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The Effect of Changing Dryer Temperature on the Gloss Characteristics of Coated Paper

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The Effect of Changing Dryer Temperature
On the Gloss Characteristics
Of Coated Paper

By

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ABSTRACT

The purpose of this study was to note the effect of varying drying temperatures on the gloss of papers coated with three different coating formulations. The three coatings studied contained Polyvinyl Acetate, a combination of styrene butadiene and casein, and a formula using casein and styrene butadiene as binders in conjunction with a fine particle size clay. Coating applications and drying were accomplished with a Keegan Laboratory Coater.

The results indicated that increasing drying temperatures decreased gloss, and that overdrying increased gloss.

INTRODUCTION

During the winter of 1966, while working on a project to develop a pigmented coating which would give improved gloss to on-machine coatings, the question arose as to what effect the drying temperature of the coating had on gloss. Upon searching the literature available, it was noted that very little had been written on this subject. It was therefore decided, upon returning to school, that a study of "The Effects of Coater Dryer Temperatures on Gloss" might be both interesting and educational.

It should be noted that there is no universal definition of gloss (1) and very little is known asbout the effects of drying rates and drying times (2).

The drying of coatings may be divided into three phases. They are: The warm-up period, when the moisture in the coating is heated to the temperature at which it will evaporate; the constant rate period, during which the surface moisture is evaporated; and the falling rate, or subsurface evaporation period, where the subsurface moisture is evaporated.

There is a commonly accepted theory that binder migration follows the same pattern of water flow. Thus, during the warm-up period, when water is being absorbed by the substrate, adhesive migrates toward the substrate (3, 4, 5). This also can occur during the constant rate period. The falling rate,

or subsurface evaporation seems to have the greatest effect on gloss (2). In this period, the coating must be dried quickly enough to prevent excess adhesive absorption by the substrate, which can cause dusting and coating pick during printing, (3, 4, 5, 6) and slowly enough to allow sufficient adhesive to penetrate the substrate and give a good bond (3, 5, 6). Excessive evaporation rates during this period causes migration of the adhesive to the surface, which causes a loss of brightness (2) and a loss of gloss (2, 3, 4, 5).

Kraske (7) feels that this loss of gloss is due to the inability of the clay platlets to realign themselves furing calendering due to excess adhesive on the surface. This theory states that the less adhesive holding the clay platlets, the more easily they are packed and aligned by calendering, and thus a higher may be obtained.

If gloss can obtain by adjusting the drying temperatures, not only sheet appearance, but printing quality is favored. Less loading is required on the calender, thus the coated paper would be more resilient, retain more caliper, and therefore be more suitable for printing (8).

EXPERIMENTAL PLAN

It was planned to run trials on the Keegan Coater (Figure 8) holding the coat weight, base stock, machine speed, viscosity, and solids content of a given coating constant. The drying Temperature would remain as the principle variable. The coated paper would then be calendered with the laboratory supercalender using nip pressures of 500 pli and 1800 pli. The supercalender is a conventional three roll calender with the center roll the filled roll. The pressure is applied pneumatically by two 30 sq. in. pistons. The reason for calendering at two different nip pressures is to note the difference between pressures that are applicable to on-machine operations (500 pli) and those strictly for off-machine operations (1800 pli).

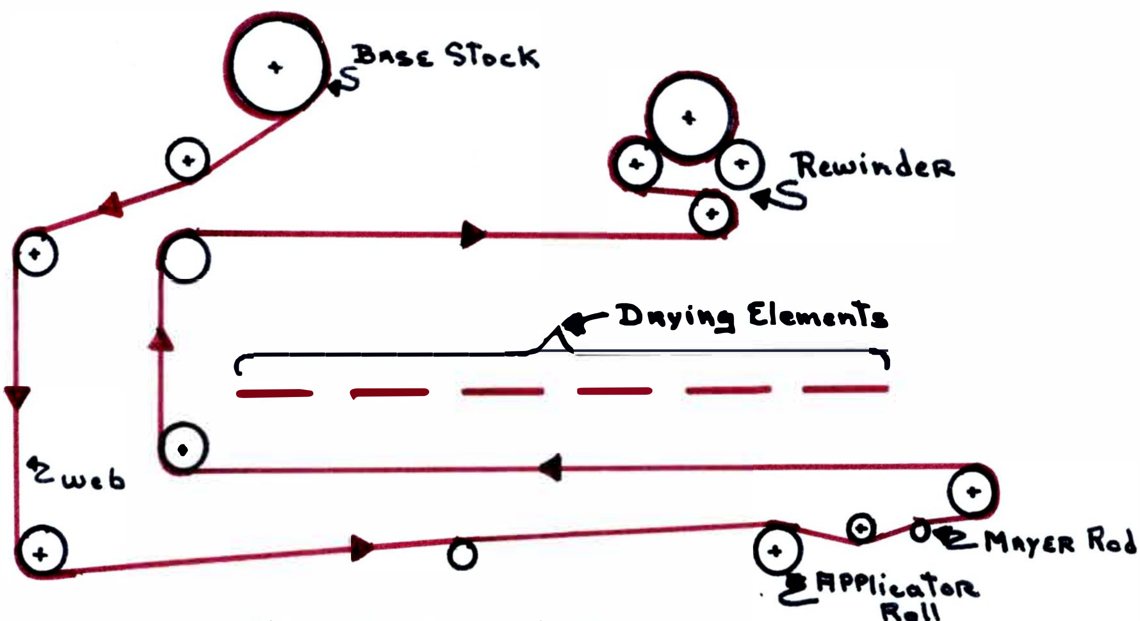

Figure 8 - Keegan Coater

After calendering, the sheets were to be evaluated as to Hunter 75^{o} Gloss, K & N Ink absorbtion, and IGT surface strength tests. It was felt that these tests would give an indication of adhesive migration with varying temperature (3,4,5,9).

Materials

Three different coating formulas were chosen for use in this study:

FORMULA #1

Hydragloss Clay	93 parts
TiO_2	7 parts
TSPP	.2 parts
Daxiad 30	.3 parts
Naoh	.5 parts
Fuller SB-201 (PVA_c	20-22 parts

FORMULA #2

Hydragloss Clay	93 parts
TiO_2	7 parts
TSPP	.2 parts
Naoh	.5 parts
Casein (Argentine)	10 parts
Dow 636 SBR	10 parts

FORMULA #3

Hydragloss Clay	93 parts
TiO_2	7 parts
TSPP	.2 parts
Starch (Penford gum 280)	10 parts
Dow 636 SBR	10 parts

EXPERIMENTAL PROCEDURE

All coatings were prepared by dispersing the pigments in a laboratory model sigma blade kneader for thirty minutes at 74 percent solids. The adhesive was added to the mixer and allowed to blend for twenty-five minutes. The coating was then diluted to the deslered solids content and the rheological characteristics were noted.

The coatins were applied using the Keegan Coater. The coating was applied by the reverse roll and metered by a Mayer Rod. The Rod was selected to give coat weights of 17 to 19 pounds. It was felt that coat weights in this area would give optimum results.

The drying rates were varied by progressively increasing the number of drying units used. (keeping machine speed constant). This was accomplished by turning on the first dryer, allowing it to warm-up, and applying the coating. After sufficient paper was coated for testing, the rewind roll was flagged and the second dryer was turned on. After sufficient warm-up period, the rewind roll was again flagged, to mark the good paper from that dried during the dryer warm-up periods. Sufficient paper was coated in this drying range. This procedure was followed for all five drying ranges. Air dry samples were also coated to be used as a control.

The sheets were then calendered and Hunter 75 percent gloss readings were taken. K & N Ink absorbtion and IGT surface strength tests were made. Four to five tests were made within a given group of samples to reduce the change of error. The results

of these tests were averaged and may be found in the following section of this report.

