4-1968

Profile Studies on Pigmented Coatings under Different Drying Conditions

Andrew M. Lukas
Western Michigan University

Profile Studies on Pigmented Coatings Under Different Drying Conditions

A Thesis Submitted to the
Department of Paper Technology
School of Applied Arts and Sciences
Western Michigan University

In Partial Fulfillment of the
Requirement for the Degree of Bachelor
of Science

by
Andrew M. Lukas

April, 1968

Table of Contents

Abstract:

Experimental procedures were conducted to observe the latex migration tendencies under various drying conditions, by physical and optical analysis. Gloss, calendered and uncalendered and smoothness may be increased by heat drying the coated side of the sheet while brightness tends to decrease. Magnifications of 1200 X and 17000 X were used to optimetrically observe the latex particle distribution in the sheet.

I Literature Survey

Adhesive redistribution or binder migration, as it is more commonly called is the selective movement of adhesive though a pigment coating. The small adhesive particles in relation to the larger pigment particles tend to be redistributed during the application and drying of the paper coating. The fact that binder migration does take place, and the problems migration causes, have long been recongnized by paper coating personnel. Variations in surface coating properties with the same formulations under different machine conditions have been attributed to binder migration (9).

A sheet of paper viewed microscopically is very rough and nonuniform. The coating fills these recesses and levels out the surface of the sheet in a bonding, intermingling process. For this leveling process to be effective in bonding or holding the coating to the sheet there must be a certain amount of inherent mechanical strength in the coating mixture according to Singletery (4). In coated papers, the coating provides a smoother, more even, and more continuous surface which makes a far better printing surface than that provided by an uncoated sheet. The pigment of the coating is primarily responsible for these desirable physical properties, whereas the adhesive's function is to bind the pigment particles to one another and to the surface of the sheet so that

the coating will not be pulled loose by the printing inks.

According to Dappen (2) the mechanism of adhesive distribution is thought to involve primarily capillary interraction for the vehicle between the coating and the substrate. Varying with the coated side, the adhesive (starch) migrated to the top of the coating, thus producing a nonuniform distribution with less starch at the coating-fiber interface than at the top surface of the coating. Experimentally, it was found that the amount of adhesive lost to the substrate was 3-4 percent with 28-32 percent water in the starch adhered system. Also it was shown that penetration of the adhesive into the substrate decreases with increased coating solids and increasing the percent adhesive.

Heiser and Cullen (1) also substantiated that high solids coatings were less prone toward binder (latex) migration than low solids coatings. Also, they concluded that the degree of latex binder migration to the surface was proportional to the drying rate. The prime factors controlling the direction of latex migration were the drying rates and the absorbancy of the coating raw stock. At slow drying rates, the direction of migration seems to be primarily toward the substrate; while at fast drying rates the direction of migration was toward the surface as well as the substrate. If a latex coating is dried by a fast hot air blast

on its surface, the latex migrates towards the coating layer, but is quite weaker in strength than a slow air dried sheet. This phenomenon can be explained by the reduction of time for the adhesive to migrate and orient itself throughout the sheet of the hot air's quick "setting" and immobilization action on the coating. Also in agreement with Dappen(2), the quantity of binder migration was found to be inversely proportional to the total coating solids. It becomes apparent that the rheological flow-behavior of latex-pigment coating colors is quite similiar to Dappen's starch adhesive migration properties.

Casey and Libbey (3) suggest that the depth of penetration of the adhesive (starch) into the base paper is decreased by increased sheet density, increased sizing, decreased sheet moisture content, and to a lesser extent by the presence of alumina in the sheet. They also elaborate on the fact that the measurement of penetration is an exceedingly difficult process becaused the coating complex may penetrate as a whole, may penetrate preferentially in parts, or the water may penetrate faster than the adhesive or pigment.

