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Patrick T. Gibney
Western Michigan University

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A STUDY OF THE WATER RETENTION OF LATEX BOUND PIGMENTED COATING COLORS

by

Patrick T. Gibney

A Thesis submitted
in partial fulfillment of
the course requirements for
The Bachelor of Science Degree

Western Michigan University
Kalamazoo, Michigan

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ABSTRACT

The purpose of this study was to examine the effects of three types of commercially used hydrocolloid; CMC 7M, CMC 7L, HEC 250M and KELGIN MV on water retention and on coated paper properties. It was found that the concentration of hydrocolloid was an important factor in water retention values. Carboxyl groups were theorized to be another factor in water retention. Hydrocolloids were found to lower opacity,brightness and gloss over the blank coating. Increasing hydrocolloid levels decreased the openess of the coating.When increasing the amount of hydrocolloid the IGT pick decreased. KELGIN MV gave the highest water retention value.

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INTRODUCTION

A phenomenon observed in paper color is the lack of release of water or aqueous vehicle from the coating color to an absorbent base sheet. This phenomenon is called water retention. Water retention is sometimes called the following names: water holding, water loss, vehicle retention, coating holdup, water holdout, and vehicle holdout. The water retention of coating color is effected by pH, temperature, type of coating formulation, level and nature of additive, and type of raw stock used. A coating color with high water retention value generally denotes a color having increased ability to prevent the continuous phase from penetrating into the base paper. The application of pigment suspensions on paper is always followed by transport of water and binder into the base stock. This process was first studied in 1930 by Cobb and Lowe (1) and has been discussed by several investigators (2, 3). Years ago the interest was focused on roll coating and it's effect on paper coated this way. With the development of the blade coater more emphasis has been put on binder migration during the coating operation. The influence of the pigment suspension on the migration process may be ascribed to many variables such as the rheological properties, the solids content, the surface tension, and the less precisely defined property of water retention. Frost (4) showed that the conversion of starch affected the surface strength of the coated paper, and that this change in surface strength could be correlated with the ability of a starch-based clay suspension to retain water. Frost believed that the water retention was a fundamental property of a pigment suspension. The problem then became how do we measure the water retention of a coating color?

The first method used to measure water retention was quite similar to the dry indicator method used to measure paper sizing. The blotter test (5) used an unsized piece of standard test paper, on which a dry indicator has been sprinkled. The test paper is then dropped on the coating color to be tested. The water retention is the time for the aqueous phase to leave the coating, pass through the paper and show on the indicator on the top side. The blotter test is limited to coating color formulations that are in the low solids ranges. At the higher solids, variations in readings become greater than the accuracy of the test. Operator judgement on when to stop the timer account for some of the error associated with this test. In the past people tried many ways to measure water retention. The following will be a description of the major tests which were used to measure water retention or a variable related to water retention.

The roll-inclined plane tester (6) consisted of a plate of glass mounted on a plank and inclined at a convenient angle. A chrome-plated machined roll which has been dynamically balanced is wrapped with the raw stock to be tested. Hemispherical drops of coating color are placed with a micrometer syringe at predetermined position on the glass incline. Knowing the velocity of the roll moving down the inclined plane and knowing the viscosity of the coating a value for the wet film thickness is calculated. The wet film thickness is considered to be measurement of the water retention. This test has many disadvantages, the placing of the coating drops, the change in velocity as it is slowed down by the coating. The test does not measure water retention directly and the relationship between water retention and the wet film thickness is not completely understood.

A modification of the roll-inclined plane tester was the rubber roll (7). This apparatus consists of a pair of soft rubber-covered rolls which are driven by a variable speed device. The raw stock is formed in a V Shape. Just before the V is fed into the nip an automatic pipet measures out a definite volume of coating color. The nip spreads the coating color between the raw stock. The theory is, while the spreading occurs, the solution strikes into the paper. A wetted pattern is formed on the raw stock. This pattern is largely governed by the rate of strike in. The area of the pattern is measured in square cm. This test removes some of the variables found in the inclined plane but it still is only related to water retention.

One of the first attempts to measure water retention directly was the sonic tester (8). The equipment used was a sonic pulse propagation meter equipped with a strip chart recorder. The procedure was simply to spread the coating color onto the raw stock between the two sonic probes. The speed of sound through the sheet decreased as water leaves the coating color and penetrates the sheet. The reason for the decreases is as water enters the base stock the fibers swell thus decreasing the sonic waves. The rate of adsorption was charted by a strip recorder as an increase in sonic transit time. The ratio of sonic velocity at 15 sec. to that of the uncoated base stock was found to be convenient for comparison of different coating colors. The main problem with this tester is the application of the coating color at the start of the test. Also, the cost of the equipment is a factor in not using this tester.

All of the above tests did not relate to any one coating process. The first water retention tester to corrolate water retention with the type of coating process to be used was the film splitting techniques (9). In the film splitting test a coating color layer identical in thickness to that of the coating process is applied to a flat piece of plate glass. The color is applied by means of an applicator with a variable slit width to give the desired coating thickness. The base paper is brought into contact with the coating layer at a given pressure and for a given period of time. During this period of contact, penetration of the vehicle occurs. After the selected time of contact the pressure is released and the paper is drawn off causing the coating layer to split.

If the film that remains on the glass plate is easily deformed, coherent, and is still wet due to the presence of still continuous phase, then the critical pigment volume concentration has not been reached. The critical pigment volume concentration is defined to be "when the film is difficult to deform, granular and incoherent"

(10). The test is repeated with longer and longer contact time until the critical pigment volume concentration is reached. The largest error in this test is in the operators judgement to when the film has reached critical pigment volume concentration.

In recent years new types of testers have been introduced. The design of these testers is based upon the fact that the conductivity of the paper is a function of its moisture content. The first of these was the static terminal ring cell (11). This tester consists of a terminal ring cell, plexigals stopper, plastic film, and a brass plate. The coating color to be tested is placed in the ring cell. The paper stock is covered by the plastic film and placed on the base plate. The plexiglass stopper with the ring cell is placed on top of the plastic film. The plastic film is pulled out and this starts an automatic timer. The timer is stopped when the current flow through the paper reaches 1.0 mA. The problem with the ring cell tester is it can only be used for a small range of solids. The cell tester is also very difficult to clean.

The next tester was designed by Stinchfield and coworkers (12). This instrument has been used by Sikstrom (13), Hagerman and coworkers (14) and Harsveldt (15). The tester is called the warren tester and consist of a steel plate and a weight and each is connected to a ampmeter and a voltage regulator. The paper stock is placed between two electrodes. Water then migrates from the suspension into the paper, and if an electrical potential is applied across the electrodes, the current will increase with time. The time required to yield a current of .5 mA with a short-circuit current of 1 mA is reported as the water retention time, and used as a measure of water retention ability.

Both Stinchfield and Sikstrom have discussed the different sources of error. The conductivity of the paper is not only a function of the moisture content, but also of the electrolyte content in the paper and the pigment suspension. Sikstrom (16) found that the variations in electrolyte content of different pigment suspensions were quite small.

Another source of error is the polarization of the electrodes. Polorization is also reduced by using alternating currents, and an increase in frequency was found to be advantageous. If the frequency is too high, however, capacitance rather than conductivity is measured.

Stinchfield (17) found that the water retention time decreased with increasing temperature. He found that the effect of a temperature change was less than reported previously, but temperature control is still required.

By changing the weight of the top electrodes, pressures similar to what are found on the blade coater can be obtained. If a fixed volume of pigment suspension is used, the area of the paper covered with color will depend upon the viscosity. Since the current through the paper is proportional to this area, the water retention value must be referred to a standard area, corresponding to a circle of diameter 70 mm. If the time measured for this standard area and standard current of 0.5 mA is used as the standard water retention time, the following equation may be used to adjust a different area A_1 to the same standard:

$$I = 0.5\, A_1 / 70^2 \left(\frac{\pi}{4}\right) \quad [1]$$

Poor contact has been the problem with this test in the past. If care is taken this problem can be overcome.

A modification to the warren tester (18) is a cell that admits the color to both sides of the raw stock simultaneously. The tester also removes any external pressure on the coating color. The raw stock is clamped between two identical cells. The cells are filled with coating color and the stoppers are removed together. The test is stopped when 1 m amp of current is reached on the meter. This tester is also supposed to give better electrode contact. D.C. current is used but as discussed earlier this caused polarization of the electrodes.

There are many variations of the warren tester and many other types of water retention. The above was a background to show how water retention was and is measured and how the measurements have improved through the years.

When one talks of water retention, adhesive redistribution or binder migration, must also be mentioned binder migration is the selective movement of adhesive through the pigmented coating (19). The theory is that the binder migration follows the same pattern as water flows within the pigmented coating before the coating losses enough water to be solidified. The prime factor governing binder migration seemed to be the solids content of the coating formulation (20). A test showed that higher solids content coating colors were less prone toward binder migration.

In order to reduce excessive binder migration, controlling dewatering of the color and promote the proper color rheology the hydrocolloids are added. The most frequently used high molecular weight water-soluble polymers are carboxymethylcellulose (CMC), hydroxyethylcelluse (HEC) and sodium alginate. These hydrocolloids are added at levels of .1 - 1.5 parts per 100 parts of pigment.

The mechanism by which hydrocolloids modify rheology, retain water and reduce binder migration depends to a great extent upon the presence of certain functional groups. The large number of carboxyl and hydroxyl groups along the carboxymethylcellulose (CMC) and sodium alginate polymer (see figures 1 and 2). Chains form associations with the other coating color components: dispersed pigment, latex and most importantly water (21). This association is through dipole adsorption, ionic attraction and hydrogen bonding (22). The hydroxyethylcellulose (HEC) forms associations through hydroxyl groups on the anhydroglucose units (see figure 3) and the hydroxyls on the ends of the hydroxyethyl chains (23). Adsorption of non-ionic HEC on pigment surfaces extends the particle's radius outward, yielding a protective colloid action or a "bumper" effect, as suggested by Athey (24).

Since these hydrocolloids effect rheology an understanding of rheology is necessary in studying these effects. There are four types of non-Newtonian flow important to paper coatings; pseudoplastic, thixotropic, dilatant and pseudoplastic-thixotropic, see figures 4 and 5.

Pseudoplasticity frequently occurs in polymer solutions since high molecular weight polymers usually tend to orientate themselves in the direction of the flow. As the applied force, or shear stress, is increased, the resistance to flow, or viscosity, is decreased. When shear is removed, the viscosity returns. Such shear-sensitive flow is exhibited by most paper coatings. Without pseudoplasticity the paper coater would be restricted to low viscosity coating colors.

Thixotropic flow occurs if there is interaction between long chain polymers, or in some cases if dispersed particles are present (25). Thixotropic solutions show a viscosity return with time after shearing.

Dilantency is usually a condition to be avoided. Dilatent flow describes a system that increases in viscosity with an increasing rate of shear. A dilatent coating however can cause endless problems to the coater (26). Scratches and streaks become uncontrollable, pumping and filtering can be blocked by the coating becoming almost solid under shear.

Frequently, coating colors exhibit pseudoplastic-thixotropic flow. This is apparent when viscosity is decreased with shear, but with the removal of shear, viscosity increases with time.

Experience has shown the blade coating colors must have suitable flow properties over a wide shear rate range. In the Hercules Hi-shear viscometer range of 10^4 sec^{-1} coating runnability seems to be in the order of 40-200 cps (27). If the color is below 40 cps, the water phase is not retained sufficiently to reduce water loss and binder migration into the base stock. With water loss the color becomes more dilatant. Hydrocolloids help prevent dilatancy by reducing water loss and by modifying the flow characteristics of the color through lubrication. In high solids coating color (66-68%) range water retention becomes critical in that each unit of water loss leads to an increase in dilatancy.

Furthermore one should note the relationship between water retention and other wetting variables. With the warren tester, which is the tester that I have chosen to use in testing water retention, the water retention is measured under static pressure, therefore the penetration of the liquid component must be due to capillary flow. This migration of water and binder can be described by a modification of poiseuille's equation (28).

$$dh/dt = r\gamma\cos\theta/4\mu h \qquad [2]$$

where h is the depth of penetration, γ the surface tension, μ is the viscosity, r the capillary radius and θ the angle of contact between liquid and capillary wall. According to eq. 2, the rate of penetration should then be directly proportional to the surface of the liquid and the cosine of the contact angle between the liquid and the capillary wall, and inversely proportional to the viscosity.

Changes in these variables should therefore be expected to give corresponding changes in the water retention. An investigator reported that alginate increase the contact angle between pigment suspension and the paper (29). If the alginate effected the water retention values then the water retention values might not be a special property of a pigment suspension, but could be regarded as a function of surface tension, contact angle and viscosity. His results, however, do not indicate that any such relationship exists, the correlation of these wetting variables are complicated by the fact that the pigment suspensions are two phased, therefore, the surface tension and the contact angle are hard to define. Since the properties of the migration fluid phase is undefined, the correlation of the wetting variables and the water retention values are uncertain.

EXPERIMENTAL PROCEDURE

The thirteen coatings were made up in the following way. The blank or standard coating is made up to 100 parts number two clay and 15 parts of styrene-butadiene latex (Dow-620). The other coating colors consisted of the blank color formulation plus one of the following; low vicosity carboxmethyl cellulose (CMC 7L), medium viscosity carboxmethyl cellulose (CMC 7M), medium viscosity hydroxyethyl cellulose (HEC 250M), and sodium alginate (Kelgin MV) at .3, .6 and .9 parts per 100 parts of dry pigment. The coating colors solids ranged from 59% to 60%.

The additives were added to the clay slip under high shear mixing. After the additives became dispersed, the mixing rate was slowed down and the Dow 620 was added. The coating slips were tested on the Brookfield, Hercules High Shear Viscometer, and the water retention tester before being applied to the base stock. The coating slip was kept mixing at slow speed and samples were drawn off as needed. The Brookfield was run at 10, 20, 50 and 100 R.P.M. The Hercules High Shear a (A) bob was used at 2,200 R.P.M. The last test run before coating the sheet was the water retention test.

The water retention tester was modeled after the Warren tester which was described earlier. The only modification to the tester was a strip-chart recorder to measure the change in current instead of the millampmeter which would only give a stopping point and not a curve. The top electrode was weighed to give a pressure of .214 PSI.

The tester power supply was designed by the Electrical Engineering Department. The problem was to change the A.C. current used by the tester, and convert it to D.C. for the strip-chart recorder. See Figure 6 for the electrical diagram for changing A.C. current to D.C. current. The Electrical Engineering Department also designed a calibration circuit that gives a one millamp reading on the strip-chart recorder. This one millamp reading is used to calibrate the sensor part of the Warren tester. This test was run in the humidity room to reduce the effects of temperature on water retention valves. The base stock was also kept in the humidity room to reduce the effects of moisture content of the base stock on the water retention valves. The coating colors were brought into the humidity room and cooled to 20°C. The bottom electrode was washed off with distilled water which was also kept at 20°C. with the temperature at 20°C. This kept it from being variable in the water retention valves. See Figure 7 for a diagram of the set-up of the water retention tester. Since the water retention tester was a new test a standard error of estimate was determined for the tester and its S valve was found to be 1.27 sec.

After running these tests, the coating colors were applied to the base stock by the Keegan Coater. The base stock used was a Consolidated base stock with a brightness of 80, as basis weight of 70 g/m^2 and an opacity of 88. The sheets were then conditioned in the humidity room. After conditioning the following tests were run;

brightness, opacity and gloss before supercalendering. The sheets were then supercalendered four nips at 1,500 pound per linear inch. The above tests were run again after supercalendering.

The IGT pick test was run on the supercalendered coated paper using a number 4 tack ink. The speed was changed in order to keep the end-point in the center of the scale.

The K & N ink holdout and the Vandercook print gloss were run on the coated supercalendered paper samples. The K & N Ink was applied to the samples by means of an ink roller. The ink was then wiped off the sheet after 2 minutes and the brightness taken on that area. The number recordered was the decrease in brightness from the uninked area. On the Vandercook print gloss a plate was used to give a solid printed area. The ink used was a heat-set ink. The coated samples were printed and then heated for 15 sec. in front of a space heater. Gloss was then run on the solid area and recordered as the increase in gloss over the unprinted area.

RESULTS AND DISCUSSION

The purpose of this study was to examine the effects of three types of commercially used hydrocolloids on water retention and on coated paper properties. The products studied were HEC 250 medium viscosity, CMC 7 low and medium viscosity, and kegin MV medium viscosity.

Coating Color Properties

The water retention test times increased with increased levels of hydrocolloids. Figure 8 shows that Kelgin MV had the greatest increase in water retention time. This is possibly due to the presence of carboxyl groups (see Figure 2). CMC7M, and 7L also have carboxyl groups but their water retention is lower than Kelgin MV. The CMC's have a very large side group (CH_2oCH_2CooNa) which could restrict the availability of the carboxyl groups (see Figure 1). All these polymers contain hydroxyl groups but only the CMC's and Kelgin have carboxyl groups. This might explain why HEC has the lowest water retention time. It would therefore seem that these carboxyl groups are very important to water binding. The two CMC's differed in viscosity but not in water retention times. This would indicate that viscosity is not a factor in water retention time. Even though Kelgin MV had the highest viscosity and water retention time and HEC had the lowest, this does not mean viscosity is a factor. As Kelgin MV ties up the liquid phase, giving a higher water retention time it also would increase the viscosity of the coating. The inverse of this is true for the HEC. The concentration of hydrocolloid is also an important factor in water retention time.

It was also noted when the water retention test was run on the blank coating color the base stock fell apart at the end of the test. This was possibly due to massive amounts of water penetrating into the base stock which caused the fibers to come apart. The curve produced by the water retention tester showed that once penetrating of the base stock occured, the slopes were approximately the same. The time difference came from the amount of time to start the initial penetrating or the upward movement of the curve. Since the water retention is measured under static pressure, the penetration of the liquid into the base stock is due to capillary flow. With the slope being the same and the time depending on the initial penetration this may suggest that once capillary flow begins, the force behind it may be strong enough to break other hydrogen bonds.

With respect to rheological behavior, the Brookfield viscosity data, in appendix one, showed the coating colors with the hydrocolloids were pseudoplastic. This type of flow is suitable for blade coating. The Hercules high shear rheograms, in appendix two, show pseudoplastic-thixotropie flow in all but the blank coating color. The hydrocolloids all showed the phenomenon known as shear-thinning. This shear-thinning should also occur under the pressure of the blade in the Keegan coater. It can be seen in Figure 9 the viscosity increases with increased amounts of hydrocolloids. This could possibly be due to the fact that the water phase is tied up by the long chain polymers. Figure 10 shows the thixotropic index and how it varies with increasing amounts of hydrocolloids. From this graph it can be seen that Kelgin MV and CMC 7M had the most increased thixotropic index while CMC 7L and HEC 250M did not change much. This increase found in Kelgin MV and CMC 7M possibly were due to a release of the water phase. The high shear in the Hercules high shear tester may have had enough force to break the chemical bonding that held the water. If the force becomes too great the polymer itself may begin to break up. If this is indeed what happens this would change the water retention values. This theory could be verified by running these coatings on the pilot coater. Water retention values could be run on the coating before application and on the run off from the blade. Figure 11 shows what happens to the leveling index when increasing the amounts of hydrocolloids. Kelgin MV had the highest leveling index and also had the largest change from .3 to .9 percent. Leveling index gives an indication of the flow after it is applied to the sheet. This correlates well with Figure 9 since it showed Kelgin MV to have the highest shear-thinning under force. This correlation is also observed with CMC 7M, CMC 7L and HEC 250M.