PRESENTATION AND DISCUSSION OF DATA

TABLE I

Results Obtained On Paper Coated With Coating Formula Number One

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75^{o} Gloss
0	1	500	51.4
1	1	500	50.8
2	1	500	50.9
3	1	500	50.8
4	1	500	51.4
5	1	500	48.4
6	1	500	48.2
0	2	500	62.9
1	2	500	61.2
2	2	500	60.3
3	2	500	60.2
4	1	500	60.2
5	2	500	59.3
6	2	500	57.0
0	3	500	66.8
1	3	500	65.6
2	3	500	64.7
3	3	500	64.5
4	3	500	63.5
5	3	500	62.6
6	3	500	61.5

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75^{o} Gloss
0	4	500	72.8
1	4	500	70.8
2	4	500	69.9
3	4	500	69.6
4	4	500	65.3
5	4	500	63.9
6	4	500	65.6
0	1	1,820	59.9
1	1	1,820	58.6
2	1	1,820	57.4
3	1	1,820	57.1
4	1	1,820	55.7
5	1	1,820	55.1
6	1	1,820	55.6
0	2	1,820	72.4
1	2	1,820	69.4
2	2	1,820	69.0
3	2	1,820	68.6
4	2	1,820	65.8
5	2	1,820	63.9
6	2	1,820	63.0
0	3	1,820	75.3
1	3	1,820	71.8
2	3	1,820	70.7
3	3	1,820	66.8

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75° Gloss
4	3	1,820	69.2
5	3	1,820	67.8
6	3	1,820	68.1
0	4	1,820	79.1
1	4	1,820	75.7
2	4	1,820	74.9
3	4	1,820	74.7
4	4	1,820	70.9
5	4	1,820	71.7
6	4	1,820	72.3