The possibility of preferential penetration is brought out by Cobb (10) who believes that the casein adhesive in a color penetratrates to a greater extent that the pigment, thus resulting in a separation of the adhesive and pigment. Davidson

(8) shows that in most coatings a large proportion of the total casein will preferentially migrate into the body stock if the papers are weakly sized.

Eames (5) concluded that coating (clay-starch) tended to lose more binder to the substrate as the pore size of the substrate decreased. This effect is probably due to the fact that the smaller pores created a greater capillary action. It was shown that coatings dried with hot air blasts retained more adhesive but were of decreased strength. This phenomena is partially due to the fact that the adhesive had less time to orient itself throughout the coating to draw and bind the pigment particles together (7). Eames also suggests that these major losses of adhesive to the substrate occurs in the saturated state and that low rates of vehicle penetration favored this condition of flow.

Much work has shown that there is little definite relationship between the depth of penetration and the Dennison wax number or IGT value (3 I). Generally the wax number or the IGT value tend to increase with increased density of the base paper and decreased if either size or clay is added to the paper (2 9). Logically the IGT pick readings should correlate with penetration of the latex adhesive, but Cullen and Heiser could show no relation.

Apparently because the coated sheet's surface is of varying and random nature,(6) these tests give only an isolate non-average reading of the surface strength of the entire sheet.

In general, the depth of the adhesive penetration into the sheet was shown to be proportional to the coating's ink receptivity (3). A shorter less-harsh drying action gives the adhesive less time to migrate and thus yields a more printable, smoother sheet.

II Experimental Procedure

A..... Physical Analysis

The base stock used for all coatings was a 35 pound offset sheet made by Kalamazoo Paper Company. The sheets, before and after hand coatings, were conditioned in a constant humidity room at 72°F and 49 percent relative humidity. All sheets were conditioned for a period of at least 24 hours prior to testing.

The basic procedure for the preparation of the coating slips were as follows: slips were made up at 40 percent, 50 percent and 60percent solids (based on total weight of pigment) with the following constituents:

1) Pigment....20% Titanium Dioxide (New Jersey Zinc R-770)

   80% Clay (Ultra White "90")

2) Binder.... 18% Dow Latex 620 (based on total grams of pigment)

3) Distilled H_2O and H_2O from latex solution

4) .4% T.S.P.P. (Based on total grams of pigment)

Using the above constituents, an example for a 40 percent solids color makeup is as follows:

> Mix 80 grams clay and 20 grams titanium dioxide in 158.5 grams distilled H_2O with 0.4 grams of T.S.P.P. by hand and then blend for 10 minutes in a malted milk mixer at "low" speed. Finally add 37.5 grams latex solution and thoroughly mix by hand.

Once the coatings were made, drawdowns were made on the base stock with .0005", .001", .003", Byrd Film Applicators and with numbers 9,15,20, and 30 "R and D Specialty" rods. All drawdowns were done on a glass based tray designed especially for this function.

After coating, the sheets were dried in two manners:

1) Air dried at room temperature

2) High speed, high temperature dried

The high speed (velocity) high temperature drying apparatus consisted of an electric filamentous, heating coil backed by a fan system and was capable of impinging a constant forced heat source within a 120° to 140° C temperature range.

The dried coated sheets were then conditioned, and tested on the I.P.C. Brightness meter, Hunter Glossimeter and Beck Smoothness Tester. Samples were also calendered under 35 P.S.I. through four nips and then were tested on the Hunter Glossimeter.

Graphs were then prepared of Meyer Rod (on the abscissa) vs. I.P.C. brightness, Hunter gloss (calendered and uncalendered), Bekk smoothness, and coat weight respectively (on the ordinate).

II Experimental Procedure (continued)

E. Optimetric Analysis

In order to optimetrically study the distribution of latex through the coating, coated, conditioned samples were embedded, microtomed and evaluated with the aid of the Paper Technology's microscope and New Jersey Zinc's electron microscope.