Color Properties Related to Operability

The color operability appeared to be a function of the ease with which the polymer was dispersed in the clay slurry. The Kelgin MV was the hardest polymer to get wetted out. All the hydrocolloids were added at high shear mixing. The higher the viscosity of the final coating slip the harder it was to get the hydrocolloid dispersed. The problem of runnability followed that of viscosity. The higher the level of hydrocolloids, the higher viscosity, the harder it was to run. The only problem occured with the Kelgin MV and the .9% CMC 7M. The problem was that the coating not under the pressure of the blade did not flow to replace the coating under the blade. This goes along with the viscosity data found in the Brookfield and Hercules high shear. In order to run them a spatula was used to keep the coating flowing to the nip. The coating color that contained hydrocolloid did not become dilatant in the nip due to dewatering of the coating into the base stock. The blank did show some dewatering at the nip. In fact no coating color had any build-up on the blade which is a good sign of runnability.

Coated Paper Properties

The hydrocolloids had various effects on the optical and printing properties of the coated supercalendered paper. The type and amount of hydrocolloid added did not effect opacity and brightness (see Figure 12 and 13). It was noted that the hydrocolloid optical properties were lower than the blank. This possibly results from the long-chain polymers hindering the natural alignment of the clay platelets. This hindering of the natural alignment of clay platelets has been shown to lower the gloss values (30). Turning to Figure 14, an increase in the amounts of hydrocolloid in the coating does lower the gloss. This would confirm that the hydrocolloids do effect the natural alignment of the clay platelets.

The first printing property to look at is Figure 15 the Vandercook print gloss. As the level of hydrocolloid is increased so does the print gloss. The way in which this increase takes place is puzzeling. CMC 7M has the lowest print gloss at .3% and .6% but jumps to the highest at .9%. All the hydrocolloids increased the print gloss over the blank coating. This could possibly indicate that they all gave a closer pigment packing than did the blank. In order to determine which one of the hydrocolloid effects the packing of the pigment the most we must turn to another test. This test is the K & N ink holdout (see Figure 16). The K & N ink holdout gives some indication as to the openess of the coating. This openess could possibly be related to the packing of the pigment. The K & N ink holdout showed a decrease with an increase in the amount of hydrocolloid. As the hydrocolloid is increased the openess of the coating seems to decrease. This could mean that the pigment particals are becoming more packed as the hydrocolloid concentration is increased.

The last coated paper property to look at is the IGT pick. Figure 17 shows that as the level of hydrocolloids increases the IGT pick decreases. The blank coating gives the highest pick, therefore the hydrocolloids definitely have a negative effect on pick. In Figure 18 a plot of pick vs. water retention we see that negative relationship on pick again. It has been theorized that the higher water holding hydrocolloids gives a more even distribution of the adhesive in the coating and therefore a higher pick. Kegin MV did have the highest pick and water retention values of the hydrocolloids tested. HEC 250M had the lowest water retention value but the second highest pick. Therefore other variable(s) are involved and further investigation is needed.

CONCLUSIONS

Hydrocolloids give desired rheological and water holding properties to pigmented paper coatings. Hydrocolloids produce not only pseudoplastic coatings but under shear a pseudoplastic-thixotropic flow. Therefore hydrocolloids give the flow properties suitable for the blade coater. Kelgin MV had the highest leveling index which indicates good flow properties under the pressure of the blade. Kelgin MV was found hardest to disperse and the hardest to run on the coater due to its higher viscosity. HEC 250M was the easiest to disperse. All coatings had good runnability. The concentration of hydrocolloid is an important factor in water retention values. It was also theorized that the carboxyl groups are very important to water binding. Viscosity was found not to be a factor in water retention directly. Once penetration starts it is theorized that the driving force of capillary action is the same for each hydrocolloid.

Hydrocolloids were found to lower opacity, brightness and gloss. The amounts of hydrocolloid added did not effect opacity and brightness but did effect gloss. Increasing the amount of hydrocolloid lowered the gloss. It was theorized that hydrocolloids increased the packing of the pigment particles as compared to the blank. This was shown in the Vandercook print gloss. The K & N ink holdout indicated that as hydrocolloid was increased the openess of the coating decreased. When increasing the amount of hydrocolloid, which increases water holding, the pick decreased. Therefore water retention was shown to have a negative effect on IGT Pick.

IDEALIZED UNIT STRUCTURE OF CELLULOSE GUM, WITH A DS. OF 1.0

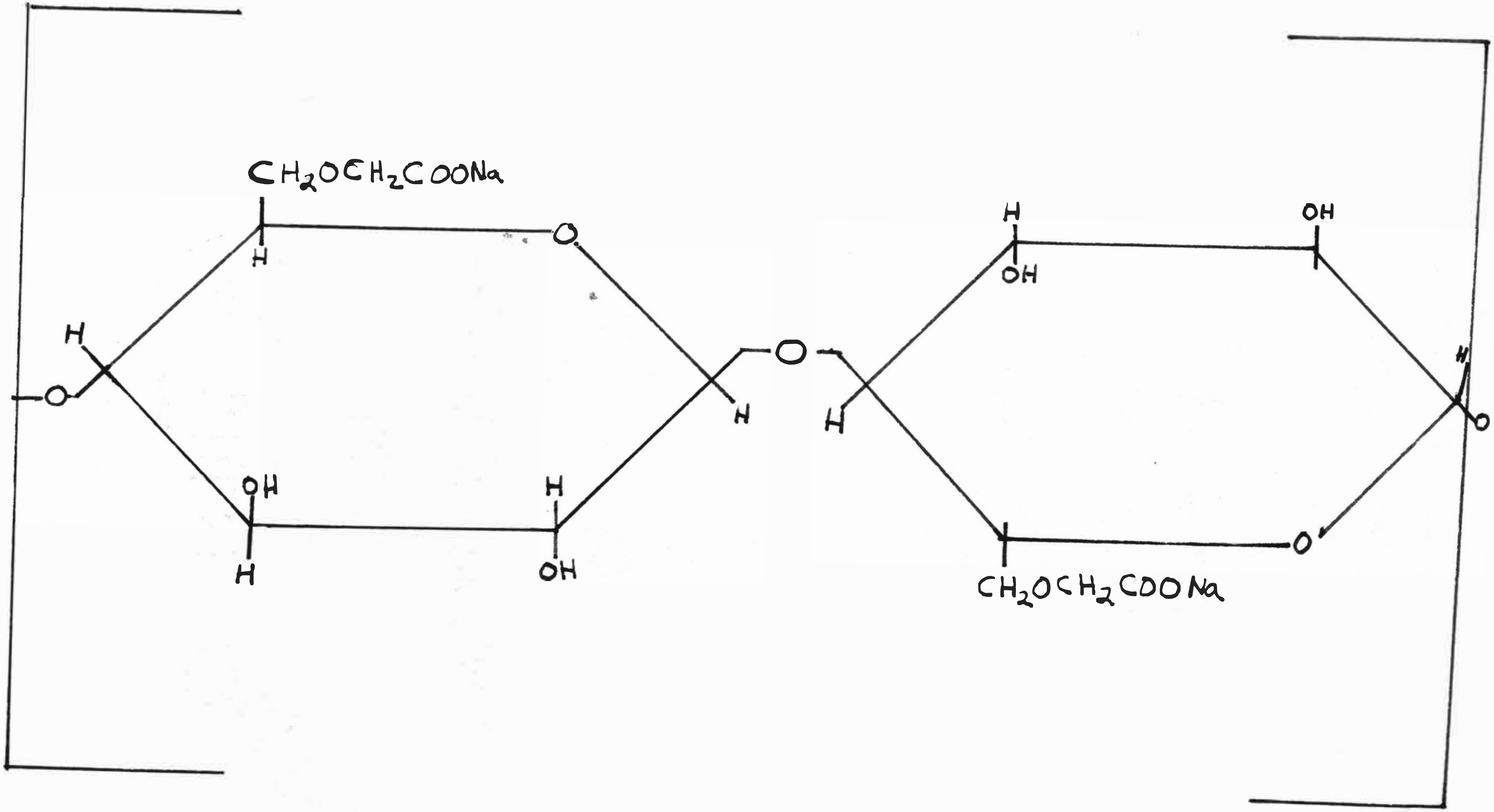
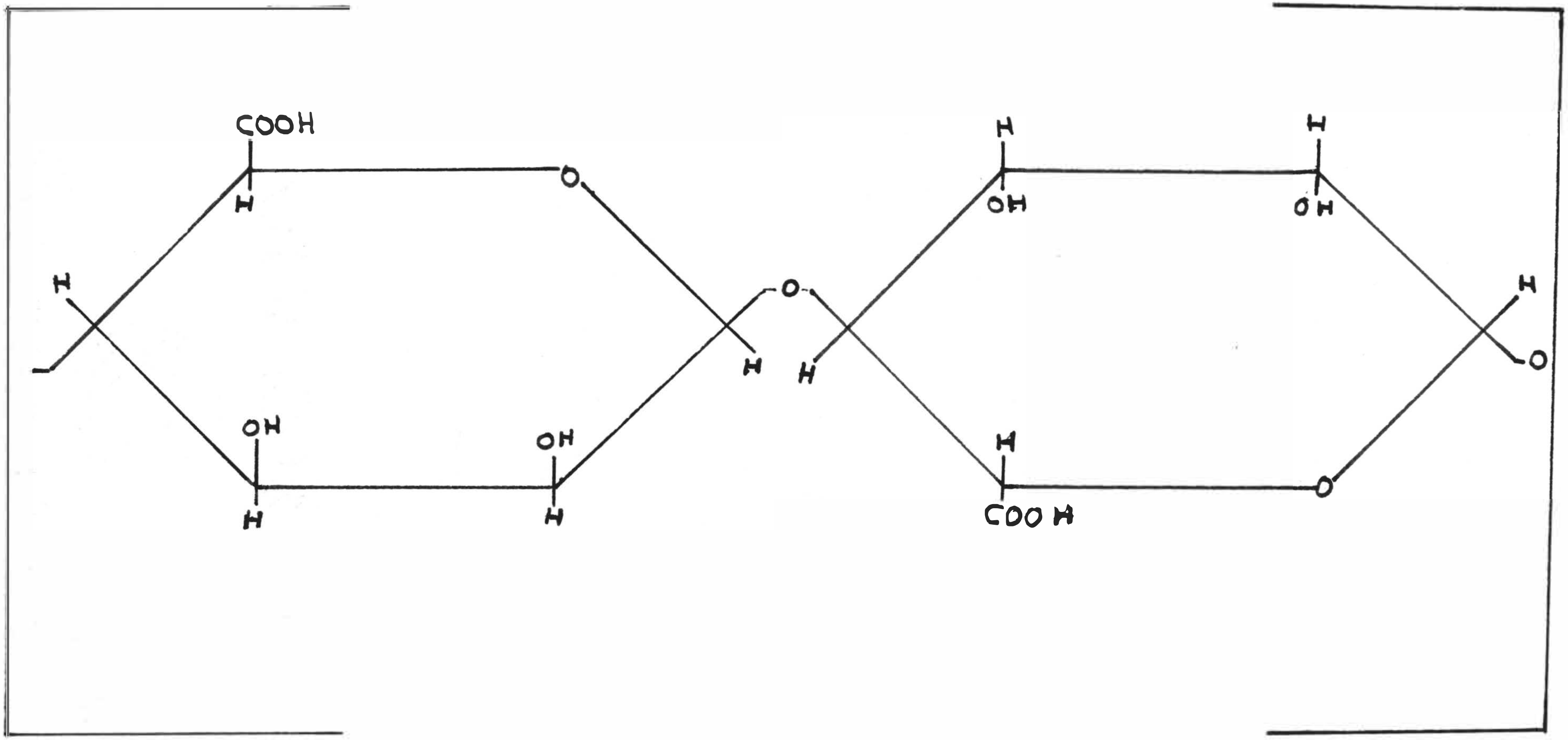


FIGURE (1)

ALGINIC ACID



FIGURE(2)

IDEALIZED STRUCTURE OF HEC 250

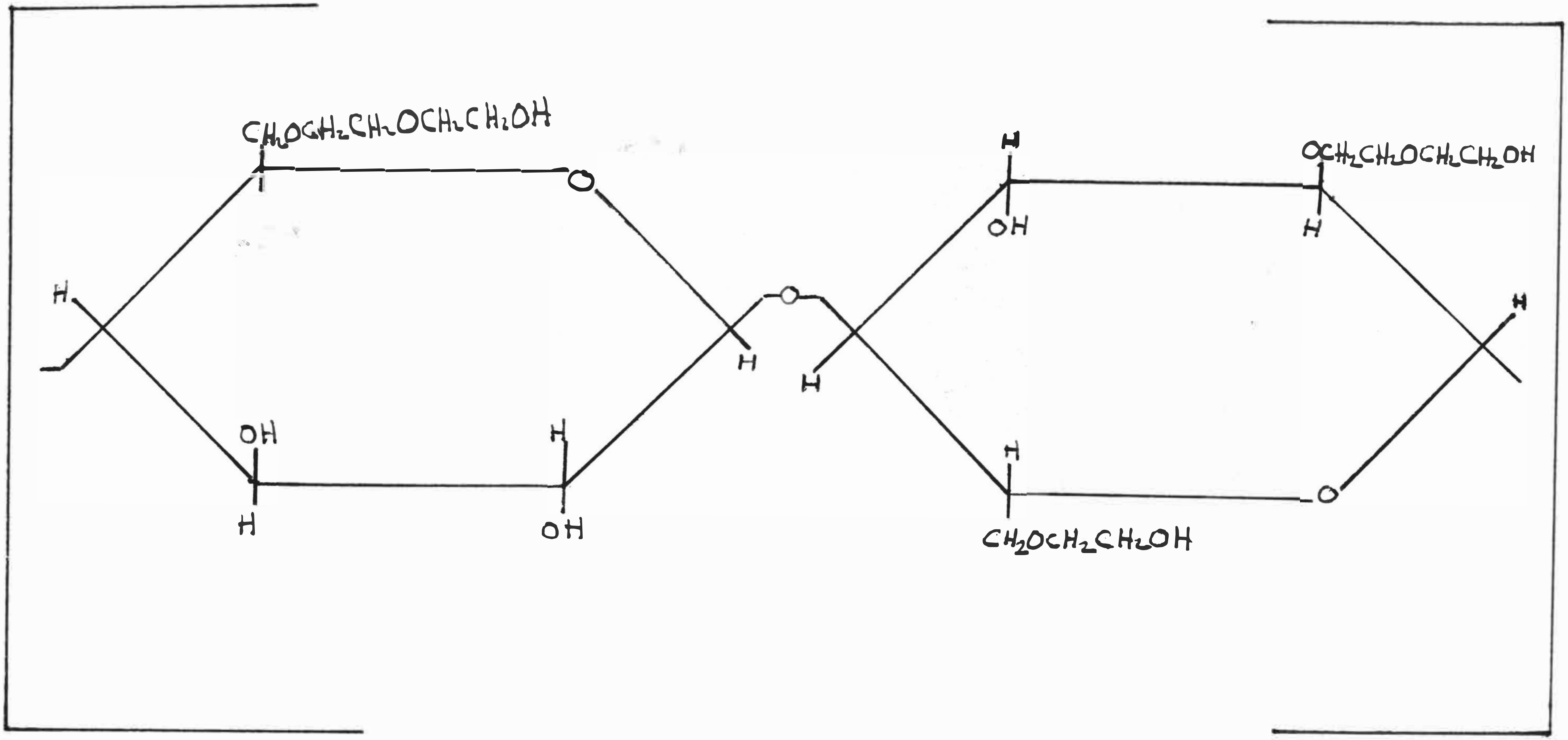
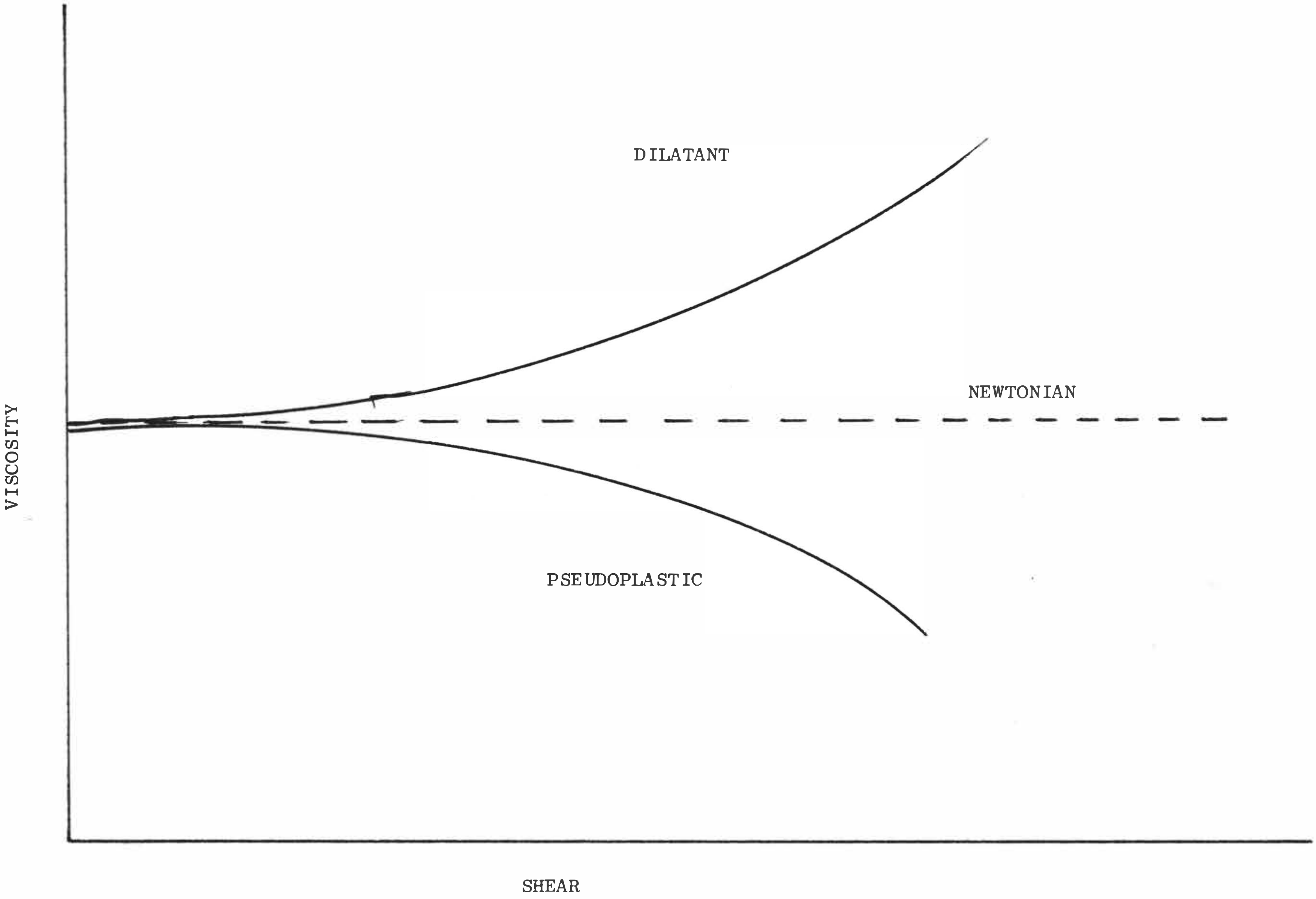
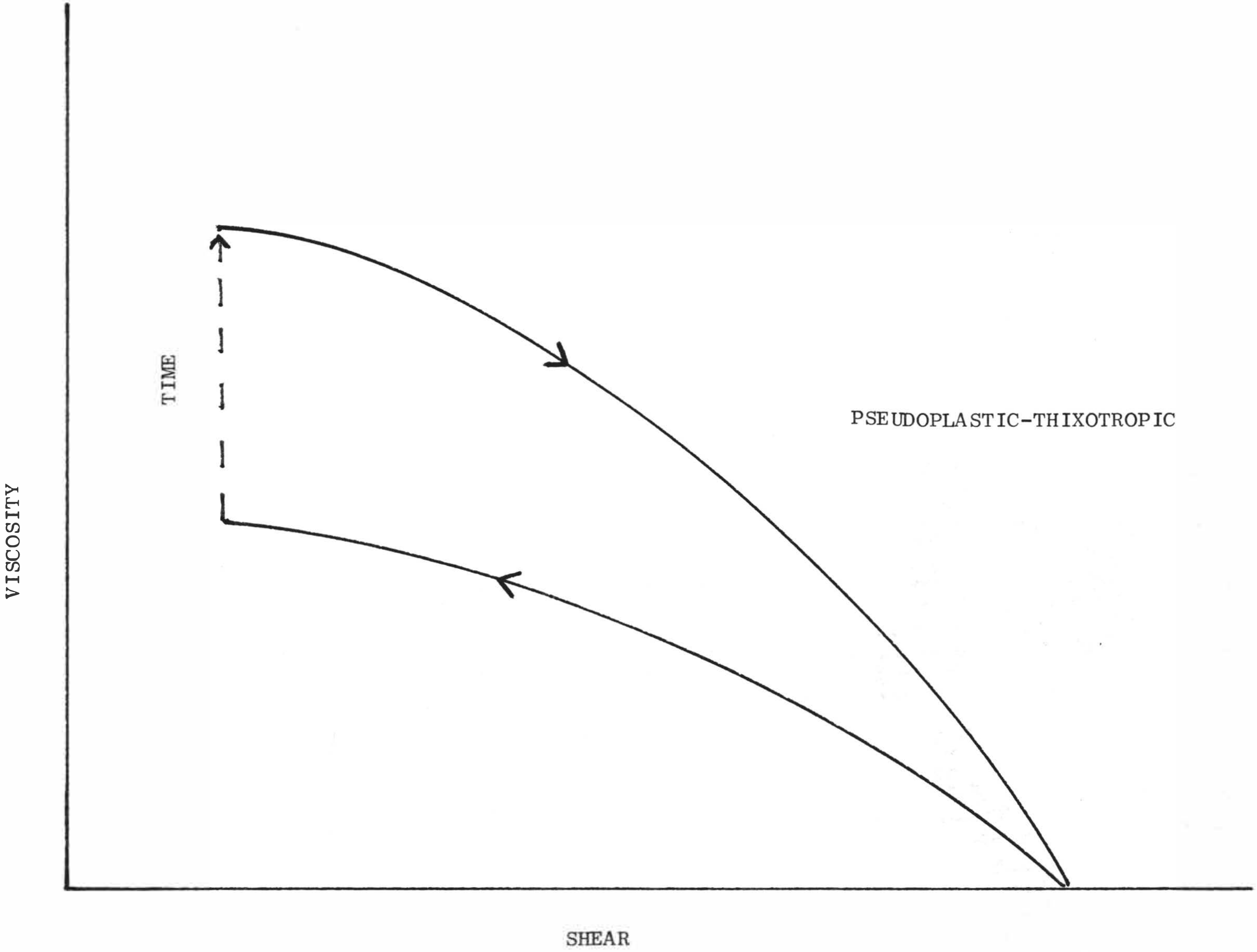