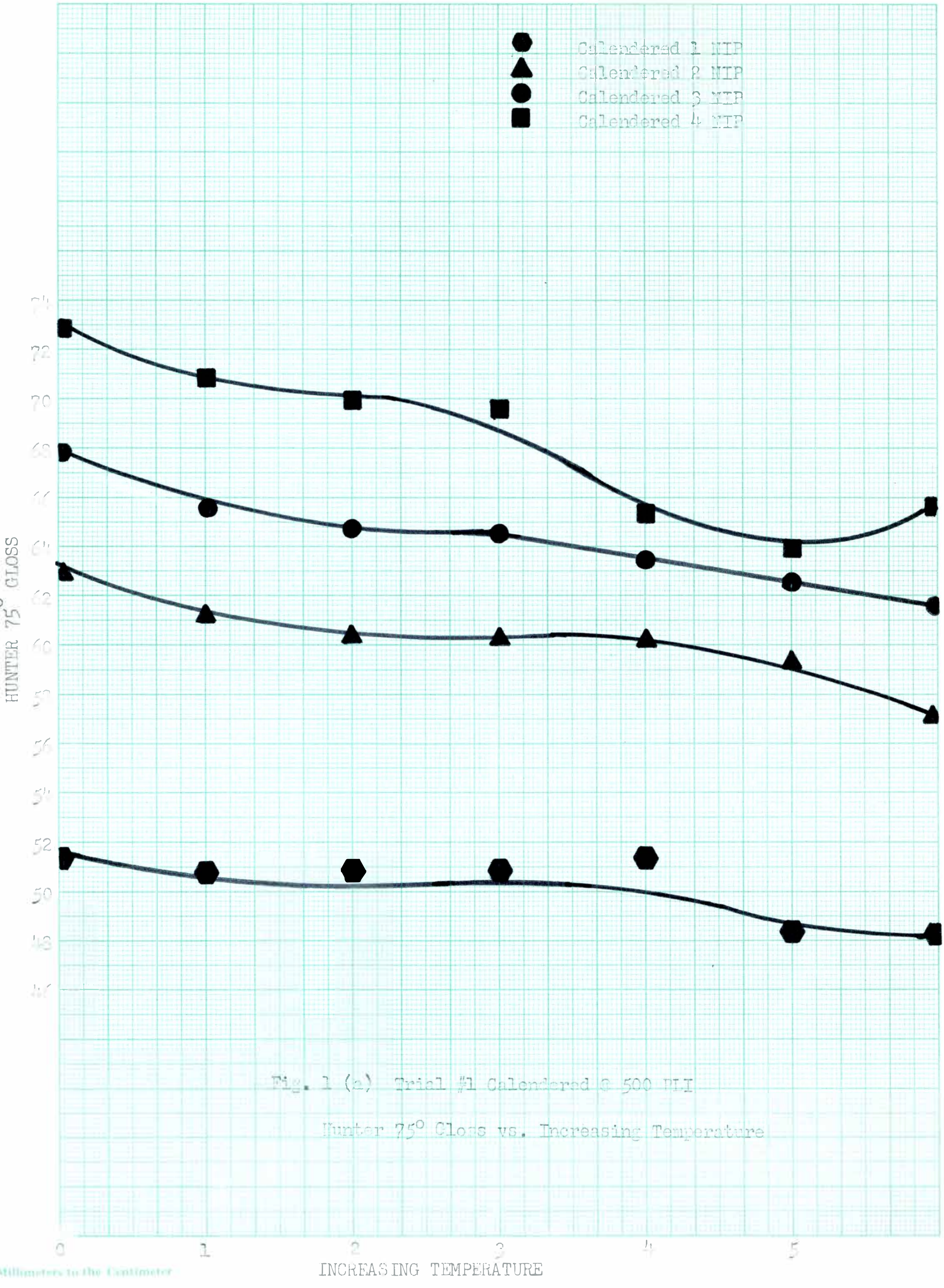

Fig. 1 (a) Trial #1 Calendered @ 500 PLI

Hunter 75° Gloss vs. Increasing Temperature

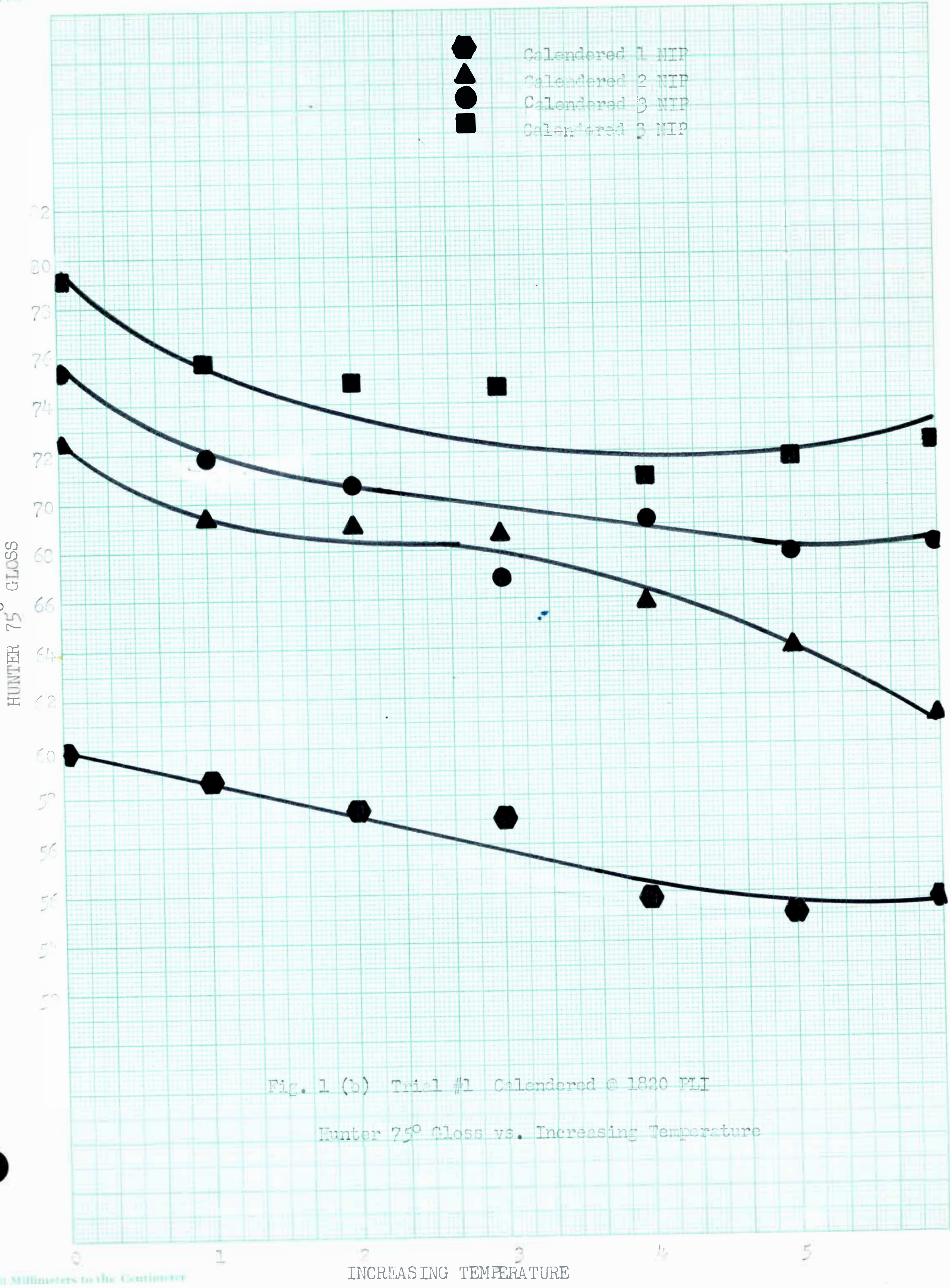

Fig. 1 (b) Trial #1 Calendered @ 1820 PLI

Hunter 75° Gloss vs. Increasing Temperature

The data shown in Table I and figures 1(a) and 1(b) indicate that that gloss values decrease with increasing drying temperatures, except those samples calendered to a more excessive degree (4 nips). These samples showed an increase in gloss with increasing drying temperature to the fourth drying unit. After this unit, gloss values began to increase slightly.

In studies made by Heiser, Duppan and Eames (3,4,5), their results indicated that as drying temperature increased, gloss decreased. Their studies quantitivly showed that as drying temperatures increased, adhesive migration toward the surface also increased. They, therefore, concluded that the migration to the coating surface effectivly decreased gloss. This conclusion was also reached by Kraske (7), in which the surface packing and gloss of coated papers decreased as adhesive content in the surface layers of the coatings was increased.

With these findings in mind, it was felt that some error, or as yet unexplained phenomenon had occured and it was therefore decided that a second trial should be made to note if these results could be duplicated. The results from this trial follow.

TABLE II

Results Obtained For Coating Formula Number One, Trial Number Two

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75^o Gloss
0	1	500	51.5
1	1	500	51.7
2	1	500	50.2
3	1	500	47.9
4	1	500	48.8
5	1	500	49.1
0	2	500	62.9
1	2	500	60.5
2	2	500	58.5
3	2	500	54.5
4	2	500	53.9
5	2	500	57.3
0	3	500	66.9
1	3	500	63.6
2	3	500	62.3
3	3	500	60.0
4	3	500	58.7
5	3	500	61.2
0	4	500	72.7
1	4	500	66.5
2	4	500	65.7
3	4	500	62.7

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75^{o} Gloss
4	4	500	64.3
5	4	500	65.7
0	1	1,820	60.0
1	1	1,820	57.8
2	1	1,820	57.0
3	1	1,820	52.7
4	1	1,820	53.3
5	1	1,820	52.4
0	2	1,820	72.6
1	2	1,820	67.2
2	2	1,820	66.0
3	2	1,820	61.0
4	2	1,820	63.4
5	2	1,820	63.4
0	3	1,820	75.7
1	3	1,820	70.5
2	3	1,820	69.2
3	3	1,820	65.7
4	3	1,820	68.1
5	3	1,820	69.7
0	4	1,820	79.0
1	4	1,820	75.5
2	4	1,820	74.3
3	4	1,820	69.1

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75^{o} Gloss
4	4	1,820	71.8
5	4	1,820	72.3

TABLE VI

Sheet Moisture For Formulas Number One, Number Two and Number Three At The Various Drying

Number of Dryers	Formula	% Moisture
1	1	16.2%
2	1	10.4%
3	1	6.6%
4	1	2.0%
5	1	.7%
1	2	17.8%
2	2	11.3%
3	2	7.7%
4	2	2.8%
5	2	1.2%
1	3	18.0%
2	3	11.7%
3	3	8.9%
4	3	5.6%
5	3	3.1%