The samples were first embedded in a butyl methracrylate solution prepared in the following manner:

1) The butyl methraclate monomer (with inhibitor) was first washed in a 2% NaOH solution in a separatory funnel, (two times).

2) The monomer was then washed twice in distilled H_2O to yield butyl methracrylate without inhibitor.

3) A 2% benzoyl peroxide (catylist) was then added to the monomer (based on total monomer).

4) The pH was then adjusted to a pH of 6.5 to 7.5 (to nullify the dissolution of the gelatin capsules).

To embed the samples, the adjusted, catalyzed inhibitor free monomer was then placed in gelatin capsules with the prepared samples and allowed to cure overnight in a constant temperature oven set at 50° C.

The paper samples were pre-prepared for embedding in the following manner:

1) Strips of the desired sheets were cut into size fitting the gelatin capsules.

2) These strips were soaked consecutively in the following solutions:
   a) one hour in ethyl alcohol (denatured)
   b) one hour in 50% ethyl alcohol (denatured) and 50% butyl methracylate monomer
   c) one hour in butyl methracrylate monomer

The speciments were prepared in this manner to minimize the amount of water and air trapped in the sample.

The prepared, cured samples were then microtomed on the Bausch and Lomb microtoming apparatus and mounted on glass slides with "Canadian Balsam" and cover glasses. The specimens were microtomed down to 3-4 micron cross sections, mounted, and observed under the Paper Technology's microscope. Other microtomed samples without the Canadian Balsam were sent to New Jersey Zinc Corporation for transmitted light, electron microanalysis of the cross sections. Also, unmounted sheets were sent for surface shadowing electron microanalysis.

III Data and Graphs

1) 50 percent solids air dried coating:

	#9 R&D	#15 R&D	#20 R&D	#30 R&D
Coat Weight (#/3000 ft^3)	13	18	22	32
I.P.C. Brightness	80.4	83.4	84.9	86.6
Hunter Gloss	20.9	24.6	27.4	30.3
Hunter Gloss (calendered)	62.1	68.5	70.4	73.0
Bekk Smoothness (sec.)	28.3	33.9	38.7	44.1

2) 50 percent solids heat dried coating:

	#9 R&D	#15 R&D	#20 R&D	#30 R&D
Coat Weight (#/3000 ft^3)	13	17	22	31
I.P.C. Brightness	76.2	80.9	83.8	86.2
Hunter Gloss	24.0	27.8	30.5	39.0
Hunter Gloss	67.1	70.9	73.9	75.5
Bekk Smothness (sec.)	34.4	39.6	42.5	46.2

3) 60 percent solids air dried coating:

