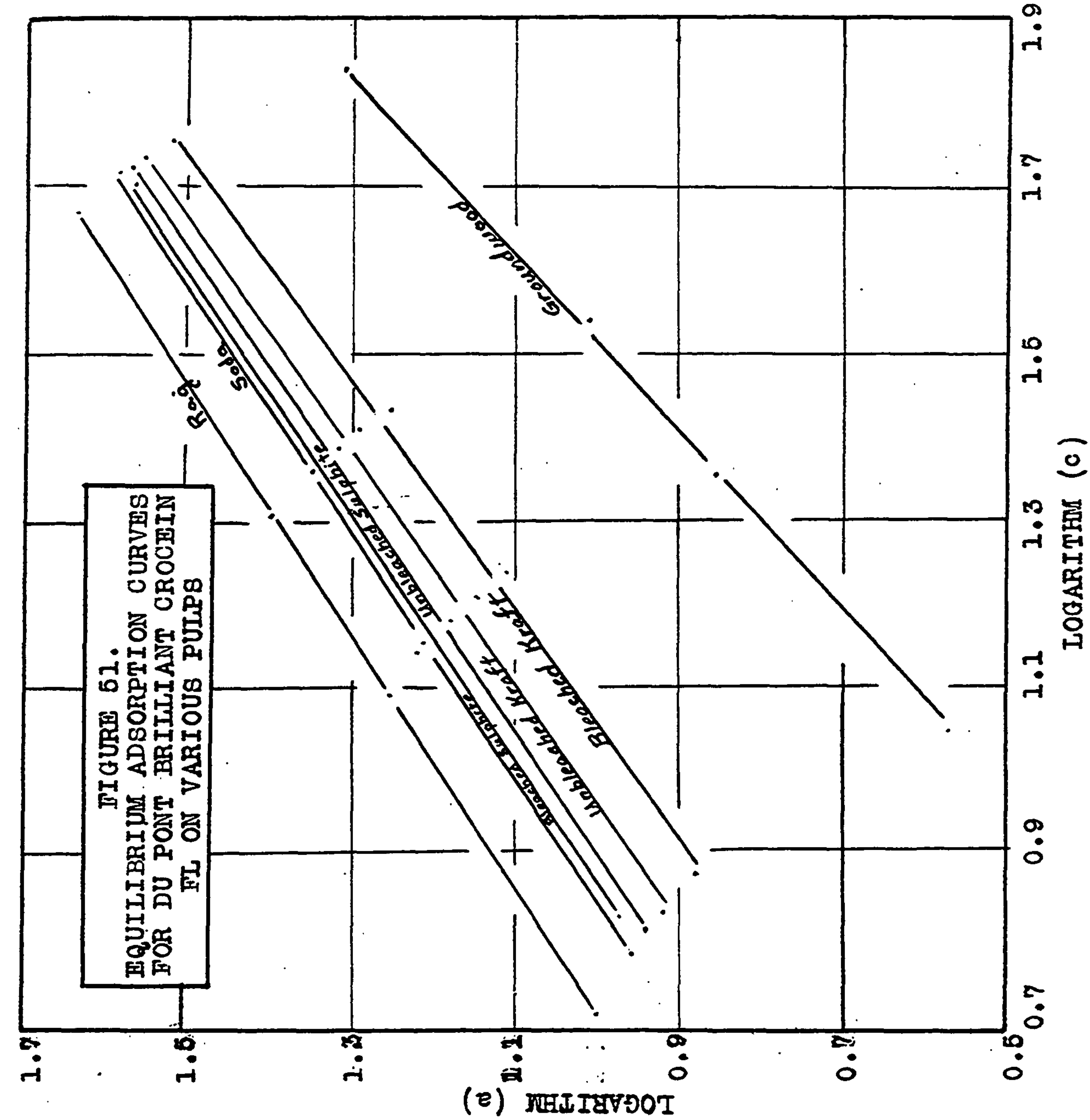



FIGURE 51.
EQUILIBRIUM ADSORPTION CURVES
FOR DU PONT BRILLIANT CROCEIN
FL ON VARIOUS PULPS

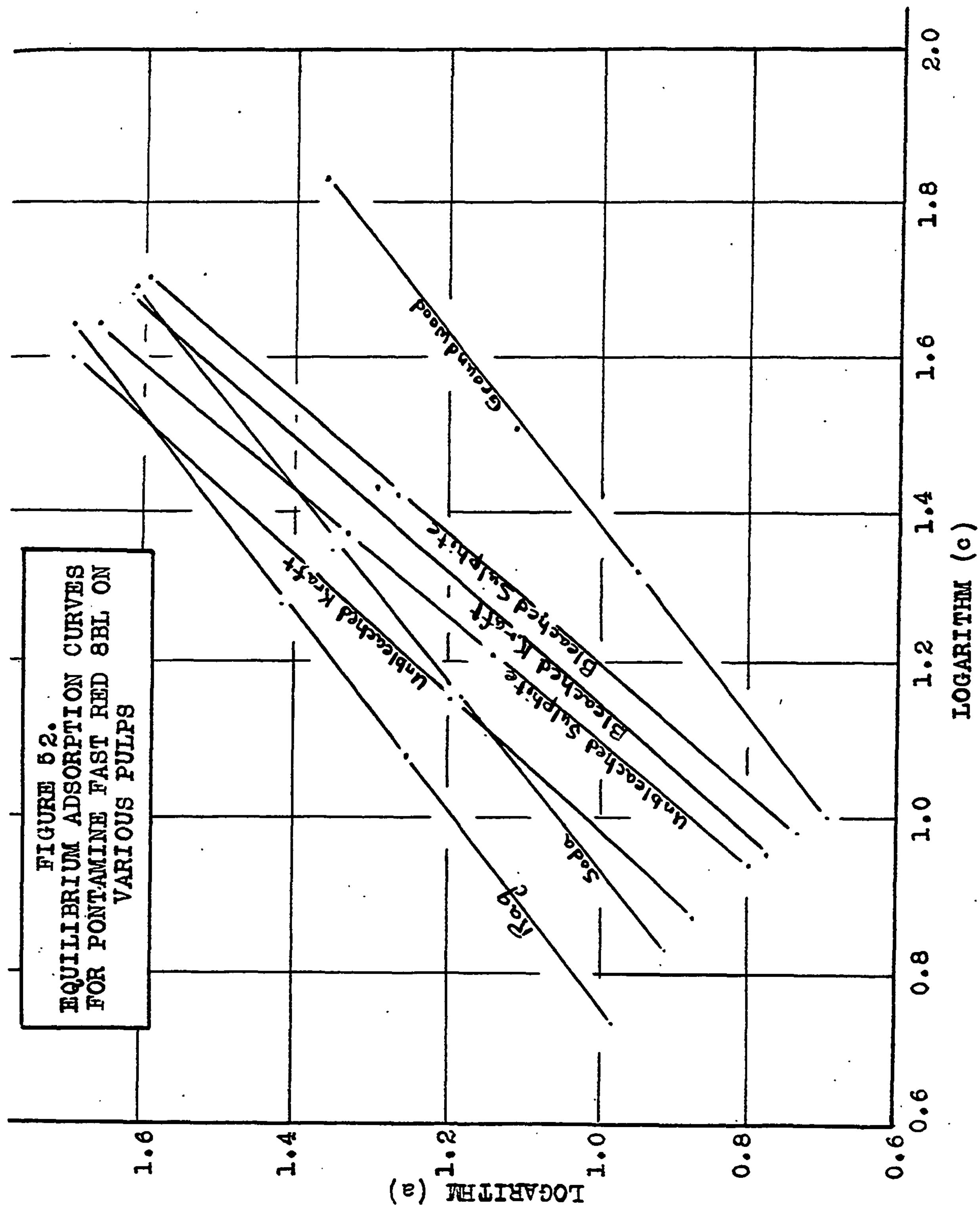



FIGURE 52.
EQUILIBRIUM ADSORPTION CURVES
FOR PONTAMINE FAST RED 8BL ON
VARIOUS PULPS

# CHAPTER V

## CONCLUSIONS

In reviewing the retention data obtained above by analyzing white waters spectrophotometrically, a number of conclusions can be made.

At very low dye concentrations, relatively large percentages of dye are held on the fiber. As the dye concentration is increased, the amount held on the fiber at the end of a given time also increases, but at a much less rapid rate than would correspond to linear distribution.

Basic dyestuffs are attracted strongly by lignified fibers giving dye retentions above ninety per cent. These fibers, however, when bleached, attract this dyestuff to a lesser extent except when the character of the lignin has been changed by the addition of small amounts of bleach. It can be said without reservation that the fiber is the most important variable in so far as basic dyes are concerned. The temperature, time, and hydrogen ion concentration of the reaction mixture have very little effect on the retention of this class of dyestuff while increased consistencies and lower freenesses show considerable increases in retention.

With acid dyestuffs, the fiber variable is not so important to dye retention. Relatively small changes are obtained when the fiber is changed giving higher retentions for the purer pulps except in the case where the lignin present has been changed by the action of small amounts of bleach. The temperature of the reaction apparently has very little affect on the retention of acid dyes. Hydrogen ion concentration affects the retention probably more than any other variable, giving the higher results at a pH of less than five. With high consistencies and low freenesses, increases in retention are noticed, while increases in time have only small effects.

The retention of direct dyestuffs are affected some by the type of pulp being dyed. Bleached and refined pulps produce slightly higher retentions than the highly lignified pulps. If lignin is present, its character when slightly bleached decreases the retention to some extent when chlorinated. The hydrogen ion concentration and the temperature of the reaction mixture have very little effect on the retention. Increased time of reaction, increased consistency, and decreased freeness, however, produce considerable increases in the retention of this class of dyestuff.

In addition, a method for determining dye retention was developed which uses the Kubelka and Monk equation as its fundamental principle. The results obtained by this method were in good agreement with those obtained by the method using Beer's law. From this it can be concluded that the Kubelka and Monk equation, which shows scattering and absorption coefficients as a function of reflectivity, is sound from the standpoint of applicability.

With proof of the validity of this equation certain, it may possibly be used as a stepping stone in developing a method for predicting the shade which would be obtained for various dyes on various stocks. In addition, it is not at all impossible to conceive that this equation could be used in control work, especially in the case of coated papers where one hundred per cent retention is obtained.

In the course of this investigation the dye retention results were applied to the Freundlich adsorption equation. It was found that, when the logarithm of the weight of dye adsorbed is plotted against the logarithm of the weight of dye left in the white water, straight adsorption isotherms were obtained. No definite generalization concerning the behavior of adsorption can be formulated, but, with such good agreement of these results with the equation in question, it is believed that the method as studied and described will be of value in future work dealing with a study of the mechanism of paper dyeing.

# CHAPTER VI

## SUMMARY

1. A spectrophotometric method for determining dye retention was developed which uses Beer's law as its fundamental principle.

2. Dye retentions for twenty dyes were determined on fourteen pulps under varying conditions of hydrogen ion concentration, consistency, temperature, time, and freeness.

3. A spectrophotometric method for determining dye retention was developed which uses the Kubelka and Monk equation as its fundamental principle. The results obtained by this method checked the results obtained by the method outlined above, thereby establishing the validity of the applicability of this equation.

4. The Freundlich adsorption equation was found to represent the retention data.

# CHAPTER VII

## BIBLIOGRAPHY

1. Clark, E.P., J. Assoc. Official Agr. Chem., 15: 136-40 (1932). C.A. 26: 2395 (1932).

2. Hardy, A.C. and Perrin, F.H., "The Principles of Optics," page 24-5, New York, McGraw-Hill Book Company, Inc., 1932.

3. Holzer, W.F., Tech. Assoc. Papers, 18, no. 1: 517-29 (1935).

4. Ritter, G.J., Seborg, R.M., and Mitchell, R.L., Ind. Eng. Chem. Anal. Ed., 4: 202-4 (1932).

5. Rys, S., Tech. Assoc. Papers, 11, no. 1: 181-7 (1928).

6. Steele, F.A., Tech. Assoc. Papers, 18, no. 1: 299-304 (1935).

7. T. A. P. P. I. Standard T 205m.

8. Walker, W.H., Lewis, W.K., and McAdams, W.H., "Principles of Chemical Engineering," page 645-7, New York, McGraw-Hill Book Company, Inc., 1927.

9. Wiles, R.H., Tech. Assoc. Papers, 17, no. 1: 146-8 (1934).

10. Willetts, W.R., Tech. Assoc. Papers, 14, no. 1: 121 (1931).

# APPENDIX A

## CALCULATIONS

TABLE 1A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN ON SULPHITE PULP BLEACHED TO VARIOUS DEGREES

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.7 | 97.9 | 1.991 | .000064 | .000030 | .0015 | .001470 | 97.9 |
| | 1 | 82.7 | 96.8 | 1.986 | .000234 | .000110 | .0030 | .002890 | 96.5 |
| | 1½ | 81.7 | 95.7 | 1.981 | .000383 | .000180 | .0045 | .004320 | 96.0 |
| | 3 | 79.0 | 92.5 | 1.965 | .000995 | .000420 | .0090 | .008580 | 95.3 |
| 3 | 0 | 82.4 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 82.3 | 98.2 | 1.992 | .000032 | .000015 | .0015 | .001485 | 98.9 |
| | 1 | 81.7 | 97.5 | 1.989 | .000117 | .000055 | .0030 | .002945 | 98.2 |
| | 1½ | 81.1 | 96.8 | 1.986 | .000234 | .000110 | .0045 | .004390 | 97.6 |
| | 3 | 78.8 | 94.0 | 1.973 | .000638 | .000300 | .0090 | .008700 | 96.7 |
| 6 | 0 | 85.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 84.6 | 97.9 | 1.991 | .000059 | .000028 | .0015 | .001472 | 98.2 |
| | 1 | 83.9 | 97.0 | 1.987 | .000191 | .000090 | .0030 | .002910 | 97.0 |
| | 1½ | 82.9 | 95.9 | 1.982 | .000340 | .000160 | .0045 | .004340 | 96.4 |
| | 3 | 80.3 | 92.9 | 1.968 | .000830 | .000390 | .0090 | .008610 | 95.7 |

(Continued)

TABLE 1A (Continued)

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 87.3 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 86.7 | 97.7 | 1.990 | .000085 | .000040 | .0015 | .001460 | 97.3 |
| | 1 | 85.8 | 96.6 | 1.985 | .000255 | .000120 | .0030 | .002880 | 96.0 |
| | 1½ | 84.5 | 95.1 | 1.978 | .000468 | .000220 | .0045 | .004280 | 95.1 |
| | 3 | 80.7 | 90.8 | 1.958 | .001105 | .000520 | .0090 | .008480 | 94.2 |
| 20 | 0 | 89.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 87.7 | 96.8 | 1.986 | .000223 | .000105 | .0015 | .001395 | 93.0 |
| | 1 | 85.6 | 94.6 | 1.976 | .000553 | .000260 | .0030 | .002740 | 91.2 |
| | 1½ | 83.2 | 92.0 | 1.964 | .000936 | .000440 | .0045 | .004060 | 90.2 |
| | 3 | 77.0 | 85.1 | 1.930 | .002080 | .000980 | .0090 | .008020 | 89.1 |
| 30 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.8 | 95.7 | 1.981 | .000383 | .000180 | .0015 | .001320 | 87.9 |
| | 1 | 85.8 | 92.5 | 1.966 | .000866 | .000407 | .0030 | .002593 | 86.4 |
| | 1½ | 82.8 | 89.3 | 1.951 | .001360 | .000640 | .0045 | .003860 | 85.8 |
| | 3 | 74.7 | 80.5 | 1.906 | .002870 | .001350 | .0090 | .007650 | 85.0 |

TABLE 2A

CALCULATION OF RETENTION OF DU PONT BRILLIANT OROCEIN FL ON SULPHITE PULP BLEACHED TO VARIOUS DEGREES

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 72.2 | 90.4 | 1.956 | .001350 | .000635 | .0015 | .000865 | 57.7 |
| | 1 | 68.5 | 85.7 | 1.933 | .003190 | .001500 | .0030 | .001500 | 50.0 |
| | 1 1/2 | 64.5 | 80.7 | 1.907 | .005200 | .002440 | .0045 | .002060 | 45.7 |
| | 3 | 54.4 | 68.1 | 1.833 | .011100 | .005240 | .0090 | .003760 | 41.8 |
| 3 | 0 | 72.8 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 69.9 | 90.2 | 1.955 | .001470 | .000690 | .0015 | .000810 | 54.0 |
| | 1 | 65.8 | 84.9 | 1.929 | .003520 | .001652 | .0030 | .001348 | 44.9 |
| | 1 1/2 | 61.6 | 79.4 | 1.900 | .005730 | .002695 | .0045 | .001805 | 40.1 |
| | 3 | 50.8 | 65.5 | 1.816 | .012400 | .005850 | .0090 | .003150 | 35.0 |
| 6 | 0 | 76.2 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 73.1 | 90.2 | 1.955 | .001440 | .000676 | .0015 | .000824 | 54.9 |
| | 1 | 69.0 | 85.1 | 1.930 | .003450 | .001620 | .0030 | .001380 | 46.0 |
| | 1 1/2 | 64.7 | 79.8 | 1.902 | .005640 | .002650 | .0045 | .001850 | 41.2 |
| | 3 | 53.7 | 66.2 | 1.821 | .012000 | .005660 | .0090 | .003340 | 37.1 |

(Continued)

TABLE 2A (Continued)

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 78.0 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 75.0 | 90.4 | 1.956 | .001390 | .000654 | .0015 | .000846 | 56.4 |
| | 1 | 70.8 | 85.3 | 1.931 | .003380 | .001590 | .0030 | .001410 | 47.1 |
| | 1½ | 66.5 | 80.2 | 1.904 | .005470 | .002570 | .0045 | .001930 | 42.8 |
| | 3 | 55.6 | 67.0 | 1.826 | .011660 | .005480 | .0090 | .003520 | 39.1 |
| 20 | 0 | 79.3 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 71.4 | 90.6 | 1.957 | .001276 | .000600 | .0015 | .000900 | 60.0 |
| | 1 | 72.6 | 86.1 | 1.935 | .003060 | .001440 | .0030 | .001560 | 52.0 |
| | 1½ | 68.5 | 81.3 | 1.910 | .005020 | .002360 | .0045 | .002140 | 47.6 |
| | 3 | 57.7 | 68.4 | 1.835 | .011000 | .005180 | .0090 | .003820 | 42.4 |
| 30 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.2 | 90.2 | 1.955 | .001425 | .000670 | .0015 | .000930 | 62.0 |
| | 1 | 75.0 | 86.5 | 1.937 | .002940 | .001385 | .0030 | .001615 | 53.8 |
| | 1½ | 70.8 | 81.7 | 1.912 | .004870 | .002290 | .0045 | .002210 | 49.0 |
| | 3 | 59.4 | 68.5 | 1.836 | .010850 | .005100 | .0090 | .003900 | 43.3 |

TABLE 3A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON SULPHITE PULP BLEACHED TO VARIOUS DEGREES

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 72.9 | 89.9 | 1.954 | .001340 | .000630 | .0015 | .000870 | 58.0 |
| | 1 | 68.8 | 84.9 | 1.929 | .002940 | .001380 | .0030 | .001620 | 54.0 |
| | 1 1/2 | 64.8 | 80.0 | 1.903 | .004570 | .002150 | .0045 | .002350 | 52.2 |
| | 3 | 53.8 | 66.4 | 1.822 | .009750 | .004580 | .0090 | .004420 | 49.1 |
| 3 | 0 | 74.8 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 70.4 | 88.9 | 1.949 | .001640 | .000773 | .0015 | .000727 | 48.4 |
| | 1 | 65.8 | 83.0 | 1.919 | .003550 | .001670 | .0030 | .001330 | 44.3 |
| | 1 1/2 | 61.3 | 77.4 | 1.889 | .005520 | .002595 | .0045 | .001905 | 42.3 |
| | 3 | 49.2 | 62.1 | 1.793 | .011650 | .005480 | .0090 | .003520 | 39.1 |
| 6 | 0 | 77.4 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 73.2 | 89.3 | 1.951 | .001535 | .000722 | .0015 | .000778 | 51.8 |
| | 1 | 68.7 | 83.8 | 1.923 | .003290 | .001545 | .0030 | .001455 | 48.5 |
| | 1 1/2 | 64.3 | 78.5 | 1.895 | .005130 | .002410 | .0045 | .002090 | 46.5 |
| | 3 | 52.3 | 63.8 | 1.805 | .010900 | .005110 | .0090 | .003890 | 43.2 |

(Continued)

TABLE 3A (Continued)

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 79.9 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 75.8 | 89.7 | 1.953 | .001380 | .000648 | .0015 | .000852 | 56.8 |
| | 1 | 71.7 | 84.7 | 1.928 | .003020 | .001420 | .0030 | .001580 | 52.6 |
| | 1½ | 67.4 | 79.6 | 1.901 | .004700 | .002210 | .0045 | .002290 | 50.9 |
| | 3 | 56.4 | 66.7 | 1.824 | .009670 | .004640 | .0090 | .004360 | 48.4 |
| 20 | 0 | 81.2 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 77.5 | 90.2 | 1.955 | .001280 | .000601 | .0015 | .000899 | 59.9 |
| | 1 | 73.5 | 85.5 | 1.932 | .002770 | .001300 | .0030 | .001700 | 56.7 |
| | 1½ | 69.4 | 80.7 | 1.907 | .004320 | .002030 | .0045 | .002470 | 54.9 |
| | 3 | 58.3 | 67.8 | 1.831 | .009240 | .004340 | .0090 | .004660 | 51.8 |
| 30 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.7 | 90.6 | 1.957 | .001150 | .000540 | .0015 | .000960 | 64.0 |
| | 1 | 75.9 | 86.3 | 1.936 | .002490 | .001170 | .0030 | .001830 | 61.0 |
| | 1½ | 72.1 | 82.0 | 1.914 | .003910 | .001840 | .0045 | .002660 | 59.1 |
| | 3 | 61.3 | 69.7 | 1.843 | .008400 | .003950 | .0090 | .005050 | 56.2 |

TABLE 4A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON KRAFT PULP BLEACHED TO VARIOUS DEGREES

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 80.1 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 79.7 | 97.9 | 1.991 | .000053 | .000025 | .0015 | .001475 | 98.3 |
| | 1 | 79.3 | 97.3 | 1.988 | .000170 | .000080 | .0030 | .002920 | 97.2 |
| | 1 1/2 | 78.1 | 95.9 | 1.982 | .000340 | .000160 | .0045 | .004340 | 96.6 |
| | 3 | 75.4 | 92.5 | 1.966 | .000872 | .000410 | .0090 | .008590 | 95.5 |
| 5 | 0 | 82.1 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 81.6 | 97.7 | 1.990 | .000085 | .000040 | .0015 | .001460 | 97.3 |
| | 1 | 80.5 | 96.4 | 1.984 | .000276 | .000130 | .0030 | .002870 | 95.7 |
| | 1 1/2 | 79.4 | 95.1 | 1.978 | .000490 | .000230 | .0045 | .004270 | 94.8 |
| | 3 | 75.3 | 90.2 | 1.955 | .001255 | .000590 | .0090 | .008410 | 93.4 |
| 15 | 0 | 84.1 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 83.0 | 97.0 | 1.987 | .000185 | .000087 | .0015 | .001413 | 94.2 |
| | 1 | 81.4 | 95.1 | 1.978 | .000468 | .000220 | .0030 | .002780 | 92.6 |
| | 1 1/2 | 79.7 | 93.1 | 1.969 | .000788 | .000370 | .0045 | .004130 | 91.6 |
| | 3 | 74.4 | 86.9 | 1.939 | .001785 | .000840 | .0090 | .008160 | 90.7 |

(Continued)

TABLE 4A (Continued)

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 0 | 86.3 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 84.6 | 96.4 | 1.984 | .000276 | .000130 | .0015 | .001370 | 91.4 |
| | 1 | 82.5 | 94.0 | 1.973 | .000660 | .000310 | .0030 | .002690 | 89.8 |
| | 1½ | 80.2 | 91.4 | 1.961 | .001064 | .000500 | .0045 | .004000 | 88.8 |
| | 3 | 73.2 | 83.4 | 1.921 | .002380 | .001120 | .0090 | .007880 | 87.6 |
| 40 | 0 | 88.1 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 85.9 | 95.9 | 1.982 | .000366 | .000172 | .0015 | .001328 | 88.5 |
| | 1 | 83.2 | 92.9 | 1.968 | .000830 | .000390 | .0030 | .002610 | 87.1 |
| | 1½ | 80.3 | 89.7 | 1.953 | .001300 | .000610 | .0045 | .003890 | 86.5 |
| | 3 | 72.8 | 81.3 | 1.910 | .002740 | .001290 | .0090 | .007710 | 85.7 |

## TABLE 5A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON KRAFT PULP BLEACHED TO VARIOUS DEGREES

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 70.2 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 67.3 | 90.2 | 1.955 | .001450 | .000682 | .0015 | .000818 | 54.5 |
| | 1 | 63.5 | 85.1 | 1.930 | .003430 | .001610 | .0030 | .001390 | 46.3 |
| | 1½ | 59.7 | 80.0 | 1.903 | .005500 | .002585 | .0045 | .001915 | 42.6 |
| | 3 | 50.0 | 67.0 | 1.826 | .011600 | .005450 | .0090 | .003550 | 39.4 |
| 5 | 0 | 73.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 69.8 | 89.3 | 1.951 | .001785 | .000840 | .0015 | .000660 | 44.0 |
| | 1 | 65.5 | 83.8 | 1.923 | .004020 | .001890 | .0030 | .001110 | 37.0 |
| | 1½ | 61.2 | 78.3 | 1.894 | .006240 | .002930 | .0045 | .001570 | 34.2 |
| | 3 | 50.0 | 64.0 | 1.806 | .013200 | .006200 | .0090 | .002800 | 31.1 |
| 15 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 71.5 | 89.5 | 1.952 | .001710 | .000804 | .0015 | .000696 | 46.4 |
| | 1 | 67.2 | 84.1 | 1.925 | .003840 | .001805 | .0030 | .001195 | 39.8 |
| | 1½ | 63.0 | 78.9 | 1.897 | .006030 | .002835 | .0045 | .001665 | 37.0 |
| | 3 | 51.9 | 65.0 | 1.813 | .012640 | .005940 | .0090 | .003060 | 34.0 |