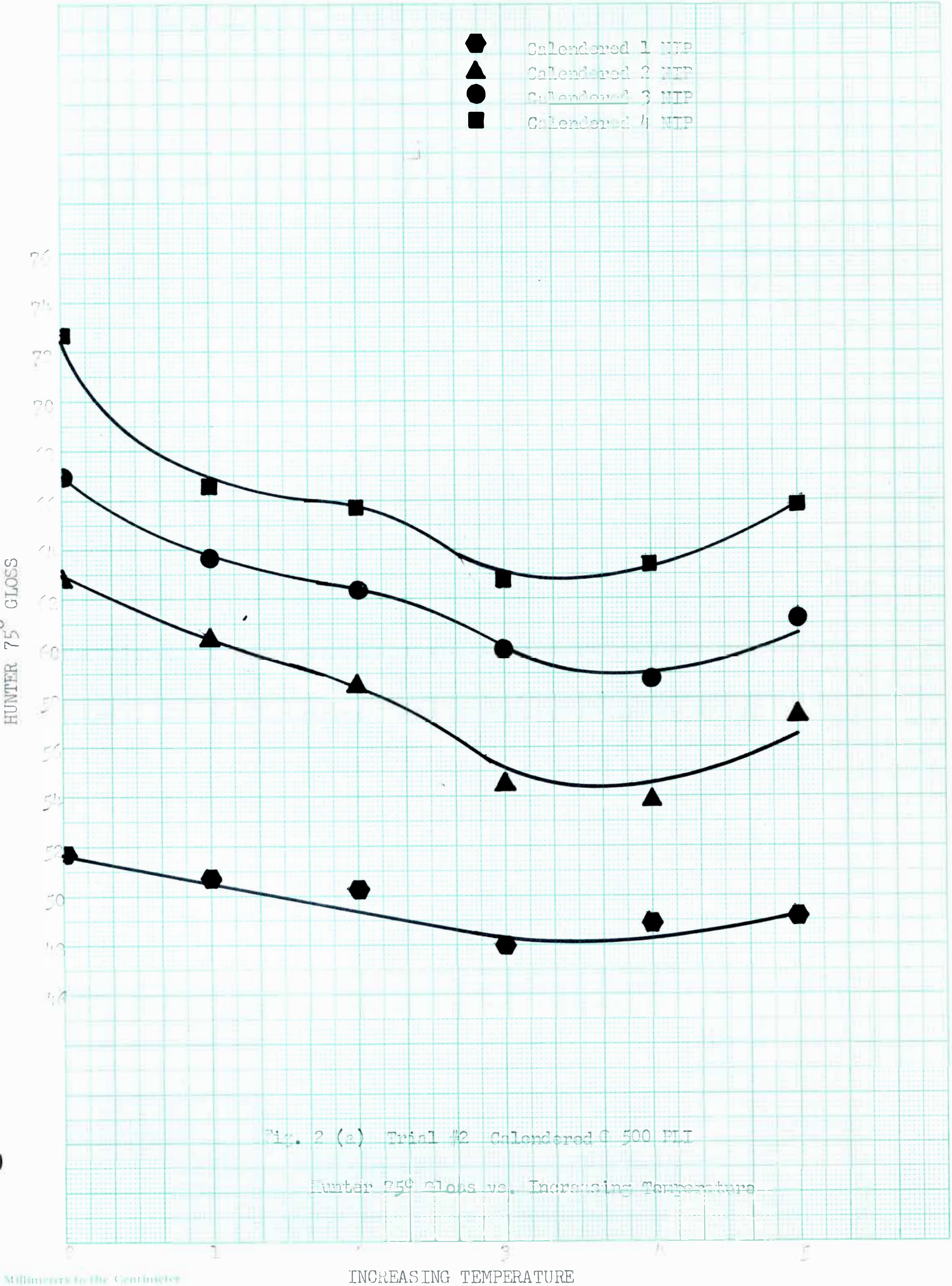

Fig. 2 (a) Trial #2 Calendered @ 500 PLI

Hunter 75° Gloss vs. Increasing Temperature

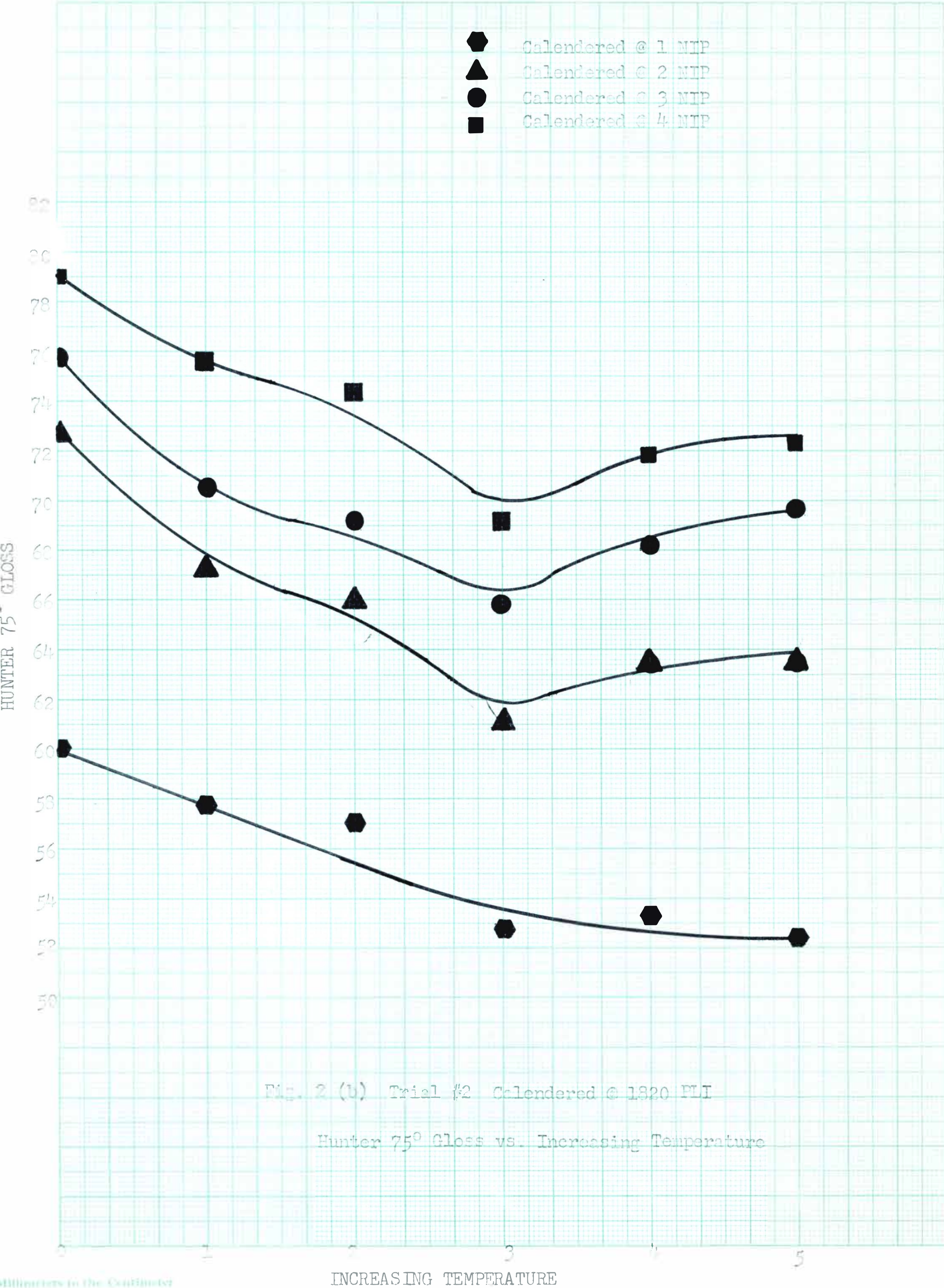

Fig. 2 (b) Trial #2 Calendered @ 1820 PLI

Hunter 75° Gloss vs. Increasing Temperature

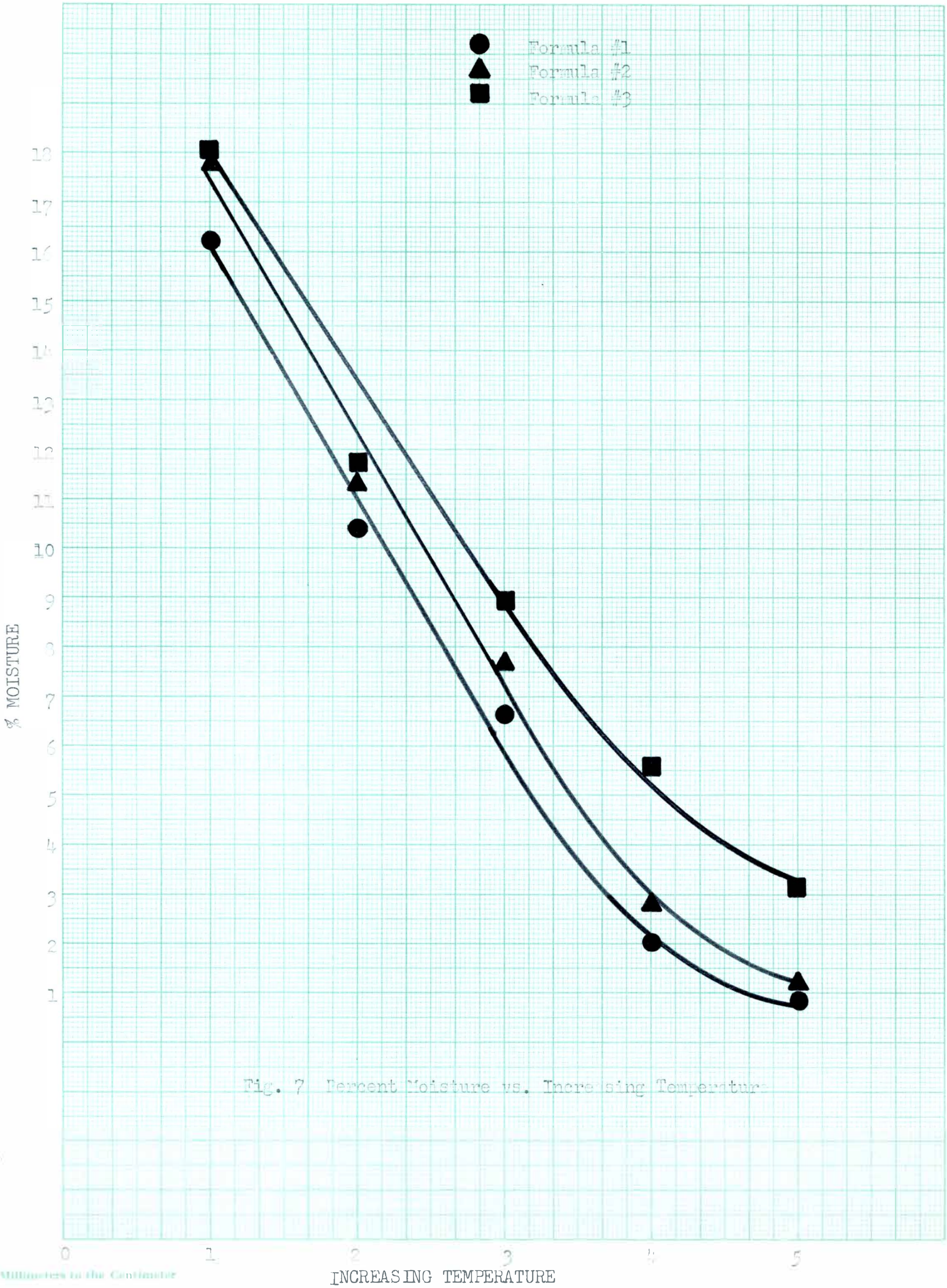

Fig. 7 Percent Moisture vs. Increasing Temperature

The results from the second trial agree with those from Trail Number One, as may be seen by Table II, and figures 2(a) and 2(b). It was therefore assumed that the data was not random and that in effect the gloss was increasing drying temperatures (above three dryers). As no quantitive test was available to measure the adhesive content of the surface layers of the coatings, only deductions could be made as to the unexplainable increase in gloss.