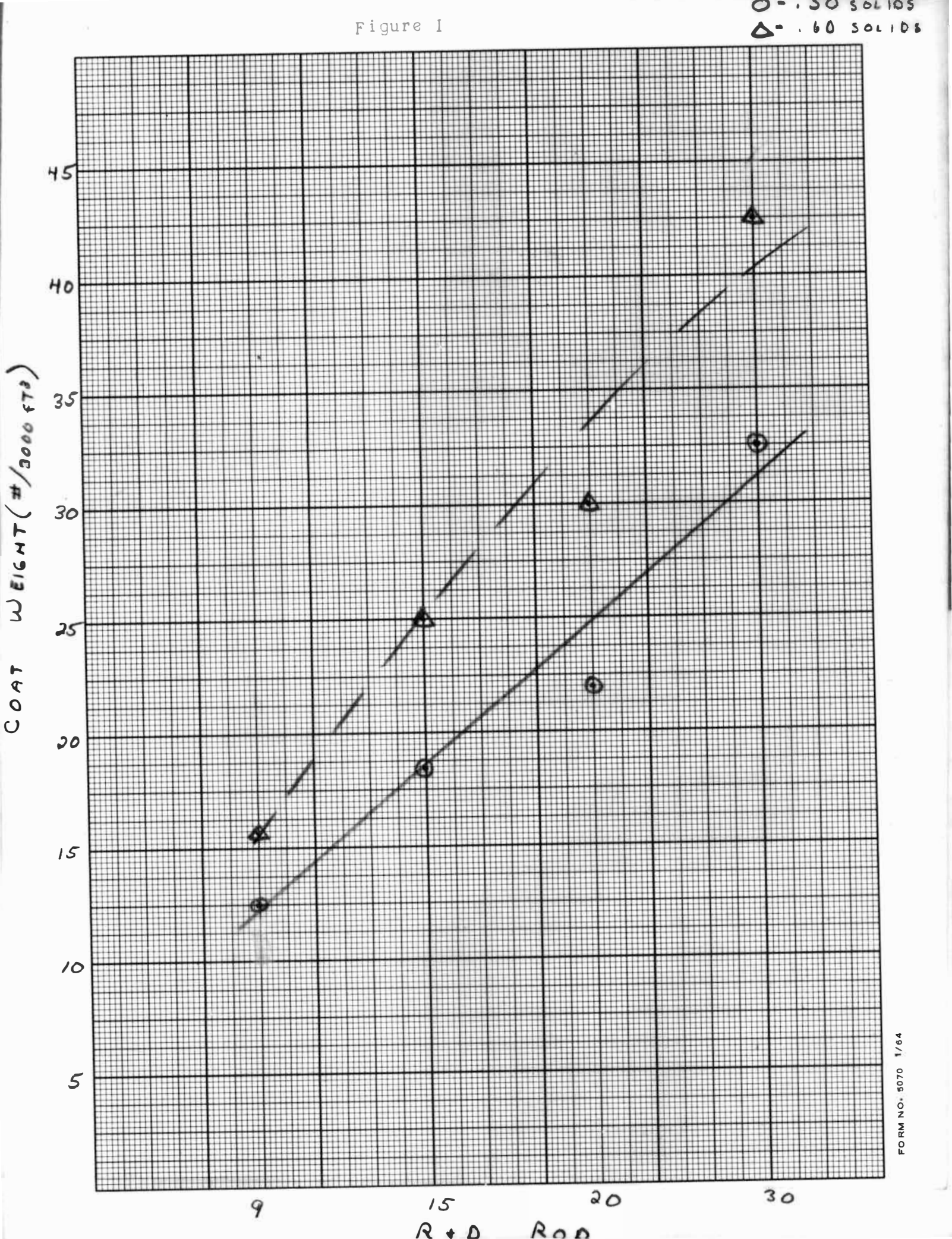
	#9 R&D	#15 R&D	#20 R&D	#30 R&D
Coat Weight (#/3000ft^3)	16	25	30	42
I.P.C. Brightness	82.9	85.6	86.0	88.0
Hunter Gloss	30.5	34.8	36.3	39.8
Hunter Gloss (calendered)	67.5	72.4	73.8	75.0
Bekk Smothness (sec.)	33.5	41.2	43.9	47.1

4) 60 per cent solids heat dried coating:

Coat Weight (#/3000ft^3)	16	25	30	42
I.P.C. Brightness	78.3	83.0	85.1	87.3
Hunter Gloss	32.5	33.7	36.4	41.7
Hunter Gloss (calendered)	69.1	73.0	75.2	74.4
Bekk Smothness	35.6	42.9	44.8	47.0

Note: All figures are averages of ten distinct readings.