FIGURE (3)



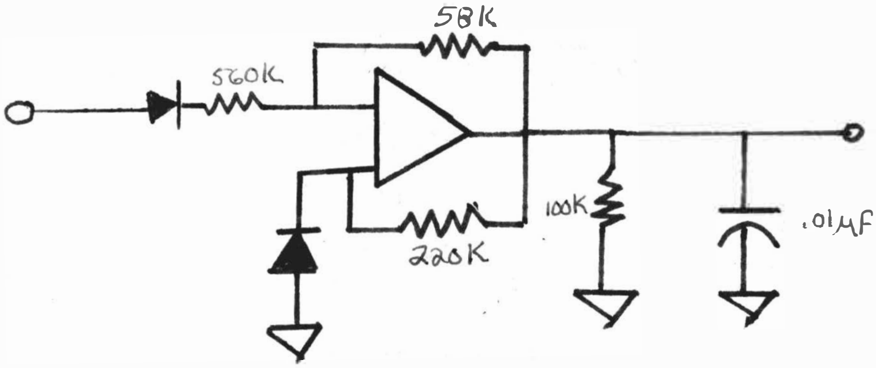
FIGURE(4)



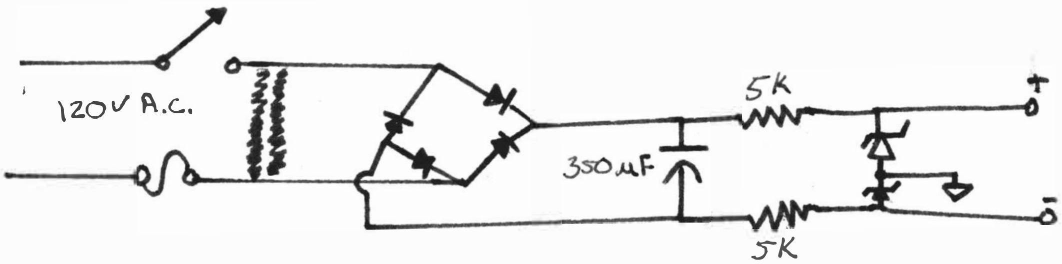
FIGURE(5)

FIGURE(6)

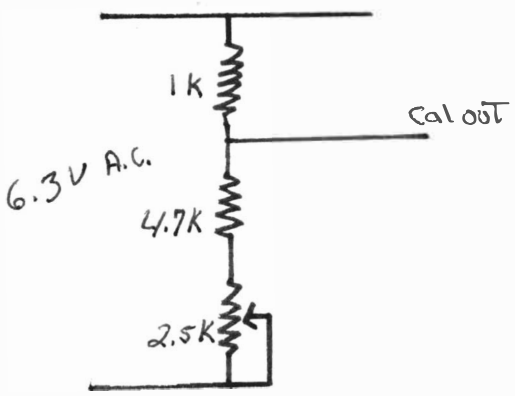
BASIC DESIGN



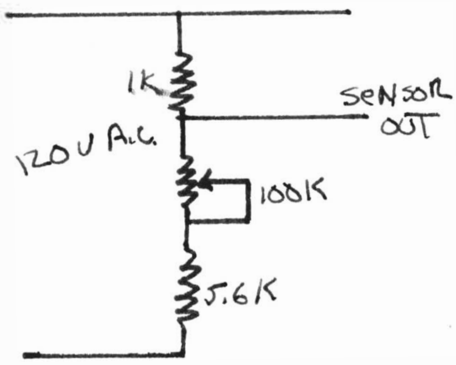
POWER SUPPLY



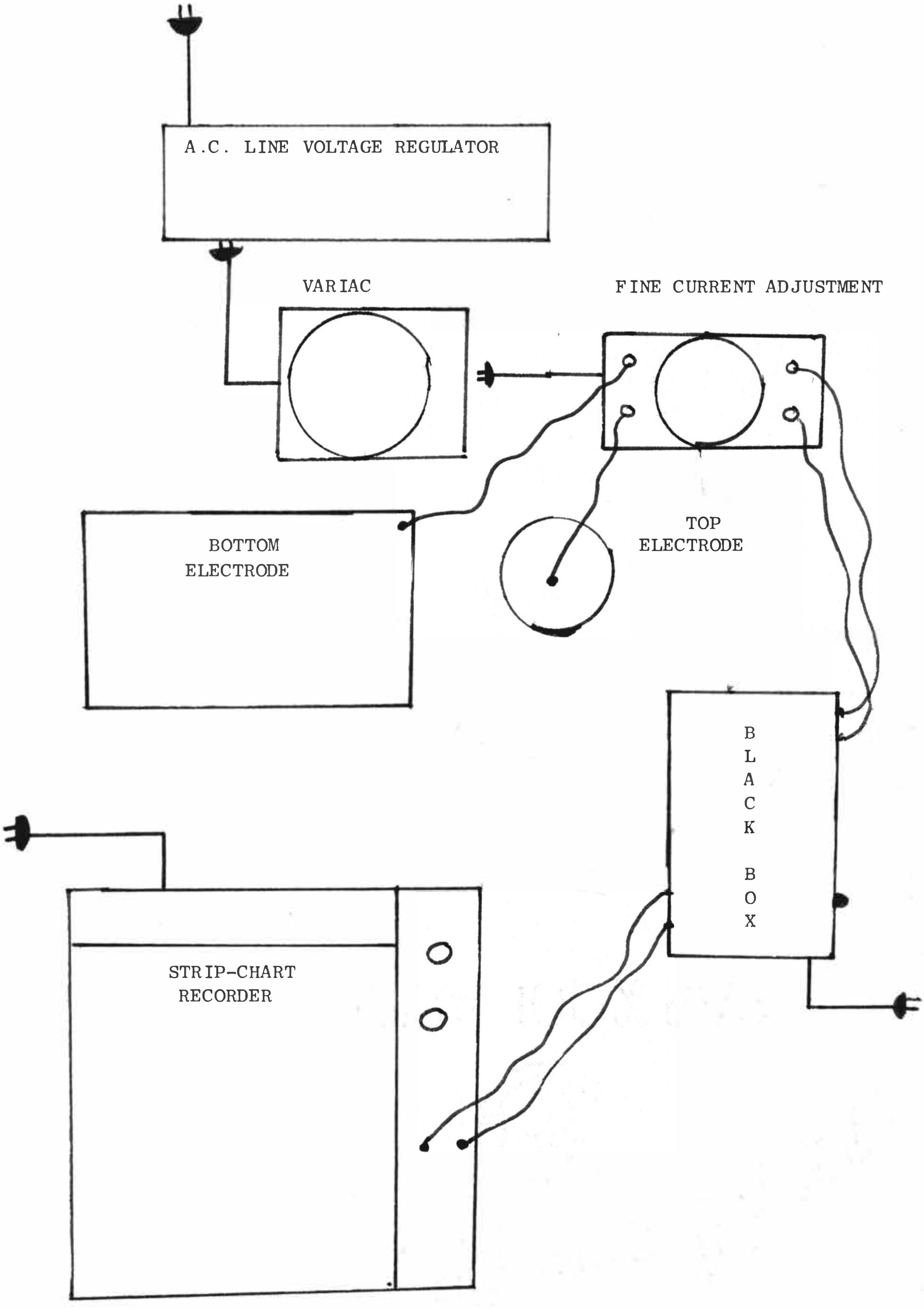
CALIBRATION CIRCUIT



SENSOR CIRCUIT

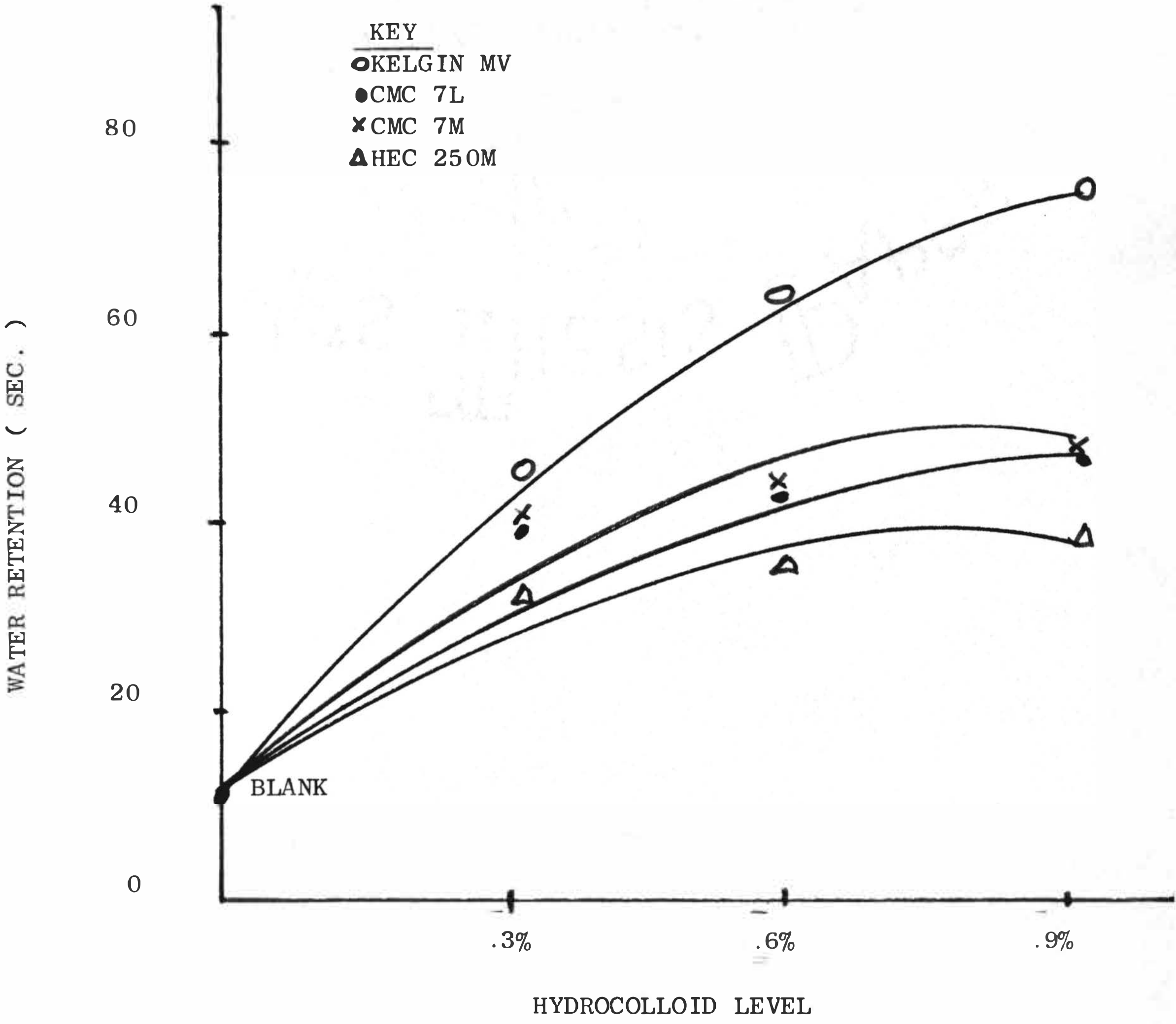


FIGURE(7)


A.C. LINE VOLTAGE REGULATOR
VARIAC
FINE CURRENT ADJUSTMENT
BOTTOM ELECTRODE
TOP ELECTRODE
BLACK BOX
STRIP-CHART RECORDER

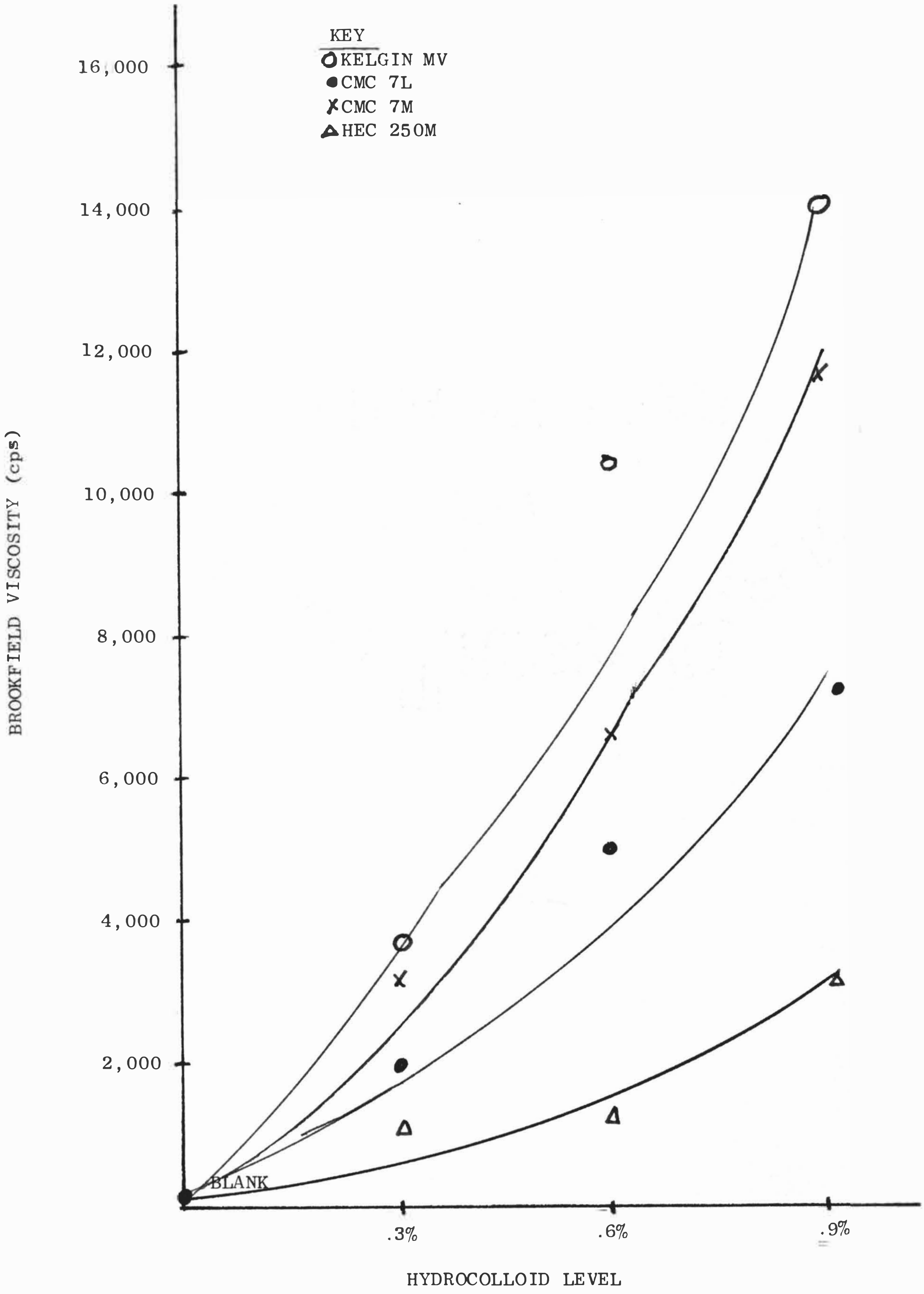
FIGURE(8)