(Continued)

TABLE 5A (Continued)

| % BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS- MISSION | COR- RECTED TRANS- MISSION | LOG COR- RECTED TRANS- MISSION | CONCEN- TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN- TION |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 0 | 77.5 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 73.8 | 89.5 | 1.952 | .001660 | .000780 | .0015 | .000720 | 48.0 |
| | 1 | 69.7 | 84.5 | 1.927 | .003770 | .001775 | .0030 | .001225 | 40.8 |
| | 1½ | 65.2 | 79.1 | 1.898 | .005950 | .002795 | .0045 | .001705 | 37.9 |
| | 3 | 54.0 | 65.5 | 1.816 | .012450 | .005860 | .0090 | .003140 | 34.9 |
| 40 | 0 | 80.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 76.4 | 89.7 | 1.953 | .001595 | .000751 | .0015 | .000749 | 49.9 |
| | 1 | 72.0 | 84.5 | 1.927 | .003660 | .001722 | .0030 | .001278 | 42.6 |
| | 1½ | 67.6 | 79.4 | 1.900 | .005780 | .002720 | .0045 | .001780 | 39.5 |
| | 3 | 56.2 | 65.9 | 1.819 | .012150 | .005713 | .0090 | .003287 | 36.5 |

TABLE 6A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON KRAFT PULP BLEACHED TO VARIOUS DEGREES

| PERCENT BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 71.9 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 67.8 | 89.1 | 1.950 | .001590 | .000750 | .0015 | .000750 | 50.0 |
| | 1 | 63.7 | 83.8 | 1.923 | .003340 | .001570 | .0030 | .001430 | 47.6 |
| | 1½ | 59.8 | 78.5 | 1.895 | .005130 | .002410 | .0045 | .002090 | 46.6 |
| | 3 | 49.2 | 64.6 | 1.810 | .010540 | .004960 | .0090 | .004040 | 45.0 |
| 5 | 0 | 75.0 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 70.6 | 88.9 | 1.949 | .001660 | .000782 | .0015 | .000818 | 54.5 |
| | 1 | 67.1 | 84.5 | 1.927 | .003070 | .001444 | .0030 | .001556 | 51.9 |
| | 1½ | 63.2 | 79.6 | 1.901 | .004740 | .002230 | .0045 | .002270 | 50.4 |
| | 3 | 52.1 | 65.6 | 1.817 | .010100 | .004640 | .0090 | .004360 | 48.4 |
| 15 | 0 | 76.9 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.4 | 90.0 | 1.954 | .001375 | .000647 | .0015 | .000853 | 56.8 |
| | 1 | 68.2 | 84.9 | 1.929 | .002930 | .001375 | .0030 | .001625 | 54.2 |
| | 1½ | 64.4 | 80.2 | 1.904 | .004510 | .002120 | .0045 | .002380 | 52.8 |
| | 3 | 53.9 | 67.1 | 1.827 | .009450 | .004440 | .0090 | .004560 | 50.7 |

TABLE 6A (Continued)

| PERCENT BLEACH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 0 | 79.0 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 75.2 | 90.0 | 1.954 | .001315 | .000618 | .0015 | .000882 | 58.8 |
| | 1 | 71.3 | 85.3 | 1.931 | .002790 | .001310 | .0030 | .001690 | 56.3 |
| | 1½ | 67.5 | 80.7 | 1.907 | .004320 | .002030 | .0045 | .002470 | 54.9 |
| | 3 | 57.0 | 68.2 | 1.834 | .009000 | .004230 | .0090 | .004770 | 53.0 |
| 40 | 0 | 81.9 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.2 | 90.2 | 1.955 | .001275 | .000600 | .0015 | .000900 | 60.0 |
| | 1 | 74.3 | 85.7 | 1.933 | .002720 | .001280 | .0030 | .001720 | 57.4 |
| | 1½ | 70.3 | 81.1 | 1.909 | .004190 | .001970 | .0045 | .002530 | 56.2 |
| | 3 | 59.3 | 68.4 | 1.835 | .008920 | .004130 | .0090 | .004870 | 54.1 |

## TABLE 7A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SO ON BLEACHED SODA, RAG, AND GROUNDWOOD PULPS

| PULP | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| Soda | 0 | 84.7 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 81.1 | 94.2 | 1.974 | .000617 | .000290 | .0015 | .001210 | 80.7 |
| | 1 | 77.0 | 89.5 | 1.952 | .001340 | .000630 | .0030 | .002370 | 79.0 |
| | 1½ | 73.6 | 85.5 | 1.932 | .002020 | .000950 | .0045 | .003550 | 78.9 |
| | 3 | 63.8 | 74.1 | 1.870 | .004080 | .001920 | .0090 | .007020 | 78.0 |
| Rag | 0 | 92.1 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 87.0 | 92.9 | 1.968 | .000810 | .000380 | .0015 | .001120 | 74.7 |
| | 1 | 81.8 | 87.3 | 1.941 | .001700 | .000800 | .0030 | .002200 | 73.3 |
| | 1½ | 76.6 | 81.8 | 1.913 | .002620 | .001230 | .0045 | .003270 | 72.6 |
| | 3 | 62.7 | 67.0 | 1.826 | .005550 | .002610 | .0090 | .006390 | 71.0 |
| Ground-wood | 0 | 77.1 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 76.3 | 97.3 | 1.988 | .000149 | .000070 | .0015 | .001430 | 95.2 |
| | 1 | 75.0 | 95.7 | 1.981 | .000383 | .000180 | .0030 | .002820 | 94.0 |
| | 1½ | 74.0 | 94.4 | 1.975 | .000595 | .000280 | .0045 | .004220 | 93.6 |
| | 3 | 69.9 | 89.1 | 1.950 | .001400 | .000660 | .0090 | .008340 | 92.8 |

TABLE 8A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON BLEACHED SODA, RAG, AND GROUNDWOOD PULPS

| PULP | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| Soda | 0 | 81.8 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 78.9 | 90.6 | 1.957 | .001275 | .000600 | .0015 | .000900 | 60.0 |
| | 1 | 75.2 | 86.5 | 1.937 | .002940 | .001380 | .0030 | .001620 | 54.0 |
| | 1 1/2 | 71.1 | 81.7 | 1.912 | .004830 | .002270 | .0045 | .002230 | 49.5 |
| | 3 | 59.3 | 68.1 | 1.833 | .011100 | .005220 | .0090 | .003780 | 42.0 |
| Rag | 0 | 83.5 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 80.8 | 91.0 | 1.959 | .001084 | .000510 | .0015 | .000990 | 66.0 |
| | 1 | 77.6 | 87.3 | 1.941 | .002590 | .001215 | .0030 | .001785 | 59.5 |
| | 1 1/2 | 73.7 | 83.0 | 1.919 | .004300 | .002020 | .0045 | .002480 | 55.0 |
| | 3 | 62.2 | 70.0 | 1.845 | .010130 | .004760 | .0090 | .004240 | 47.2 |
| Ground-wood | 0 | 74.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 69.2 | 87.7 | 1.943 | .002390 | .001125 | .0015 | .000375 | 25.0 |
| | 1 | 64.4 | 81.7 | 1.912 | .004870 | .002286 | .0030 | .000714 | 23.8 |
| | 1 1/2 | 59.8 | 75.9 | 1.880 | .007370 | .003465 | .0045 | .001035 | 23.0 |
| | 3 | 48.2 | 61.1 | 1.786 | .014760 | .006940 | .0090 | .002060 | 22.9 |

## TABLE 9A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON BLEACHED SODA, RAG, AND GROUNDWOOD PULPS

| PULP | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | CORRECTED TRANS-MISSION | LOG CORRECTED TRANS-MISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| Soda | 0 | 82.3 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 78.0 | 89.5 | 1.952 | .001435 | .000675 | .0015 | .000825 | 55.0 |
| | 1 | 73.6 | 84.5 | 1.927 | .003060 | .001440 | .0030 | .001560 | 52.0 |
| | 1 1/2 | 69.2 | 79.4 | 1.900 | .004770 | .002240 | .0045 | .002260 | 50.1 |
| | 3 | 56.6 | 64.9 | 1.812 | .010430 | .004910 | .0090 | .004090 | 45.5 |
| Rag | 0 | 85.2 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 81.6 | 90.6 | 1.957 | .001150 | .000542 | .0015 | .000958 | 63.8 |
| | 1 | 77.5 | 86.1 | 1.935 | .002550 | .001200 | .0030 | .001800 | 60.0 |
| | 1 1/2 | 73.5 | 81.7 | 1.912 | .004020 | .001890 | .0045 | .002610 | 58.0 |
| | 3 | 71.4 | 69.3 | 1.841 | .008550 | .004020 | .0090 | .004980 | 55.3 |
| Ground-wood | 0 | 74.9 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 69.4 | 87.5 | 1.942 | .002140 | .001005 | .0015 | .000495 | 33.0 |
| | 1 | 63.7 | 80.3 | 1.905 | .004470 | .002100 | .0030 | .000900 | 30.0 |
| | 1 1/2 | 58.5 | 73.8 | 1.868 | .006830 | .003210 | .0045 | .001290 | 28.6 |
| | 3 | 44.8 | 56.6 | 1.753 | .014250 | .006700 | .0090 | .002300 | 25.6 |

TABLE 10A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SO ON UNBLEACHED SULPHITE PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.3 | 97.5 | 1.989 | .000128 | .000060 | .0015 | .001440 | 96.0 |
| | 1 | 81.9 | 95.9 | 1.982 | .000362 | .000170 | .0030 | .002830 | 94.5 |
| | 1½ | 80.3 | 94.0 | 1.975 | .000575 | .000270 | .0045 | .004230 | 94.1 |
| | 3 | 77.4 | 90.6 | 1.957 | .001190 | .000560 | .0090 | .008440 | 93.8 |
| 4.9 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.5 | 97.9 | 1.991 | .000068 | .000032 | .0015 | .001468 | 97.9 |
| | 1 | 82.7 | 96.8 | 1.986 | .000223 | .000105 | .0030 | .002895 | 96.5 |
| | 1½ | 81.7 | 95.7 | 1.981 | .000383 | .000180 | .0045 | .004320 | 96.0 |
| | 3 | 79.0 | 92.5 | 1.966 | .000895 | .000420 | .0090 | .008580 | 95.3 |
| 5.9 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.4 | 97.7 | 1.990 | .000079 | .000037 | .0015 | .001463 | 97.7 |
| | 1 | 82.6 | 96.8 | 1.986 | .000240 | .000113 | .0030 | .002887 | 96.2 |
| | 1½ | 81.6 | 95.7 | 1.981 | .000404 | .000190 | .0045 | .004310 | 95.9 |
| | 3 | 78.4 | 91.8 | 1.963 | .000980 | .000460 | .0090 | .008540 | 94.9 |

TABLE 11A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON BLEACHED SULPHITE PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.4 | 95.3 | 1.979 | .000453 | .000213 | .0015 | .001287 | 85.8 |
| | 1 | 85.0 | 91.6 | 1.962 | .001010 | .000475 | .0030 | .002525 | 84.8 |
| | 1½ | 82.1 | 88.5 | 1.947 | .001520 | .000715 | .0045 | .003785 | 84.2 |
| | 3 | 73.0 | 78.7 | 1.896 | .003210 | .001510 | .0090 | .007490 | 83.2 |
| 4.9 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.8 | 95.7 | 1.981 | .000387 | .000182 | .0015 | .001318 | 87.9 |
| | 1 | 85.8 | 92.5 | 1.966 | .000872 | .000410 | .0030 | .002590 | 86.4 |
| | 1½ | 83.0 | 89.5 | 1.952 | .001360 | .000640 | .0045 | .003860 | 85.8 |
| | 3 | 74.7 | 80.5 | 1.906 | .002870 | .001350 | .0090 | .007650 | 85.0 |
| 5.9 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.8 | 95.7 | 1.981 | .000391 | .000184 | .0015 | .001316 | 87.8 |
| | 1 | 85.8 | 92.5 | 1.966 | .000880 | .000413 | .0030 | .002587 | 86.3 |
| | 1½ | 82.8 | 89.3 | 1.951 | .001380 | .000650 | .0045 | .003850 | 85.6 |
| | 3 | 74.8 | 80.7 | 1.907 | .002850 | .001340 | .0090 | .007660 | 85.1 |

TABLE 12A

CALCULATION OF RETENTION OF BRILLIANT CROCEIN FL ON UNBLEACHED SULPHITE PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.2 | 90.4 | 1.956 | .001350 | .000635 | .0015 | .000865 | 57.7 |
| | 1 | 68.6 | 85.9 | 1.934 | .003180 | .001495 | .0030 | .001505 | 50.1 |
| | 1½ | 64.5 | 80.7 | 1.907 | .005220 | .002450 | .0045 | .002050 | 45.6 |
| | 3 | 54.4 | 68.1 | 1.833 | .011100 | .005230 | .0090 | .003770 | 41.9 |
| 4.9 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.2 | 90.4 | 1.956 | .001350 | .000635 | .0015 | .000865 | 57.7 |
| | 1 | 68.3 | 85.5 | 1.932 | .003190 | .001500 | .0030 | .001500 | 50.0 |
| | 1½ | 64.5 | 80.7 | 1.907 | .005200 | .002445 | .0045 | .002055 | 45.7 |
| | 3 | 54.2 | 67.9 | 1.832 | .011140 | .005235 | .0090 | .003765 | 41.8 |
| 5.9 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 71.7 | 89.7 | 1.953 | .001590 | .000748 | .0015 | .000752 | 50.1 |
| | 1 | 67.5 | 84.5 | 1.927 | .003690 | .001735 | .0030 | .001265 | 42.2 |
| | 1½ | 63.2 | 79.1 | 1.898 | .005930 | .002785 | .0045 | .001715 | 38.1 |
| | 3 | 52.1 | 65.2 | 1.814 | .012600 | .005930 | .0090 | .003070 | 34.1 |

## TABLE 13A

### CALCULATION OF RETENTION OF BRILLIANT CROCEIN FL ON BLEACHED SULPHITE PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.7 | 90.8 | 1.958 | .001200 | .000570 | .0015 | .000930 | 62.0 |
| | 1 | 74.8 | 86.3 | 1.936 | .002970 | .001395 | .0030 | .001605 | 53.5 |
| | 1½ | 71.0 | 82.0 | 1.914 | .004900 | .002300 | .0045 | .002200 | 48.9 |
| | 3 | 67.9 | 68.4 | 1.835 | .010900 | .005120 | .0090 | .003880 | 43.1 |
| 4.9 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.7 | 90.8 | 1.958 | .001210 | .000570 | .0015 | .000930 | 62.0 |
| | 1 | 74.7 | 86.3 | 1.936 | .002950 | .001385 | .0030 | .001615 | 53.8 |
| | 1½ | 70.8 | 81.7 | 1.912 | .004880 | .002295 | .0045 | .002205 | 49.0 |
| | 3 | 59.3 | 68.5 | 1.836 | .010850 | .005100 | .0090 | .003900 | 43.3 |
| 5.9 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.1 | 90.2 | 1.955 | .001470 | .000690 | .0015 | .000810 | 54.0 |
| | 1 | 73.5 | 84.9 | 1.929 | .003530 | .001660 | .0030 | .001340 | 44.7 |
| | 1½ | 69.0 | 79.6 | 1.901 | .005700 | .002680 | .0045 | .001820 | 40.5 |
| | 3 | 57.0 | 65.9 | 1.819 | .012200 | .005750 | .0090 | .003250 | 36.1 |

TABLE 14A

CALCULATION OF RETENTION OF FAST RED 8BL ON UNBLEACHED SULPHITE PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.9 | 90.0 | 1.954 | .00134 | .000627 | .0015 | .000873 | 58.2 |
| | 1 | 68.8 | 84.9 | 1.929 | .00293 | .001378 | .0030 | .001622 | 54.1 |
| | 1½ | 64.8 | 80.0 | 1.903 | .00458 | .002150 | .0045 | .002350 | 52.2 |
| | 3 | 53.9 | 66.5 | 1.823 | .00975 | .004580 | .0090 | .004420 | 49.1 |
| 4.9 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.9 | 90.0 | 1.954 | .00134 | .000630 | .0015 | .000870 | 58.0 |
| | 1 | 68.8 | 84.9 | 1.929 | .00294 | .001380 | .0030 | .001620 | 54.0 |
| | 1½ | 64.8 | 80.0 | 1.903 | .00458 | .002150 | .0045 | .002350 | 52.2 |
| | 3 | 53.9 | 66.5 | 1.823 | .00975 | .004580 | .0090 | .004420 | 49.1 |
| 5.9 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.7 | 89.7 | 1.953 | .00140 | .000659 | .0015 | .000841 | 56.1 |
| | 1 | 68.5 | 84.5 | 1.927 | .00303 | .001426 | .0030 | .001574 | 52.4 |
| | 1½ | 64.5 | 79.6 | 1.901 | .00474 | .002230 | .0045 | .002270 | 50.4 |
| | 3 | 53.2 | 65.6 | 1.817 | .01010 | .004740 | .0090 | .004260 | 47.3 |

TABLE 15A

CALCULATION OF RETENTION OF FAST RED 8BL ON BLEACHED SULPHITE PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.6 | 90.6 | 1.957 | .00114 | .000535 | .0015 | .000965 | 64.4 |
| | 1 | 76.0 | 86.5 | 1.937 | .00246 | .001155 | .0030 | .001845 | 61.5 |
| | 1½ | 72.1 | 82.0 | 1.914 | .00389 | .001830 | .0045 | .002670 | 59.4 |
| | 3 | 61.6 | 70.1 | 1.846 | .00827 | .003890 | .0090 | .005110 | 56.8 |
| 4.9 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.6 | 90.6 | 1.957 | .00115 | .000540 | .0015 | .000960 | 64.0 |
| | 1 | 75.9 | 86.3 | 1.936 | .00249 | .001170 | .0030 | .001830 | 61.0 |
| | 1½ | 71.9 | 81.8 | 1.913 | .00392 | .001840 | .0045 | .002660 | 59.1 |
| | 3 | 61.4 | 69.8 | 1.844 | .00840 | .003950 | .0090 | .005050 | 56.2 |
| 5.9 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.4 | 90.4 | 1.956 | .00121 | .000568 | .0015 | .000932 | 62.1 |
| | 1 | 75.5 | 85.9 | 1.934 | .00262 | .001231 | .0030 | .001769 | 58.9 |
| | 1½ | 71.6 | 81.5 | 1.911 | .00409 | .001920 | .0045 | .002580 | 57.3 |
| | 3 | 60.6 | 68.9 | 1.838 | .00874 | .004110 | .0090 | .004890 | 54.3 |

TABLE 16A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON UNBLEACHED KRAFT PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.4 | 97.7 | 1.990 | .000083 | .000039 | .0015 | .001461 | 97.5 |
| | 1 | 82.7 | 96.8 | 1.986 | .000213 | .000100 | .0030 | .002900 | 96.5 |
| | 1½ | 81.7 | 95.7 | 1.981 | .000383 | .000180 | .0045 | .004320 | 96.0 |
| | 3 | 78.6 | 92.0 | 1.964 | .000958 | .000450 | .0090 | .008550 | 94.9 |
| 4.9 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.6 | 97.9 | 1.991 | .000053 | .000025 | .0015 | .001475 | 98.3 |
| | 1 | 83.1 | 97.3 | 1.988 | .000170 | .000080 | .0030 | .002920 | 97.2 |
| | 1½ | 82.2 | 96.2 | 1.983 | .000340 | .000160 | .0045 | .004340 | 96.6 |
| | 3 | 79.0 | 92.5 | 1.966 | .000873 | .000410 | .0090 | .008590 | 95.5 |
| 5.9 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.6 | 97.9 | 1.991 | .000059 | .000028 | .0015 | .001472 | 98.2 |
| | 1 | 82.9 | 97.1 | 1.987 | .000191 | .000090 | .0030 | .002910 | 97.1 |
| | 1½ | 81.9 | 95.9 | 1.982 | .000362 | .000170 | .0045 | .004330 | 96.4 |
| | 3 | 78.8 | 92.3 | 1.965 | .000915 | .000430 | .0090 | .008580 | 95.4 |

TABLE 17A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON BLEACHED KRAFT PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.7 | 95.7 | 1.981 | .000374 | .000176 | .0015 | .001324 | 88.2 |
| | 1 | 86.1 | 92.9 | 1.968 | .000819 | .000385 | .0030 | .002615 | 87.1 |
| | 1½ | 83.2 | 89.7 | 1.953 | .001300 | .000610 | .0045 | .003890 | 86.4 |
| | 3 | 75.0 | 80.9 | 1.908 | .002810 | .001320 | .0090 | .007680 | 85.4 |
| 4.9 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.9 | 95.9 | 1.982 | .000366 | .000172 | .0015 | .001328 | 88.5 |
| | 1 | 86.1 | 92.9 | 1.968 | .000819 | .000385 | .0030 | .002615 | 87.1 |
| | 1½ | 83.5 | 90.0 | 1.954 | .001290 | .000605 | .0045 | .003895 | 86.5 |
| | 3 | 75.7 | 81.5 | 1.911 | .002720 | .001280 | .0090 | .007720 | 85.7 |
| 5.9 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.9 | 95.9 | 1.982 | .000366 | .000172 | .0015 | .001328 | 88.5 |
| | 1 | 86.0 | 92.7 | 1.967 | .000830 | .000390 | .0030 | .002610 | 87.0 |
| | 1½ | 83.5 | 90.0 | 1.954 | .001290 | .000605 | .0045 | .003895 | 86.5 |
| | 3 | 75.1 | 80.9 | 1.908 | .002790 | .001310 | .0090 | .007690 | 85.5 |

TABLE 18A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON UNBLEACHED KRAFT PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.0 | 90.2 | 1.935 | .001440 | .000679 | .0015 | .000821 | 54.8 |
| | 1 | 68.1 | 85.3 | 1.931 | .003400 | .001600 | .0030 | .001400 | 46.6 |
| | 1½ | 64.0 | 80.2 | 1.904 | .005470 | .002570 | .0045 | .001930 | 42.9 |
| | 3 | 53.8 | 67.3 | 1.828 | .011500 | .005400 | .0090 | .003600 | 40.0 |
| 4.9 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.0 | 90.2 | 1.955 | .001450 | .000683 | .0015 | .000817 | 54.5 |
| | 1 | 68.0 | 85.1 | 1.930 | .003420 | .001610 | .0030 | .001390 | 46.3 |
| | 1½ | 63.8 | 80.0 | 1.903 | .005500 | .002585 | .0045 | .019150 | 42.6 |
| | 3 | 53.5 | 67.0 | 1.826 | .011600 | .005450 | .0090 | .003550 | 39.4 |
| 5.9 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 71.7 | 89.7 | 1.953 | .001590 | .000750 | .0015 | .000750 | 50.0 |
| | 1 | 67.5 | 84.5 | 1.927 | .003660 | .001720 | .0030 | .001280 | 42.6 |
| | 1½ | 63.2 | 79.1 | 1.898 | .005920 | .002785 | .0045 | .017150 | 38.1 |
| | 3 | 52.4 | 65.6 | 1.817 | .012400 | .005840 | .0090 | .003160 | 35.1 |

TABLE 19A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON BLEACHED KRAFT PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 77.7 | 89.7 | 1.953 | .001585 | .000747 | .0015 | .000753 | 50.2 |
| | 1 | 73.3 | 84.7 | 1.928 | .003640 | .001710 | .0030 | .001290 | 43.0 |
| | 1½ | 68.8 | 79.4 | 1.900 | .005750 | .002700 | .0045 | .001800 | 40.0 |
| | 3 | 57.3 | 66.1 | 1.820 | .012100 | .005680 | .0090 | .003320 | 36.9 |
| 4.9 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 77.7 | 89.7 | 1.953 | .001595 | .000751 | .0015 | .000749 | 49.9 |
| | 1 | 73.2 | 84.5 | 1.927 | .003660 | .001720 | .0030 | .001280 | 42.6 |
| | 1½ | 68.8 | 79.4 | 1.900 | .005780 | .002722 | .0045 | .001778 | 39.5 |
| | 3 | 57.1 | 65.9 | 1.819 | .012140 | .005710 | .0090 | .003290 | 36.5 |
| 5.9 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 77.3 | 89.3 | 1.951 | .001770 | .000832 | .0015 | .000668 | 44.6 |
| | 1 | 72.6 | 83.8 | 1.923 | .003970 | .001865 | .0030 | .001135 | 37.8 |
| | 1½ | 67.8 | 78.3 | 1.894 | .006270 | .002950 | .0045 | .001550 | 34.4 |
| | 3 | 55.7 | 64.3 | 1.808 | .013000 | .006100 | .0090 | .002890 | 32.1 |