Figure I



FORM NO. 5070 1/64

Figure 2

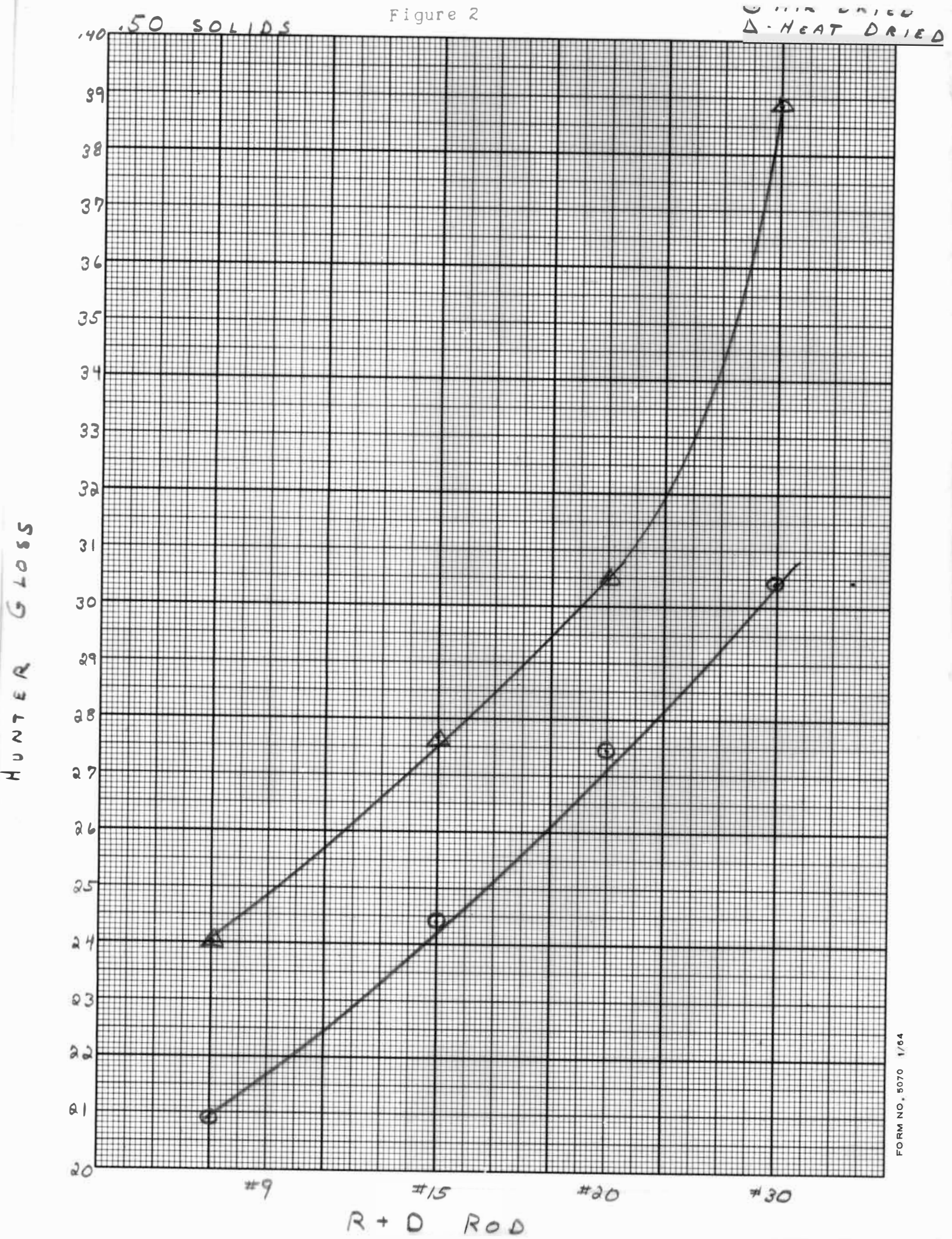
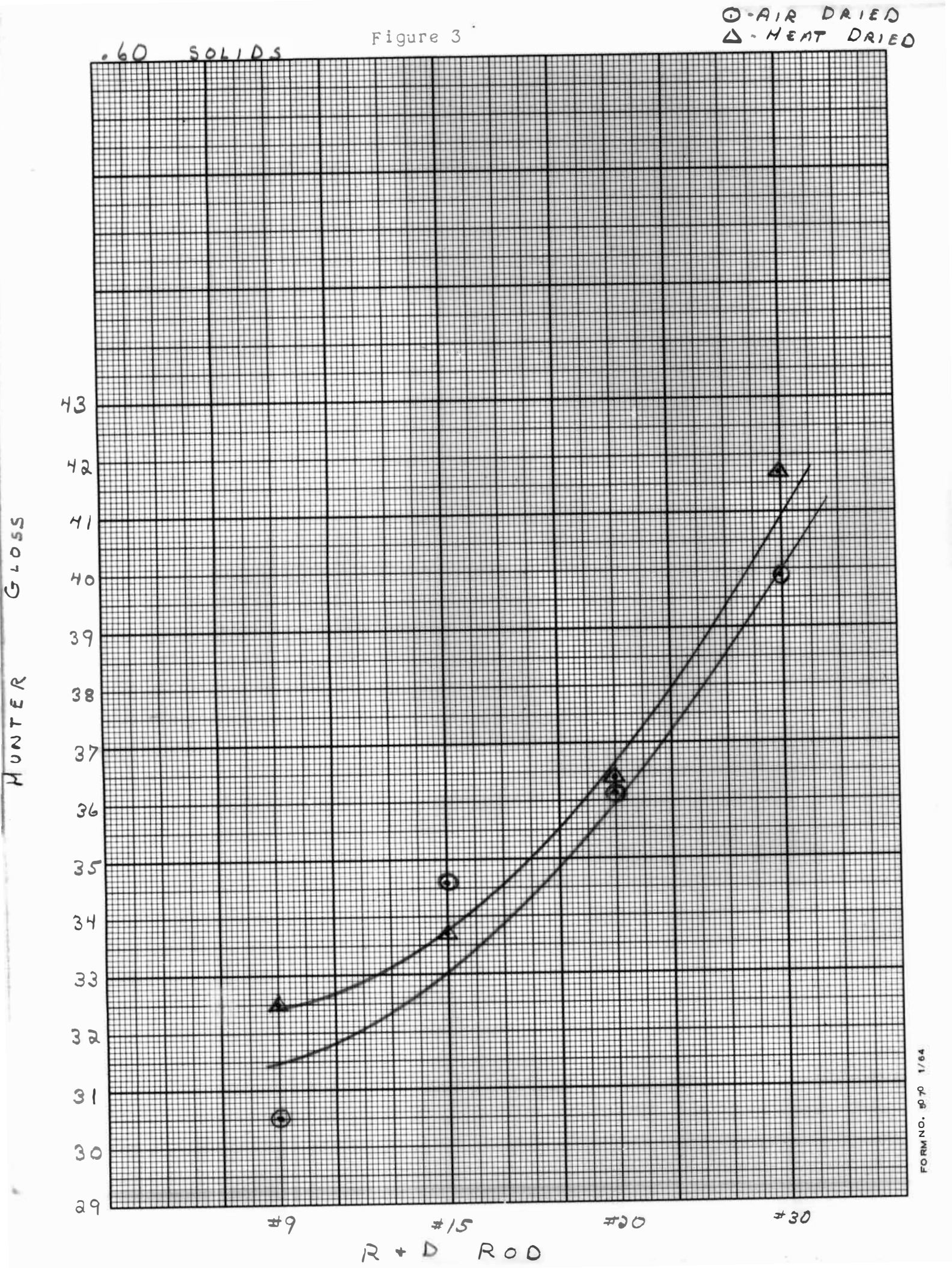