WATER RETENTION VS LEVEL OF HYDROCOLLOID



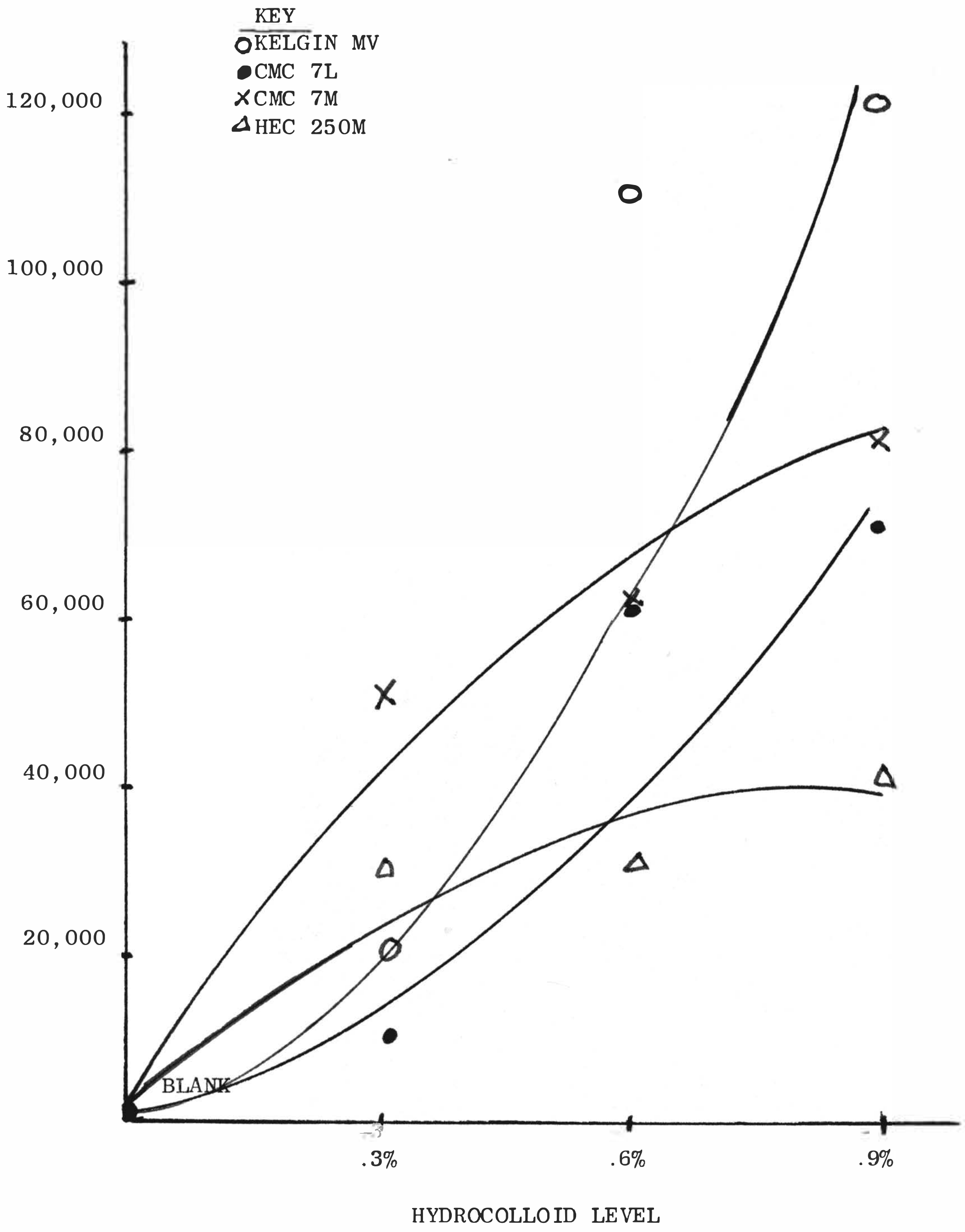
FIGURE(9)

BROOKFIELD VISCOSITY VS LEVEL OF HYDROCOLLOID
(at 10 rpm)



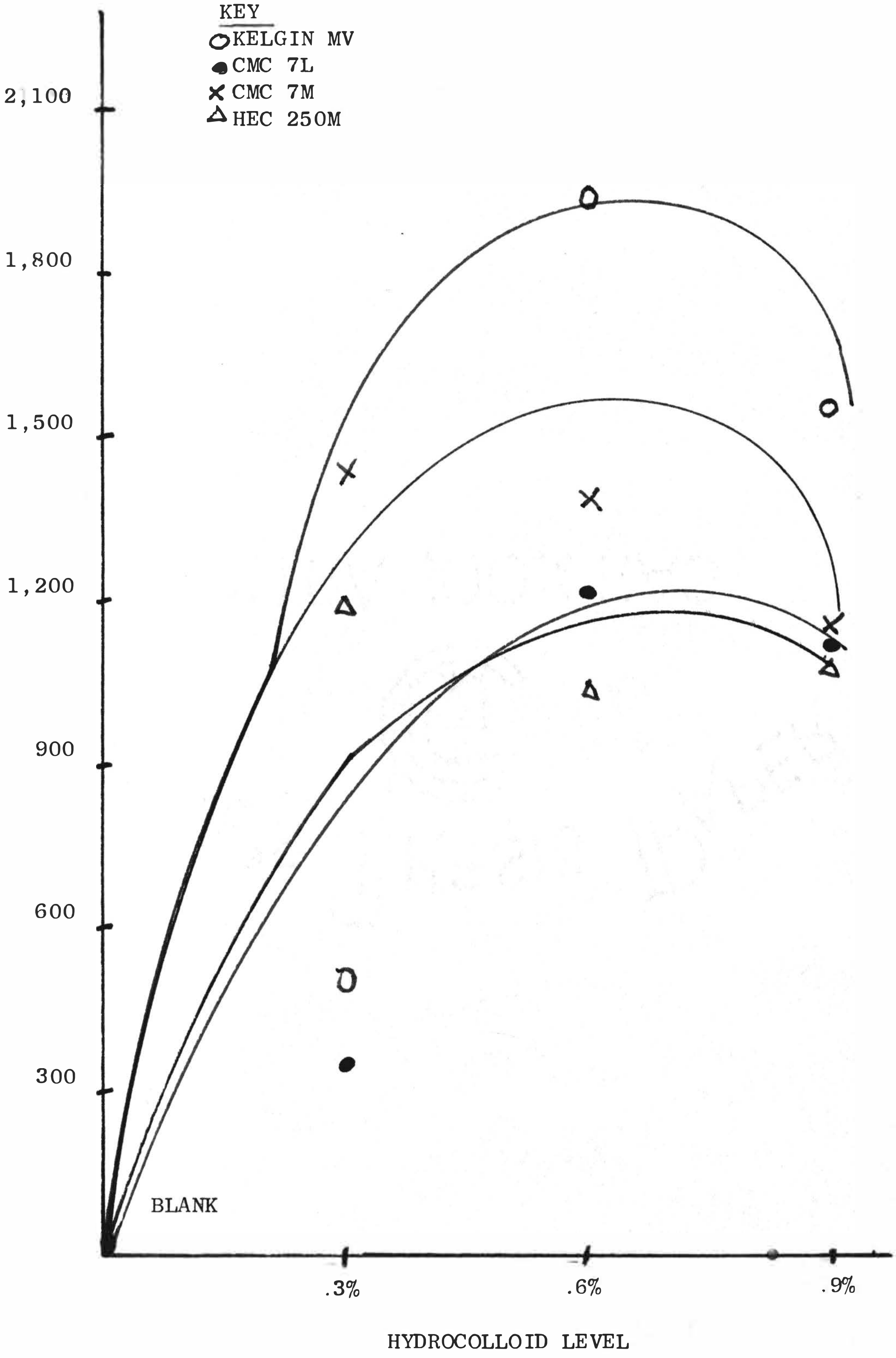
FIGURE(10)

THIXOTROPIC INDEX VS LEVEL OF HYDROCOLLOID



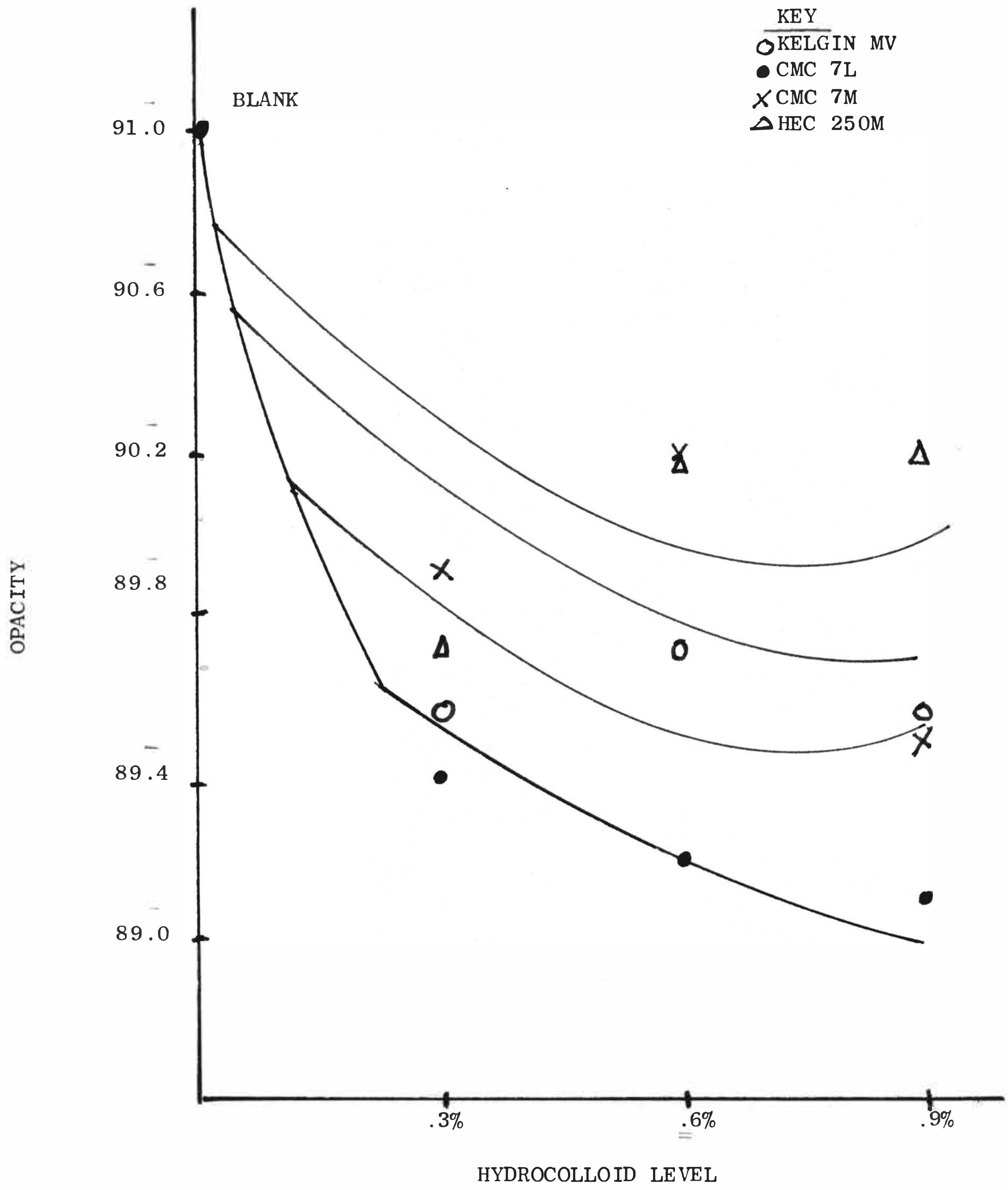
FIGURE(11)

LEVELING INDEX VS LEVEL OF HYDROCOLLOID



FIGURE(12)

OPACITY VS LEVEL OF HYDROCOLLOID



FIGURE(13)

BRIGHTNESS VS LEVEL OF HYDROCOLLOID

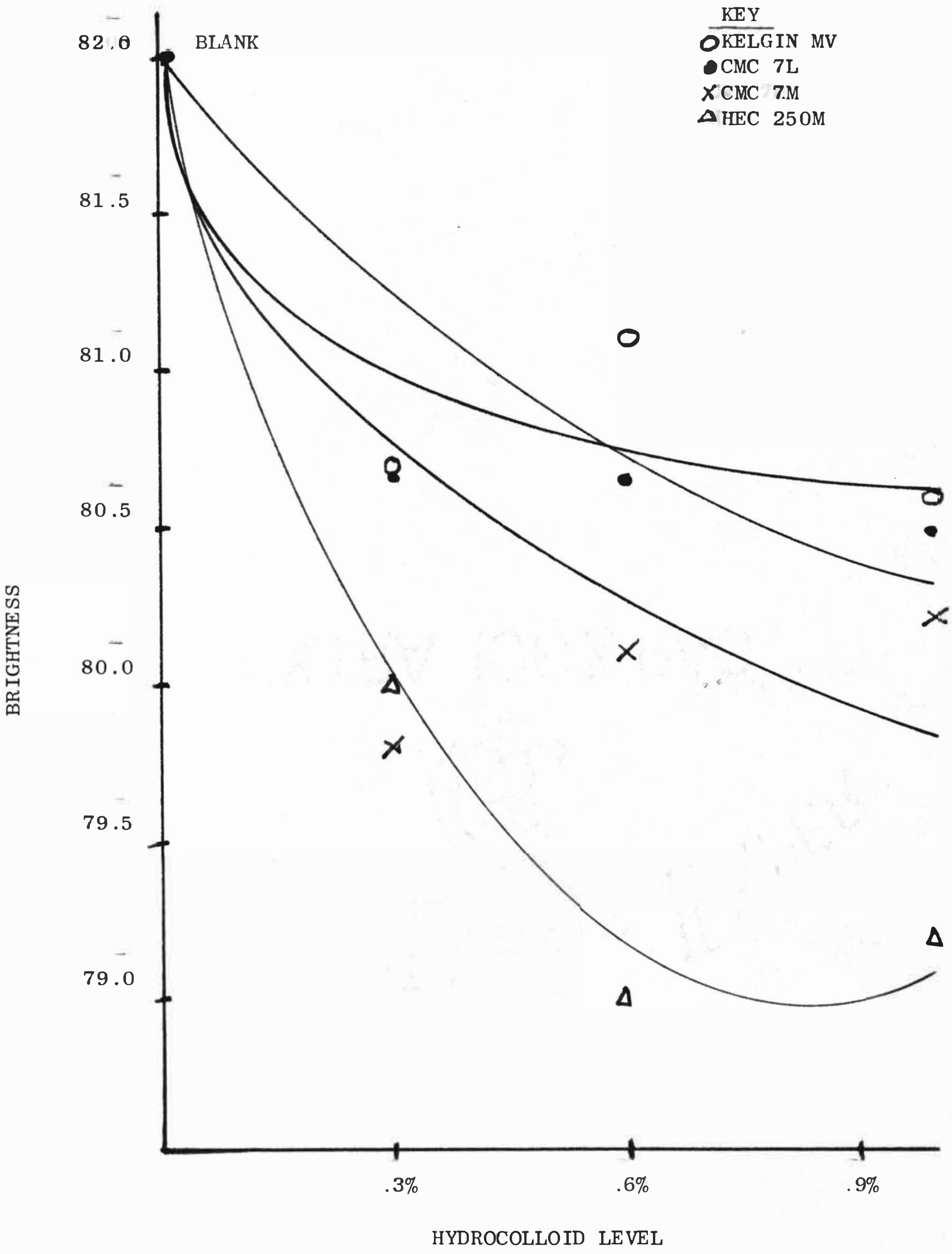
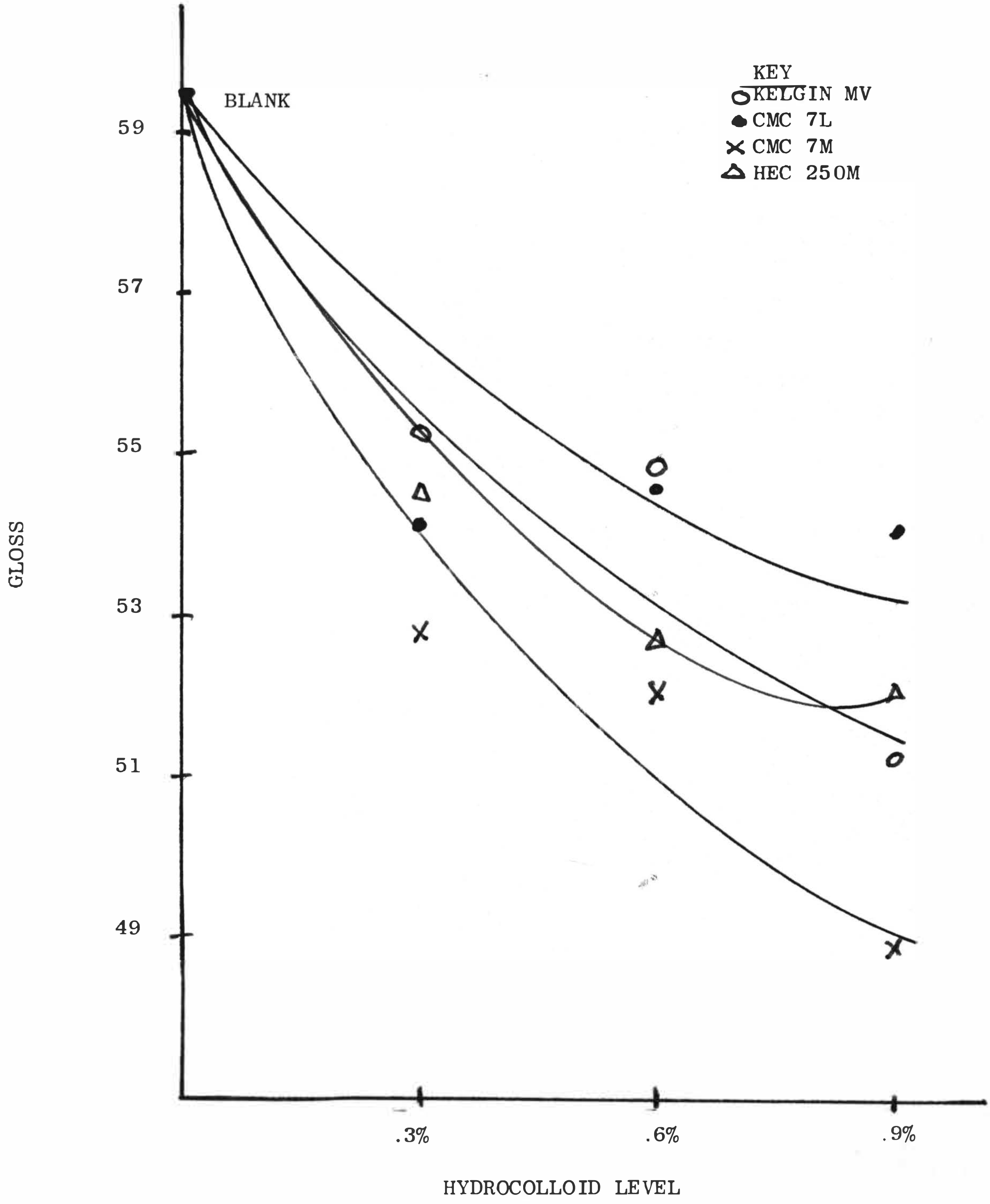