TABLE 20A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON UNBLEACHED KRAFT PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.3 | 89.1 | 1.950 | .001590 | .000748 | .0015 | .000752 | 50.1 |
| | 1 | 67.8 | 83.6 | 1.922 | .003340 | .001570 | .0030 | .001430 | 47.6 |
| | 1½ | 63.7 | 78.5 | 1.895 | .005090 | .002390 | .0045 | .002110 | 46.8 |
| | 3 | 52.5 | 64.7 | 1.811 | .010500 | .004950 | .0090 | .004050 | 45.0 |
| 4.9 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.3 | 89.1 | 1.950 | .001595 | .000750 | .0015 | .000750 | 50.0 |
| | 1 | 67.8 | 83.6 | 1.922 | .003340 | .001570 | .0030 | .001430 | 47.6 |
| | 1½ | 63.5 | 78.3 | 1.894 | .005120 | .002405 | .0045 | .002095 | 46.6 |
| | 3 | 52.5 | 64.7 | 1.811 | .010500 | .004950 | .0090 | .004050 | 45.0 |
| 5.9 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.1 | 88.9 | 1.949 | .00165 | .000775 | .0015 | .000725 | 48.3 |
| | 1 | 68.0 | 83.8 | 1.923 | .00330 | .001550 | .0030 | .001450 | 45.9 |
| | 1½ | 63.1 | 77.8 | 1.891 | .00533 | .002505 | .0045 | .001995 | 44.3 |
| | 3 | 51.8 | 63.8 | 1.805 | .01090 | .005120 | .0090 | .003880 | 43.1 |

## TABLE 21A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON BLEACHED KRAFT PULP AT VARIOUS pH'S

| pH | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 3.9 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.3 | 90.2 | 1.955 | .001260 | .000592 | .0015 | .000902 | 60.1 |
| | 1 | 75.3 | 85.7 | 1.933 | .002690 | .001265 | .0030 | .001735 | 57.8 |
| | 1½ | 71.5 | 81.3 | 1.910 | .004130 | .001940 | .0045 | .002560 | 56.8 |
| | 3 | 60.7 | 69.0 | 1.839 | .008700 | .004080 | .0090 | .004920 | 54.7 |
| 4.9 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.3 | 90.2 | 1.955 | .001275 | .000600 | .0015 | .000900 | 60.0 |
| | 1 | 75.2 | 85.5 | 1.932 | .002720 | .001280 | .0030 | .001720 | 57.4 |
| | 1½ | 71.3 | 81.1 | 1.909 | .004200 | .001970 | .0045 | .002530 | 56.2 |
| | 3 | 60.3 | 68.7 | 1.837 | .008800 | .004130 | .0090 | .004870 | 54.1 |
| 5.9 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.0 | 89.9 | 1.954 | .001340 | .000632 | .0015 | .000868 | 57.8 |
| | 1 | 74.8 | 85.1 | 1.930 | .002870 | .001350 | .0030 | .001650 | 55.0 |
| | 1½ | 70.7 | 80.4 | 1.905 | .004410 | .002075 | .0045 | .002425 | 53.9 |
| | 3 | 59.4 | 67.6 | 1.831 | .009210 | .004330 | .0090 | .004670 | 51.9 |

## TABLE 22A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON UNBLEACHED SULPHITE PULP AT VARIOUS CONSISTENCIES

| PERCENT CONSISTENCY | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 0.3 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.3 | 97.5 | 1.989 | .000117 | .000055 | .0015 | .001445 | 96.3 |
| | 1 | 82.3 | 96.4 | 1.984 | .000298 | .000140 | .0030 | .002860 | 95.4 |
| | 1½ | 81.3 | 95.1 | 1.978 | .000490 | .000230 | .0045 | .004270 | 94.9 |
| | 3 | 77.7 | 90.8 | 1.958 | .001150 | .000540 | .0090 | .008460 | 94.0 |
| 0.6 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.7 | 98.0 | 1.991 | .000068 | .000032 | .0015 | .001468 | 97.9 |
| | 1 | 82.7 | 96.8 | 1.986 | .000234 | .000110 | .0030 | .002890 | 96.5 |
| | 1½ | 81.7 | 95.7 | 1.981 | .000383 | .000180 | .0045 | .004320 | 96.0 |
| | 3 | 79.0 | 92.5 | 1.966 | .000895 | .000420 | .0090 | .008580 | 95.3 |
| 1.0 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.9 | 98.2 | 1.992 | .000045 | .000021 | .0015 | .001479 | 98.6 |
| | 1 | 83.3 | 97.5 | 1.989 | .000138 | .000065 | .0030 | .002935 | 97.8 |
| | 1½ | 82.6 | 96.6 | 1.985 | .000255 | .000120 | .0045 | .004380 | 97.3 |
| | 3 | 80.2 | 93.8 | 1.972 | .000703 | .000330 | .0090 | .008670 | 96.3 |

## TABLE 23A

### CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON BLEACHED SULPHITE PULP AT VARIOUS CONSISTENCIES

| PERCENT CONSISTENCY | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 0.3 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 88.4 | 95.3 | 1.979 | .000442 | .000208 | .0015 | .001292 | 86.1 |
| | 1 | 85.3 | 92.0 | 1.964 | .000958 | .000450 | .0030 | .002550 | 85.1 |
| | 1 1/2 | 82.3 | 88.7 | 1.948 | .001470 | .000690 | .0045 | .003810 | 84.6 |
| | 3 | 73.8 | 79.6 | 1.901 | .003060 | .001440 | .0090 | .007560 | 83.9 |
| 0.6 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 88.8 | 95.7 | 1.981 | .000390 | .000183 | .0015 | .001317 | 87.9 |
| | 1 | 85.8 | 92.5 | 1.966 | .000873 | .000410 | .0030 | .002590 | 86.4 |
| | 1 1/2 | 82.8 | 89.3 | 1.951 | .001360 | .000640 | .0045 | .003860 | 85.8 |
| | 3 | 74.6 | 80.5 | 1.906 | .002870 | .001350 | .0090 | .007650 | 85.0 |
| 1.0 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 88.7 | 95.7 | 1.981 | .000370 | .000174 | .0015 | .001326 | 88.4 |
| | 1 | 86.4 | 93.1 | 1.969 | .000787 | .000370 | .0030 | .002630 | 87.6 |
| | 1 1/2 | 83.7 | 90.2 | 1.955 | .001250 | .000590 | .0045 | .003910 | 87.0 |
| | 3 | 75.8 | 81.7 | 1.912 | .002660 | .001250 | .0090 | .007750 | 86.1 |

TABLE 24A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON UNBLEACHED SULPHITE PULP AT VARIOUS CONSISTENCIES

| PERCENT CONSISTENCY | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 0.3 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.1 | 90.2 | 1.955 | .001485 | .000698 | .0015 | .000802 | 53.3 |
| | 1 | 68.0 | 85.1 | 1.930 | .003430 | .001610 | .0030 | .001390 | 46.0 |
| | 1½ | 64.1 | 80.2 | 1.904 | .005460 | .002565 | .0045 | .001935 | 43.0 |
| | 3 | 53.7 | 67.1 | 1.827 | .011550 | .005440 | .0090 | .003560 | 39.6 |
| 0.6 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.2 | 90.4 | 1.956 | .001350 | .000634 | .0015 | .000866 | 57.7 |
| | 1 | 68.5 | 85.7 | 1.933 | .003190 | .001500 | .0030 | .001500 | 50.0 |
| | 1½ | 64.5 | 80.7 | 1.907 | .005200 | .002440 | .0045 | .002060 | 45.7 |
| | 3 | 54.3 | 67.9 | 1.832 | .011150 | .005240 | .0090 | .003760 | 41.8 |
| 1.0 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 74.0 | 92.5 | 1.966 | .000788 | .000370 | .0015 | .001130 | 76.3 |
| | 1 | 70.9 | 88.7 | 1.948 | .002040 | .000960 | .0030 | .002040 | 68.1 |
| | 1½ | 68.0 | 85.1 | 1.930 | .003440 | .001620 | .0045 | .002880 | 64.0 |
| | 3 | 59.6 | 74.5 | 1.872 | .008050 | .003780 | .0090 | .005220 | 58.0 |

TABLE 25A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON BLEACHED SULPHITE PULP AT VARIOUS CONSISTENCIES

| PERCENT CONSISTENCY | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 0.3 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.5 | 90.6 | 1.957 | .001320 | .000622 | .0015 | .000878 | 58.8 |
| | 1 | 74.2 | 85.7 | 1.933 | .003140 | .001475 | .0030 | .001525 | 50.8 |
| | 1½ | 70.1 | 80.9 | 1.908 | .005130 | .002410 | .0045 | .002090 | 46.8 |
| | 3 | 67.7 | 68.1 | 1.833 | .011100 | .005220 | .0090 | .003780 | 42.0 |
| 0.6 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.7 | 90.8 | 1.958 | .001210 | .000569 | .0015 | .000931 | 62.0 |
| | 1 | 74.7 | 88.7 | 1.948 | .002950 | .001385 | .0030 | .001615 | 53.8 |
| | 1½ | 70.7 | 81.5 | 1.911 | .004900 | .002300 | .0045 | .002200 | 49.0 |
| | 3 | 59.5 | 68.6 | 1.836 | .010850 | .005100 | .0090 | .003900 | 43.3 |
| 1.0 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 80.1 | 92.5 | 1.966 | .000575 | .000270 | .0015 | .001230 | 81.3 |
| | 1 | 77.4 | 89.3 | 1.951 | .001720 | .000810 | .0030 | .002190 | 73.1 |
| | 1½ | 74.6 | 86.1 | 1.935 | .003040 | .001430 | .0045 | .003070 | 68.2 |
| | 3 | 65.8 | 75.9 | 1.880 | .007400 | .003480 | .0090 | .005520 | 61.3 |

TABLE 26A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON UNBLEACHED SULPHITE PULP AT VARIOUS CONSISTENCIES

| PERCENT CONSISTENCY | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 0.3 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 71.9 | 88.7 | 1.948 | .001710 | .000804 | .0015 | .000696 | 46.4 |
| | 1 | 67.0 | 82.6 | 1.917 | .003650 | .001715 | .0030 | .001285 | 42.8 |
| | 1½ | 62.7 | 77.3 | 1.888 | .005570 | .002620 | .0045 | .001880 | 41.8 |
| | 3 | 50.1 | 61.7 | 1.790 | .011900 | .005600 | .0090 | .003400 | 37.8 |
| 0.6 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.7 | 89.7 | 1.953 | .001340 | .000630 | .0015 | .000870 | 58.0 |
| | 1 | 68.7 | 84.7 | 1.928 | .002940 | .001380 | .0030 | .001620 | 54.0 |
| | 1½ | 64.9 | 80.0 | 1.903 | .004580 | .002150 | .0045 | .002350 | 52.2 |
| | 3 | 53.8 | 66.4 | 1.822 | .009750 | .004580 | .0090 | .004420 | 49.1 |
| 1.0 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 74.5 | 91.8 | 1.963 | .000680 | .000320 | .0015 | .001180 | 78.7 |
| | 1 | 71.8 | 88.5 | 1.947 | .001720 | .000810 | .0030 | .002190 | 73.1 |
| | 1½ | 68.8 | 84.9 | 1.929 | .002870 | .001350 | .0045 | .003150 | 70.0 |
| | 3 | 60.1 | 74.1 | 1.870 | .006760 | .003180 | .0090 | .005820 | 64.7 |

TABLE 27A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON BLEACHED SULPHITE PULP AT VARIOUS CONSISTENCIES

| PERCENT CONSISTENCY | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 0.3 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.4 | 89.1 | 1.950 | .001520 | .000713 | .0015 | .000787 | 52.4 |
| | 1 | 73.3 | 83.4 | 1.921 | .003380 | .001585 | .0030 | .001415 | 47.2 |
| | 1½ | 68.8 | 78.2 | 1.893 | .005210 | .002450 | .0045 | .002050 | 45.7 |
| | 3 | 55.4 | 63.0 | 1.799 | .011130 | .005240 | .0090 | .003760 | 41.7 |
| 0.6 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 80.0 | 91.0 | 1.956 | .001147 | .000540 | .0015 | .000960 | 64.0 |
| | 1 | 75.7 | 86.1 | 1.935 | .002490 | .001170 | .0030 | .001830 | 61.0 |
| | 1½ | 72.0 | 81.8 | 1.913 | .003910 | .001840 | .0045 | .002660 | 59.1 |
| | 3 | 61.4 | 69.8 | 1.844 | .008370 | .003940 | .0090 | .005060 | 56.2 |
| 1.0 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 82.1 | 93.3 | 1.970 | .000291 | .000137 | .0015 | .001363 | 91.0 |
| | 1 | 80.0 | 91.0 | 1.959 | .000968 | .000455 | .0030 | .002545 | 84.9 |
| | 1½ | 77.7 | 88.3 | 1.946 | .001820 | .000855 | .0045 | .003645 | 81.1 |
| | 3 | 70.2 | 79.8 | 1.902 | .004620 | .002170 | .0090 | .006830 | 75.8 |

TABLE 28A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SO ON UNBLEACHED SULPHITE PULP AT VARIOUS TEMPERATURES

| TEMPERATURE | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 83.7 | 98.0 | 1.991 | .000068 | .000032 | .0015 | .001468 | 97.9 |
| | 1 | 82.7 | 96.8 | 1.986 | .000234 | .000110 | .0030 | .002890 | 96.5 |
| | 1 1/2 | 81.7 | 95.7 | 1.981 | .000383 | .000180 | .0045 | .004320 | 96.0 |
| | 3 | 79.0 | 92.5 | 1.966 | .000895 | .000420 | .0090 | .008580 | 95.3 |
| 40 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 83.5 | 97.7 | 1.990 | .000087 | .000041 | .0015 | .001459 | 97.2 |
| | 1 | 82.7 | 96.8 | 1.986 | .000234 | .000110 | .0030 | .002890 | 96.4 |
| | 1 1/2 | 81.6 | 95.5 | 1.980 | .000404 | .000190 | .0045 | .004310 | 95.9 |
| | 3 | 78.8 | 92.3 | 1.965 | .009570 | .000450 | .0090 | .008550 | 95.0 |
| 60 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 83.7 | 98.0 | 1.991 | .000064 | .000030 | .0015 | .001470 | 98.0 |
| | 1 | 82.8 | 97.0 | 1.987 | .000191 | .000090 | .0030 | .002910 | 97.0 |
| | 1 1/2 | 81.8 | 95.7 | 1.981 | .000383 | .000180 | .0045 | .004320 | 96.0 |
| | 3 | 78.8 | 92.3 | 1.965 | .000910 | .000430 | .0090 | .008570 | 95.3 |

## TABLE 29A

### CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON BLEACHED SULPHITE PULP AT VARIOUS TEMPERATURES

| TEMPERATURE | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.8 | 95.7 | 1.981 | .000390 | .000183 | .0015 | .001317 | 87.9 |
| | 1 | 85.8 | 92.5 | 1.966 | .000873 | .000410 | .0030 | .002590 | 86.4 |
| | 1½ | 82.8 | 89.3 | 1.951 | .001360 | .000640 | .0045 | .003860 | 85.8 |
| | 3 | 74.6 | 80.5 | 1.906 | .002870 | .001350 | .0090 | .007650 | 85.0 |
| 40 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.7 | 95.7 | 1.981 | .000387 | .000182 | .0015 | .001318 | 87.8 |
| | 1 | 86.4 | 93.1 | 1.967 | .000861 | .000405 | .0030 | .002595 | 86.5 |
| | 1½ | 82.8 | 89.3 | 1.951 | .001380 | .000650 | .0045 | .003850 | 85.7 |
| | 3 | 74.7 | 80.5 | 1.906 | .002880 | .001350 | .0090 | .007650 | 85.0 |
| 60 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 88.6 | 95.5 | 1.980 | .000396 | .000186 | .0015 | .001314 | 87.5 |
| | 1 | 86.0 | 92.7 | 1.967 | .000861 | .000405 | .0030 | .002595 | 86.5 |
| | 1½ | 83.0 | 89.5 | 1.952 | .001360 | .000640 | .0045 | .003860 | 85.9 |
| | 3 | 74.5 | 80.4 | 1.905 | .002900 | .001360 | .0090 | .007640 | 85.4 |

TABLE 30A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON UNBLEACHED SULPHITE PULP AT VARIOUS TEMPERATURES

| TEMPERATURE | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.2 | 90.4 | 1.956 | .001350 | .000635 | .0015 | .000865 | 57.7 |
| | 1 | 68.5 | 85.7 | 1.933 | .003190 | .001500 | .0030 | .001500 | 50.0 |
| | 1½ | 64.5 | 80.7 | 1.907 | .005250 | .002470 | .0045 | .002030 | 45.7 |
| | 3 | 54.3 | 67.9 | 1.832 | .001115 | .005240 | .0090 | .003760 | 41.8 |
| 40 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.2 | 90.4 | 1.956 | .001320 | .000620 | .0015 | .000880 | 58.6 |
| | 1 | 68.7 | 85.9 | 1.934 | .003160 | .001485 | .0030 | .001515 | 50.5 |
| | 1½ | 64.7 | 80.9 | 1.908 | .005170 | .002430 | .0045 | .002070 | 46.0 |
| | 3 | 54.2 | 67.9 | 1.832 | .011100 | .005210 | .0090 | .003790 | 42.1 |
| 60 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 72.4 | 90.6 | 1.957 | .001270 | .000600 | .0015 | .000900 | 60.0 |
| | 1 | 68.8 | 86.1 | 1.935 | .003060 | .001440 | .0030 | .001560 | 51.9 |
| | 1½ | 64.9 | 81.3 | 1.910 | .005020 | .002360 | .0045 | .002140 | 47.5 |
| | 3 | 54.8 | 68.7 | 1.837 | .010700 | .005050 | .0090 | .003950 | 43.9 |

TABLE 31A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON BLEACHED SULPHITE PULP AT VARIOUS TEMPERATURES

| TEMPERATURE | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.7 | 90.8 | 1.958 | .001210 | .000569 | .0015 | .000931 | 62.0 |
| | 1 | 74.7 | 96.3 | 1.936 | .002950 | .001385 | .0030 | .001615 | 53.8 |
| | 1½ | 70.7 | 81.5 | 1.911 | .004900 | .002300 | .0045 | .002200 | 49.0 |
| | 3 | 59.5 | 68.6 | 1.836 | .010850 | .005100 | .0090 | .003900 | 43.3 |
| 40 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.7 | 90.8 | 1.958 | .001200 | .000565 | .0015 | .000935 | 62.3 |
| | 1 | 74.9 | 86.5 | 1.937 | .002940 | .001380 | .0030 | .001620 | 54.1 |
| | 1½ | 70.7 | 81.7 | 1.912 | .004820 | .002270 | .0045 | .002230 | 49.5 |
| | 3 | 59.5 | 68.7 | 1.837 | .010700 | .005030 | .0090 | .003970 | 44.0 |
| 60 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.8 | 91.0 | 1.959 | .001150 | .000543 | .0015 | .000957 | 63.8 |
| | 1 | 75.1 | 86.7 | 1.938 | .002860 | .001342 | .0030 | .001658 | 55.2 |
| | 1½ | 71.0 | 82.0 | 1.914 | .004680 | .002200 | .0045 | .002300 | 51.1 |
| | 3 | 59.9 | 69.2 | 1.840 | .010500 | .004950 | .0090 | .004050 | 45.0 |

TABLE 32A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON UNBLEACHED SULPHITE PULP AT VARIOUS TEMPERATURES

| TEMPERATURE | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 72.7 | 89.7 | 1.953 | .001340 | .000630 | .0015 | .000870 | 58.0 |
| | 1 | 68.7 | 84.7 | 1.928 | .002940 | .001380 | .0030 | .001620 | 54.0 |
| | 1 1/2 | 64.9 | 80.0 | 1.903 | .004580 | .002150 | .0045 | .002350 | 52.2 |
| | 3 | 53.8 | 66.4 | 1.822 | .009750 | .004580 | .0090 | .004420 | 49.1 |
| 40 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 73.2 | 90.2 | 1.955 | .001280 | .000604 | .0015 | .000896 | 59.8 |
| | 1 | 69.2 | 85.3 | 1.931 | .002840 | .001335 | .0030 | .001665 | 55.5 |
| | 1 1/2 | 65.1 | 80.3 | 1.905 | .004470 | .002100 | .0045 | .002400 | 53.4 |
| | 3 | 54.1 | 66.7 | 1.824 | .009610 | .004520 | .0090 | .004480 | 49.8 |
| 60 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 73.2 | 90.4 | 1.956 | .001220 | .000574 | .0015 | .000926 | 61.8 |
| | 1 | 69.3 | 85.5 | 1.932 | .002750 | .001290 | .0030 | .001710 | 57.1 |
| | 1 1/2 | 65.4 | 80.7 | 1.907 | .004360 | .002050 | .0045 | .002450 | 54.3 |
| | 3 | 54.4 | 67.1 | 1.827 | .009450 | .004440 | .0090 | .004560 | 50.7 |

TABLE 33A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON BLEACHED SULPHITE PULP AT VARIOUS TEMPERATURES

| TEMPERATURE | POUNDS DYE PER 1000 POUNDS PULP | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 80.0 | 91.0 | 1.956 | .001147 | .000540 | .0015 | .000960 | 64.0 |
| | 1 | 75.7 | 86.1 | 1.935 | .002490 | .001170 | .0030 | .001830 | 61.5 |
| | 1½ | 72.0 | 81.8 | 1.913 | .003910 | .001840 | .0045 | .002660 | 59.1 |
| | 3 | 61.4 | 69.8 | 1.844 | .008370 | .003940 | .0090 | .005060 | 56.2 |
| 40 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.7 | 90.6 | 1.957 | .001150 | .000514 | .0015 | .000986 | 65.8 |
| | 1 | 76.1 | 86.5 | 1.937 | .002440 | .001145 | .0030 | .001855 | 61.8 |
| | 1½ | 72.3 | 82.2 | 1.915 | .003830 | .001800 | .0045 | .002700 | 60.1 |
| | 3 | 61.7 | 70.1 | 1.846 | .008220 | .003860 | .0090 | .005140 | 57.0 |
| 60 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 80.0 | 91.0 | 1.959 | .001010 | .000475 | .0015 | .001025 | 68.4 |
| | 1 | 76.4 | 86.9 | 1.939 | .002280 | .001070 | .0030 | .001930 | 64.4 |
| | 1½ | 72.8 | 82.8 | 1.918 | .003620 | .001700 | .0045 | .002800 | 62.3 |
| | 3 | 62.8 | 71.4 | 1.854 | .007740 | .003640 | .0090 | .005360 | 59.5 |

TABLE 34A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SO ON UNBLEACHED SULPHITE PULP AT VARIOUS TIMES

| TIME IN MINUTES | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.7 | 98.0 | 1.991 | .000068 | .000032 | .0015 | .001468 | 97.9 |
| | 1 | 82.7 | 96.8 | 1.986 | .000234 | .000110 | .0030 | .002890 | 96.5 |
| | 1½ | 81.7 | 95.7 | 1.981 | .000383 | .000180 | .0045 | .004320 | 96.0 |
| | 3 | 79.0 | 92.5 | 1.966 | .000895 | .000420 | .0090 | .008580 | 95.3 |
| 30 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.7 | 98.0 | 1.991 | .000066 | .000031 | .0015 | .001469 | 97.9 |
| | 1 | 82.7 | 96.8 | 1.986 | .000234 | .000110 | .0030 | .002890 | 96.4 |
| | 1½ | 81.7 | 95.7 | 1.981 | .000383 | .000180 | .0045 | .004320 | 96.0 |
| | 3 | 79.0 | 92.5 | 1.966 | .000895 | .000420 | .0090 | .008580 | 95.4 |
| 60 | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 83.7 | 98.0 | 1.991 | .000064 | .000030 | .0015 | .001470 | 98.0 |
| | 1 | 82.7 | 96.8 | 1.986 | .000224 | .000105 | .0030 | .002895 | 96.5 |
| | 1½ | 81.9 | 95.9 | 1.982 | .000362 | .000170 | .0045 | .004330 | 96.1 |
| | 3 | 77.1 | 90.2 | 1.955 | .000895 | .000420 | .0090 | .008580 | 95.4 |

TABLE 35A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC ON BLEACHED SULPHITE PULP AT VARIOUS TIMES

| TIME IN MINUTES | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 88.8 | 95.7 | 1.981 | .000390 | .000183 | .0015 | .001317 | 87.9 |
| | 1 | 85.8 | 92.5 | 1.966 | .000873 | .000410 | .0030 | .002590 | 86.4 |
| | 1 1/2 | 82.8 | 89.3 | 1.951 | .001360 | .000640 | .0045 | .003860 | 85.8 |
| | 3 | 74.6 | 80.5 | 1.906 | .002870 | .001350 | .0090 | .007650 | 85.0 |
| 30 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 88.5 | 95.5 | 1.980 | .000415 | .000195 | .0015 | .001305 | 87.0 |
| | 1 | 85.5 | 92.3 | 1.965 | .000925 | .000435 | .0030 | .002585 | 86.2 |
| | 1 1/2 | 82.9 | 89.5 | 1.952 | .001360 | .000640 | .0045 | .003860 | 85.8 |
| | 3 | 74.6 | 80.5 | 1.906 | .002870 | .001350 | .0090 | .007650 | 85.0 |
| 60 | 0 | 91.2 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 91.0 | 98.2 | 1.992 | .000385 | .000181 | .0015 | .001319 | 87.9 |
| | 1 | 85.8 | 92.5 | 1.966 | .000870 | .000410 | .0030 | .002590 | 86.4 |
| | 1 1/2 | 83.0 | 89.5 | 1.952 | .001340 | .000630 | .0045 | .003870 | 86.0 |
| | 3 | 75.0 | 80.9 | 1.908 | .002810 | .001320 | .0090 | .007680 | 85.3 |