.50 SOLIDS
Δ - HEAT DRIED
HUNTER GLOSS
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
#9
#15
#20
#30
R + D ROD
FORM NO. 5070 1/64

Figure 3



FORM NO. 870 1/64

Figure 4

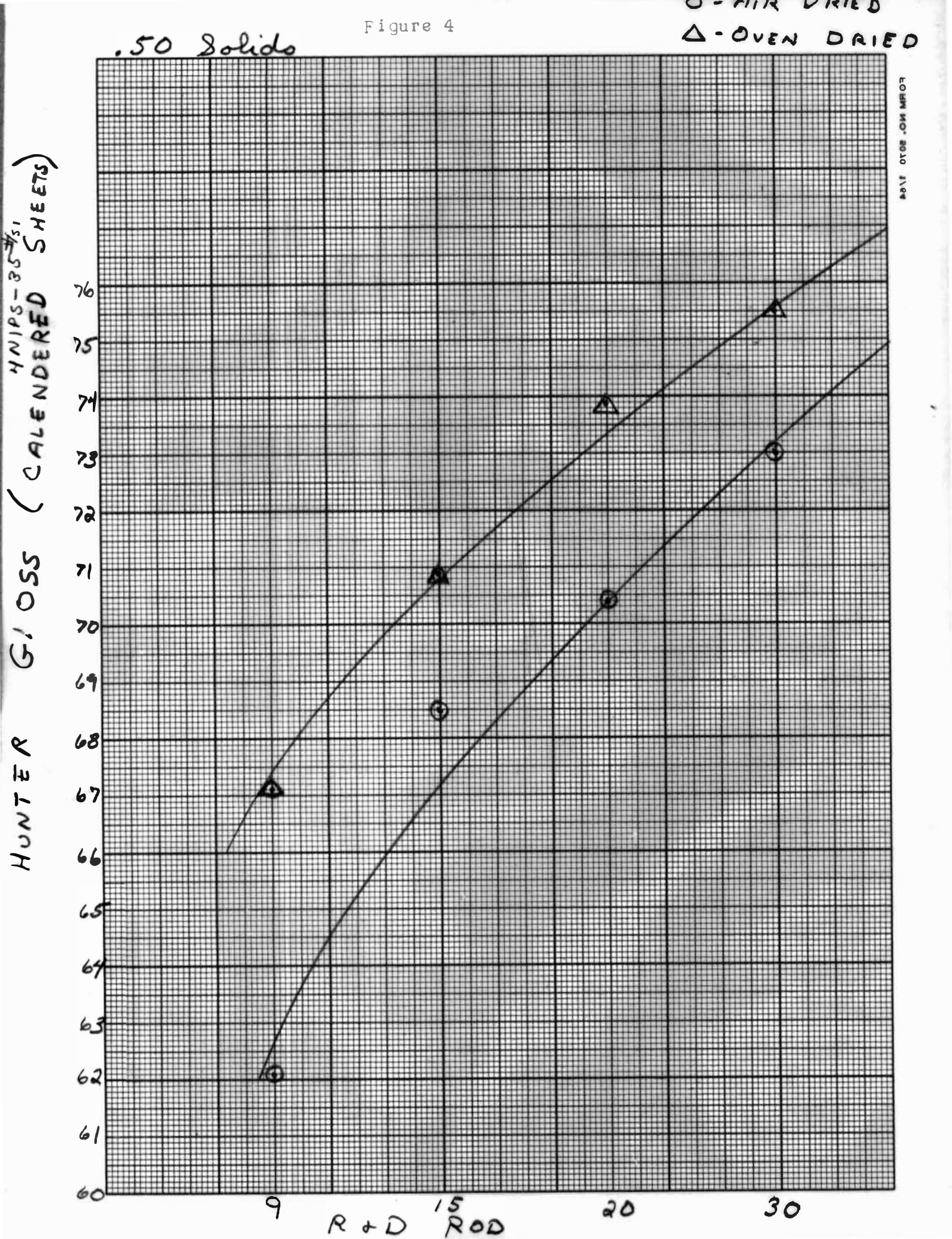

.50 Solids
○ - AIR DRIED
△ - OVEN DRIED
HUNTER GLOSS (CALENDERED SHEETS)
HNIPS-35 #51
76
75
74
73
72
71
70
69
68
67
66
65
64
63
62
61
60
9
15
20
30
R & D ROD