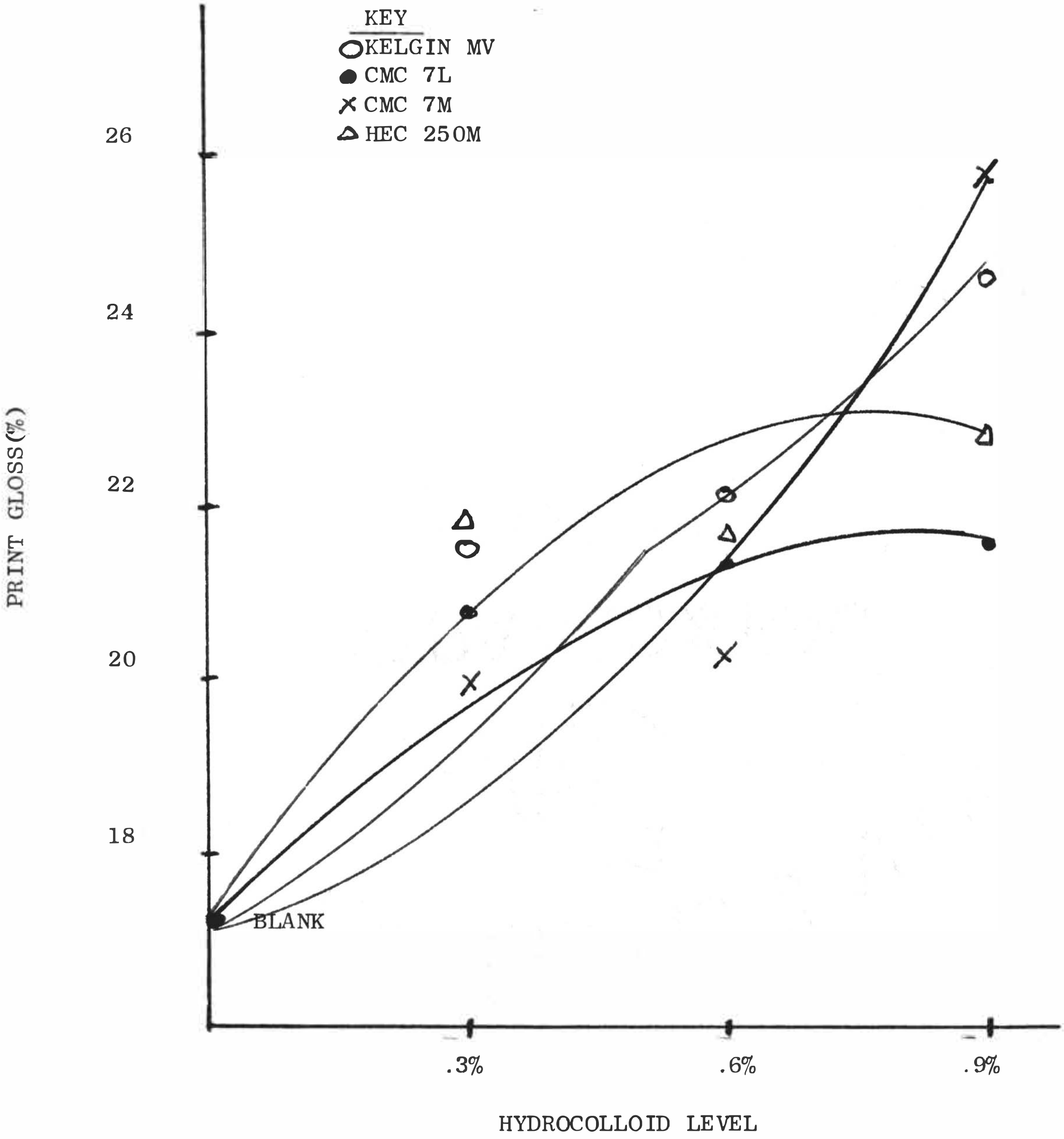
FIGURE (14)

GLOSS VS LEVEL OF HYDROCOLLOID



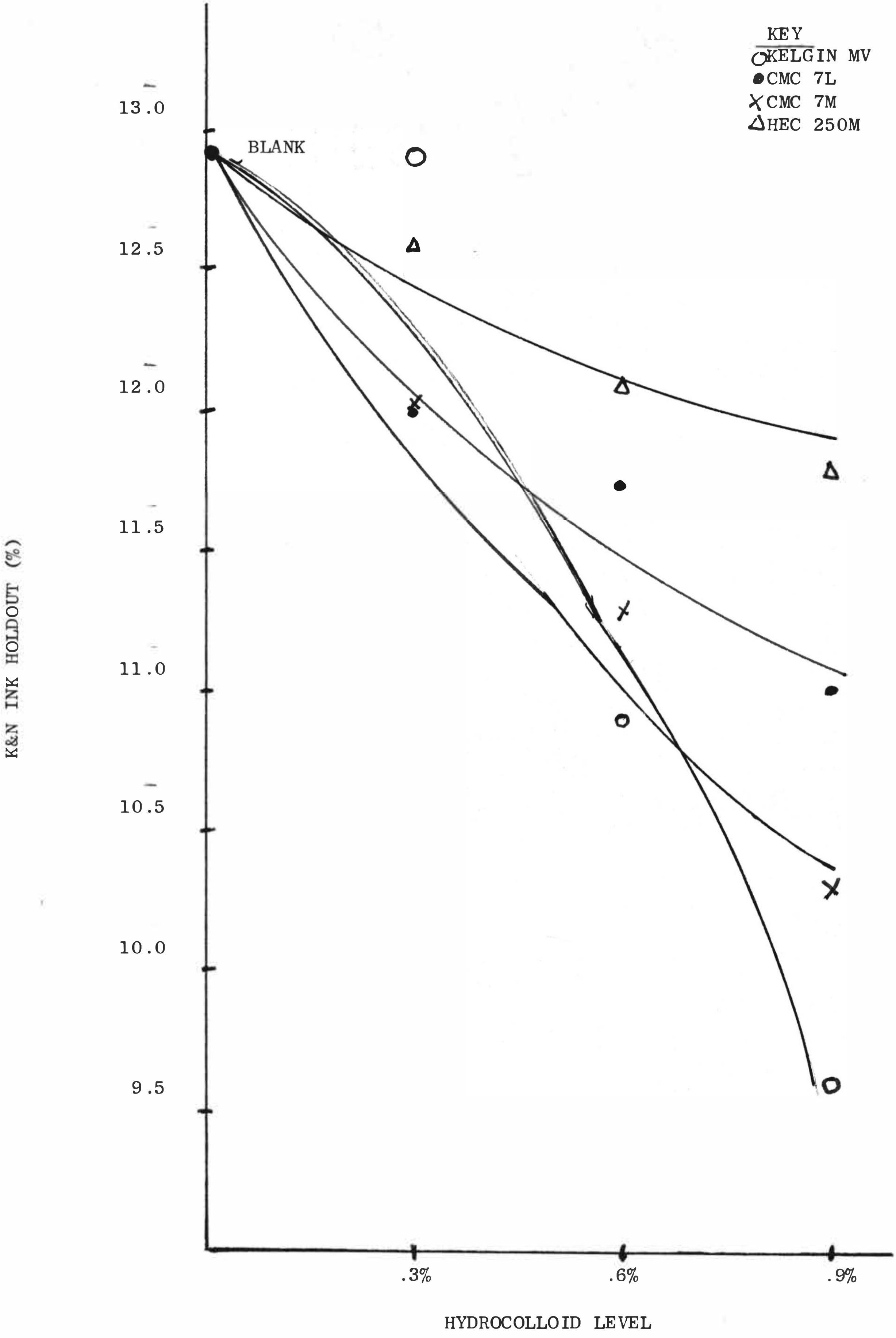
FIGURE(15)

PRINT GLOSS VS LEVEL OF HYDROCOLOID



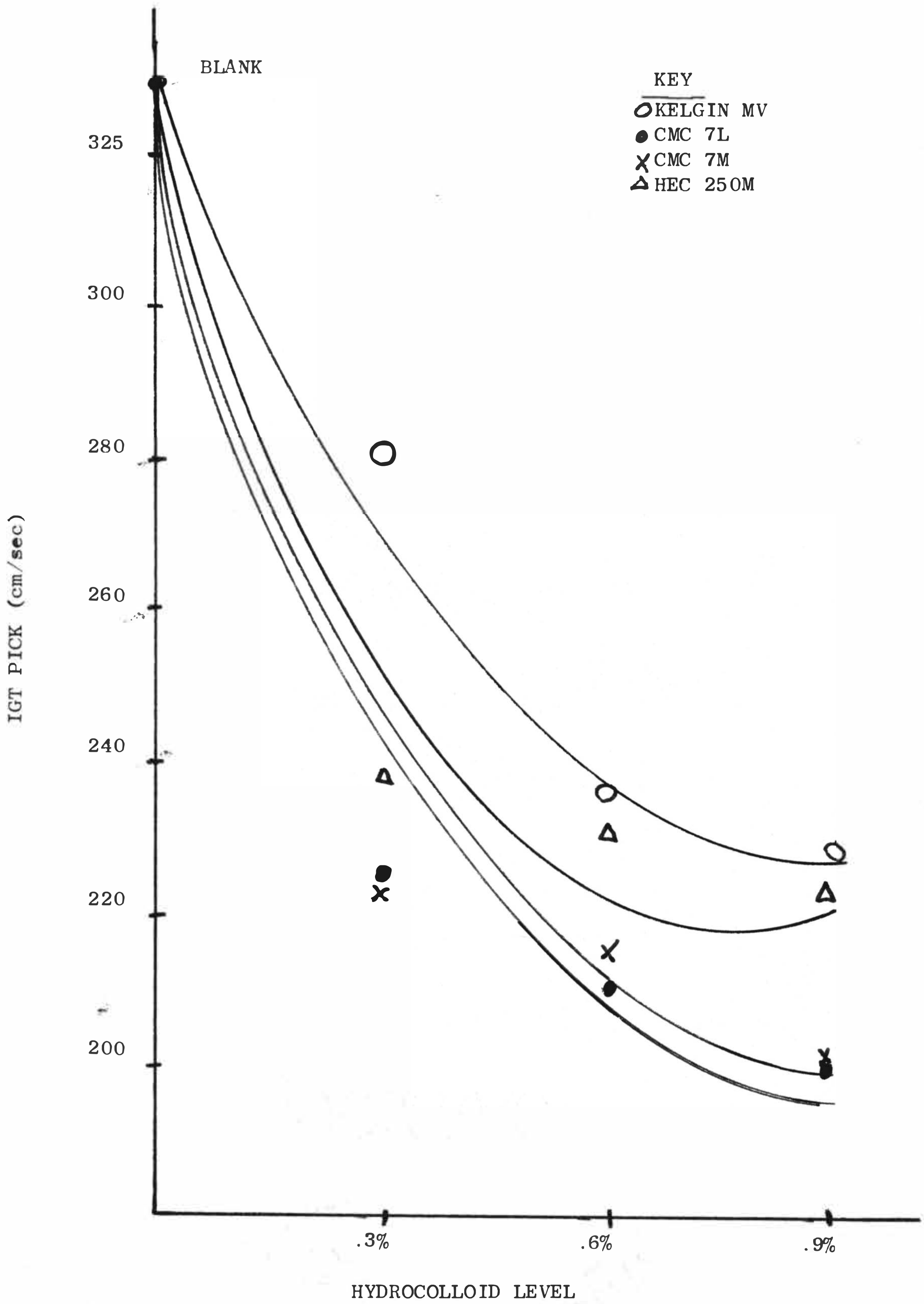
FIGURE(16)

K&N INK HOLDOUT VS LEVEL OF HYDROCOLLOID



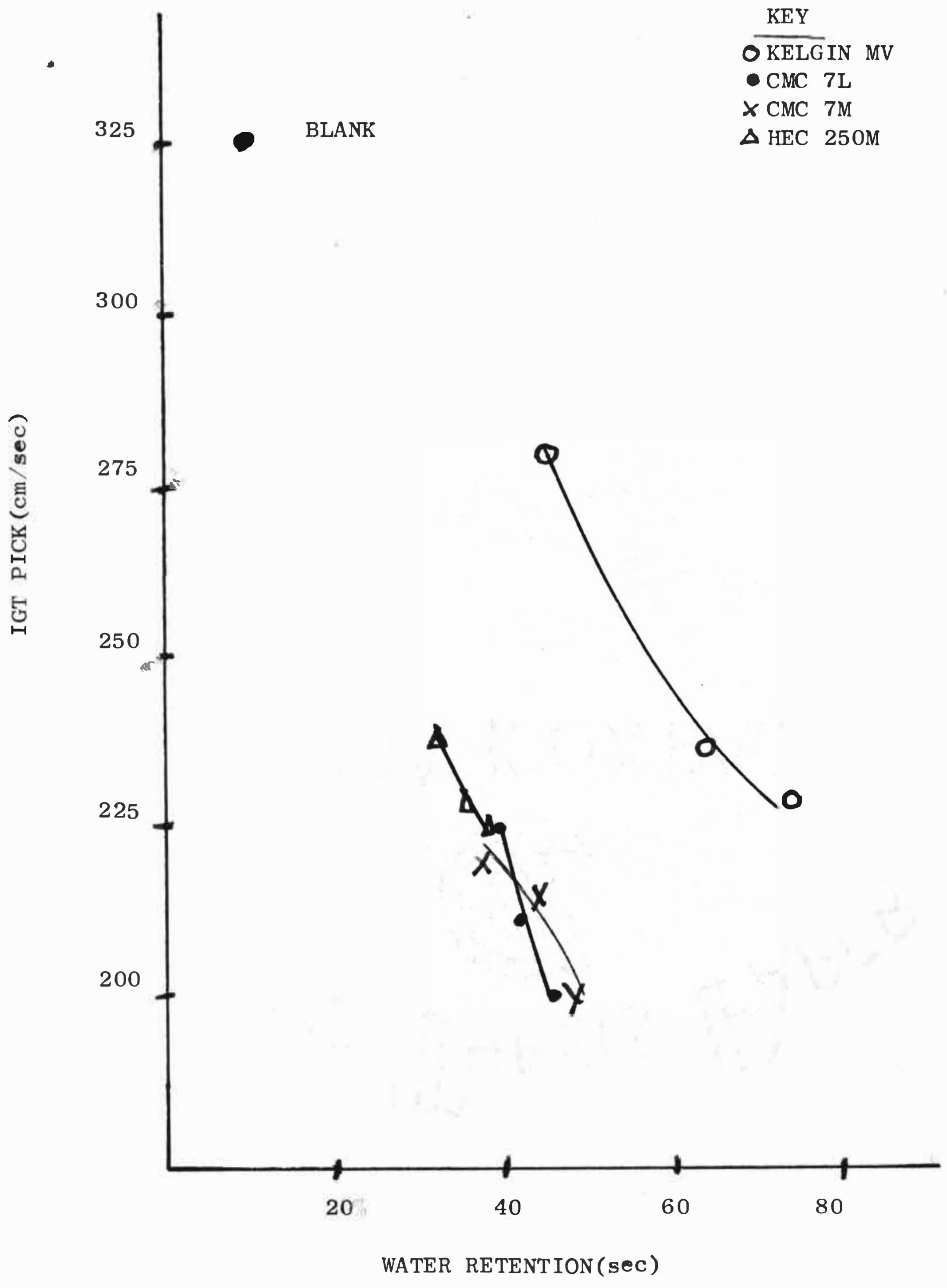
FIGURE(17)

IGT PICK VS LEVEL OF HYDROCOLLOID



FIGURE(18)

IGT PICK VS WATER RETENTION



APPENDIXES ONE

BROOKFIELD VISCOSITY DATA

Coating Number 1

BLANK

Brookfield Viscosity

Spindle #1		Reading	Factor	CPS
	10	10	10	100
	20	14	5	70
	50	31.5	2	63
	100	65	1	65

Coating Number 2

.3% CMC

Brookfield Viscosity

Spindle #3		Reading	Factor	CPS
	10	32.5	100	3,250
	20	37	50	1,850
	50	47	20	940
	100	58	10	580

Coating Number 3

.6% CMC

Brookfield Viscosity

Spindle #4		Reading	Factor	CPS
	10	33	200	6,600
	20	37	100	3,700
	50	48	40	1,920
	100	50	20	1,000

Coating Number 4

.9% CMC

Brookfield Viscosity

Spindle #5		Reading	Factor	CPS
	10	29	400	11,600
	20	34.5	200	6,900
	50	42	80	3,360
	100	52.5	40	2,100

Coating Number 5

.3% HEC

Brookfield Viscosity

Spindle #2	Reading	Factor	CPS
10	27	40	1,080
20	34	20	680
50	46	8	368
100	62	4	248

Coating Number 6

.6% HEC

Brookfield Viscosity

Spindle #2	Reading	Factor	CPS
10	29	40	1,160
20	35	20	700
50	46	8	368
100	62	4	248

Coating Number 7

.9% HEC

Brookfield Viscosity

Spindle #3	Reading	Factor	CPS
10	33	100	3,300
20	38	50	1,900
50	48.5	20	970
100	57.5	10	575

Coating Number 8

.3% Kelgin MV

Brookfield Viscosity

Spindle #3	Reading	Factor	CPS
10	37	100	3,700
20	44	50	2,200
50	54	20	1,080
100	66	10	660