## TABLE 36A

### CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON UNBLEACHED SULPHITE PULP AT VARIOUS TIMES

| TIME IN MINUTES | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 72.2 | 90.4 | 1.956 | .001350 | .000635 | .0015 | .000865 | 57.7 |
| | 1 | 68.5 | 85.7 | 1.933 | .003190 | .001500 | .0030 | .001500 | 50.0 |
| | 1 1/2 | 64.5 | 80.7 | 1.907 | .005250 | .002470 | .0045 | .002030 | 45.7 |
| | 3 | 54.3 | 67.9 | 1.832 | .011150 | .005240 | .0090 | .003760 | 41.8 |
| 30 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 72.4 | 90.6 | 1.957 | .001280 | .000605 | .0015 | .000895 | 59.7 |
| | 1 | 68.7 | 85.9 | 1.934 | .003100 | .001455 | .0030 | .001545 | 51.5 |
| | 1 1/2 | 64.8 | 81.1 | 1.909 | .005080 | .002390 | .0045 | .002110 | 47.0 |
| | 3 | 54.5 | 68.2 | 1.834 | .011000 | .005190 | .0090 | .003810 | 42.3 |
| 60 | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 72.7 | 91.0 | 1.959 | .001150 | .000539 | .0015 | .000961 | 64.1 |
| | 1 | 69.0 | 86.3 | 1.936 | .002970 | .001395 | .0030 | .001605 | 53.5 |
| | 1 1/2 | 65.0 | 81.3 | 1.910 | .004950 | .002330 | .0045 | .002170 | 48.3 |
| | 3 | 54.7 | 68.4 | 1.835 | .010900 | .005130 | .0090 | .003870 | 43.0 |

TABLE 37A

CALCULATION OF RETENTION OF DU PONT BRILLIANT CROCEIN FL ON BLEACHED SULPHITE PULP AT VARIOUS TIMES

| TIME IN MINUTES | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.7 | 90.8 | 1.958 | .001210 | .000569 | .0015 | .000931 | 62.0 |
| | 1 | 74.7 | 86.3 | 1.936 | .002950 | .001385 | .0030 | .001615 | 53.8 |
| | 1½ | 70.7 | 81.5 | 1.911 | .004900 | .002300 | .0045 | .002200 | 49.0 |
| | 3 | 59.5 | 68.6 | 1.836 | .010850 | .005100 | .0090 | .003900 | 43.3 |
| 30 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 78.8 | 91.0 | 1.959 | .001118 | .000525 | .0015 | .000975 | 65.0 |
| | 1 | 74.9 | 86.5 | 1.937 | .002900 | .001365 | .0030 | .001635 | 54.5 |
| | 1½ | 70.7 | 81.7 | 1.912 | .004810 | .002260 | .0045 | .002240 | 49.8 |
| | 3 | 59.5 | 68.7 | 1.837 | .010750 | .005070 | .0090 | .003930 | 43.7 |
| 60 | 0 | 81.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 79.3 | 91.6 | 1.962 | .000900 | .000424 | .0015 | .001076 | 67.3 |
| | 1 | 75.0 | 86.7 | 1.938 | .002860 | .001342 | .0030 | .001658 | 55.2 |
| | 1½ | 71.0 | 82.0 | 1.914 | .004720 | .002220 | .0045 | .002280 | 50.7 |
| | 3 | 59.7 | 68.9 | 1.838 | .010700 | .005040 | .0090 | .003960 | 44.0 |

TABLE 38A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON UNBLEACHED SULPHITE PULP AT VARIOUS TIMES

| TIME IN MINUTES | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 72.7 | 89.7 | 1.953 | .001340 | .000630 | .0015 | .000870 | 58.0 |
| | 1 | 68.7 | 84.7 | 1.928 | .002940 | .001380 | .0030 | .001620 | 54.0 |
| | 1 1/2 | 64.9 | 80.0 | 1.903 | .004580 | .002150 | .0045 | .002350 | 52.2 |
| | 3 | 53.8 | 66.4 | 1.822 | .009750 | .004580 | .0090 | .004420 | 49.1 |
| 30 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 73.7 | 91.0 | 1.959 | .001000 | .000470 | .0015 | .001030 | 68.7 |
| | 1 | 70.2 | 86.7 | 1.938 | .002340 | .001100 | .0030 | .001900 | 63.3 |
| | 1 1/2 | 66.6 | 82.2 | 1.915 | .003830 | .001800 | .0045 | .002700 | 60.0 |
| | 3 | 55.7 | 68.7 | 1.837 | .008800 | .004140 | .0090 | .004860 | 53.9 |
| 60 | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | 1/2 | 74.6 | 92.0 | 1.964 | .000713 | .000335 | .0015 | .001165 | 77.7 |
| | 1 | 71.4 | 88.1 | 1.945 | .001910 | .000900 | .0030 | .002100 | 70.1 |
| | 1 1/2 | 68.0 | 83.8 | 1.923 | .003300 | .001550 | .0045 | .002950 | 65.5 |
| | 3 | 56.8 | 70.1 | 1.846 | .008230 | .003870 | .0090 | .005130 | 57.0 |

TABLE 39A

CALCULATION OF RETENTION OF PONTAMINE FAST RED 8BL ON BLEACHED SULPHITE PULP AT VARIOUS TIMES

| TIME IN MINUTES | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 80.0 | 91.0 | 1.956 | .001147 | .000540 | .0015 | .000960 | 64.0 |
| | 1 | 75.7 | 86.1 | 1.935 | .002420 | .001170 | .0030 | .001830 | 61.0 |
| | 1½ | 72.0 | 81.8 | 1.913 | .003910 | .001840 | .0045 | .002660 | 59.1 |
| | 3 | 61.4 | 69.8 | 1.844 | .008370 | .003940 | .0090 | .005060 | 56.2 |
| 30 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 80.8 | 91.8 | 1.963 | .000770 | .000362 | .0015 | .001138 | 75.8 |
| | 1 | 77.1 | 87.7 | 1.943 | .002010 | .000945 | .0030 | .002055 | 68.5 |
| | 1½ | 73.5 | 83.6 | 1.922 | .003380 | .001590 | .0045 | .002910 | 64.7 |
| | 3 | 62.5 | 71.1 | 1.852 | .007830 | .003680 | .0090 | .005320 | 59.0 |
| 60 | 0 | 83.1 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | ½ | 81.7 | 92.9 | 1.968 | .000447 | .000210 | .0015 | .001290 | 86.1 |
| | 1 | 78.7 | 89.5 | 1.952 | .001450 | .000680 | .0030 | .002320 | 77.4 |
| | 1½ | 75.2 | 85.5 | 1.932 | .002740 | .001290 | .0045 | .003210 | 71.3 |
| | 3 | 63.4 | 72.1 | 1.858 | .007450 | .003500 | .0090 | .005500 | 61.1 |

TABLE 40A

CALCULATION OF RETENTION OF DU PONT VICTORIA GREEN SC, DU PONT BRILLIANT CROCEIN FL, AND PONTAMINE FAST RED 8BL ON UNBLEACHED SULPHITE PULP AT VARIOUS FREENESSES

| DYE | BEATING TIME IN MINUTES | FREENESS S.R. | TRANSMISSION | CORRECTED TRANSMISSION | LOG CORRECTED TRANSMISSION | CONCENTRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETENTION |
|---|---|---|---|---|---|---|---|---|---|---|
| Victoria Green | 0 | 860 | 79.0 | 92.5 | 1.965 | .000895 | .000420 | .009 | .008580 | 95.3 |
| | 10 | 810 | 79.4 | 92.9 | 1.968 | .000808 | .000380 | .009 | .008620 | 95.8 |
| | 20 | 705 | 80.5 | 94.2 | 1.974 | .000638 | .000300 | .009 | .008700 | 96.7 |
| | 30 | 560 | 81.3 | 95.1 | 1.978 | .000490 | .000230 | .009 | .008770 | 97.4 |
| | 40 | 400 | 81.7 | 95.7 | 1.981 | .000404 | .000190 | .009 | .008810 | 97.9 |
| | 50 | 250 | 82.2 | 96.2 | 1.983 | .000319 | .000150 | .009 | .008850 | 98.3 |
| Brilliant Crocein FL | 0 | 860 | 54.2 | 67.9 | 1.832 | .011140 | .005235 | .009 | .003765 | 41.8 |
| | 10 | 810 | 56.0 | 70.1 | 1.846 | .010070 | .004730 | .009 | .004270 | 47.5 |
| | 20 | 705 | 58.2 | 72.8 | 1.862 | .008800 | .004140 | .009 | .004860 | 54.0 |
| | 30 | 560 | 59.7 | 74.8 | 1.874 | .007770 | .003650 | .009 | .005350 | 59.5 |
| | 40 | 400 | 61.2 | 76.6 | 1.884 | .006980 | .003280 | .009 | .005720 | 63.5 |
| | 50 | 250 | 62.8 | 78.7 | 1.896 | .006120 | .002880 | .009 | .006120 | 68.0 |
| Fast Red 8BL | 0 | 860 | 53.9 | 66.5 | 1.823 | .009750 | .004580 | .009 | .004420 | 49.1 |
| | 10 | 810 | 55.5 | 68.4 | 1.835 | .008940 | .004200 | .009 | .004800 | 53.4 |
| | 20 | 705 | 59.1 | 72.9 | 1.863 | .007180 | .003380 | .009 | .005620 | 62.5 |
| | 30 | 560 | 63.2 | 77.8 | 1.891 | .005360 | .002520 | .009 | .006480 | 72.0 |
| | 40 | 400 | 66.4 | 81.8 | 1.913 | .003960 | .001860 | .009 | .007140 | 79.3 |
| | 50 | 250 | 68.7 | 84.7 | 1.928 | .002980 | .001400 | .009 | .007600 | 84.5 |

## TABLE 41A

### CALCULATION OF RETENTION OF VARIOUS DYES ON UNBLEACHED SULPHITE PULP

| DYE STUFF | WAVE LENGTH EXAM. mu | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|
| Du Pont Victoria Green SO | 620 | 79.0 | 92.5 | 1.965 | .000895 | .000420 | .009 | .008580 | 95.3 |
| Du Pont Rhodamine B | 522 | 70.4 | 86.9 | 1.939 | .002790 | .001310 | .009 | .007690 | 85.4 |
| Du Pont Auramine Conc. | 434 | 62.7 | 83.8 | 1.923 | .001000 | .000470 | .009 | .008530 | 94.8 |
| Du Pont Methylene Blue ZX | 660 | 77.4 | 89.5 | 1.952 | .000702 | .000330 | .009 | .008670 | 96.3 |
| Du Pont Basic Brown BR | 460 | 66.1 | 68.2 | 1.834 | .008850 | .004160 | .009 | .004840 | 53.8 |
| Du Pont Safranine T Extra | 520 | 70.6 | 87.1 | 1.940 | .001000 | .000470 | .009 | .008530 | 94.8 |
| Du Pont Methyl Violet NE | 580 | 66.3 | 78.5 | 1.895 | .001572 | .000740 | .009 | .008260 | 91.8 |
| Du Pont Brilliant Crocein FL | 500 | 54.4 | 68.1 | 1.823 | .011100 | .005240 | .009 | .003760 | 41.8 |
| Du Pont Anthraquinone Blue B | 600 | 59.7 | 70.0 | 1.845 | .018050 | .008496 | .009 | .000504 | 5.6 |
| Du Pont Nigrosine WSB Powder | 570 | 62.0 | 73.8 | 1.868 | .016050 | .007570 | .009 | .001430 | 15.9 |
| Du Pont Quinoline Yellow Conc. | 440 | 44.0 | 57.8 | 1.762 | .016900 | .007950 | .009 | .001050 | 11.7 |
| Du Pont Orange II Conc. | 490 | 31.1 | 39.1 | 1.592 | .016400 | .007720 | .009 | .001280 | 14.2 |
| Pontoyl Violet 54B | 550 | 42.8 | 51.6 | 1.713 | .012230 | .005750 | .009 | .003250 | 36.1 |
| Pontamine Fast Red 8BL | 520 | 53.8 | 66.4 | 1.822 | .009750 | .004580 | .009 | .004420 | 49.1 |
| Du Pont Purpurine 4B Conc. | 500 | 60.9 | 76.2 | 1.882 | .004600 | .002160 | .009 | .006840 | 76.1 |
| Pontamine Fast Scarlet 4BS | 500 | 58.2 | 72.8 | 1.862 | .008500 | .003990 | .009 | .005010 | 55.7 |
| Pontamine Black E | 500 | 63.9 | 80.0 | 1.903 | .011600 | .005440 | .009 | .003560 | 39.6 |
| Du Pont Brill. Paper Yellow Conc. | 420 | 37.1 | 49.9 | 1.698 | .015420 | .007250 | .009 | .002750 | 30.6 |
| Pontamine Yellow SXP | 460 | 58.7 | 75.9 | 1.880 | .014180 | .006670 | .009 | .002330 | 25.9 |
| Pontamine Yellow NNL | 460 | 66.4 | 85.9 | 1.934 | .007980 | .003750 | .009 | .005250 | 58.3 |

TABLE 42A

CALCULATION OF RETENTION OF VARIOUS DYES ON UNBLEACHED SULPHITE PULP USING SULPHURIC ACID, ALUM, AND SIZE AND ALUM

| DYE | ACID | POUNDS DYE PER 1000 POUNDS PULP | TRANS-MISSION | COR-RECTED TRANS-MISSION | LOG COR-RECTED TRANS-MISSION | CONCEN-TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN-TION |
|---|---|---|---|---|---|---|---|---|---|---|
| VG | $H_2SO_4$ | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 79.0 | 92.5 | 1.966 | .000895 | .000420 | .009 | .008580 | 95.3 |
| | Alum | 0 | 84.0 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 78.5 | 92.0 | 1.964 | .000936 | .000440 | .009 | .008560 | 95.2 |
| | Alum and Size | 0 | 81.9 | 98.3 | 1.993 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 77.0 | 92.5 | 1.966 | .000895 | .000420 | .009 | .008580 | 95.3 |
| FL | $H_2SO_4$ | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 54.3 | 67.9 | 1.832 | .001115 | .005240 | .009 | .003760 | 41.8 |
| | Alum | 0 | 75.1 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 53.0 | 66.4 | 1.822 | .011080 | .005220 | .009 | .003780 | 41.9 |
| | Alum and Size | 0 | 72.3 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 53.8 | 70.0 | 1.845 | .010880 | .005120 | .009 | .003880 | 43.1 |

(Continued)

TABLE 42A (Continued)

| DYE | ACID | POUNDS DYE PER 1000 POUNDS PULP | TRANS- MISSION | COR- RECTED TRANS- MISSION | LOG COR- RECTED TRANS- MISSION | CONCEN- TRATION OF WHITE WATER | GRAMS DYE IN WHITE WATER | GRAMS DYE USED | GRAMS DYE IN SHEET | PERCENT RETEN- TION |
|---|---|---|---|---|---|---|---|---|---|---|
| II | $H_2SO_4$ | 0 | 74.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 30.8 | 38.9 | 1.590 | .016420 | .007720 | .009 | .001280 | 14.2 |
| | Alum | 0 | 74.4 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 31.1 | 39.3 | 1.594 | .016300 | .007670 | .009 | .001330 | 14.7 |
| | Alum and Size | 0 | 71.5 | 94.0 | 1.973 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 31.5 | 41.3 | 1.616 | .015350 | .007220 | .009 | .001780 | 19.8 |
| 8BL | $H_2SO_4$ | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 53.8 | 66.4 | 1.822 | .009750 | .004580 | .009 | .004420 | 49.1 |
| | Alum | 0 | 76.7 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 53.6 | 66.1 | 1.820 | .009910 | .004660 | .009 | .004340 | 48.2 |
| | Alum and Size | 0 | 74.3 | 94.5 | 1.975 | 0 | 0 | 0 | 0 | 100.0 |
| | | 3 | 52.7 | 67.1 | 1.827 | .009500 | .004470 | .009 | .004530 | 50.3 |

# APPENDIX B.

## DYE-STANDARD GRAPHS

## TRANSMITTANCE DATA OF THE STANDARD SOLUTIONS AT VARIOUS CONCENTRATIONS

**VICTORIA GREEN SC AT 620 MILLIMICRONS**

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 98.3 | 1.993 |
| .003 | 79.8 | 1.902 |
| .006 | 65.0 | 1.813 |
| .009 | 53.0 | 1.724 |

**RHODAMINE B AT 522 MILLIMICRONS**

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 95.9 | 1.982 |
| .003 | 86.3 | 1.936 |
| .006 | 77.6 | 1.890 |
| .009 | 70.0 | 1.845 |

**AURAMINE CONC. AT 434 MILLIMICRONS**

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 93.4 | 1.970 |
| .003 | 67.6 | 1.831 |
| .006 | 49.2 | 1.692 |
| .009 | 36.0 | 1.556 |

**METHYLENE BLUE ZX AT 660 MILLIMICRONS**

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 99.0 | 1.997 |
| .003 | 64.3 | 1.808 |
| .006 | 41.8 | 1.621 |
| .009 | 27.5 | 1.435 |

**PONTAMINE FAST SCARLET 4BS AT 500 MILLIMICRONS**

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 94.0 | 1.973 |
| .006 | 78.7 | 1.896 |
| .012 | 66.1 | 1.820 |
| .018 | 55.3 | 1.743 |

TRANSMITTANCE DATA OF THE STANDARD SOLUTIONS AT VARIOUS CONCENTRATIONS

BASIC BROWN BR AT 460 MILLIMICRONS

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 93.0 | 1.969 |
| .003 | 83.8 | 1.923 |
| .006 | 75.4 | 1.877 |
| .009 | 67.9 | 1.832 |

SAFRANINE T EX. AT 520 MILLIMICRONS

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 94.5 | 1.975 |
| .003 | 74.2 | 1.870 |
| .006 | 58.2 | 1.765 |
| .009 | 45.7 | 1.660 |

METHYL VIOLET NE AT 580 MILLIMICRONS

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 97.0 | 1.987 |
| .003 | 64.6 | 1.810 |
| .006 | 43.3 | 1.637 |
| .009 | 29.2 | 1.465 |

BRILLIANT CROCEIN FL AT 500 MILLIMICRONS

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 94.0 | 1.973 |
| .006 | 78.9 | 1.897 |
| .012 | 66.2 | 1.821 |
| .018 | 55.7 | 1.746 |

BRILLIANT PAPER YELLOW CONC. AT 420 MILLIMICRONS

| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
|---|---|---|
| 0 | 94.1 | 1.974 |
| .006 | 73.5 | 1.866 |
| .012 | 57.3 | 1.758 |
| .018 | 44.9 | 1.652 |

TRANSMITTANCE DATA OF THE STANDARD SOLUTIONS AT VARIOUS CONCENTRATIONS

| ANTHRAQUINONE BLUE B AT 600 MILLIMICRONS | | | NIGROSINE WSB POWDER AT 570 MILLIMICRONS | | |
|---|---|---|---|---|---|
| Conc. Grams per L. | Trans-mittance | Log Trans-mittance | Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
| 0 | 97.4 | 1.989 | 0 | 96.5 | 1.985 |
| .006 | 87.3 | 1.941 | .006 | 87.3 | 1.941 |
| .012 | 78.2 | 1.893 | .012 | 78.9 | 1.897 |
| .018 | 70.0 | 1.845 | .018 | 71.5 | 1.854 |

| ORANGE II CONC. AT 490 MILLIMICRONS | | | QUINOLINE YELLOW CONC. AT 440 MILLIMICRONS | | |
|---|---|---|---|---|---|
| Conc. Grams per L. | Trans-mittance | Log Trans-mittance | Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
| 0 | 94.0 | 1.973 | 0 | 93.2 | 1.969 |
| .006 | 68.2 | 1.834 | .006 | 78.5 | 1.895 |
| .012 | 49.3 | 1.693 | .012 | 66.4 | 1.822 |
| .018 | 35.7 | 1.553 | .018 | 56.1 | 1.749 |

| PONTAMINE FAST YELLOW NNL AT 460 MILLIMICRONS | | |
|---|---|---|
| Conc. Grams per L. | Trans-mittance | Log Trans-mittance |
| 0 | 93.0 | 1.969 |
| .006 | 87.7 | 1.943 |
| .012 | 82.6 | 1.917 |
| .018 | 77.8 | 1.891 |

TRANSMITTANCE DATA OF THE STANDARD SOLUTIONS AT VARIOUS CONCENTRATIONS

PONTACYL VIOLET S4B AT 550 MILLIMICRONS

| Conc. Grams per L. | Transmittance | Log Transmittence |
|---|---|---|
| 0 | 95.9 | 1.982 |
| .006 | 70.8 | 1.850 |
| .012 | 52.4 | 1.719 |
| .018 | 38.5 | 1.586 |

PURPURINE 4B CONC. AT 500 MILLIMICRONS

| Conc. Grams per L. | Transmittence | Log Transmittence |
|---|---|---|
| 0 | 94.0 | 1.973 |
| .006 | 71.6 | 1.855 |
| .012 | 54.7 | 1.738 |
| .018 | 41.8 | 1.621 |

PONTAMINE BLACK E AT 500 MILLIMICRONS

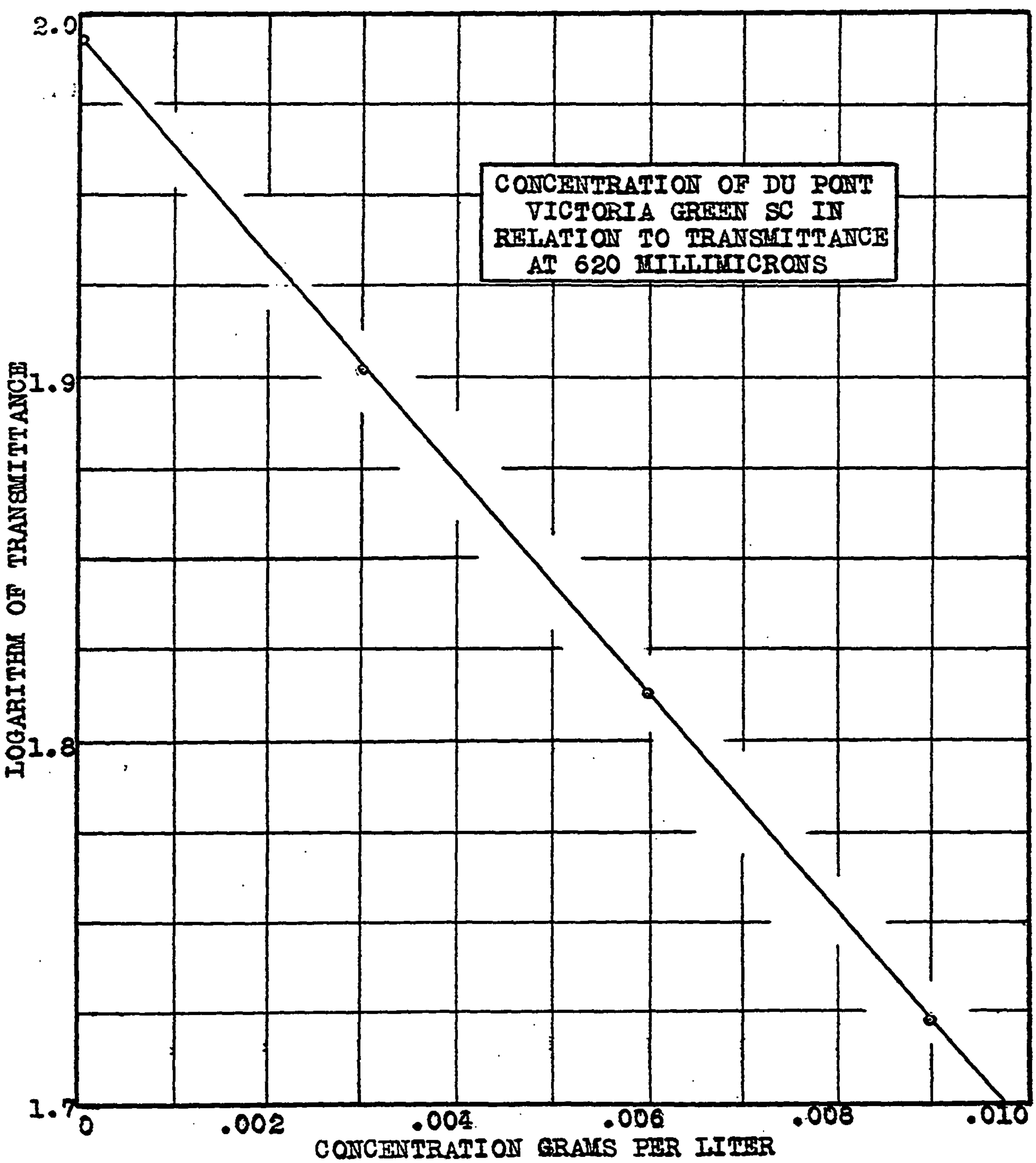
| Conc. Grams per L. | Transmittance | Log Transmittance |
|---|---|---|
| 0 | 94.0 | 1.973 |
| .006 | 86.1 | 1.935 |
| .012 | 79.1 | 1.898 |
| .018 | 72.5 | 1.860 |