It was felt that the primary reason for the increase was due to the overdrying of the coating and paper as indicated by Table VI and figure 7. This over drying either plasticized or degraded the polyvinyl acetate to the extent that upon calendering, the adhesive no longer held the clay platlets to the previously suggested. Therefore, they were more easily calendered, as indicated by the increase in gloss.

The decrease in gloss with increasing temperatures was somewhat expected, as this is the generally accepted theory (3). When increased gloss valves were obtained with high drying temperatures, other coating formulas were tried to note their behavior in this situation. As the binder is felt to cause the fluctuations in gloss with varying temperatures, this was the only variable introduced into the different formulations.

The third trial was made using formula number two and the results may be found in Table III and figures 3(a) and 3(b).

TABLE III

Showing Results Obtained From Formula Number Two

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75^{o} Gloss
0	1	500	50.3
1	1	500	48.3
2	1	500	43.1
3	1	500	42.7
4	1	500	42.6
5	1	500	40.9
0	2	500	57.1
1	2	500	56.4
2	2	500	51.3
3	2	500	48.8
4	2	500	49.9
5	2	500	48.8
0	3	500	59.5
1	3	500	58.8
2	3	500	54.6
3	3	500	53.8
4	3	500	53.2
5	3	500	55.2
0	4	500	61.5
1	4	500	59.5
2	4	500	58.2
3	4	500	55.2
4	4	500	56.9

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75° Gloss
5	1	500	57.0
0	1	1,820	51.6
1	1	1,820	49.6
2	1	1,820	51.5
3	1	1,820	52.7
4	1	1,820	52.0
5	1	1,820	52.4
0	2	1,820	65.8
1	2	1,820	64.4
2	2	1,820	62.2
3	2	1,820	62.2
4	2	1,820	59.7
5	2	1,820	60.8
0	3	1,820	67.4
1	3	1,820	66.7
2	3	1,820	66.2
3	3	1,820	64.0
4	3	1,820	64.0
5	3	1,820	66.2
0	4	1,820	70.5
1	4	1,820	67.6
2	4	1,820	68.0
3	4	1,820	67.2
4	4	1,820	67.5
5	4	1,820	69.0