Coating Number 9

.6% Kelgin MV

Brookfield Viscosity

Spindle #5	Reading	Factor	CPS
10	26	400	10,400
20	31	200	6,200
50	40	80	3,200
100	50	40	2,000

Coating Number 10

.9% Kelgin MV

Brookfield Viscosity

Spindle #5	Reading	Factor	CPS
10	35	400	14,000
20	43	200	8,600
50	55.5	80	4,400
100	60	40	2,400

Coating Number 11

.3% CMC 7L

Brookfield Viscosity

Spindle #3		Reading	Factor	CPS
	10	20	100	2,000
	20	23	50	1,150
	50	29.5	20	590
	100	37.5	10	375

Coating Number 12

.6% CMC

Brookfield Viscosity

Spindle #4		Reading	Factor	CPS
	10	25	200	5,000
	20	28	100	2,800
	50	35	40	1,400
	100	42.5	20	850

Coating Number 13

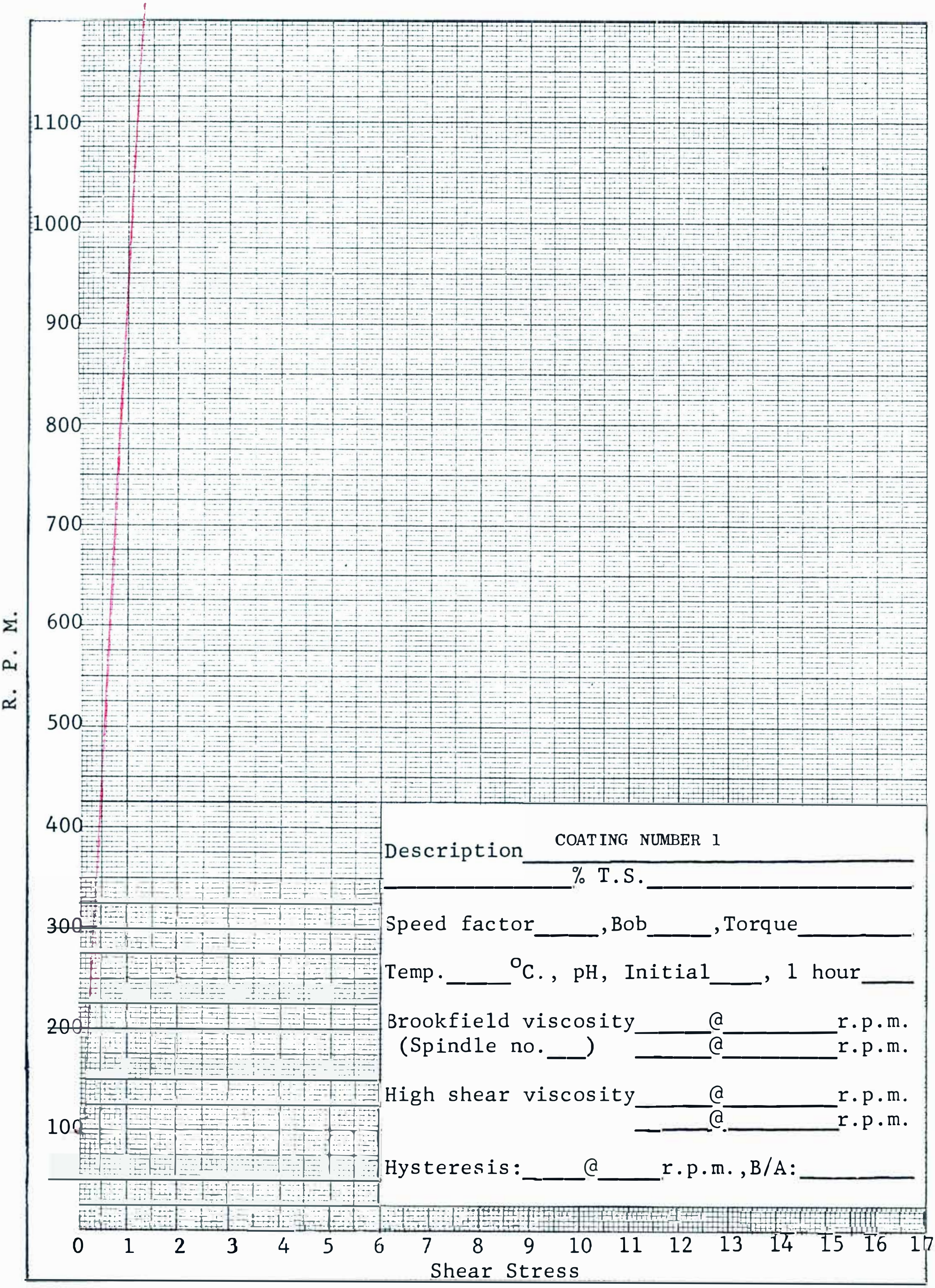
.9% CMC

Brookfield Viscosity

Spindle #4		Reading	Factor	CPS
	10	36	200	7,200
	20	40.5	100	4,050
	50	49	40	1,960
	100	63	20	1,260

APPENDIXES TWO

HERCULES HIGH SHEAR RHEOGRAMS



Description COATING NUMBER 1

_______________% T.S.______________________

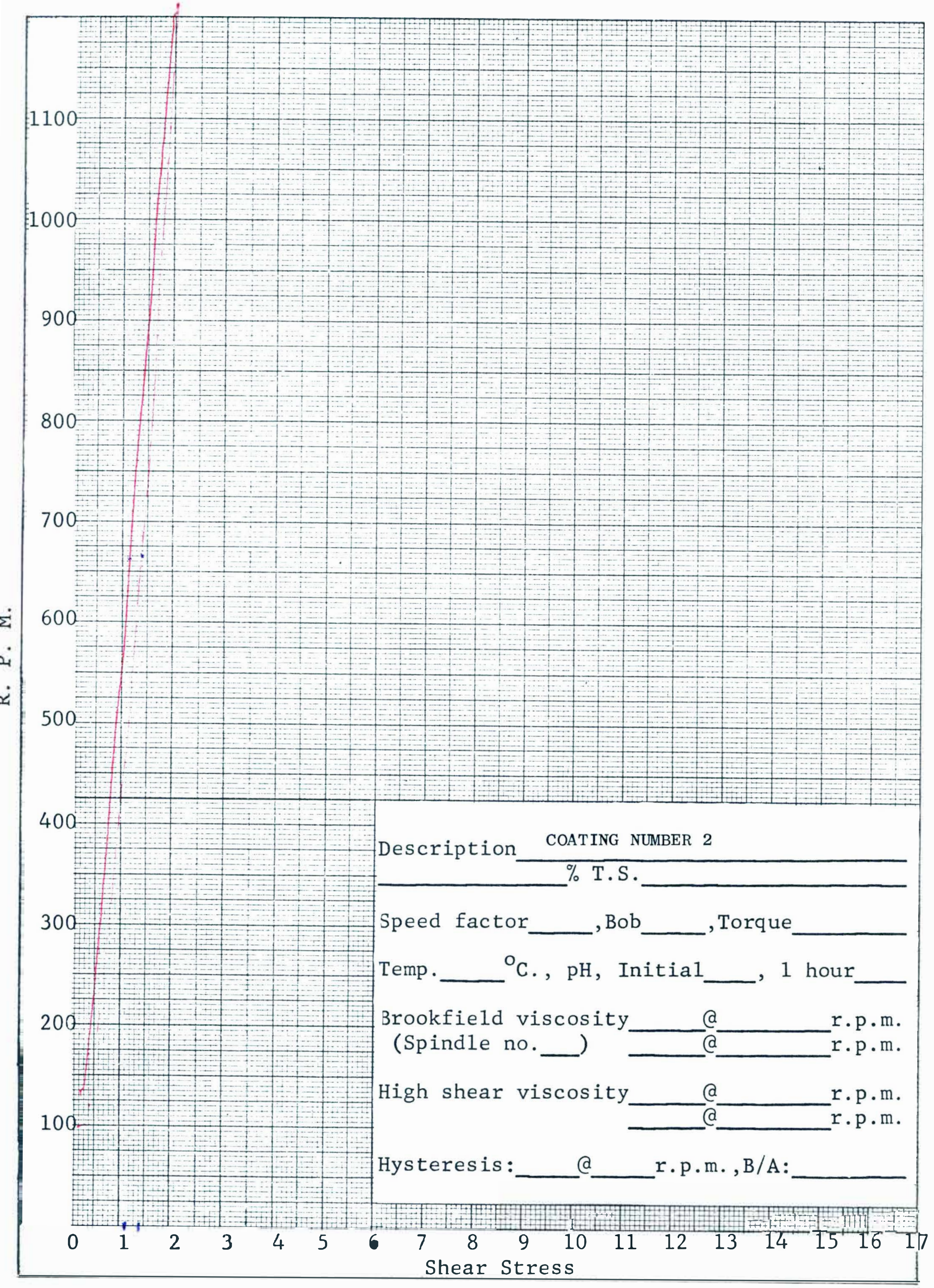
Speed factor_____,Bob_____,Torque_________

Temp._____°C., pH, Initial____, 1 hour____

Brookfield viscosity_____@_________r.p.m.
(Spindle no.___) _____@_________r.p.m.

High shear viscosity_____@_________r.p.m.
_____@_________r.p.m.

Hysteresis:_____@_____r.p.m.,B/A:_________



Description COATING NUMBER 2

______________% T.S.____________

Speed factor_____,Bob_____,Torque_________

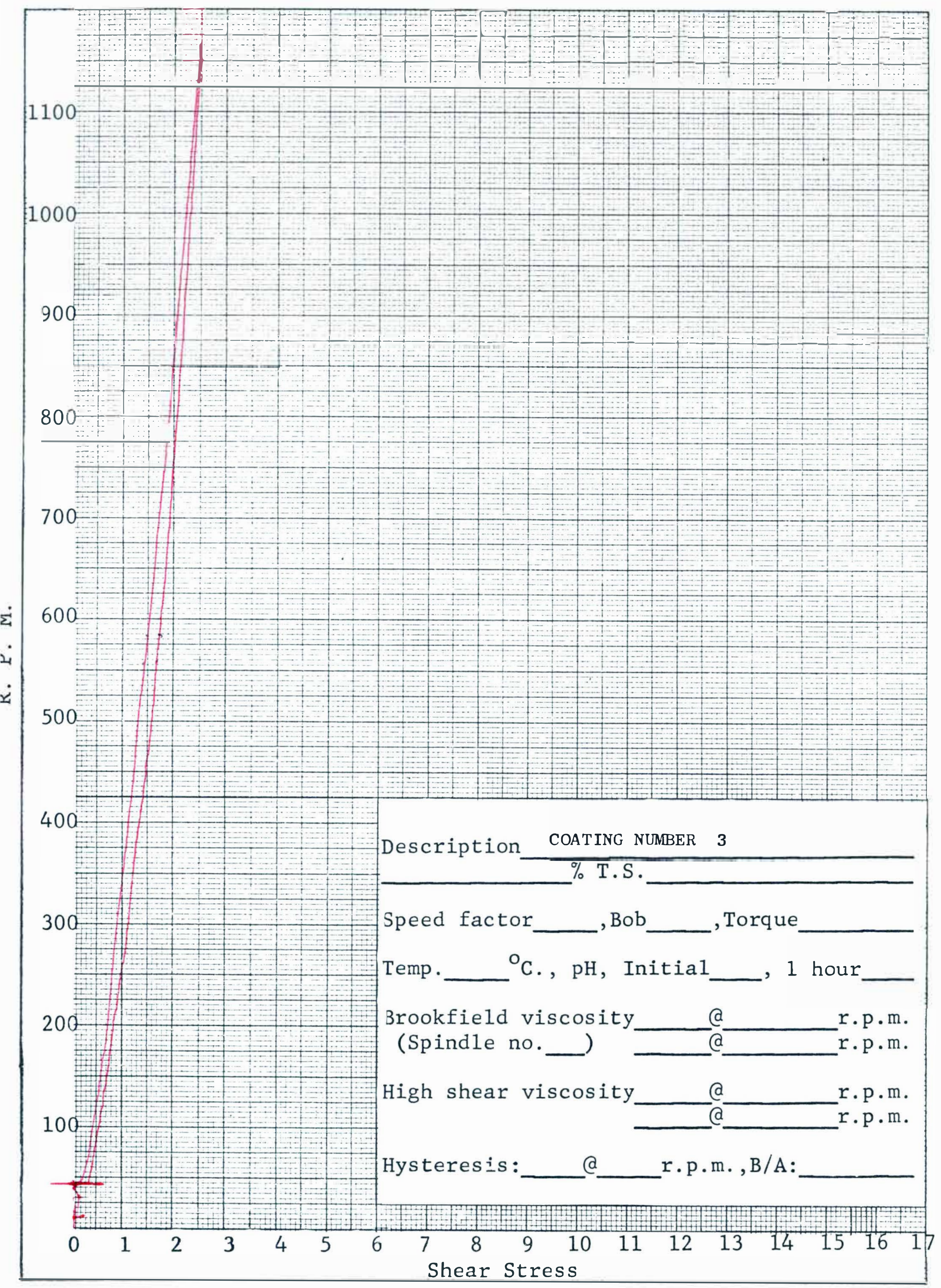
Temp._____°C., pH, Initial____, 1 hour____

Brookfield viscosity______@_________r.p.m.
(Spindle no.___) ______@_________r.p.m.

High shear viscosity______@_________r.p.m.
______@_________r.p.m.

Hysteresis:_____@_____r.p.m.,B/A:_________

2



Description COATING NUMBER 3

_______________ % T.S. _______________

Speed factor_____,Bob_____,Torque__________

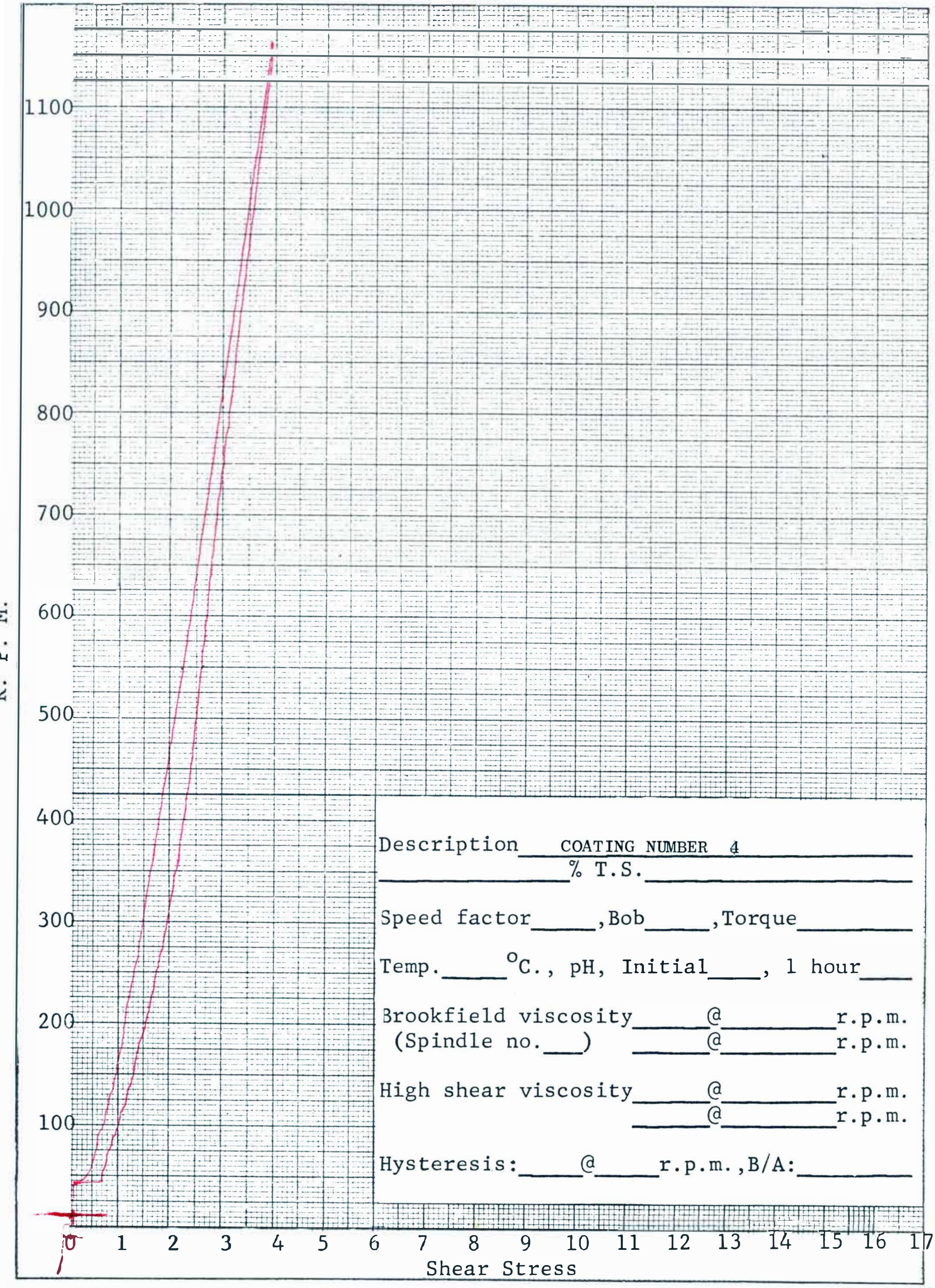
Temp._____°C., pH, Initial____, 1 hour____

Brookfield viscosity______@_________r.p.m.
(Spindle no.___) ______@_________r.p.m.

High shear viscosity______@_________r.p.m.
______@_________r.p.m.