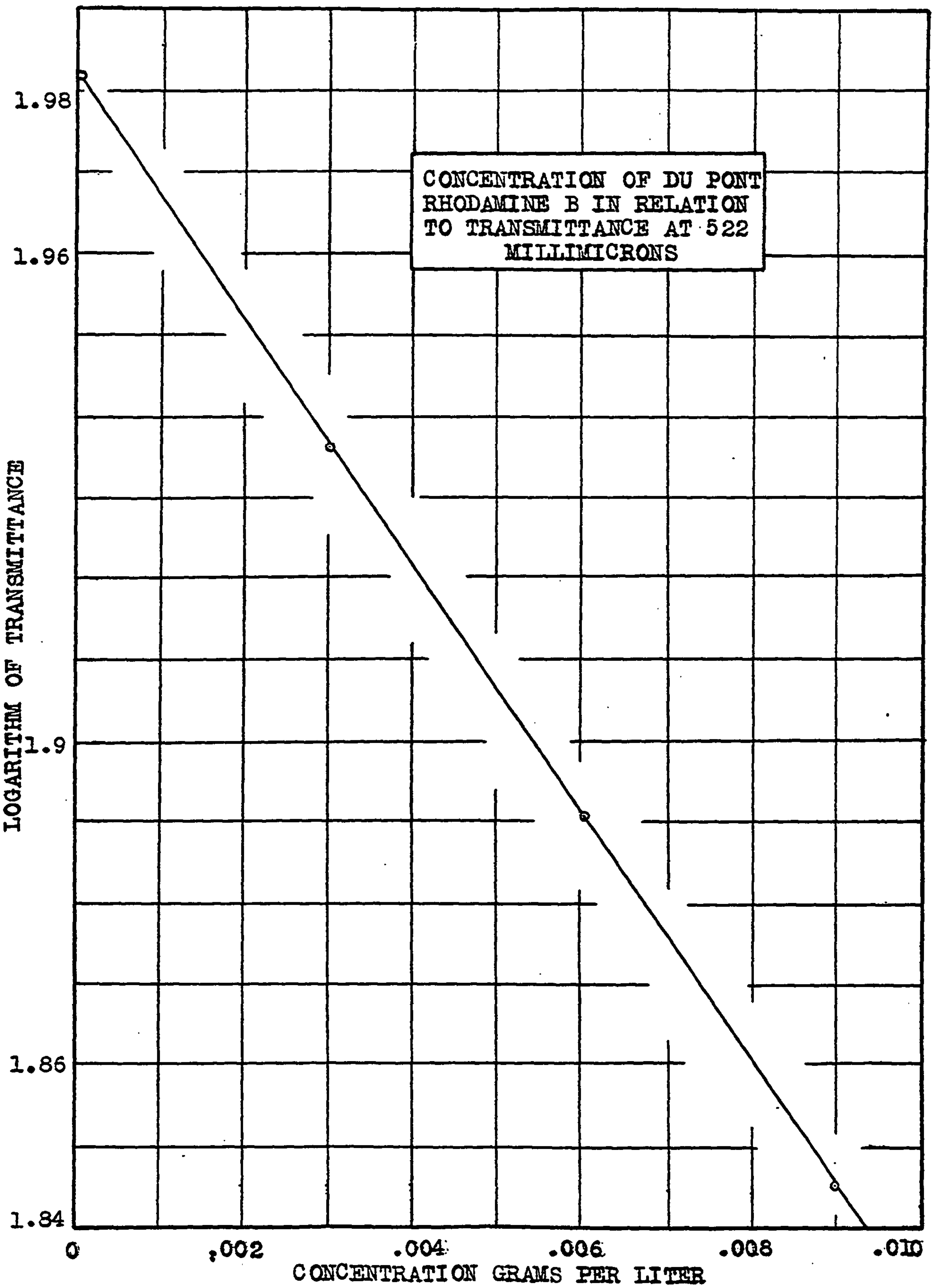
PONTAMINE YELLOW SXP AT 460 MILLIMICRONS

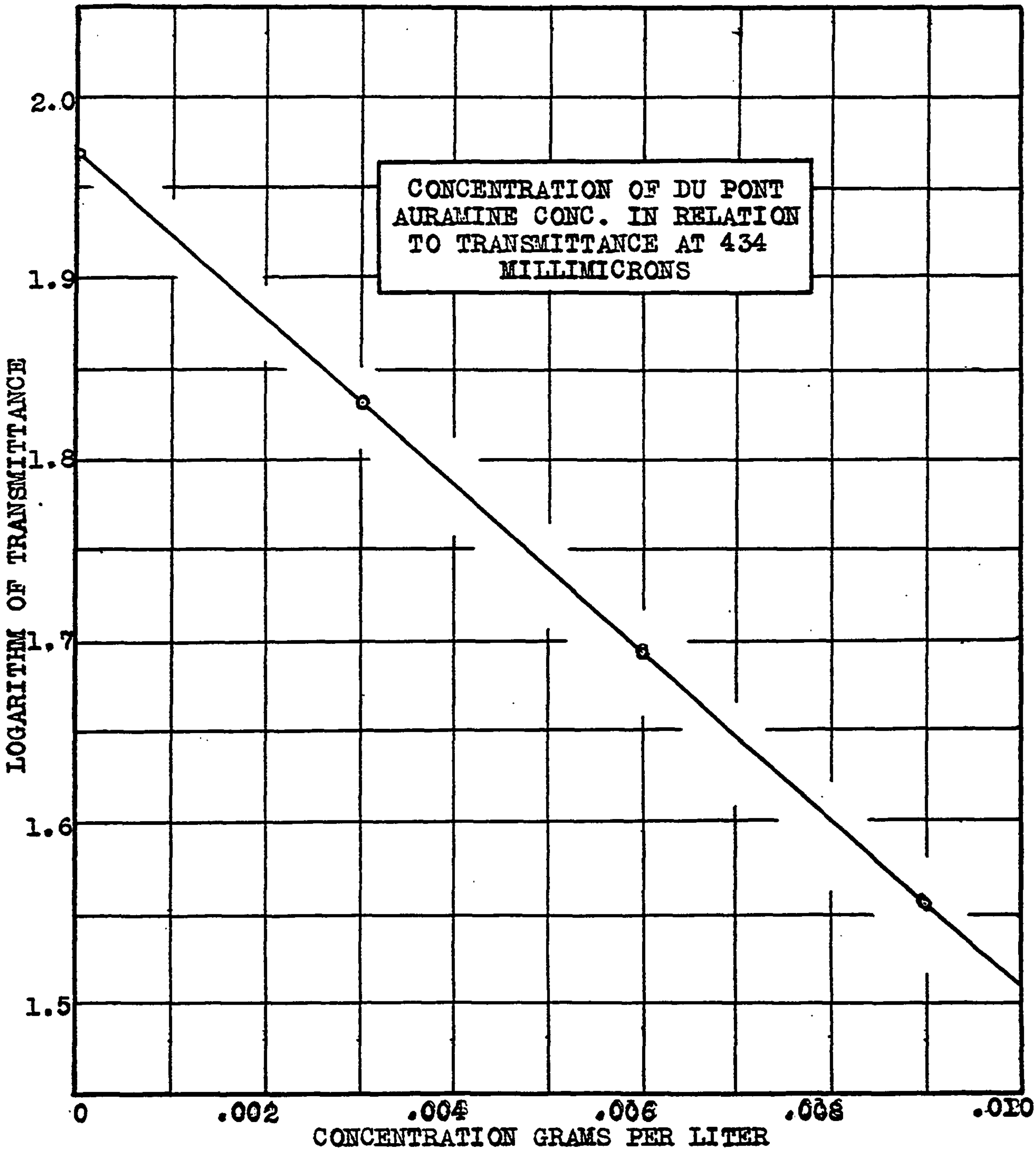
| Conc. Grams per L. | Transmittance | Log Transmittance |
|---|---|---|
| 0 | 93.0 | 1.969 |
| .006 | 85.3 | 1.931 |
| .012 | 78.3 | 1.894 |
| .018 | 71.8 | 1.856 |

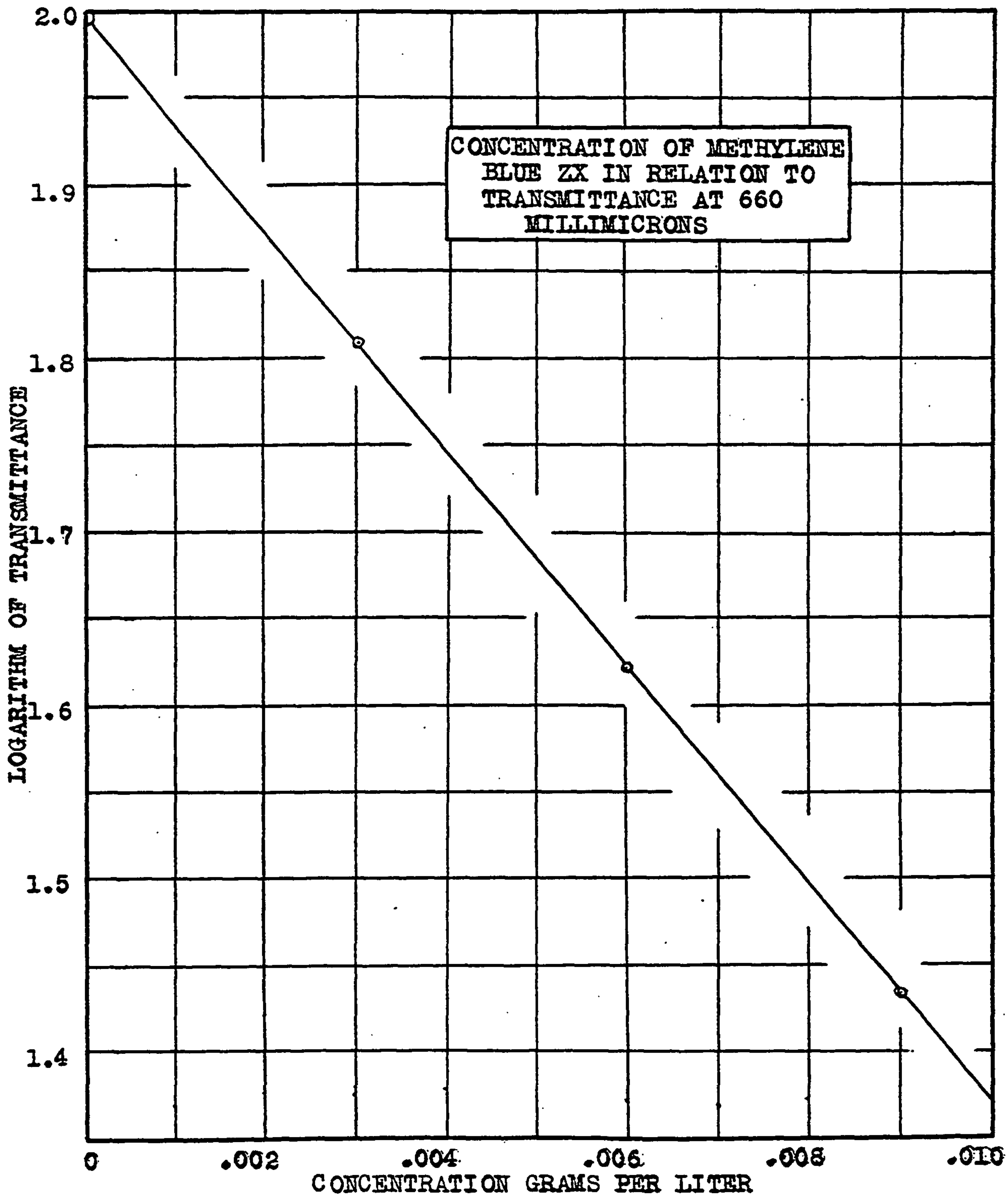
PONTAMINE FAST RED 8BL AT 520 MILLIMICRONS

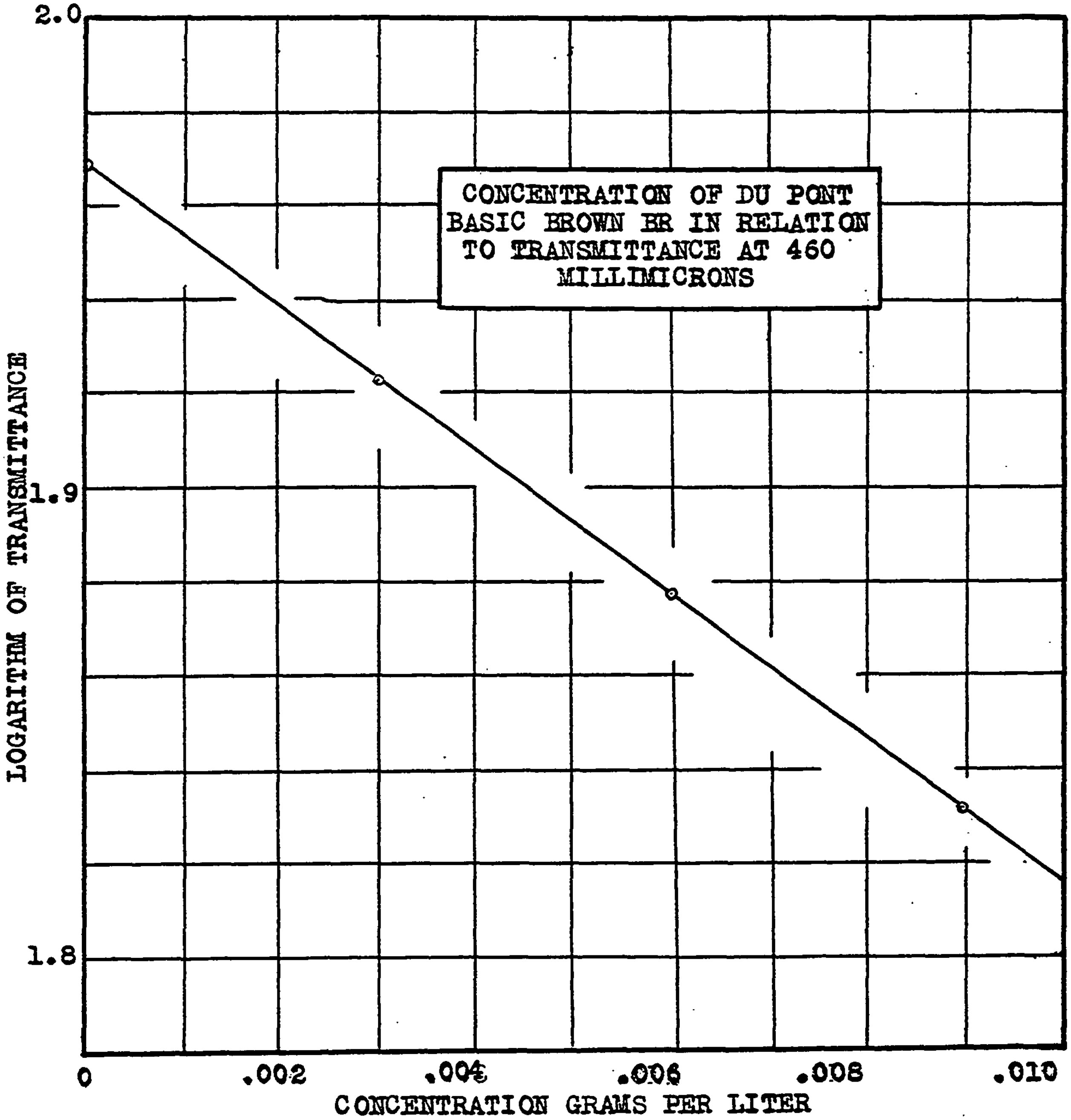
| Conc. Grams per L. | Transmittance | Log Transmittance |
|---|---|---|
| 0 | 94.5 | 1.975 |
| .006 | 76.0 | 1.881 |
| .012 | 61.4 | 1.788 |
| .018 | 49.5 | 1.695 |


CONCENTRATION OF DU PONT
VICTORIA GREEN SC IN
RELATION TO TRANSMITTANCE
AT 620 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
1.7
0
.002
.004
.006
.008
.010
CONCENTRATION GRAMS PER LITER

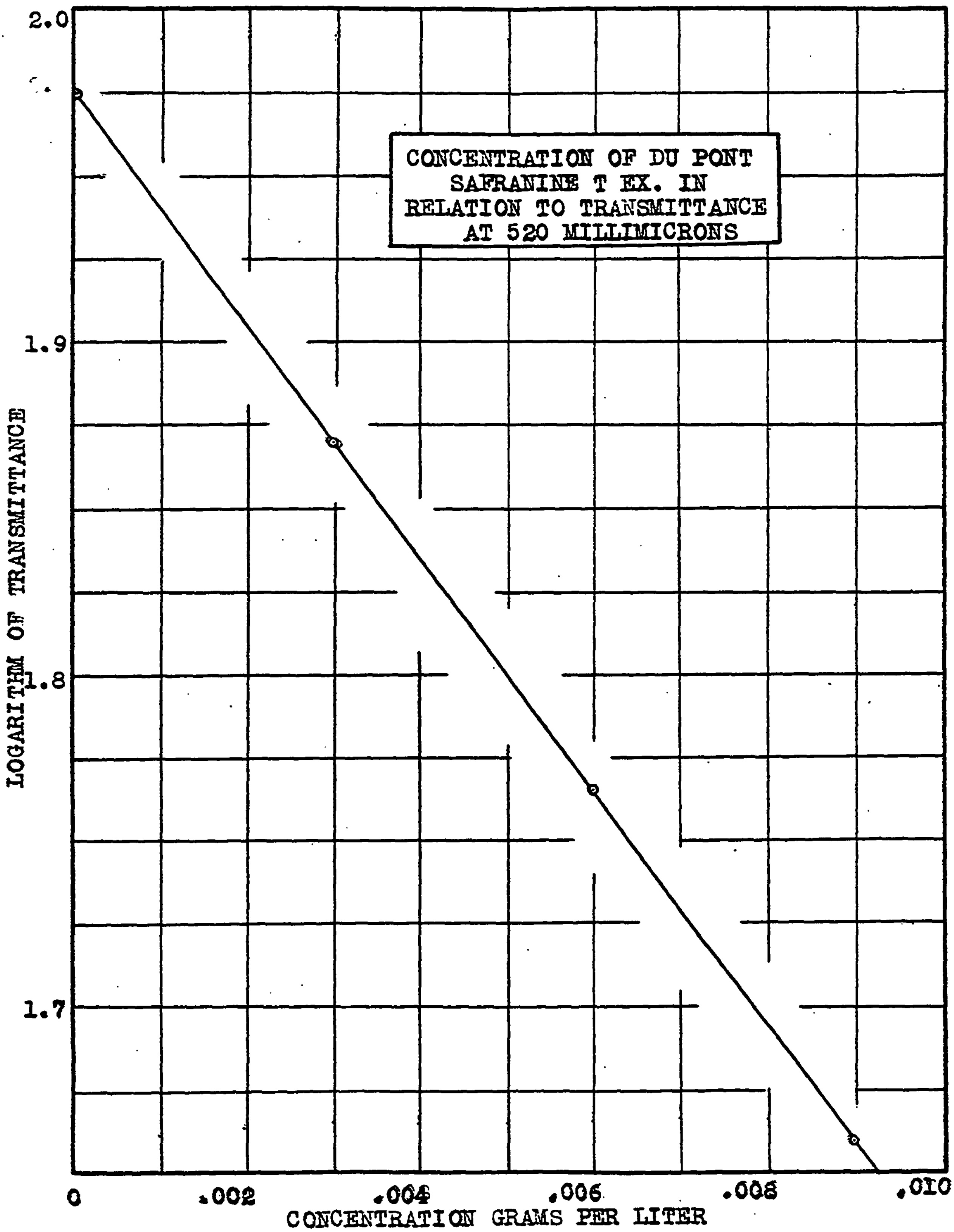

CONCENTRATION OF DU PONT RHODAMINE B IN RELATION TO TRANSMITTANCE AT 522 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
1.98
1.96
1.9
1.86
1.84
0
.002
.004
.006
.008
.010
CONCENTRATION GRAMS PER LITER


CONCENTRATION OF DU PONT AURAMINE CONC. IN RELATION TO TRANSMITTANCE AT 434 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
1.7
1.6
1.5
0
.002
.004
.006
.008
.010
CONCENTRATION GRAMS PER LITER

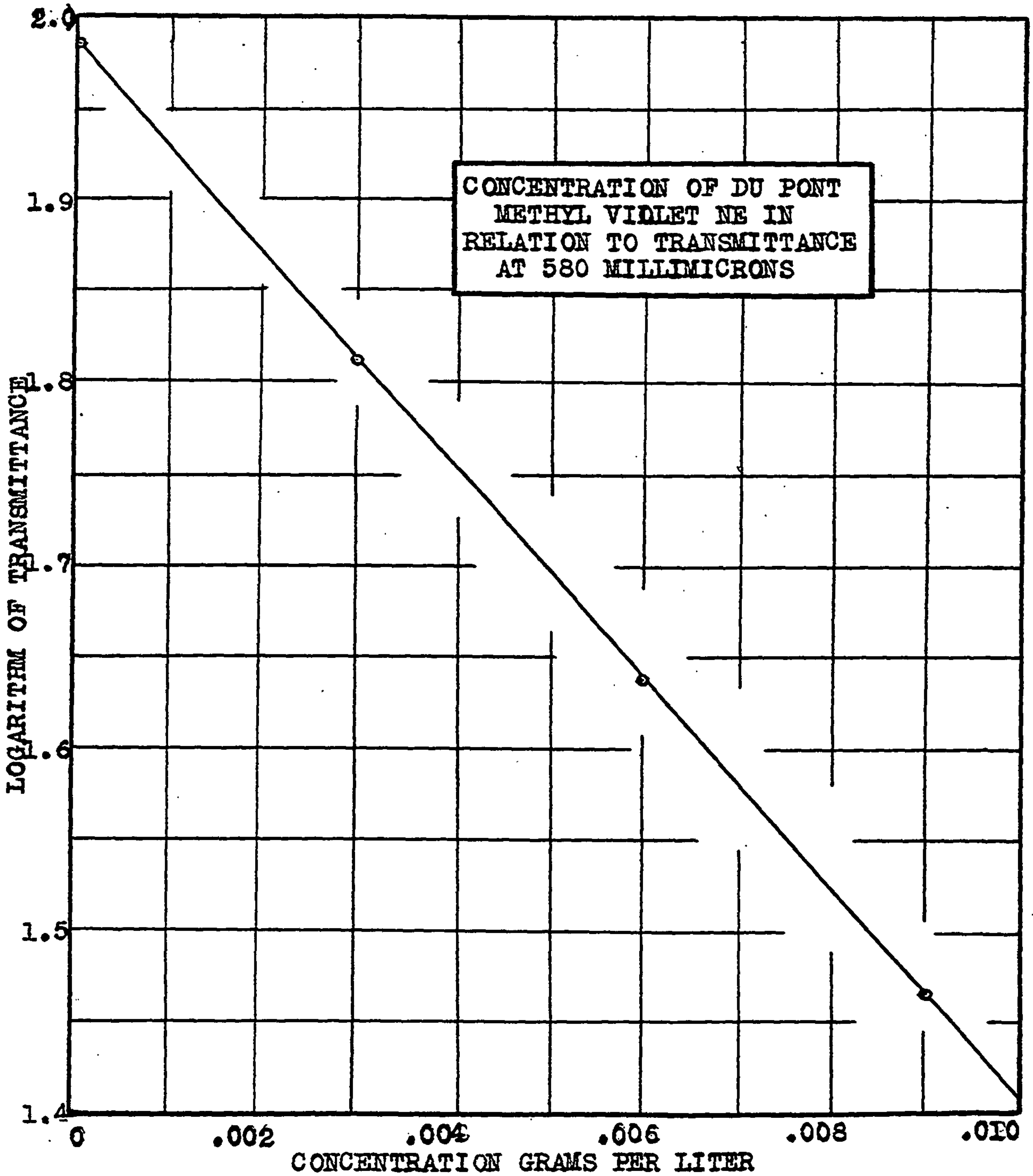

CONCENTRATION OF METHYLENE BLUE ZX IN RELATION TO TRANSMITTANCE AT 660 MILLIMICRONS
2.0
1.9
1.8
1.7
1.6
1.5
1.4
LOGARITHM OF TRANSMITTANCE
0
.002
.004
.006
.008
.010
CONCENTRATION GRAMS PER LITER