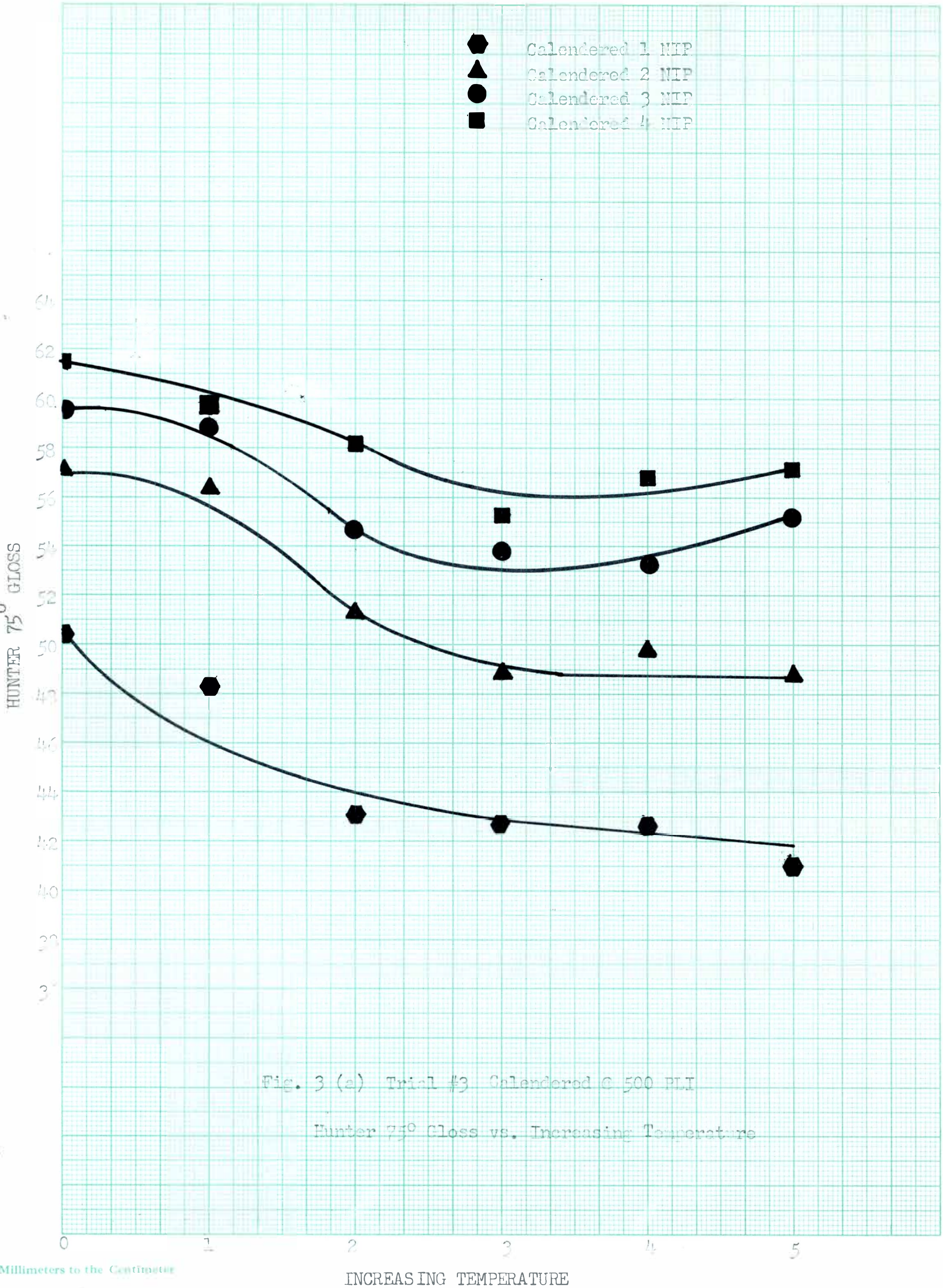

Fig. 3 (a) Trial #3 Calendered @ 500 PLI

Hunter 75° Gloss vs. Increasing Temperature

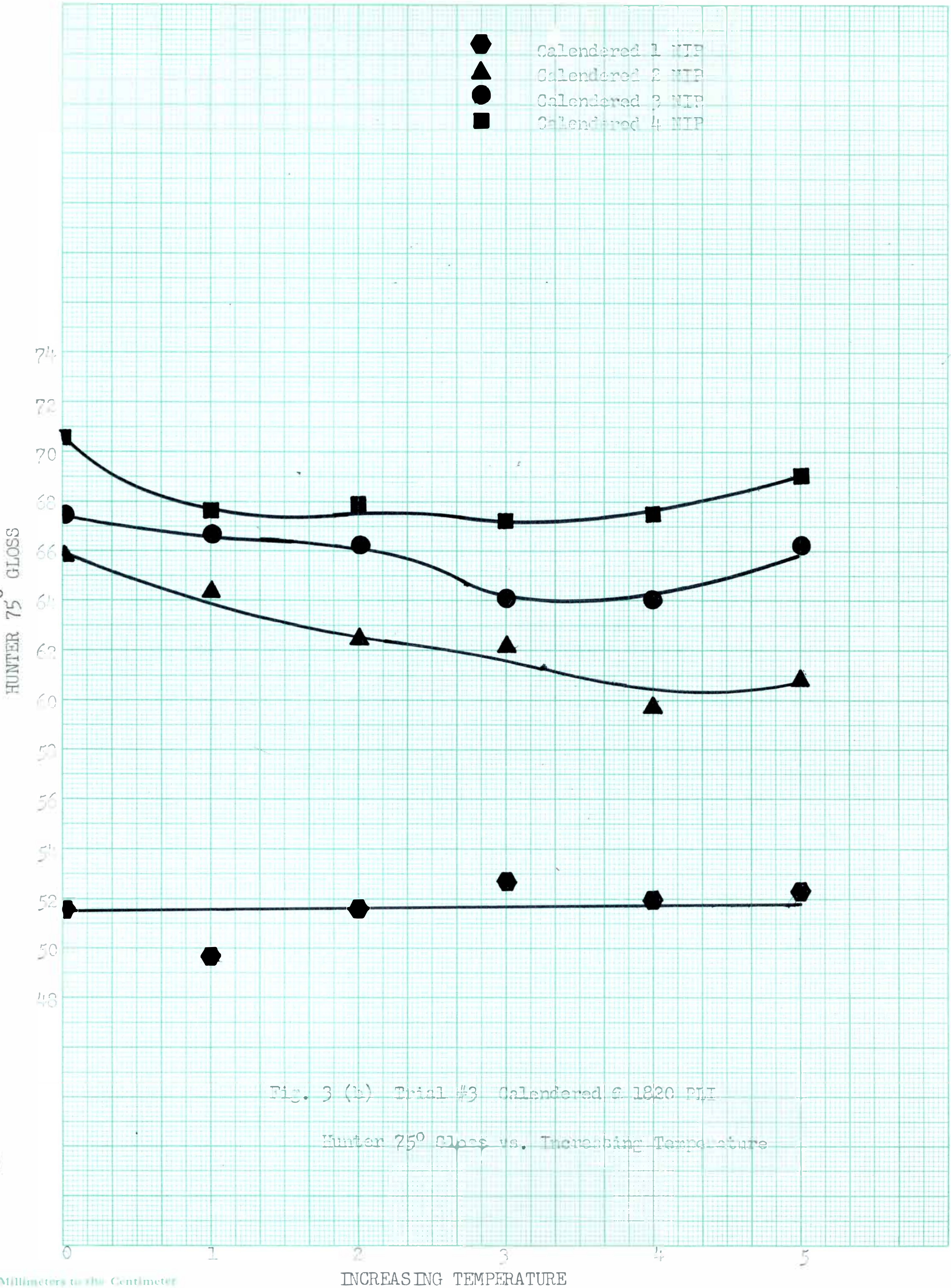

Fig. 3 (b) Trial #3 Calendered @ 1820 PLI

Hunter 75° Gloss vs. Increasing Temperature

The trial indicated that gloss valves decreased with increasing drying temperature to a given point, that point being between the third and fourth dryer, Figures 2 (a) and 2 (b), after this point, gloss either remained steady or increased slightly, depending on the degree of calendering. It was noted that when gloss valves began to increase, Figure 7, and the odor of scorching casein could increase in gloss was felt to be connected again with overdrying. Because of degradation of the binder, the surface clay platlets were not held as rigidly and therefore higher degrees of calendering were able to position the platlets and increase gloss (7).

The fourth trial involved formula number three and was carried out in the same manner as the previous trials. The test data for this trial follows in Table IV and is shown graphically in figures 4 (a) and 4 (b).

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75^{o} Gloss
0	1	500	43.3
1	1	500	41.0
2	1	500	40.4
3	1	500	38.0
4	1	500	37.8
5	1	500	36.8
0	2	500	49.4
1	2	500	47.8
2	2	500	44.8
3	2	500	46.7
4	2	500	46.0
5	2	500	47.6
0	3	500	54.0
1	3	500	52.7
2	3	500	53.3
3	3	500	51.2
4	3	500	49.6
5	3	500	50.6
0	4	500	57.5
1	4	500	55.4
2	4	500	56.5
3	4	500	54.9
4	4	500	56.1
5	4	500	54.7

Number of Dryers	Number of Nips Calendered	Nip Pressure PLI	Hunter 75° Gloss
0	1	1,820	53.1
1	1	1,820	49.8
2	1	1,820	48.6
3	1	1,820	46.1
4	1	1,820	49.0
5	1	1,820	45.7
0	2	1,820	59.3
1	2	1,820	57.5
2	2	1,820	54.7
3	2	1,820	56.7
4	2	1,820	58.8
5	2	1,820	58.5
0	3	1,820	63.8
1	3	1,820	62.6
2	3	1,820	60.6
3	3	1,820	60.7
4	3	1,820	61.5
5	3	1,820	60.6
0	4	1,820	70.6
1	4	1,820	68.1
2	4	1,820	65.8
3	4	1,820	64.5
4	4	1,820	65.8
5	4	1,820	65.5