Hysteresis:_____@_____r.p.m.,B/A:__________

3



Description___COATING NUMBER 4__________

____________% T.S.__________________

Speed factor_____,Bob_____,Torque_________

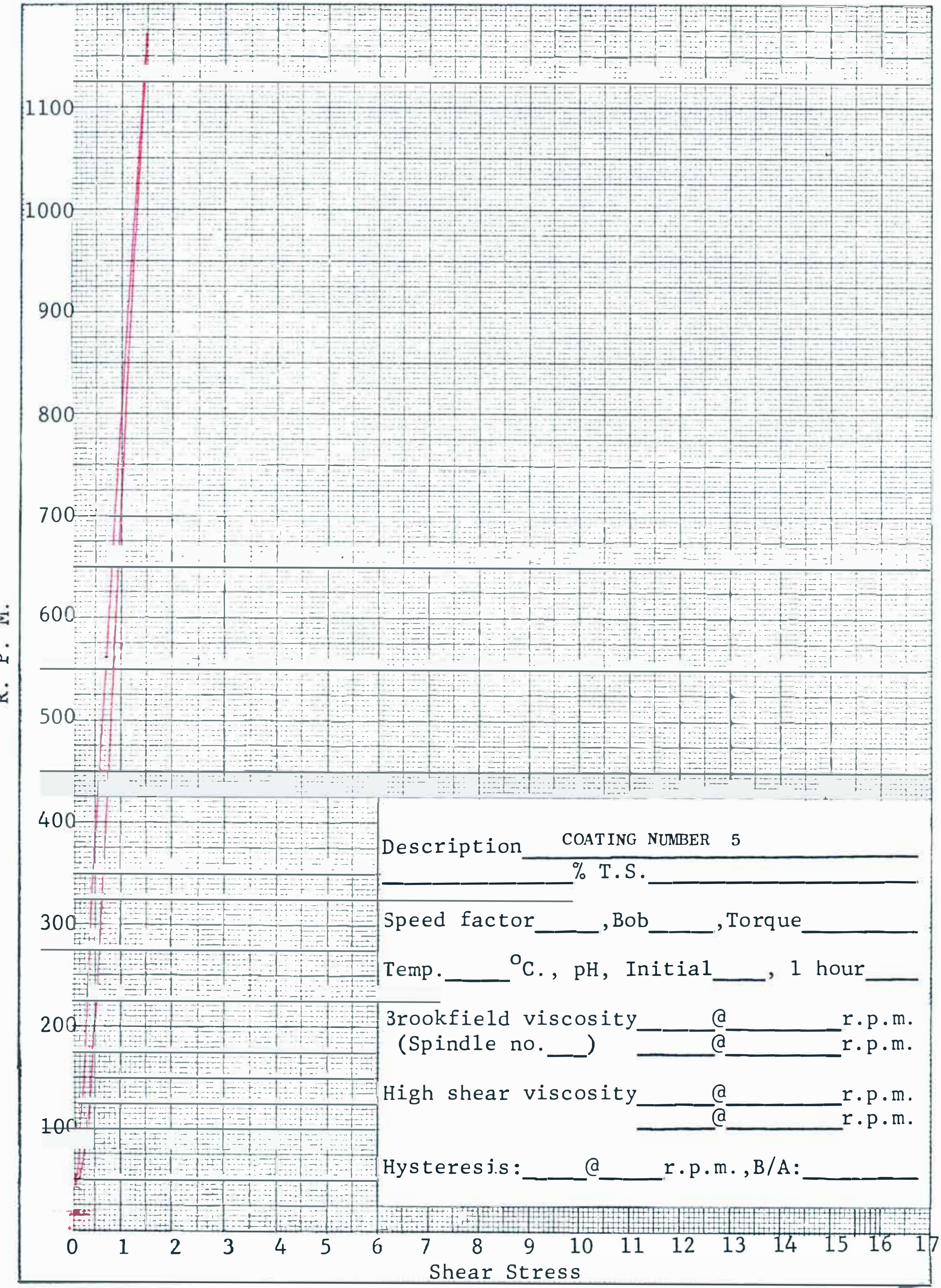
Temp._____°C., pH, Initial____, 1 hour____

Brookfield viscosity_____@_________r.p.m.
(Spindle no.___) ______@_________r.p.m.

High shear viscosity_____@_________r.p.m.
______@_________r.p.m.

Hysteresis:_____@_____r.p.m.,B/A:__________

4



Description COATING NUMBER 5

______________% T.S.____________________

Speed factor_____,Bob_____,Torque__________

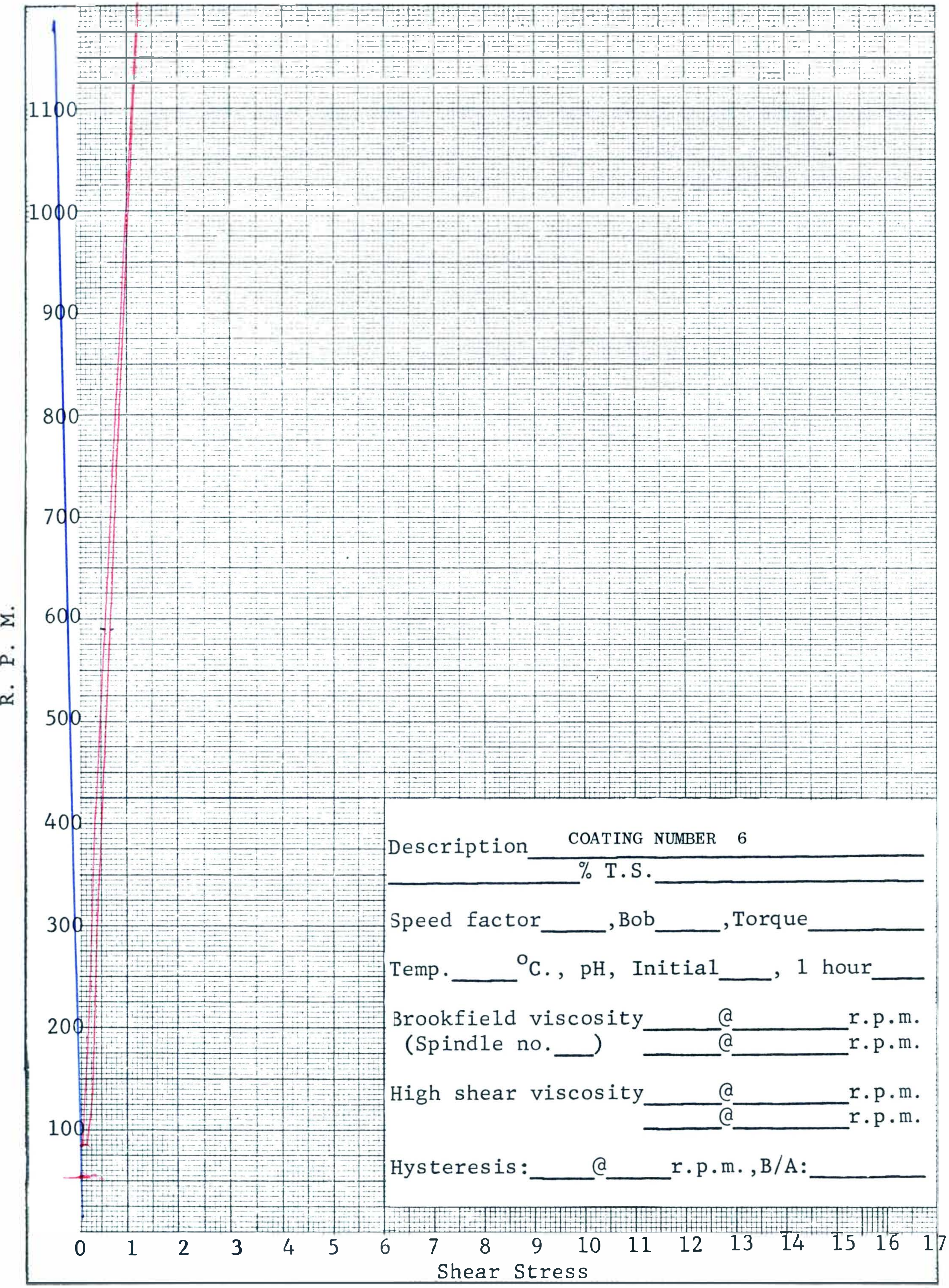
Temp._____°C., pH, Initial____, 1 hour____

Brookfield viscosity_____@_________r.p.m.
(Spindle no.__) _____@_________r.p.m.

High shear viscosity_____@_________r.p.m.
_____@_________r.p.m.

Hysteresis:____@____r.p.m.,B/A:________

5



Description COATING NUMBER 6

________ % T.S. ________

Speed factor_____,Bob_____,Torque_____

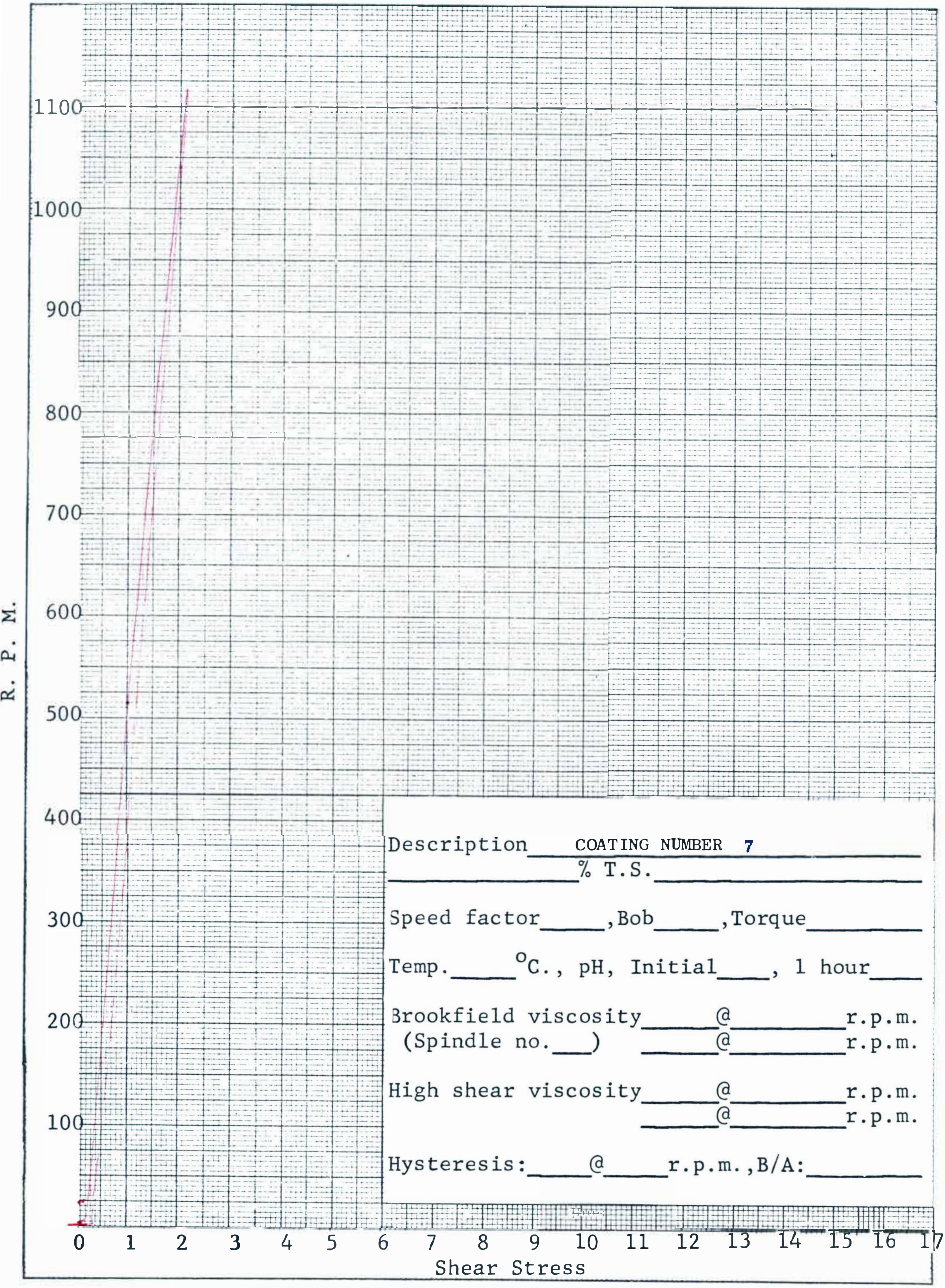
Temp._____°C., pH, Initial_____, 1 hour_____

Brookfield viscosity_____@_____r.p.m.
(Spindle no.___) _____@_____r.p.m.

High shear viscosity_____@_____r.p.m.
_____@_____r.p.m.

Hysteresis:_____@_____r.p.m.,B/A:_____

6



Description COATING NUMBER 7

% T.S.

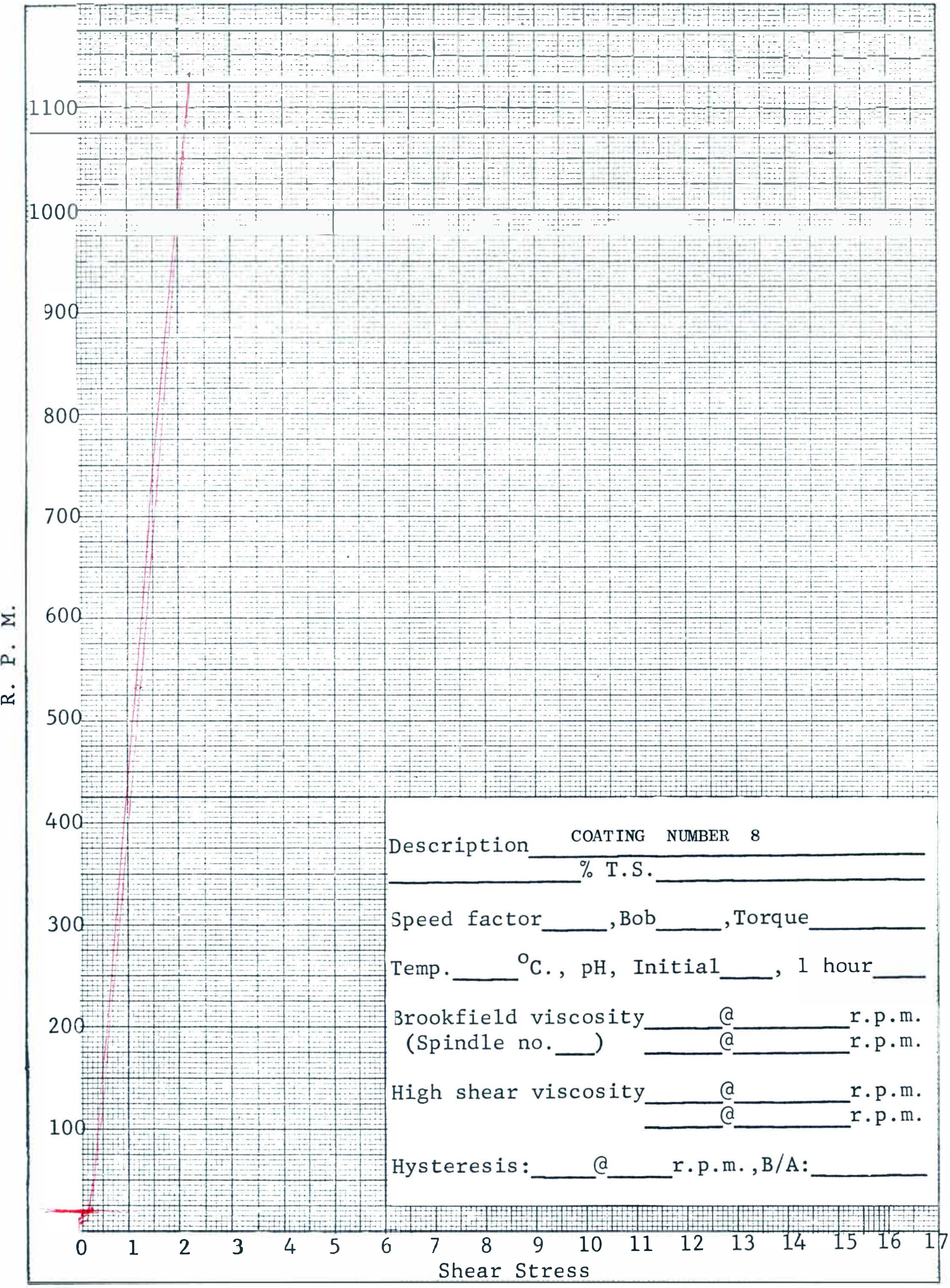
Speed factor _____, Bob _____, Torque _____

Temp. _____ °C., pH, Initial ____, 1 hour ____

Brookfield viscosity _____ @ _____ r.p.m.
(Spindle no. ___) _____ @ _____ r.p.m.

High shear viscosity _____ @ _____ r.p.m.
_____ @ _____ r.p.m.

Hysteresis: _____ @ _____ r.p.m., B/A: _____



Description ____COATING NUMBER 8____

__________ % T.S. __________

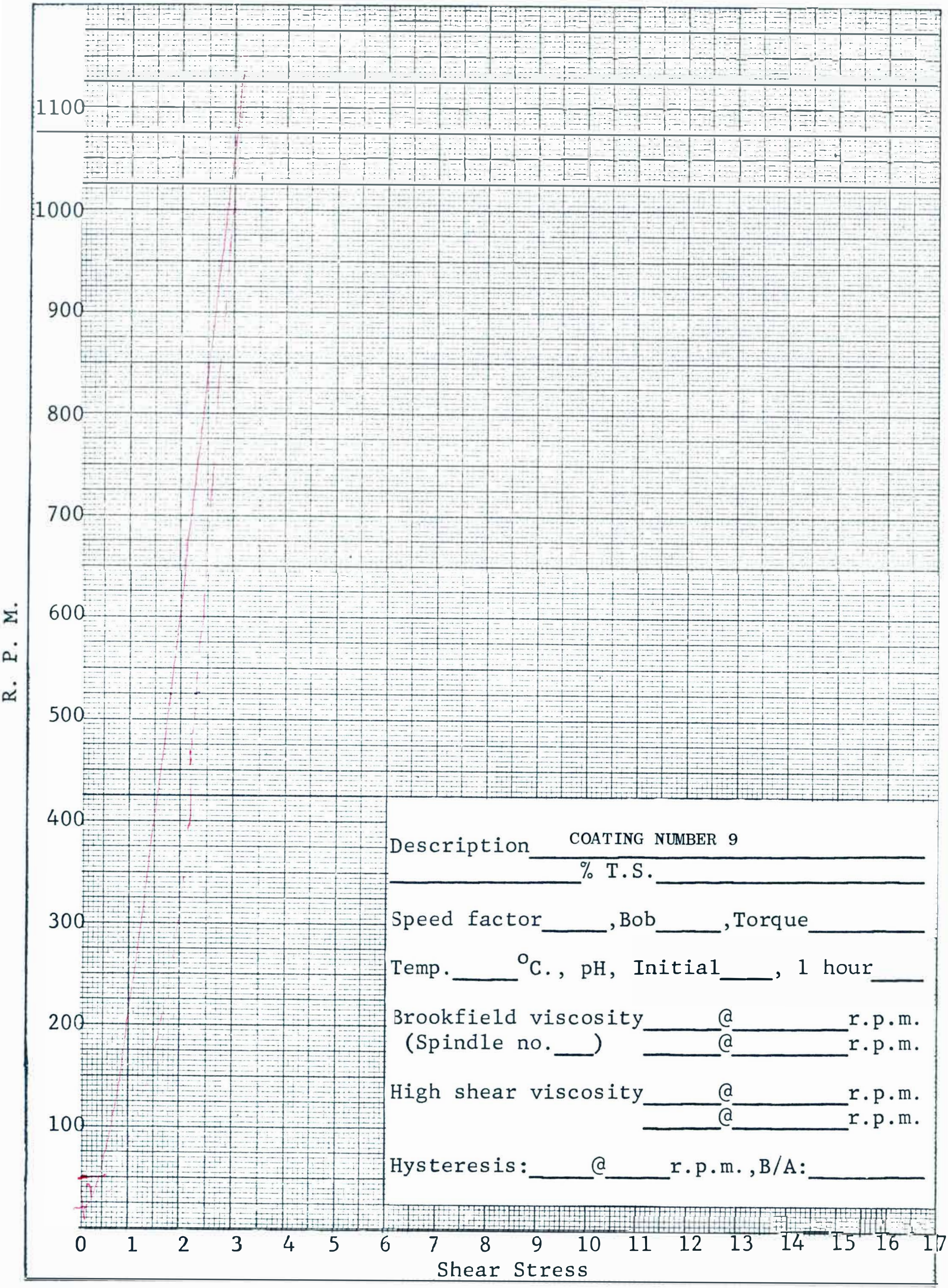
Speed factor_____, Bob_____, Torque_____

Temp._____°C., pH, Initial_____, 1 hour_____

Brookfield viscosity_____@_____r.p.m.
(Spindle no.___) _____@_____r.p.m.