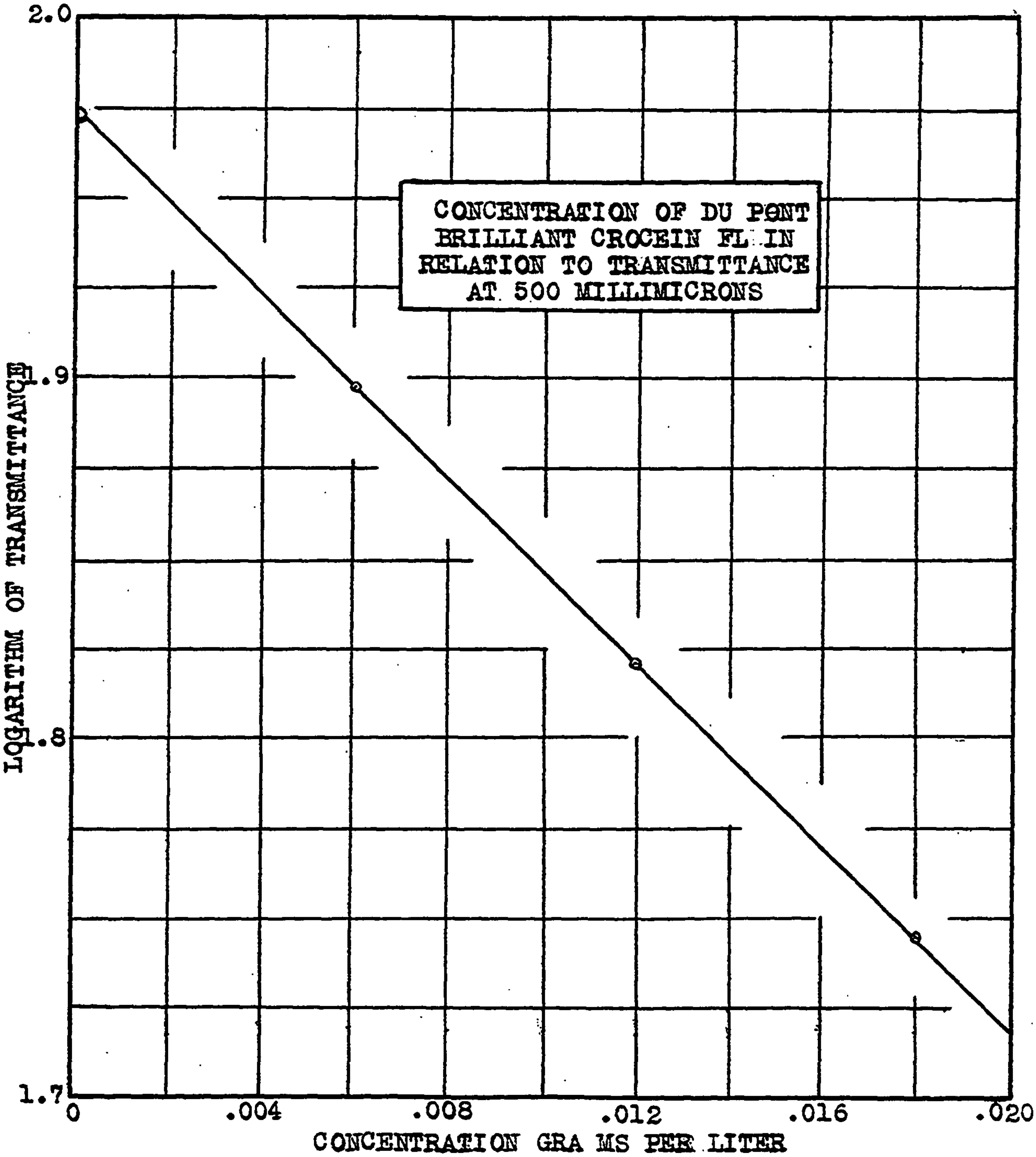


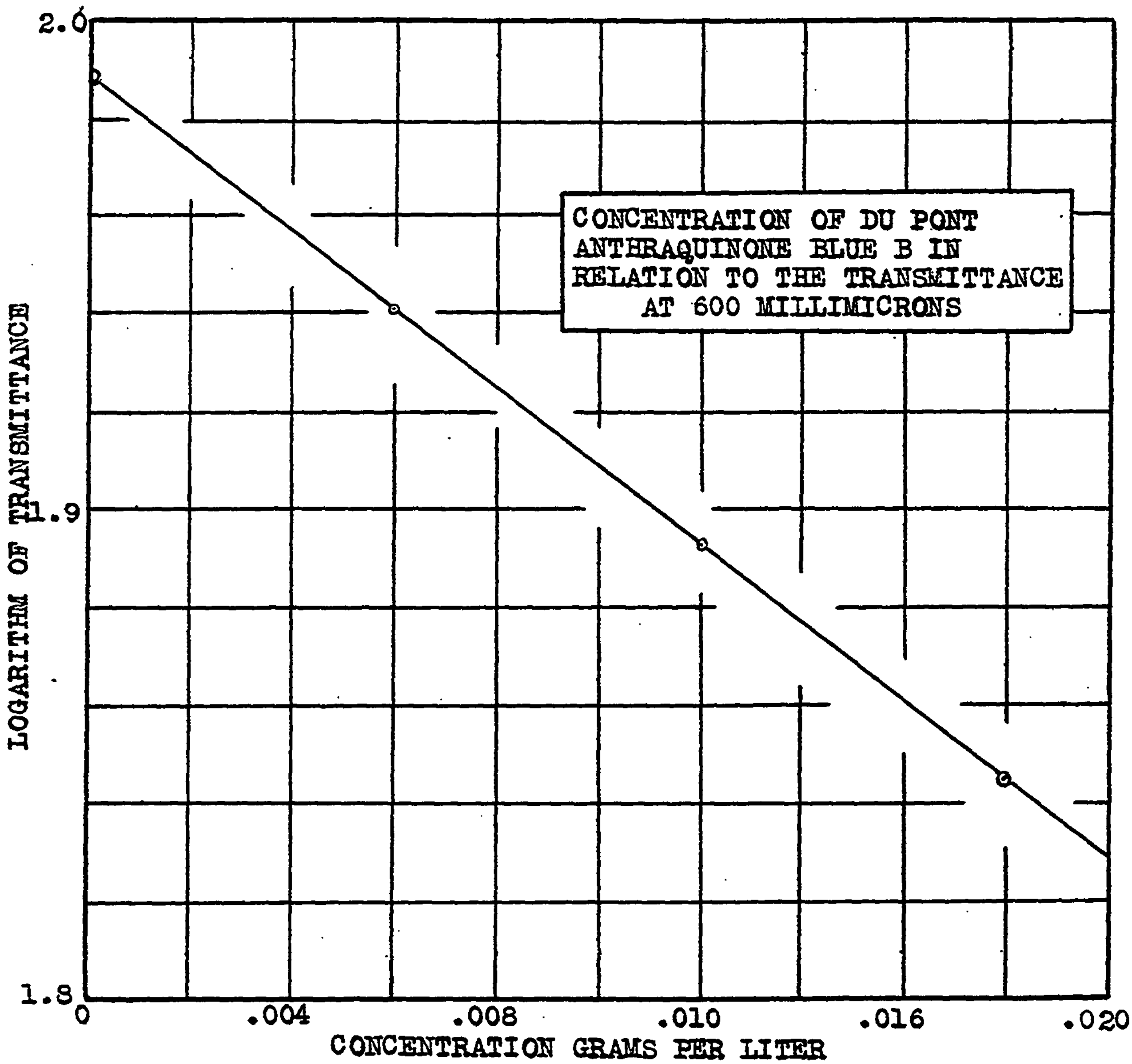
CONCENTRATION OF DU PONT BASIC BROWN BR IN RELATION TO TRANSMITTANCE AT 460 MILLIMICRONS
2.0
1.9
1.8
LOGARITHM OF TRANSMITTANCE
0
.002
.004
.006
.008
.010
CONCENTRATION GRAMS PER LITER

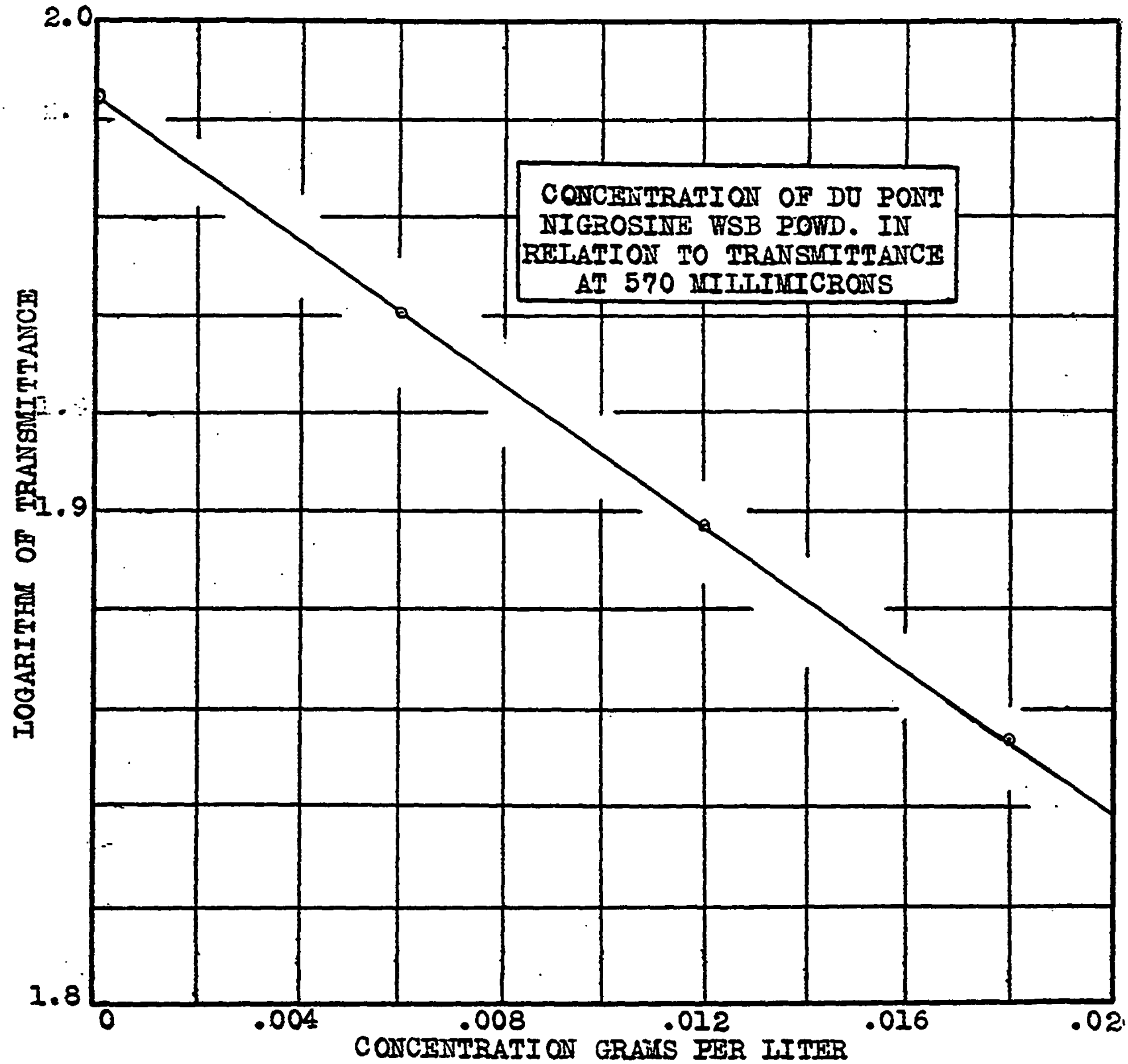


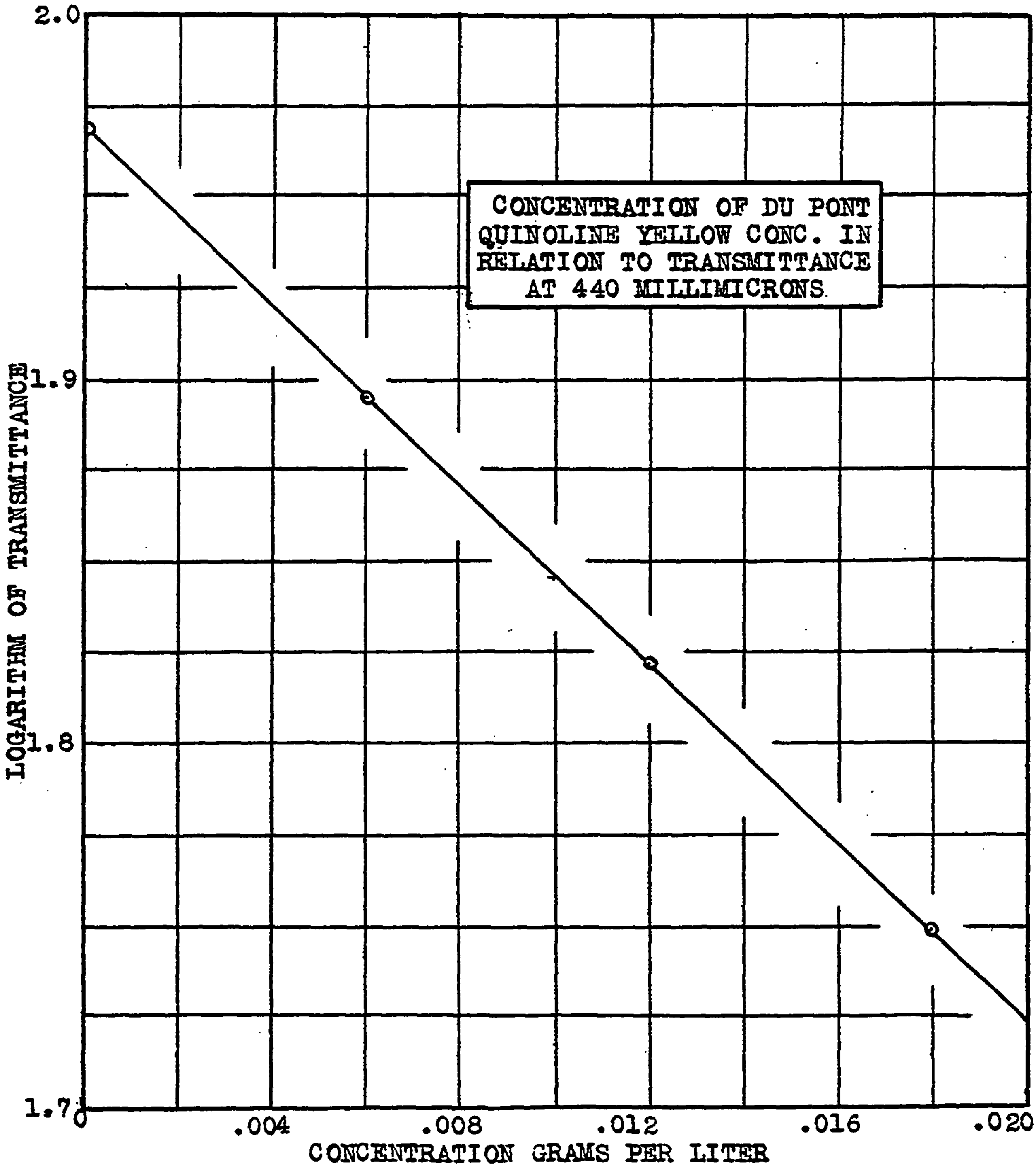
CONCENTRATION OF DU PONT SAFRANINE T EX. IN RELATION TO TRANSMITTANCE AT 520 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
1.7
0
.002
.004
.006
.008
.010
CONCENTRATION GRAMS PER LITER

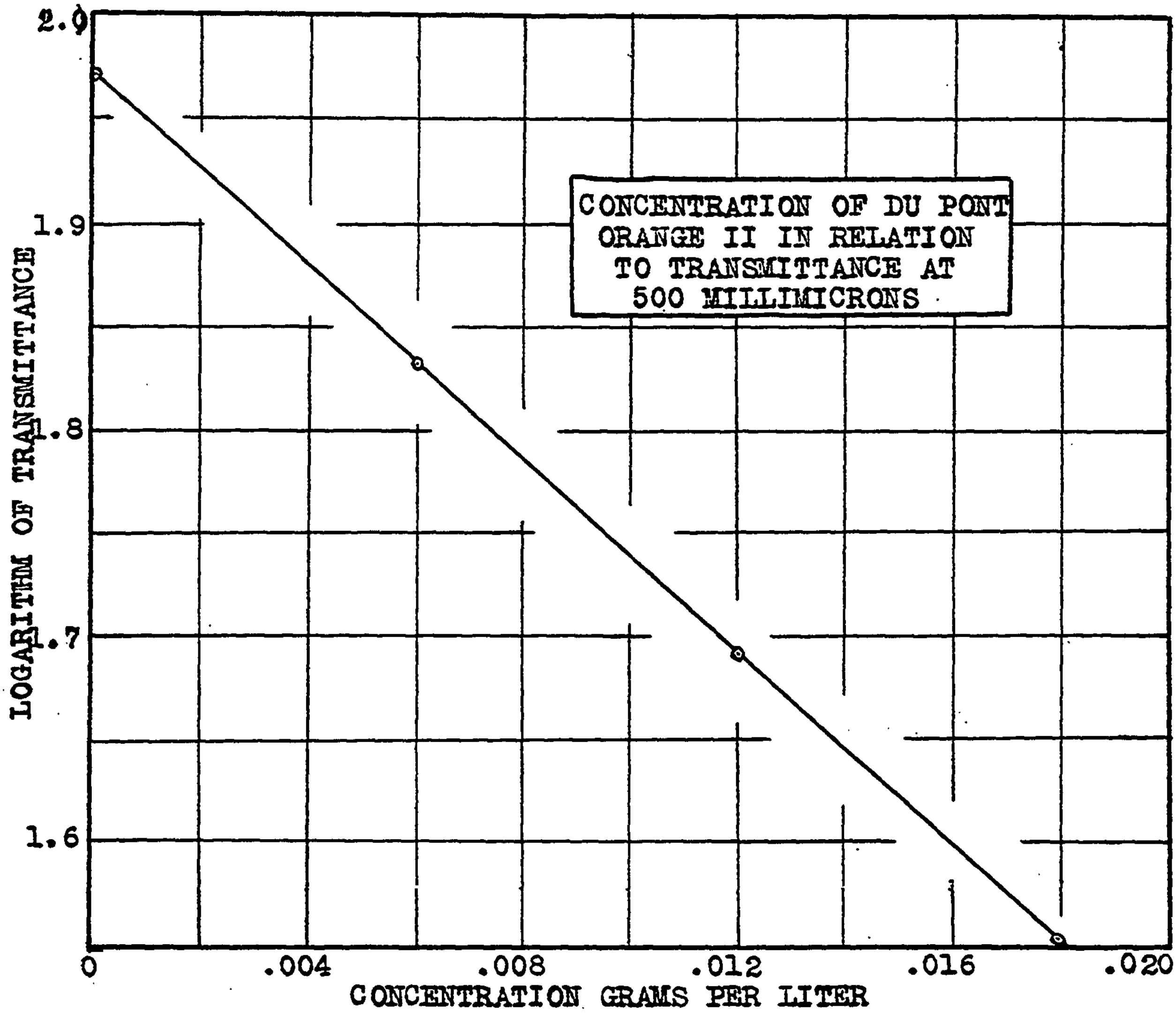

CONCENTRATION OF DU PONT METHYL VIOLET NE IN RELATION TO TRANSMITTANCE AT 580 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
1.7
1.6
1.5
1.4
0
.002
.004
.006
.008
.010
CONCENTRATION GRAMS PER LITER

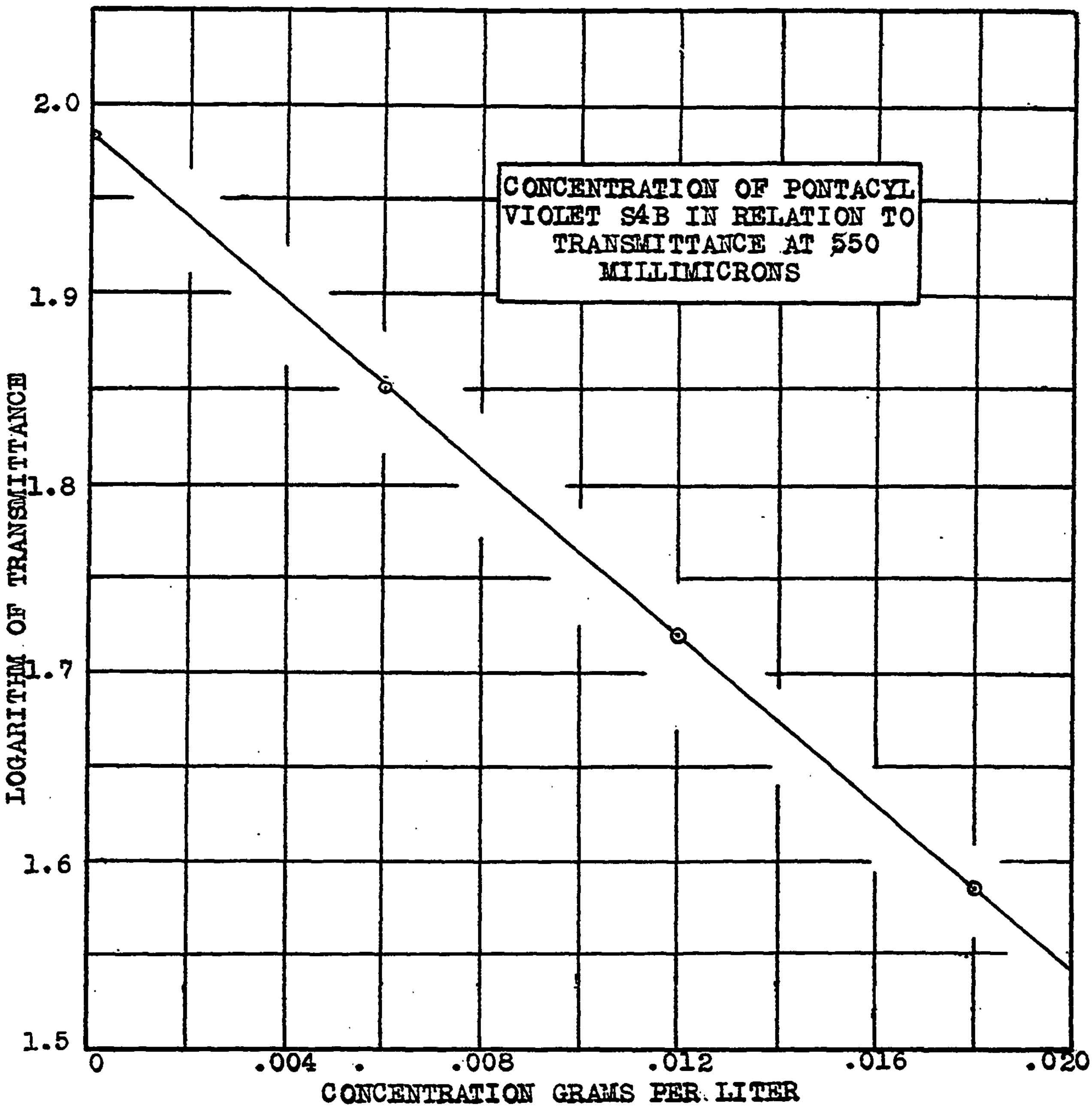

CONCENTRATION OF DU PONT BRILLIANT CROCEIN FL IN RELATION TO TRANSMITTANCE AT 500 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
1.7
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

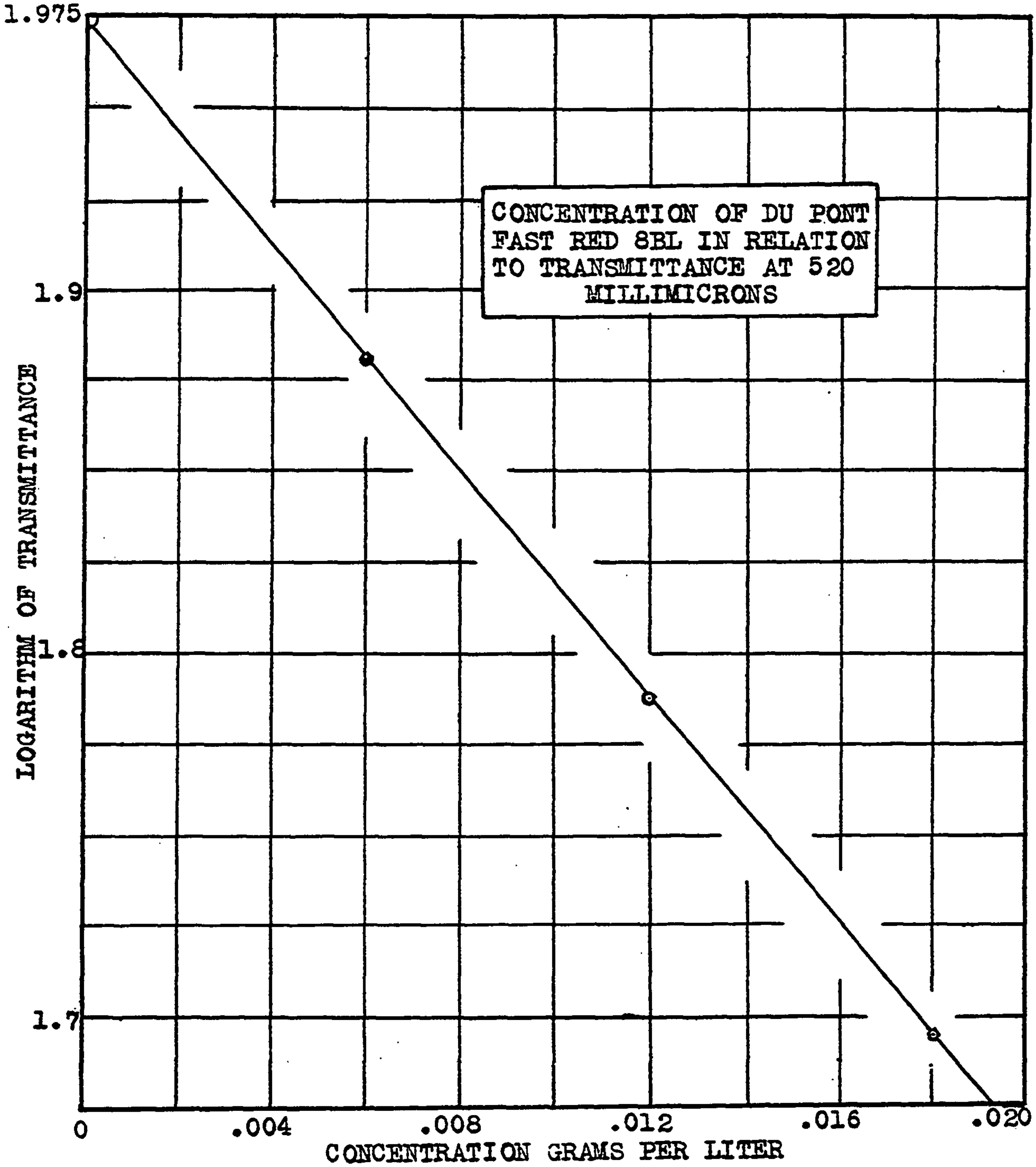

CONCENTRATION OF DU PONT ANTHRAQUINONE BLUE B IN RELATION TO THE TRANSMITTANCE AT 600 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
0
.004
.008
.010
.016
.020
CONCENTRATION GRAMS PER LITER