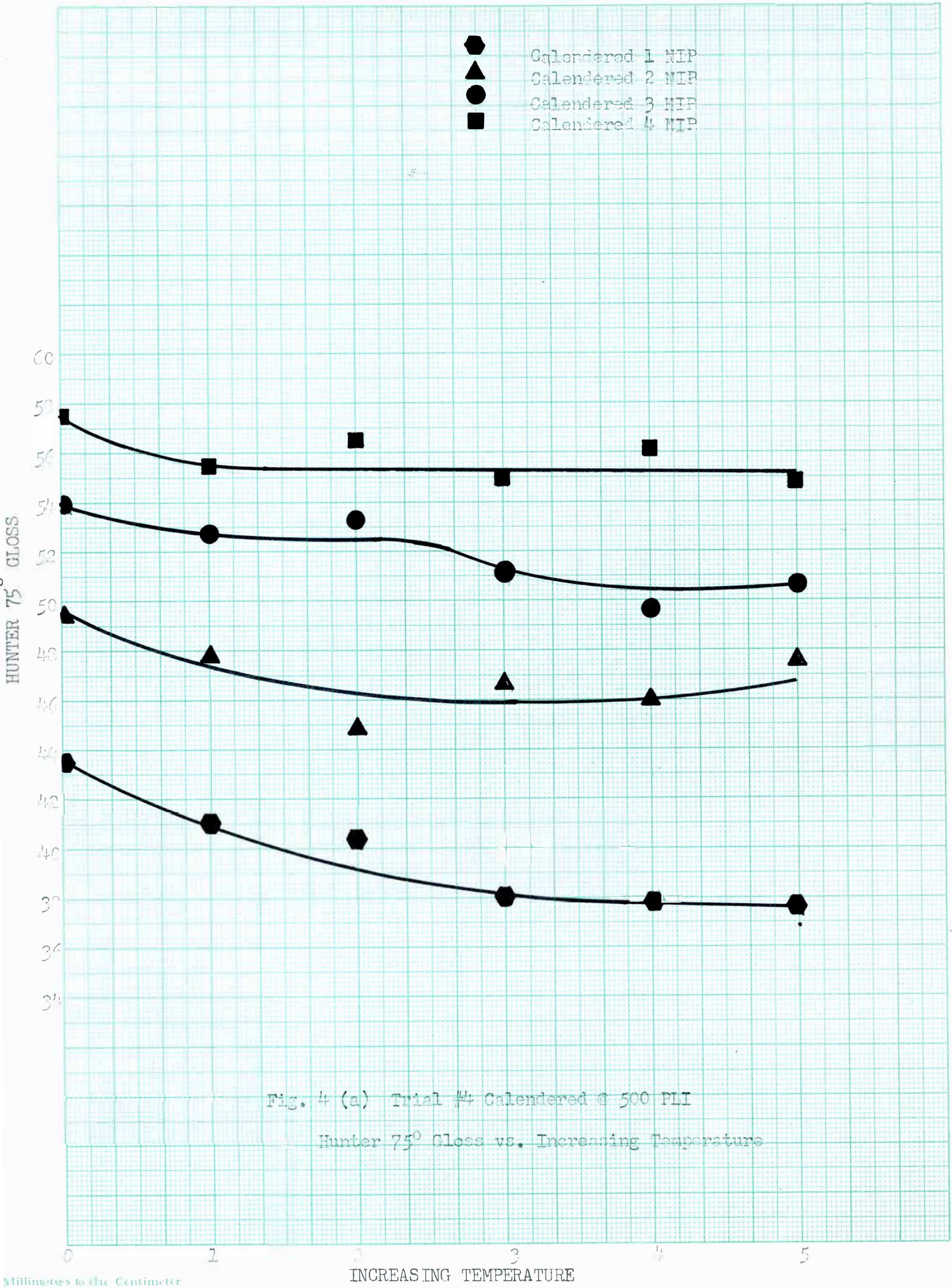

Fig. 4 (a) Trial #4 Calendered @ 500 PLI

Hunter 75° Gloss vs. Increasing Temperature

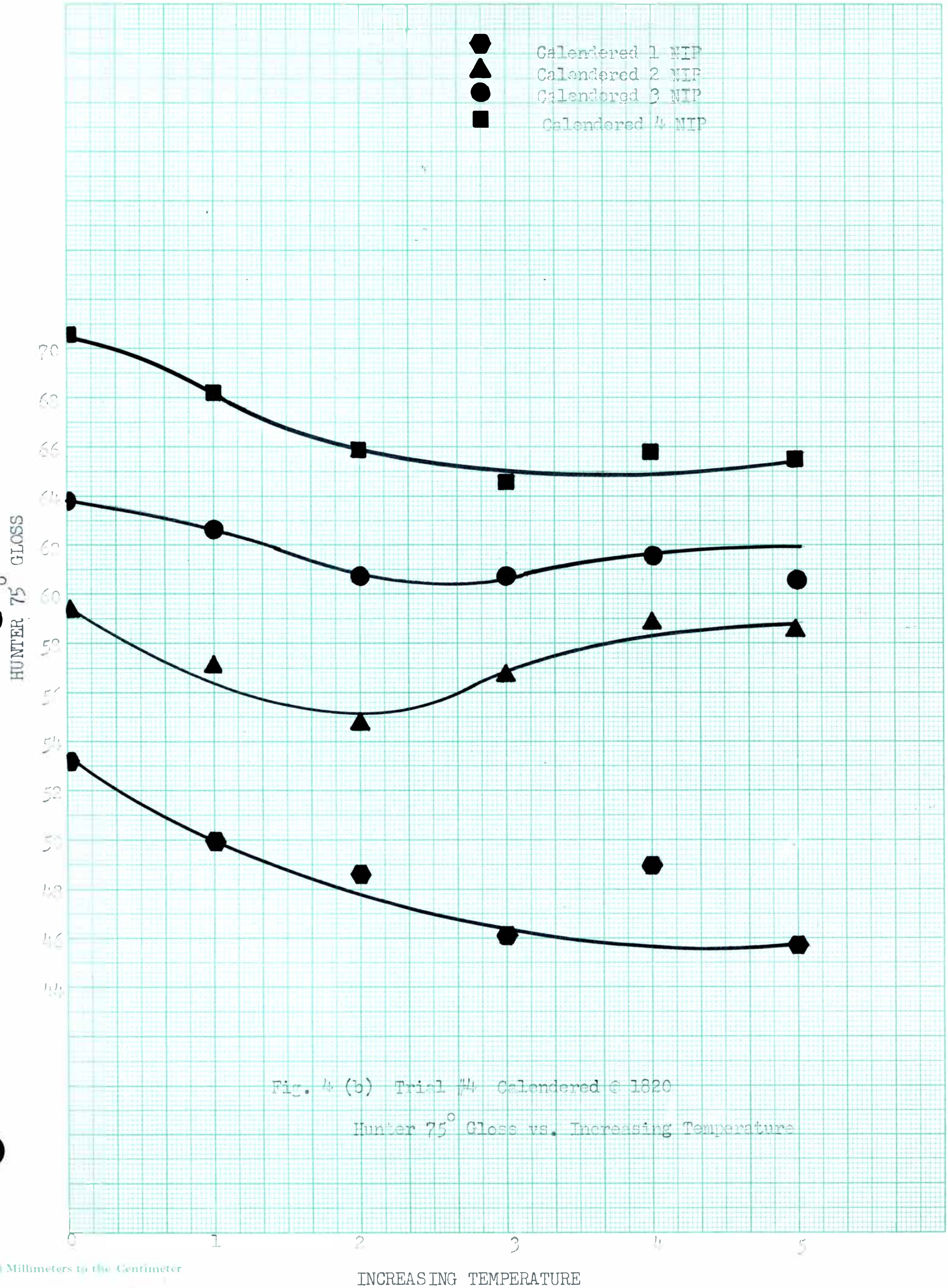

Fig. 4 (b) Trial #4 Calendered @ 1820

Hunter 75° Gloss vs. Increasing Temperature

The results of trial number four, Table IV and figures 4 (a) and 4 (b) indicate that gloss valves decrease to a minimum value between two and three dryers and then hold constant for the remainder of the drying rates. It is felt that the steady gloss values obtained after a given drying rate indicate that although adhesive migration continues throughout these varying drying rates, the additional adhesive (starch and SBR) does not effectively hinder the calendering action and thus uniform gloss was obtained. Figure 7 indicates that the moisture content of the samples from this trial did not become as low as the previous trials, at a given drying rate, and overdrying did not occur. Therefore, the adhesive was not heated to the extent as in the previous trials and gloss therefore did not increase at the high drying temperatures due to the degradation of the adhesive.

TABLE V

K & N Absorbtion for the Three Coating Formulas at Various Drying Rates *

Number of Dryers	Formula	K & N Ink (% drop in brightness)
0	1	28.24
1	1	28.84
2	1	29.50
3	1	30.50
4	1	31.11
5	1	31.22
0	2	6.65
1	2	7.04
2	2	7.41
3	2	7.40
4	2	8.42
5	2	7.64
0	3	20.0
1	3	20.3
2	3	21.7
3	3	22.0
4	3	23.0
5	3	23.77

*(All samples calendered 4 nips at 1,820 PLI)(Ave. of 5 tests)