High shear viscosity_____@_____r.p.m.
_____@_____r.p.m.

Hysteresis:_____@_____r.p.m., B/A:_____



Description COATING NUMBER 9

______% T.S.______

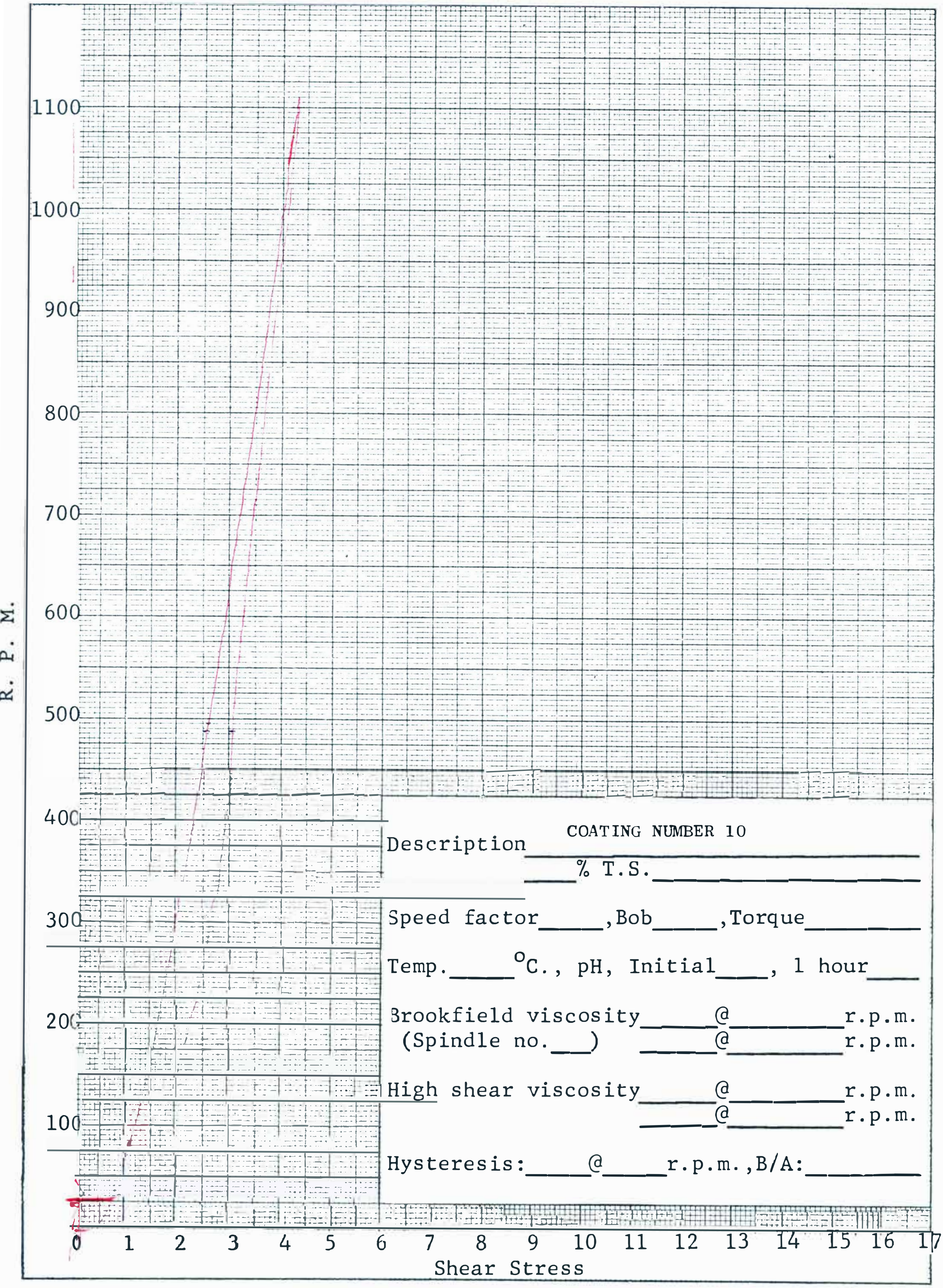
Speed factor____, Bob____, Torque______

Temp.____ °C., pH, Initial____, 1 hour____

Brookfield viscosity____@______r.p.m.
(Spindle no.___) ____@______r.p.m.

High shear viscosity____@______r.p.m.
____@______r.p.m.

Hysteresis:____@____r.p.m., B/A:______



Description COATING NUMBER 10

____% T.S.____

Speed factor____, Bob____, Torque________

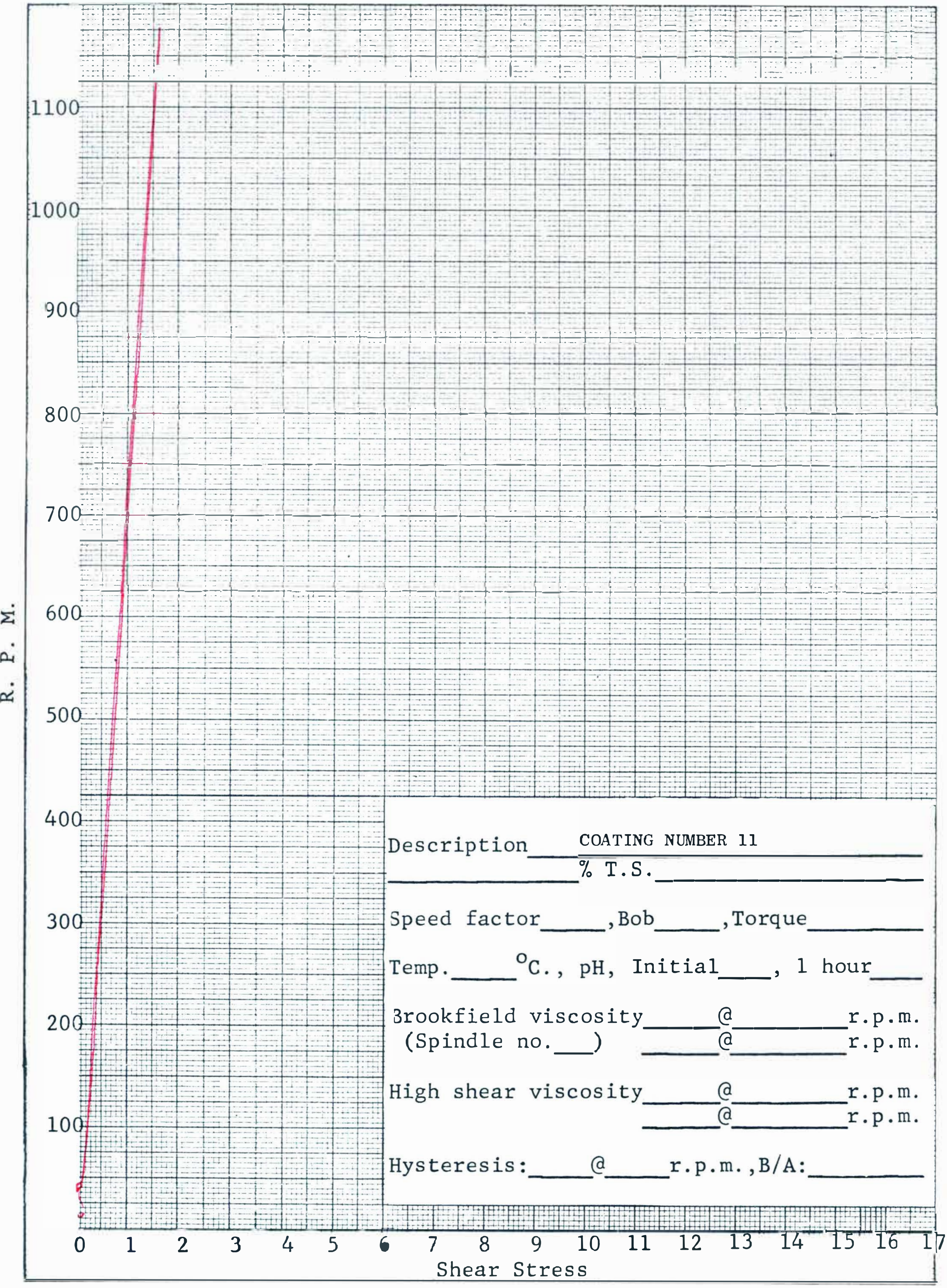
Temp.____ °C., pH, Initial___, 1 hour___

Brookfield viscosity____@________r.p.m.
(Spindle no.__) ____@________r.p.m.

High shear viscosity____@________r.p.m.
____@________r.p.m.

Hysteresis:____@____r.p.m., B/A:________

10



Description ______ COATING NUMBER 11

______________ % T.S. ______________

Speed factor _____, Bob _____, Torque __________

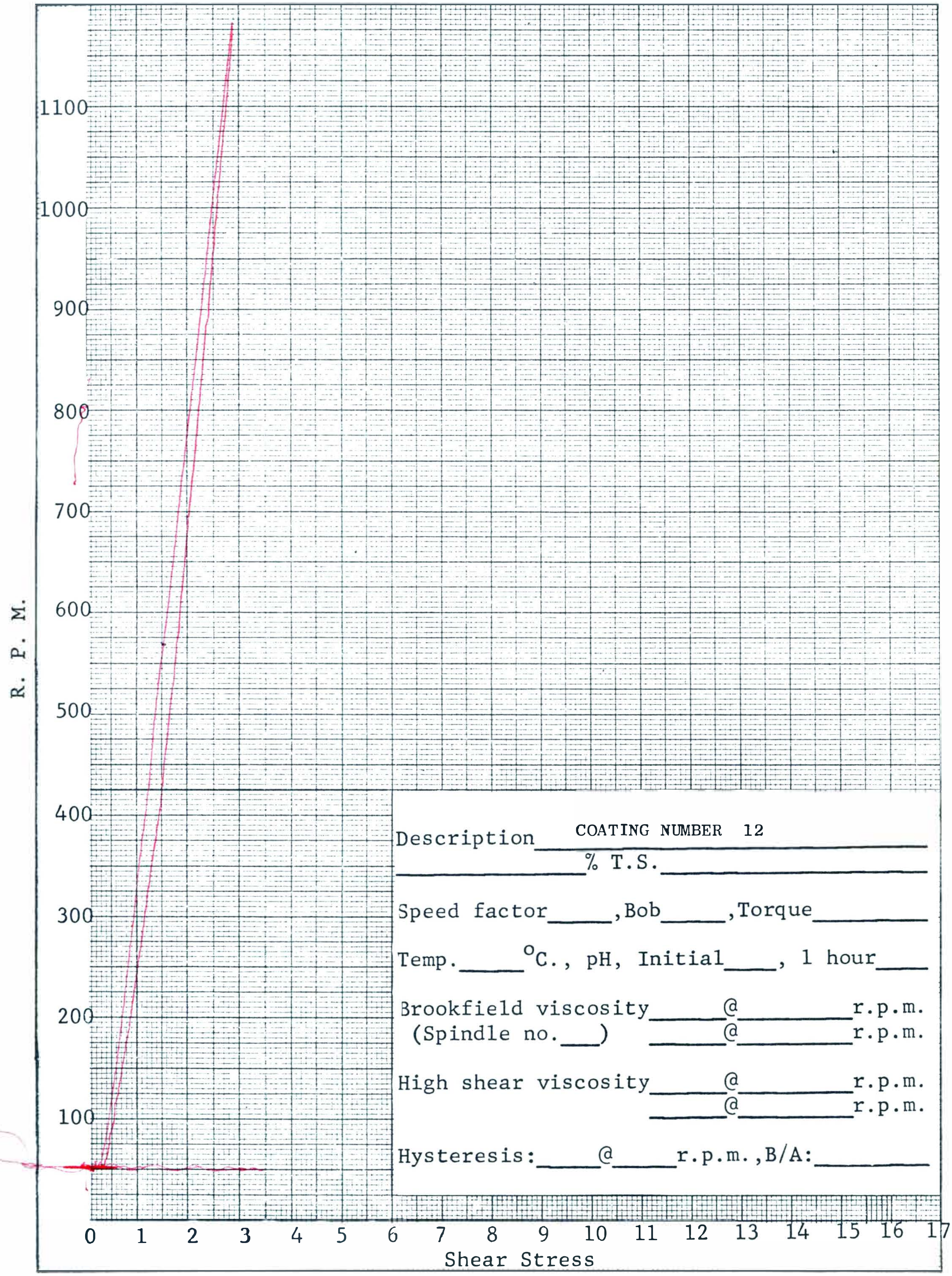
Temp. _____ °C., pH, Initial ____, 1 hour ____

Brookfield viscosity _____ @ ________ r.p.m.
(Spindle no. ___) _____ @ ________ r.p.m.

High shear viscosity _____ @ ________ r.p.m.
_____ @ ________ r.p.m.

Hysteresis: _____ @ _____ r.p.m., B/A: __________

11



Description COATING NUMBER 12

% T.S.

Speed factor_____,Bob_____,Torque__________

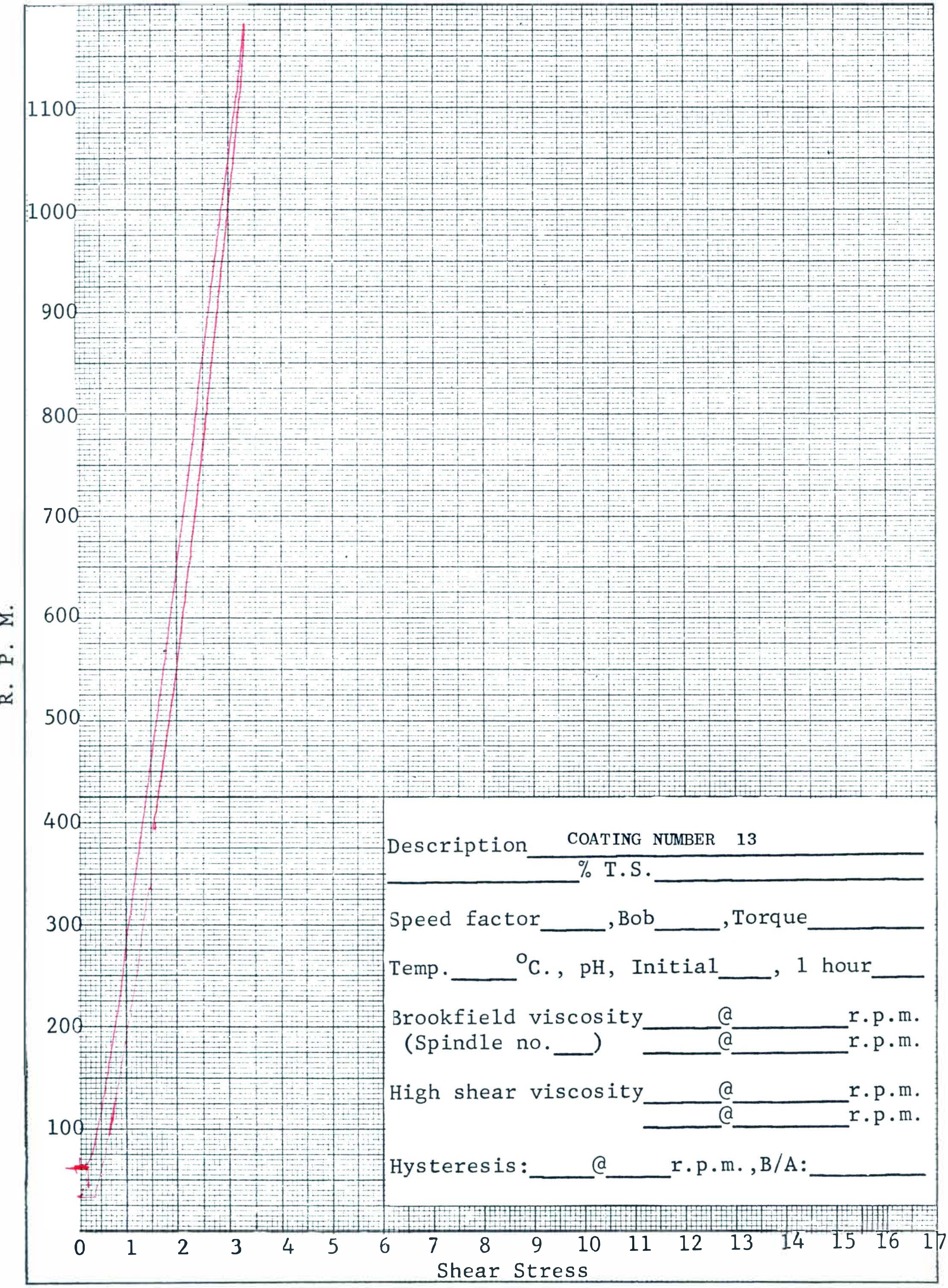
Temp._____ °C., pH, Initial____, 1 hour____

Brookfield viscosity______@__________r.p.m.
(Spindle no.___) ______@__________r.p.m.

High shear viscosity______@__________r.p.m.
______@__________r.p.m.

Hysteresis:_____@_____r.p.m.,B/A:__________

12



Description COATING NUMBER 13

______ % T.S. ______

Speed factor____, Bob____, Torque______

Temp.____ °C., pH, Initial____, 1 hour____

Brookfield viscosity______@________r.p.m.
(Spindle no.___) ______@________r.p.m.

High shear viscosity______@________r.p.m.
______@________r.p.m.

Hysteresis:____@_____r.p.m., B/A:______

13

APPENDIXES THREE

OPERATING INSTRUCTIONS FOR THE WATER RETENTION TESTER

1) Let equipment warm-up 30 min.

2) Calibrate the tester using the calibration switch
(The two electrodes don't have to be together)

3) The tester is now ready for coatings

4) Place enough coating on the bottom electrode so
as to get a 70mm area on the test paper.

5) Place top electrod and paper on top of the
coating (This is the start of the test.)

6) Remove top electrod once the strip records
pen as passed half the distance from the
calibration mark

7) Clean bottom electrode with distilled water
(Water must be at contant temp.)

8) Ready to start at step 2 again.

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