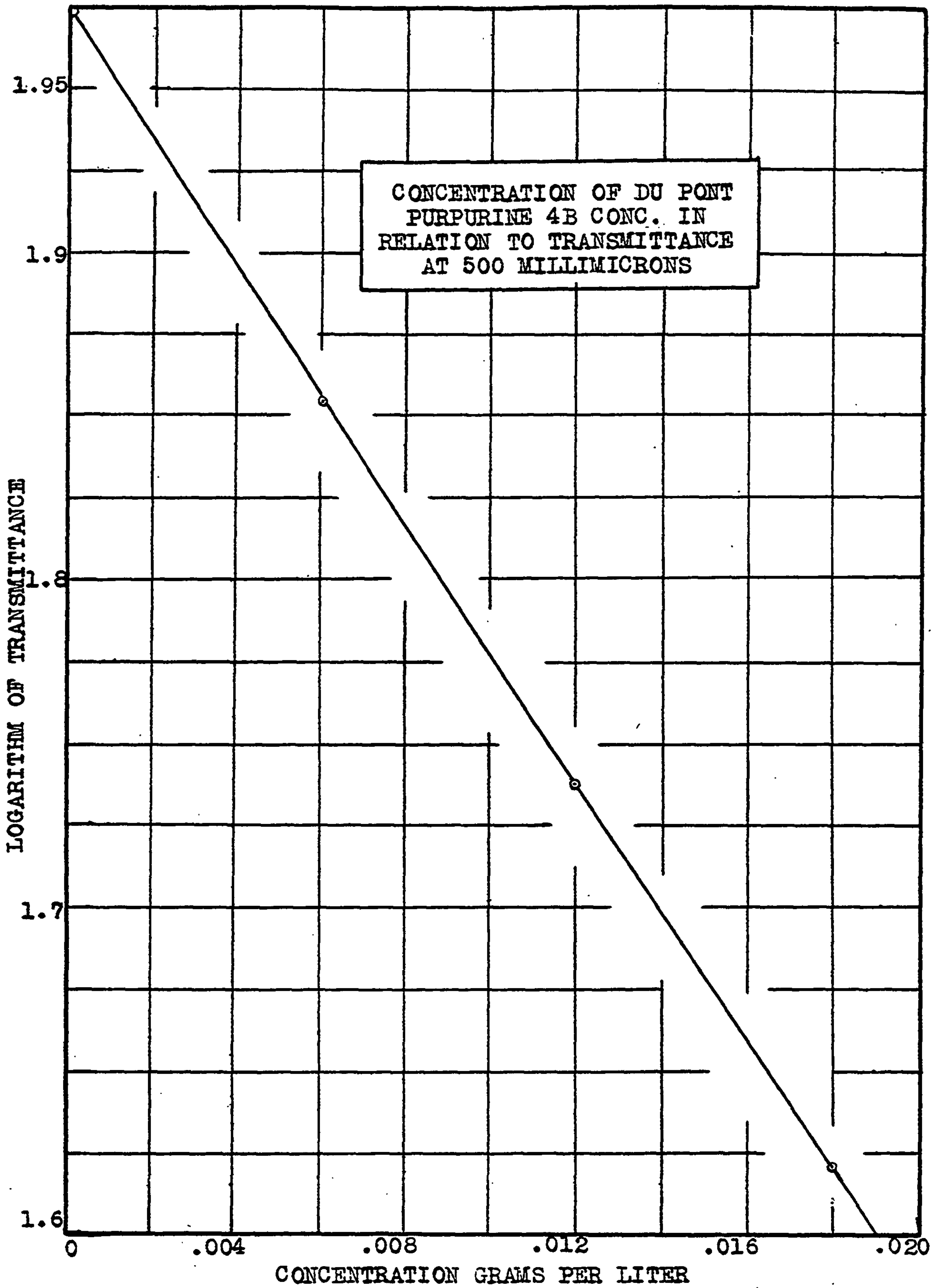

CONCENTRATION OF DU PONT NIGROSINE WSB POWD. IN RELATION TO TRANSMITTANCE AT 570 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
0
.004
.008
.012
.016
.02
CONCENTRATION GRAMS PER LITER

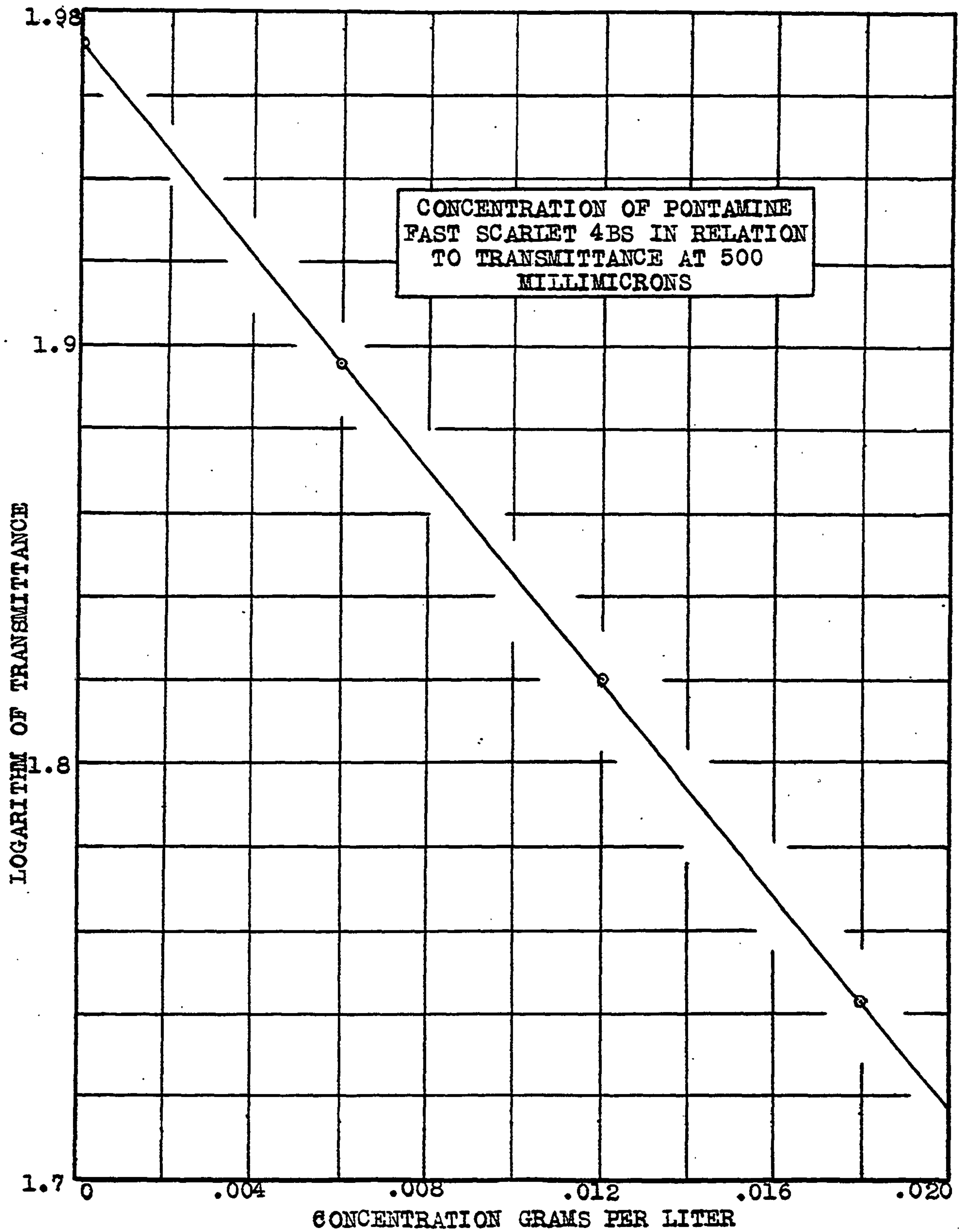

CONCENTRATION OF DU PONT QUINOLINE YELLOW CONC. IN RELATION TO TRANSMITTANCE AT 440 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
1.7
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

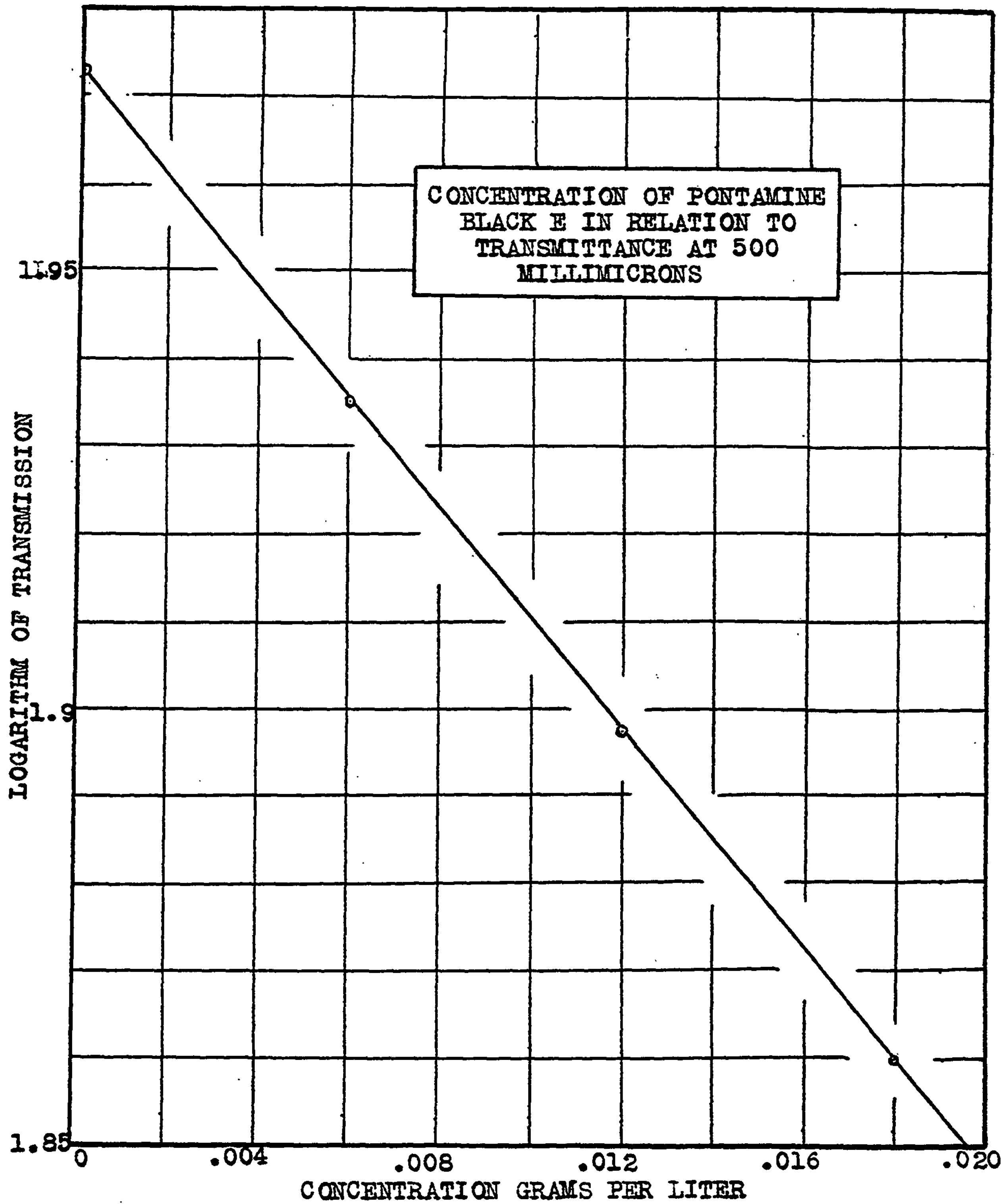

CONCENTRATION OF DU PONT ORANGE II IN RELATION TO TRANSMITTANCE AT 500 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
1.7
1.6
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

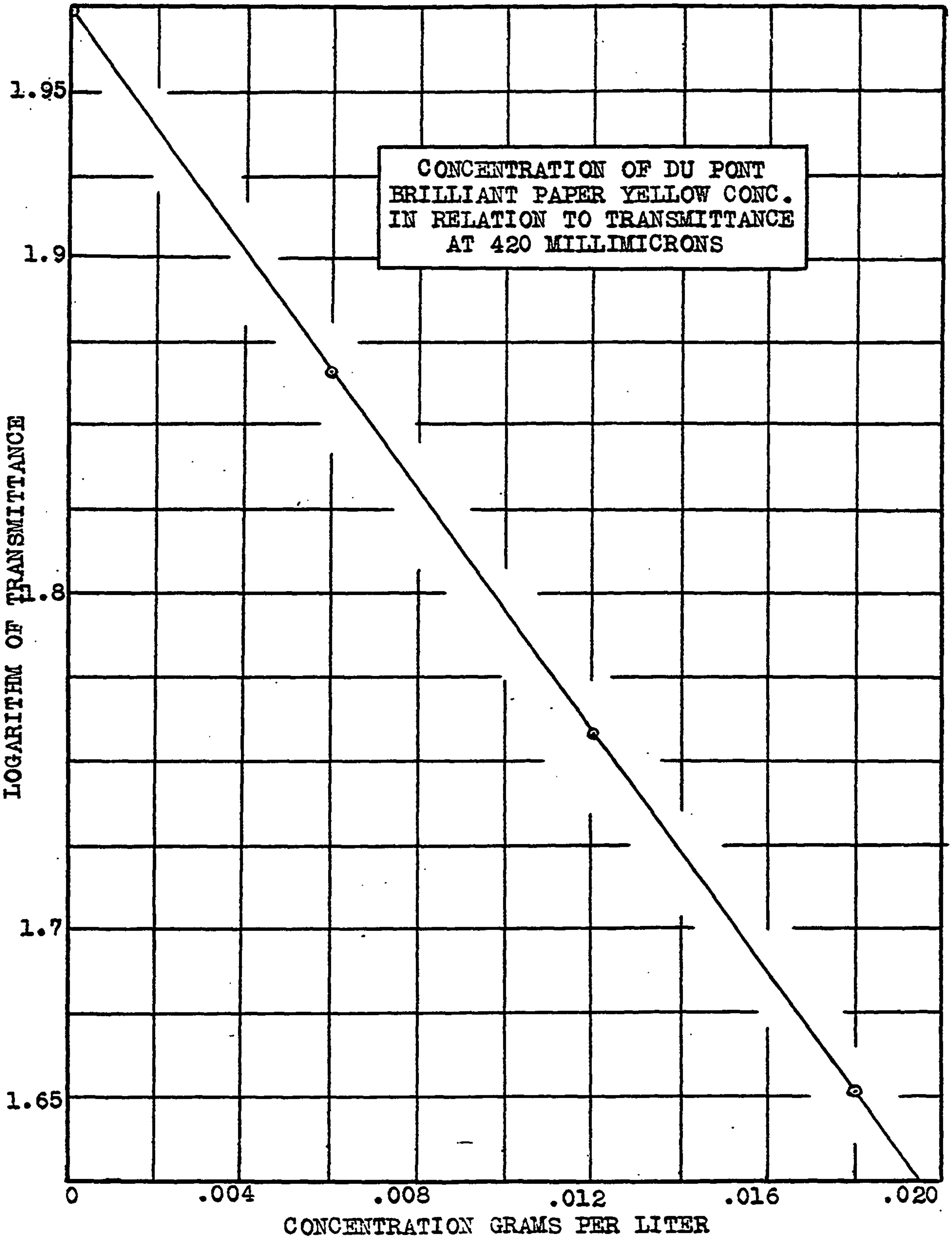

CONCENTRATION OF PONTACYL VIOLET S4B IN RELATION TO TRANSMITTANCE AT 550 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
2.0
1.9
1.8
1.7
1.6
1.5
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

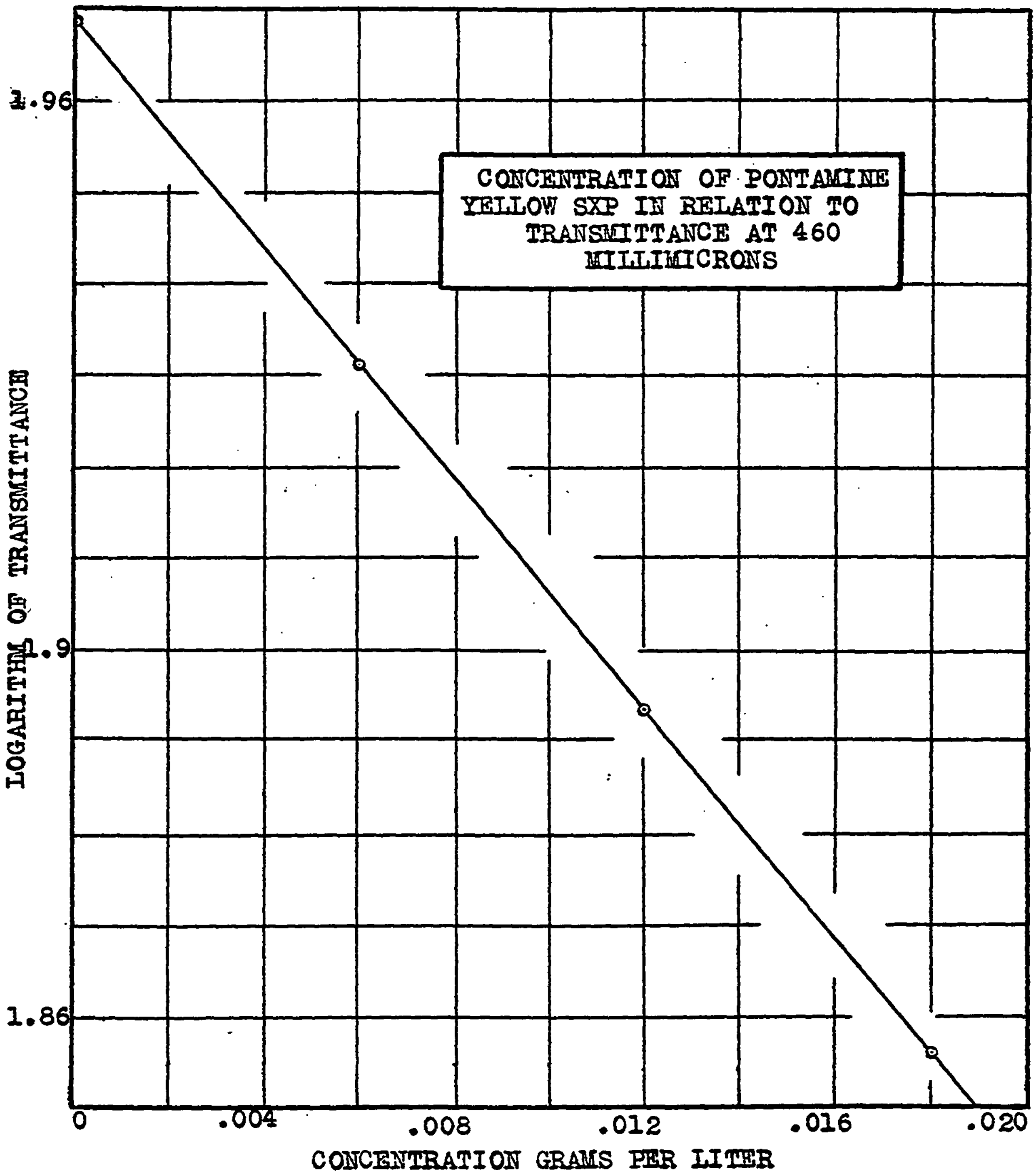

CONCENTRATION OF DU PONT FAST RED 8BL IN RELATION TO TRANSMITTANCE AT 520 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
1.975
1.9
1.8
1.7
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

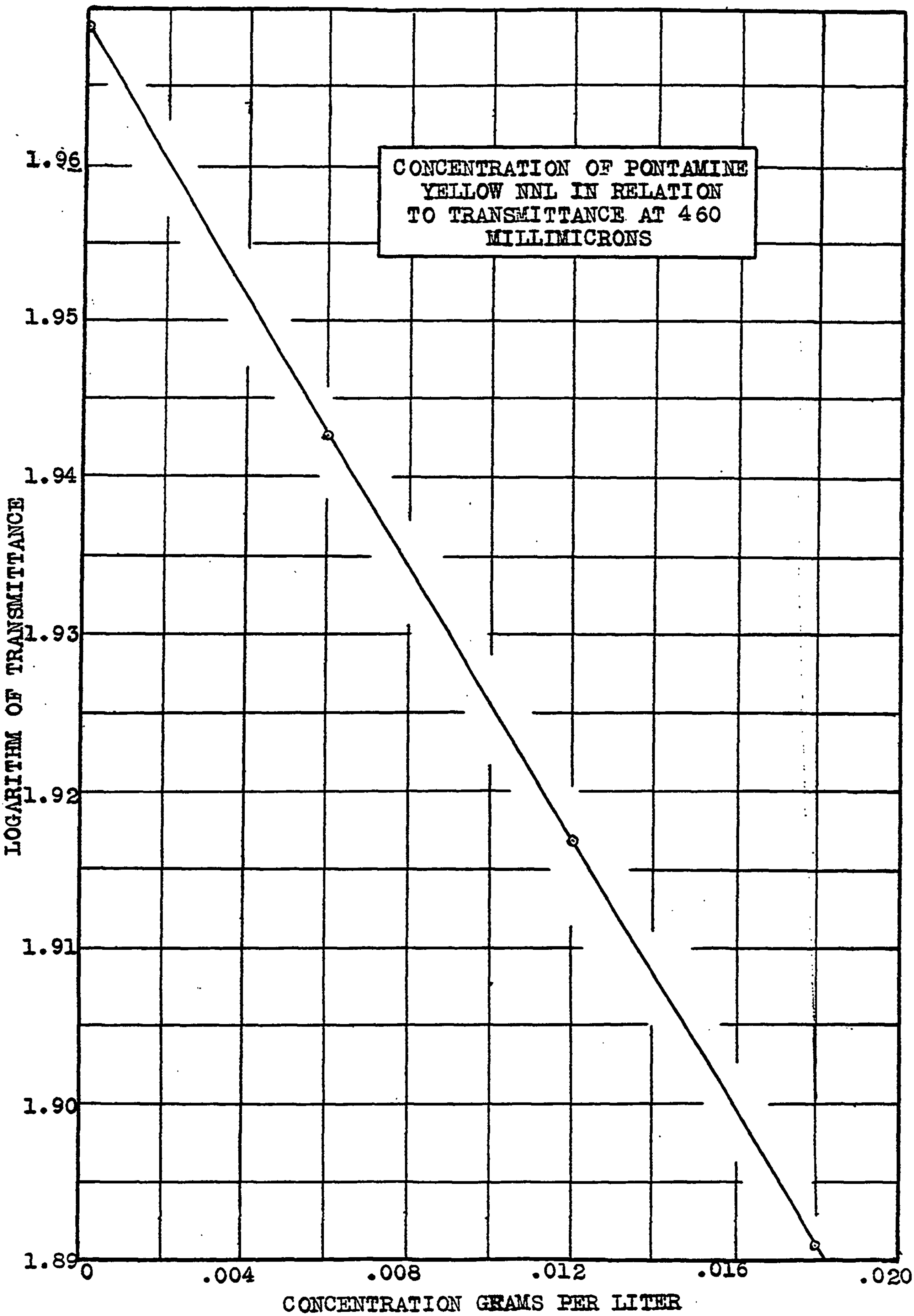

CONCENTRATION OF DU PONT PURPURINE 4B CONC. IN RELATION TO TRANSMITTANCE AT 500 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
1.95
1.9
1.8
1.7
1.6
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER


CONCENTRATION OF PONTAMINE FAST SCARLET 4BS IN RELATION TO TRANSMITTANCE AT 500 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
1.98
1.9
1.8
1.7
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER


CONCENTRATION OF PONTAMINE BLACK E IN RELATION TO TRANSMITTANCE AT 500 MILLIMICRONS
LOGARITHM OF TRANSMISSION
1.95
1.9
1.85
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