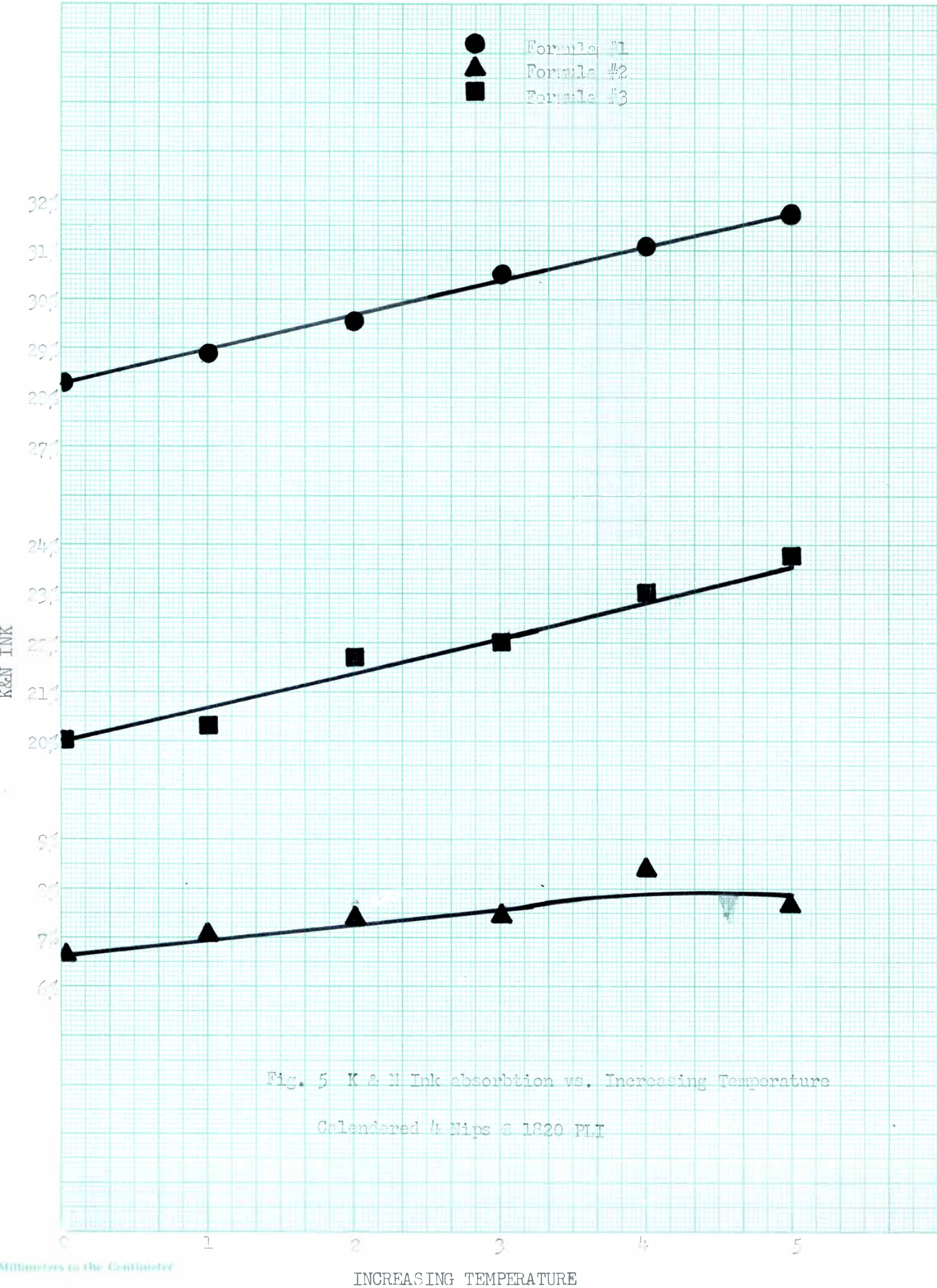

Fig. 5 K & N Ink absorbtion vs. Increasing Temperature

Calendered 4 Nips @ 1820 PLI

IGT Surface Strength Values Obtained Using Number Three Tack Ink on the Three Coating Formulas for Various Drying Rates *

Number of Dryers	Formulas	IGT(flm to failure)
0	1	270 flm
1	1	275 flm
2	1	278 flm
3	1	282 flm
4	1	298 flm
5	1	268 flm
0	2	321 flm
1	2	308 flm
2	2	283 flm
3	2	275 flm
4	2	252 flm
5	2	275 flm
0	3	226 flm
1	3	216 flm
2	3	216 flm
3	3	195 flm
4	3	187 flm
5	3	213 flm

* (All samples calendered 4 nips at 1,820 PLI) (Ave. of 5 tests)

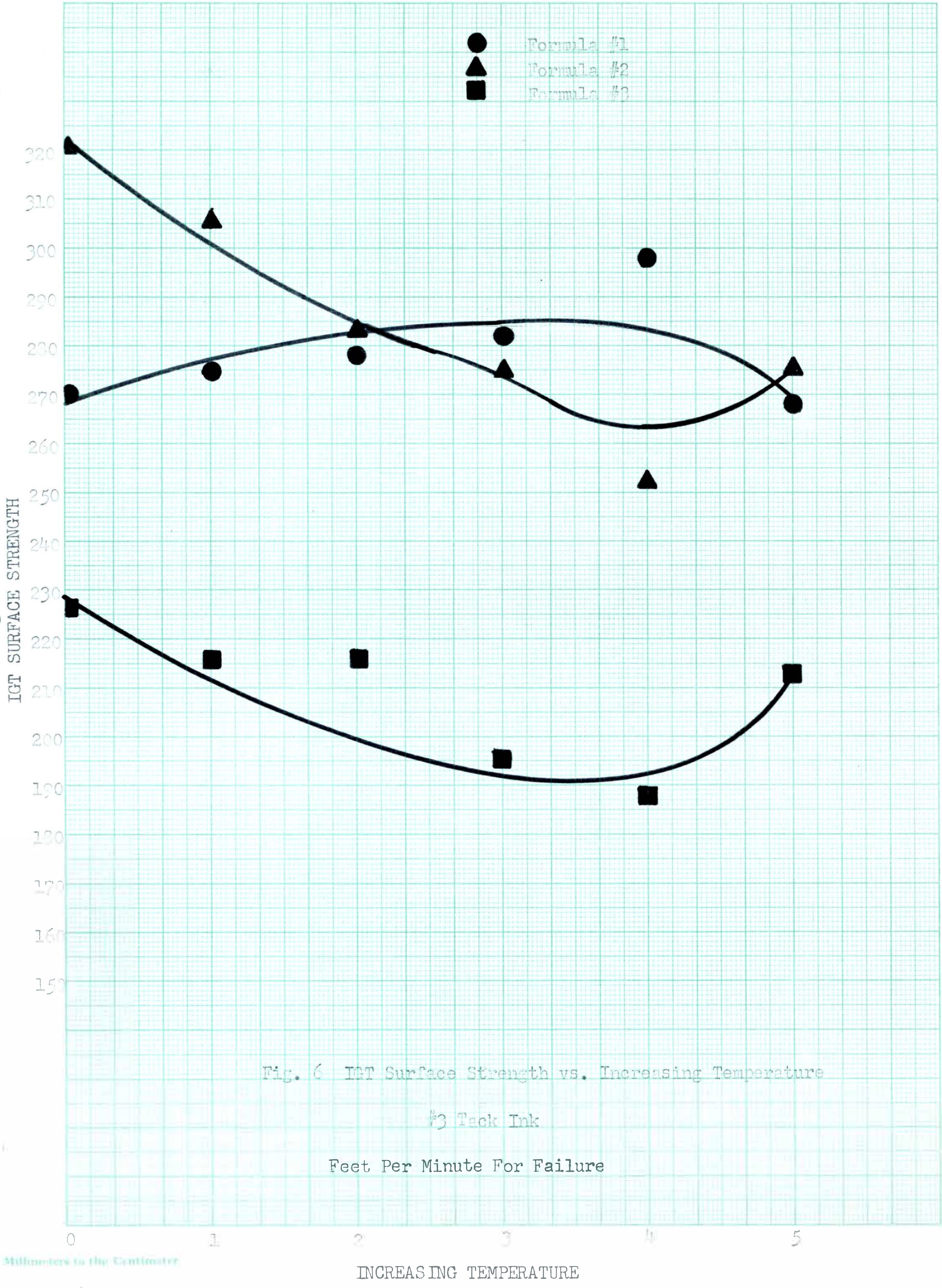

Fig. 6 IGT Surface Strength vs. Increasing Temperature

#3 Tack Ink

IGT surface strength tests and K & N Ink absorbtion tests were made because they are an indication of adhesive migration (3, 4, 5, 9). It was hoped that these tests would substantiate some of the assumptions made earlier.

As adhesive migrates toward the surface of coatings containing Styrene Butadiene binders, the absorbtion of K & N Ink decreases (3). Coatings containing starch as an adhesive increase K & N Ink absorbtion with increased surface concentration (5). No data was available for K & N Ink relationships with Polyvinyl Acetate or casein binders. Table V and Figure 5 indicate that Polyvinyl Acetate increases the reduction in brightness with increased migration to the coating surface (formula number one). Formula number two, which contains casein and styrene butadiene as adhesives, shows a slight increase in ink absorbtion as drying temperatures increase. This would indicate that the adhesive is either migrating selectively (casein faster) or that the casein tends to cancel out the effect of styrene butadiene on lowering of K & N Ink values.

Formula number three gives an increased K & N Ink absorbtion with increasing drying rates. The same conclusions may be drawn from these results as for formula number two. These being that starch migrates faster than styrene butadiene, thus gives an increasing reduction in brightness with increasing temperature.

Hemstock (9) noted in his study of adhesive migration that as adhesive migrated toward the surface, IGT surface strength (Table VI

and Figure 6) indicate that for formulas number two and number three, increased drying rates decreased IGT values while formula number one increases in IGT strength with increasing temperatures. Since no coating pick was observed and only substrate failure occured, these results were taken lightly when analyzing the overall conclusions reached in this study.

CONCLUSIONS

1. That increasing drying temperatures decreases gloss in the formulations tested.
2. That overdrying of a coated sheet increases gloss. Due to:
   a. The plastization of the adhesive
   b. The degradation of the adhesive
3. That adhesive migration effects gloss, the more adhesive migration toward the surface, the less gloss (except as noted in conclusion number two)
4. That modifications could be made to make these results more positive. These are:
   a. Incorporate a thermocouple unit so that exact drying temperatures may be obtained
   b. Use only one adhesive instead of a combination (as in formulas number two and number three) because the combination tends to cloud the results of tests designed to determine adhesive migration.
   c. Devise methods for determining the actual adhesive content of layers of coating to prove adhesive migration
   d. Installation of a fan or blower to remove evaporated moisture from area around sheet being dried.

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