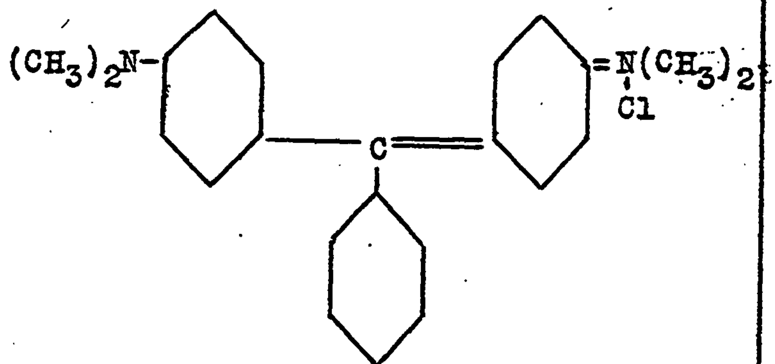
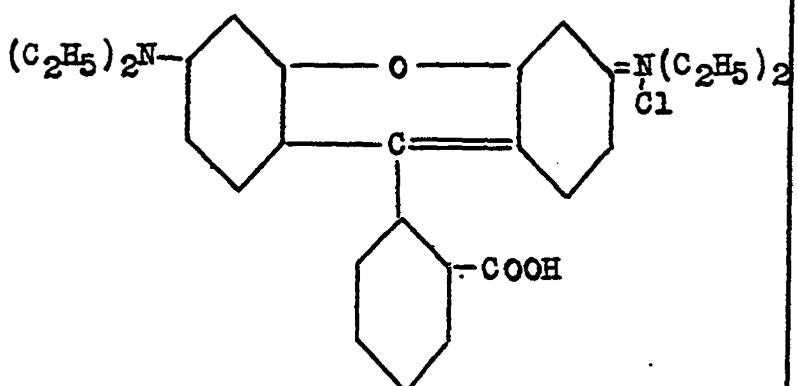
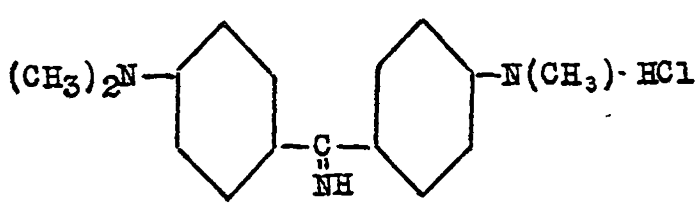

CONCENTRATION OF DU PONT BRILLIANT PAPER YELLOW CONC. IN RELATION TO TRANSMITTANCE AT 420 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
1.95
1.9
1.8
1.7
1.65
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

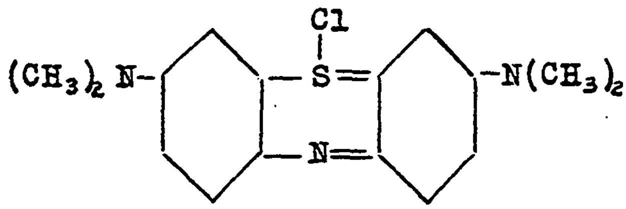
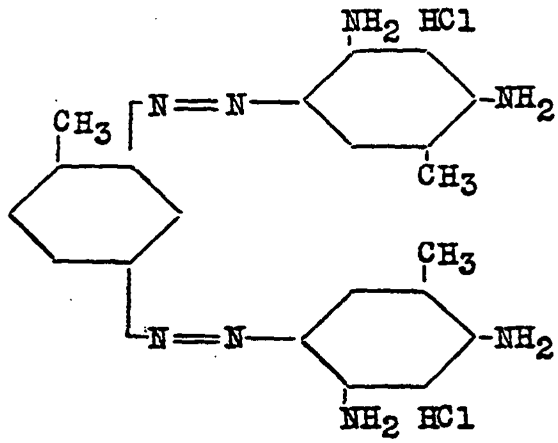
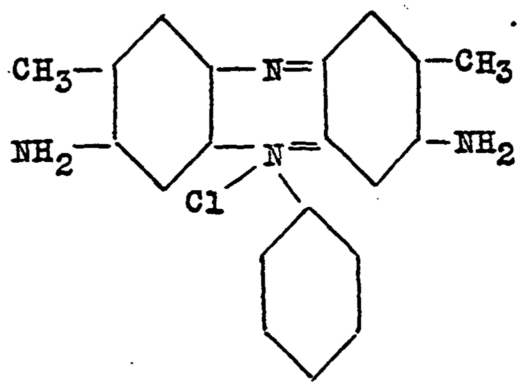
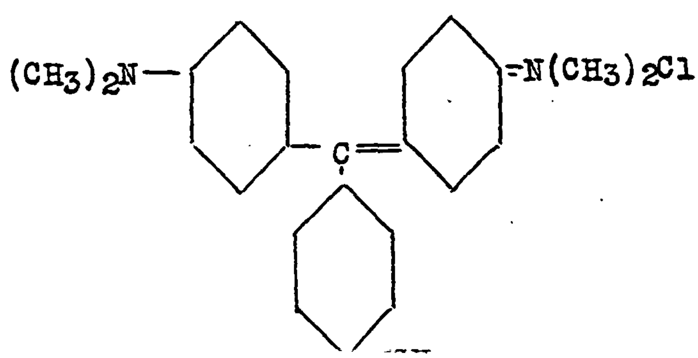

CONCENTRATION OF PONTAMINE YELLOW SXP IN RELATION TO TRANSMITTANCE AT 460 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
1.96
1.9
1.86
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

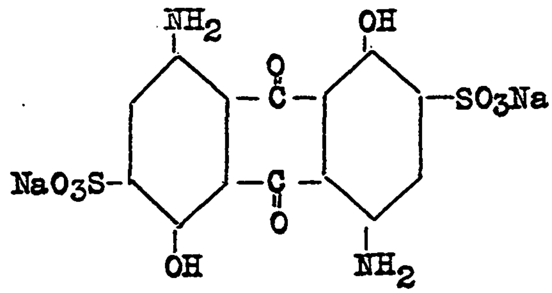
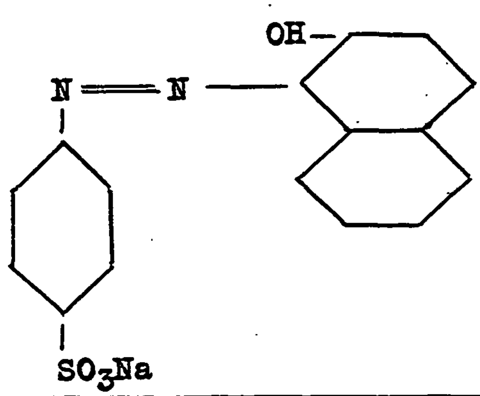
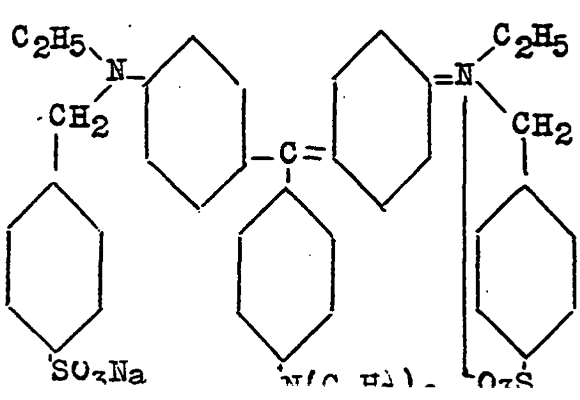

CONCENTRATION OF PONTAMINE YELLOW NNL IN RELATION TO TRANSMITTANCE AT 460 MILLIMICRONS
LOGARITHM OF TRANSMITTANCE
1.96
1.95
1.94
1.93
1.92
1.91
1.90
1.89
0
.004
.008
.012
.016
.020
CONCENTRATION GRAMS PER LITER

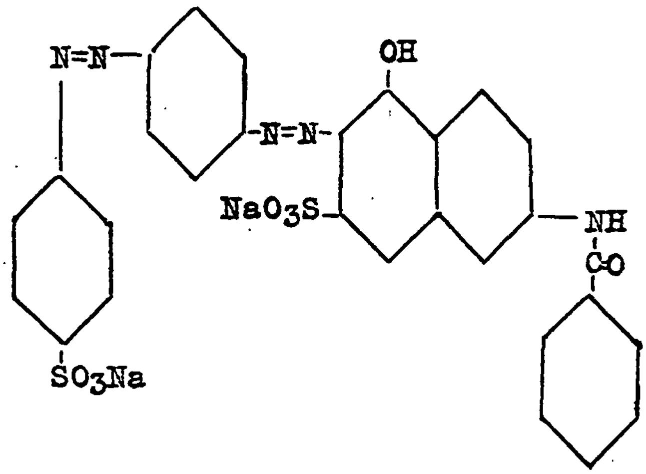
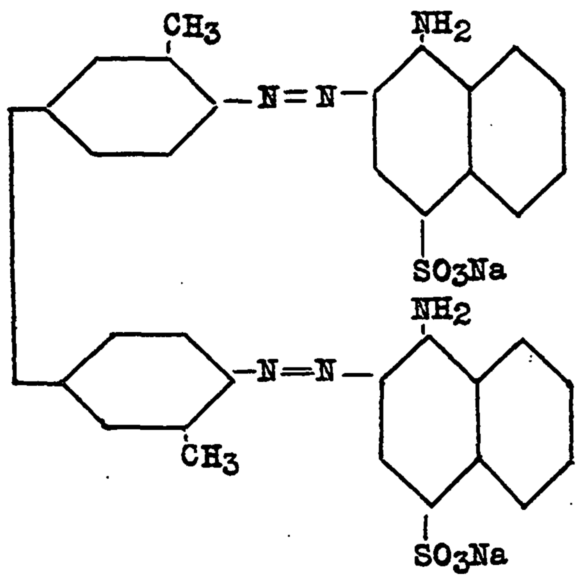
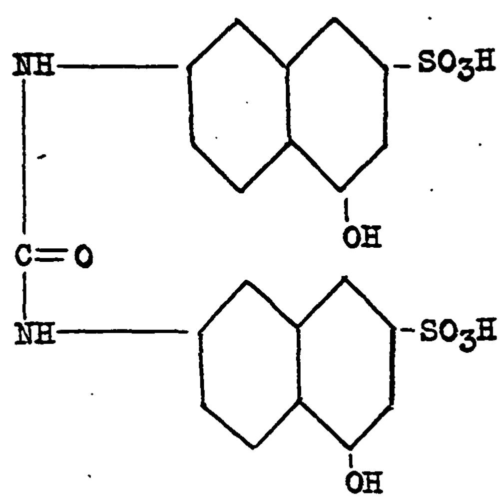
# APPENDIX C

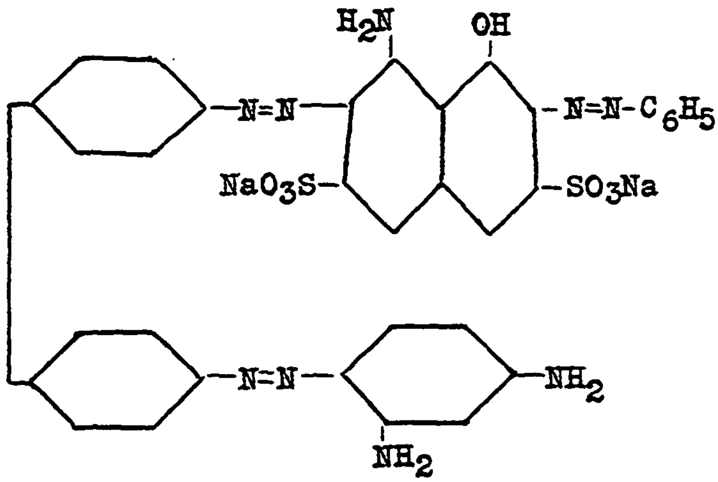
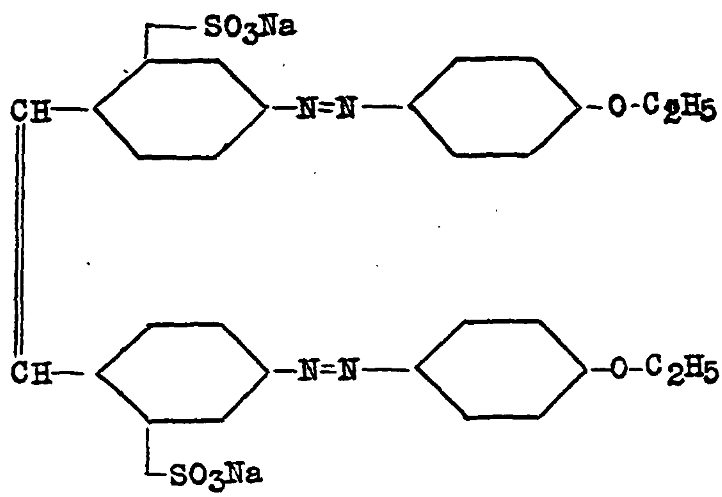
## DYE FORMULAS

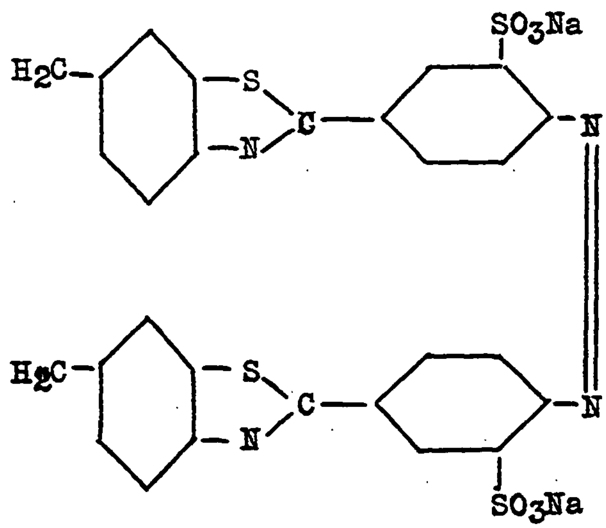
| STRUCTURAL FORMULAS OF DYES AS SHOWN IN THE GUSTAV COLOR TABLE-7TH ED. | | |
|---|---|---|
| SCHULTZ COLOR NUMBER | DYE AND FORMULA | COLOR INDEX NUMBER |
| 754 | DU PONT VICTORIA GREEN SC   | 657 |
| 864 | DU PONT RHODAMINE B   | 749 |
| 752 | DU PONT AURAMINE CONC.   | 655 |

| SCHULTZ COLOR NUMBER | DYE AND FORMULA | COLOR INDEX NUMBER |
|---|---|---|
| 1038 | DU PONT METHYLENE BLUE ZX<br> | 922 |
| 318 | DU PONT BASIC BROWN BR<br> | 332 |
| 967 | DU PONT SAFRANINE T EXTRA<br> | 841 |
| 783 | DU PONT METHYL VIOLET NEB<br> | 680 |

| SCHULTZ COLOR NUMBER | DYE AND FORMULA | COLOR INDEX NUMBER |
|---|---|---|
| 1187 | DU PONT ANTHRAQUINONE BLUE B   | 1054 |
| 986 | DU PONT NIGROSINE WSB POWDER<br>STRUCTURE VERY COMPLEX | 865 |
| 918 | DU PONT QUINOLINE YELLOW CONC.<br>$C_{18}H_9NO_8S_2Na$ - SODIUM SALT OF THE DISULFONIC ACID<br>NO STRUCTURE GIVEN | 801 |
| 189 | DU PONT ORANGE II CONCENTRATED   | 151 |
| 806 | PONTACYL VIOLET S4B   | 698 |

| SCHULTZ COLOR NUMBER | DYE AND FORMULA | COLOR INDEX NUMBER |
|---|---|---|
| 566 | PONTAMINE FAST RED 8BL<br><br> | 278 |
| 448 | DU PONT PURPURINE 4B CONCENTRATED<br><br> | 448 |
| 305 | PONTA MINE FAST SCARLET 4BS<br><br> | 326 |

| SCHULTZ COLOR NUMBER | DYE AND FORMULA | COLOR INDEX NUMBER |
|---|---|---|
| 671 | PONTAMINE BLACK E  | 581 |
| - | DU PONT BRILLIANT CROCEIN FL<br>COLOR NOT GIVEN IN SCHULTZ NOR LISTED IN THE COLOR INDEX | - |
| 724 | DU PONT BRILLIANT PAPER YELLOW CONC.  | 364 |

| SCHULTZ COLOR NUMBER | DYE AND FORMULA | COLOR INDEX NUMBER |
|---|---|---|
| - | PONTAMINE YELLOW SXP<br>COLOR NOT GIVEN IN SCHULTZ NOR LISTED IN THE COLOR INDEX | - |
| 935 | PONTAMINE FAST YELLOW NNL<br> | 814 |

# APPENDIX D.

## STANDARD WHITE WATER DATA

| TRANSMITTANCE DATA OF DISTILLED WATER AND NATURAL WHITE WATERS AT VARIOUS WAVELENGTHS | | | | | |
|---|---|---|---|---|---|
| WAVE LENGTHS MILLIMICRONS | DISTILLED WATER | UNBLEACHED SULPHITE | BLEACHED SULPHITE 3% BLEACH | BLEACHED SULPHITE 6% BLEACH | BLEACHED SULPHITE 10% BLEACH |
| 400 | 95.9 | 69.3 | 67.0 | 70.0 | 71.9 |
| 410 | 95.0 | 69.5 | 67.3 | 70.3 | 72.0 |
| 420 | 94.1 | 70.0 | 67.7 | 70.9 | 72.5 |
| 430 | 93.8 | 70.2 | 68.0 | 71.3 | 72.9 |
| 440 | 93.2 | 70.9 | 68.5 | 71.8 | 73.3 |
| 450 | 93.0 | 71.2 | 68.9 | 72.1 | 74.0 |
| 460 | 93.0 | 71.8 | 69.6 | 72.6 | 74.8 |
| 470 | 93.1 | 72.4 | 70.2 | 73.3 | 75.5 |
| 480 | 93.3 | 73.5 | 71.0 | 74.4 | 76.2 |
| 490 | 93.6 | 74.4 | 72.0 | 75.3 | 77.0 |
| 500 | 94.0 | 75.1 | 72.8 | 76.2 | 78.0 |
| 510 | 94.2 | 75.8 | 73.8 | 77.0 | 78.9 |
| 520 | 94.5 | 76.7 | 74.8 | 77.4 | 79.9 |
| 530 | 95.1 | 77.8 | 75.6 | 78.6 | 80.9 |
| 540 | 95.5 | 78.8 | 76.7 | 79.8 | 82.0 |
| 550 | 95.9 | 79.7 | 77.9 | 80.7 | 82.9 |
| 560 | 96.1 | 80.5 | 78.8 | 81.9 | 83.8 |
| 570 | 96.5 | 81.1 | 79.5 | 82.6 | 84.3 |
| 580 | 97.0 | 81.9 | 80.1 | 83.0 | 85.0 |
| 590 | 97.2 | 82.1 | 80.5 | 83.5 | 85.5 |
| 600 | 97.4 | 83.0 | 81.1 | 83.9 | 86.2 |
| 610 | 97.8 | 83.2 | 81.7 | 84.2 | 86.8 |
| 620 | 98.3 | 84.0 | 82.4 | 85.0 | 87.3 |
| 630 | 98.5 | 85.1 | 82.9 | 85.6 | 87.8 |
| 640 | 98.7 | 85.3 | 83.2 | 86.1 | 88.4 |
| 650 | 99.0 | 85.4 | 83.4 | 86.9 | 89.0 |
| 660 | 99.0 | 85.6 | 83.6 | 87.0 | 89.2 |
| 670 | 99.0 | 85.6 | 83.7 | 87.1 | 89.3 |
| 680 | 99.0 | 85.8 | 83.8 | 87.2 | 89.4 |
| 690 | 99.0 | 85.9 | 83.9 | 87.3 | 89.5 |
| 700 | 99.0 | 86.0 | 83.9 | 87.3 | 89.5 |

| TRANSMITTANCE DATA OF DISTILLED WATER AND NATURAL WHITE WATERS AT VARIOUS WAVELENGTHS | | | | | | |
|---|---|---|---|---|---|---|
| WAVELENGTH MILLIMICRONS | BLEACHED SULPHITE 20% BLEACH | BLEACHED SULPHITE 30% BLEACH | RAG | SODA | GROUND-WOOD | UNBLEACHED SULPHITE WITH SIZE AND ALUM |
| 400 | 73.4 | 75.0 | 76.0 | 76.0 | 69.0 | 66.5 |
| 410 | 73.9 | 75.5 | 76.4 | 76.5 | 69.5 | 66.8 |
| 420 | 74.4 | 76.0 | 77.0 | 77.2 | 70.2 | 67.2 |
| 430 | 74.9 | 76.6 | 77.7 | 78.0 | 71.1 | 67.5 |
| 440 | 75.3 | 77.0 | 78.3 | 78.8 | 71.8 | 68.0 |
| 450 | 76.0 | 77.5 | 79.4 | 79.4 | 72.1 | 68.3 |
| 460 | 76.3 | 78.1 | 80.4 | 79.9 | 72.5 | 69.0 |
| 470 | 76.8 | 78.7 | 81.0 | 80.4 | 73.1 | 69.7 |
| 480 | 77.5 | 79.8 | 82.2 | 81.0 | 73.4 | 70.5 |
| 490 | 78.5 | 80.5 | 82.8 | 81.4 | 73.8 | 71.5 |
| 500 | 79.3 | 81.4 | 83.5 | 81.8 | 74.1 | 72.3 |
| 510 | 80.1 | 82.2 | 84.3 | 82.0 | 74.5 | 73.3 |
| 520 | 81.2 | 83.1 | 85.2 | 82.3 | 74.9 | 74.3 |
| 530 | 82.8 | 84.3 | 86.0 | 82.8 | 75.2 | 75.0 |
| 540 | 83.6 | 85.0 | 86.7 | 83.1 | 75.6 | 76.2 |
| 550 | 84.4 | 85.8 | 87.5 | 83.5 | 76.0 | 77.4 |
| 560 | 85.1 | 86.7 | 88.5 | 83.9 | 76.3 | 78.3 |
| 570 | 86.0 | 87.5 | 89.1 | 84.0 | 76.7 | 79.0 |
| 580 | 86.8 | 88.4 | 89.8 | 84.2 | 76.9 | 79.5 |
| 590 | 87.2 | 89.0 | 90.1 | 84.3 | 77.0 | 80.0 |
| 600 | 87.8 | 89.5 | 90.8 | 84.4 | 77.0 | 80.6 |
| 610 | 88.4 | 90.4 | 91.5 | 84.5 | 77.1 | 81.2 |
| 620 | 89.0 | 91.2 | 92.1 | 84.7 | 77.1 | 81.9 |
| 630 | 89.6 | 91.8 | 92.8 | 84.9 | 77.2 | 82.4 |
| 640 | 90.1 | 92.2 | 93.2 | 85.0 | 77.4 | 82.7 |
| 650 | 90.8 | 92.3 | 93.9 | 85.1 | 77.7 | 82.8 |
| 660 | 91.2 | 92.4 | 94.2 | 85.2 | 77.9 | 83.1 |
| 670 | 91.3 | 92.5 | 94.6 | 85.3 | 77.9 | 83.2 |
| 680 | 91.4 | 92.6 | 94.7 | 85.4 | 78.0 | 83.3 |
| 690 | 91.5 | 92.6 | 95.0 | 85.5 | 78.1 | 83.4 |
| 700 | 91.5 | 92.6 | 95.0 | 85.5 | 78.1 | 83.4 |

| TRANSMITTANCE DATA OF DISTILLED WATER AND NATURAL WHITE WATERS AT VARIOUS WAVELENGTHS | | | | | |
|---|---|---|---|---|---|
| WAVELENGTH MILLIMICRONS | UNBLEACHED KRAFT | KRAFT 5% BLEACH | KRAFT 15% BLEACH | KRAFT 30% BLEACH | KRAFT 40% BLEACH |
| 400 | 63.0 | 65.8 | 69.1 | 71.3 | 74.8 |
| 410 | 64.0 | 66.5 | 69.6 | 72.0 | 75.5 |
| 420 | 64.8 | 67.5 | 70.3 | 73.0 | 76.0 |
| 430 | 65.5 | 68.3 | 71.0 | 73.6 | 76.4 |
| 440 | 66.4 | 69.1 | 71.8 | 74.0 | 76.8 |
| 450 | 67.1 | 69.8 | 72.4 | 74.5 | 77.0 |
| 460 | 67.6 | 70.6 | 73.0 | 75.0 | 77.3 |
| 470 | 68.3 | 71.3 | 73.5 | 75.6 | 78.0 |
| 480 | 69.1 | 72.2 | 74.1 | 76.2 | 78.5 |
| 490 | 69.5 | 72.9 | 74.6 | 76.8 | 79.4 |
| 500 | 70.2 | 73.4 | 75.1 | 77.5 | 80.1 |
| 510 | 71.1 | 74.1 | 76.0 | 78.1 | 81.0 |
| 520 | 71.9 | 75.0 | 76.9 | 79.0 | 81.9 |
| 530 | 72.9 | 75.9 | 77.9 | 80.0 | 82.6 |
| 540 | 74.0 | 77.0 | 78.9 | 80.9 | 83.1 |
| 550 | 75.1 | 77.9 | 79.6 | 81.5 | 84.0 |
| 560 | 76.2 | 78.8 | 80.2 | 82.2 | 84.6 |
| 570 | 77.0 | 79,3 | 81.0 | 82.9 | 85.3 |
| 580 | 78.0 | 80.0 | 81.4 | 83.5 | 86.0 |
| 590 | 78.8 | 80.8 | 82.2 | 84.0 | 87.0 |
| 600 | 79.3 | 81.4 | 83.0 | 84.8 | 87.3 |
| 610 | 79.8 | 82.0 | 83.8 | 85.9 | 87.9 |
| 620 | 80.1 | 82.1 | 84.1 | 86.3 | 88.1 |
| 630 | 80.2 | 82.3 | 84.3 | 86.4 | 88.5 |
| 640 | 80.4 | 82.4 | 84.5 | 86.5 | 88.6 |
| 650 | 80.5 | 82.5 | 84.6 | 86.6 | 88.6 |
| 660 | 80.6 | 82.6 | 84.7 | 86.7 | 88.7 |
| 670 | 80.7 | 82.7 | 84.9 | 86.8 | 88.8 |
| 680 | 80.8 | 82.9 | 85.0 | 86.9 | 88.9 |
| 690 | 80.9 | 82.9 | 85.1 | 87.0 | 89.0 |
| 700 | 80.9 | 83.0 | 85.1 | 87.0 | 89.0 |