Figure 5

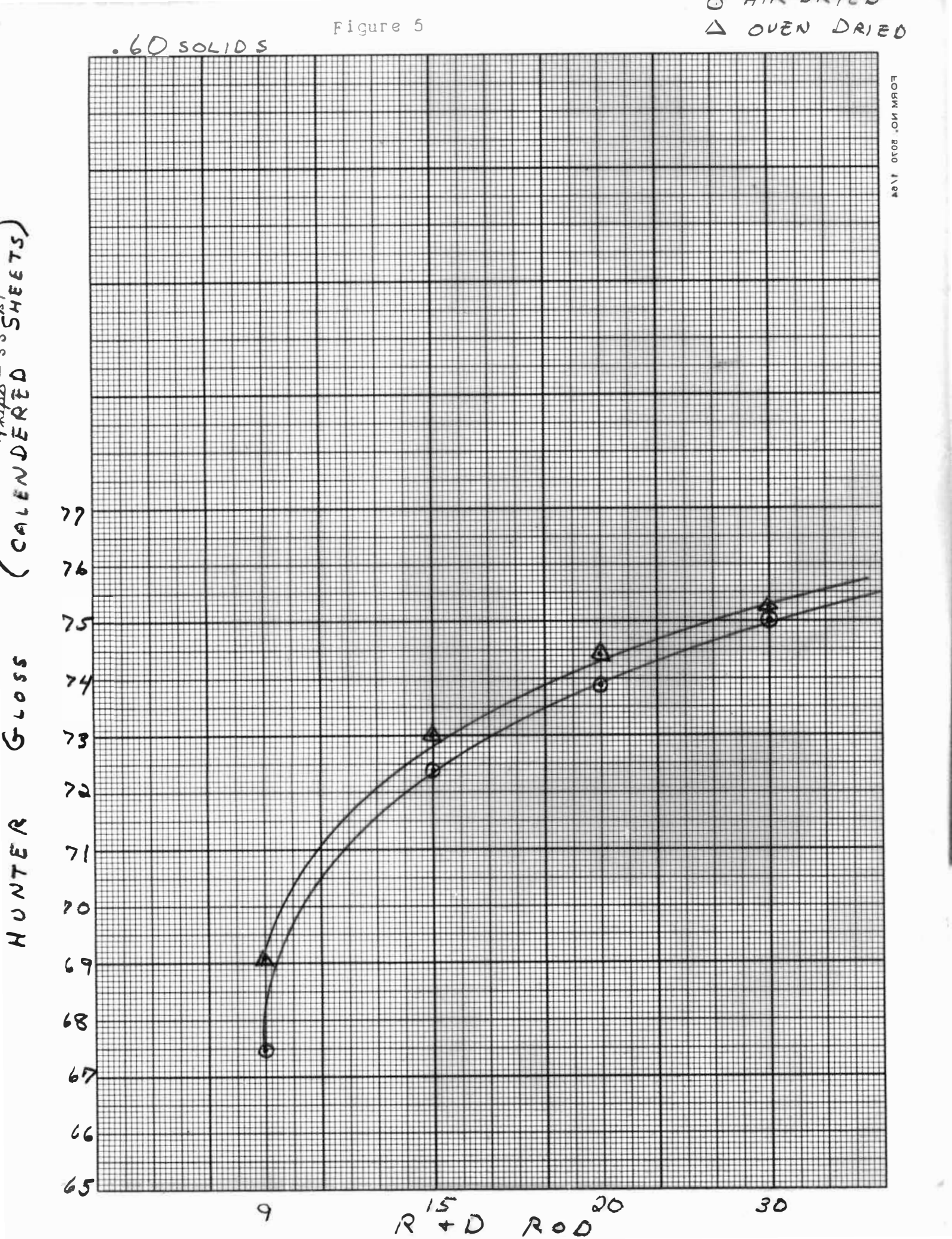
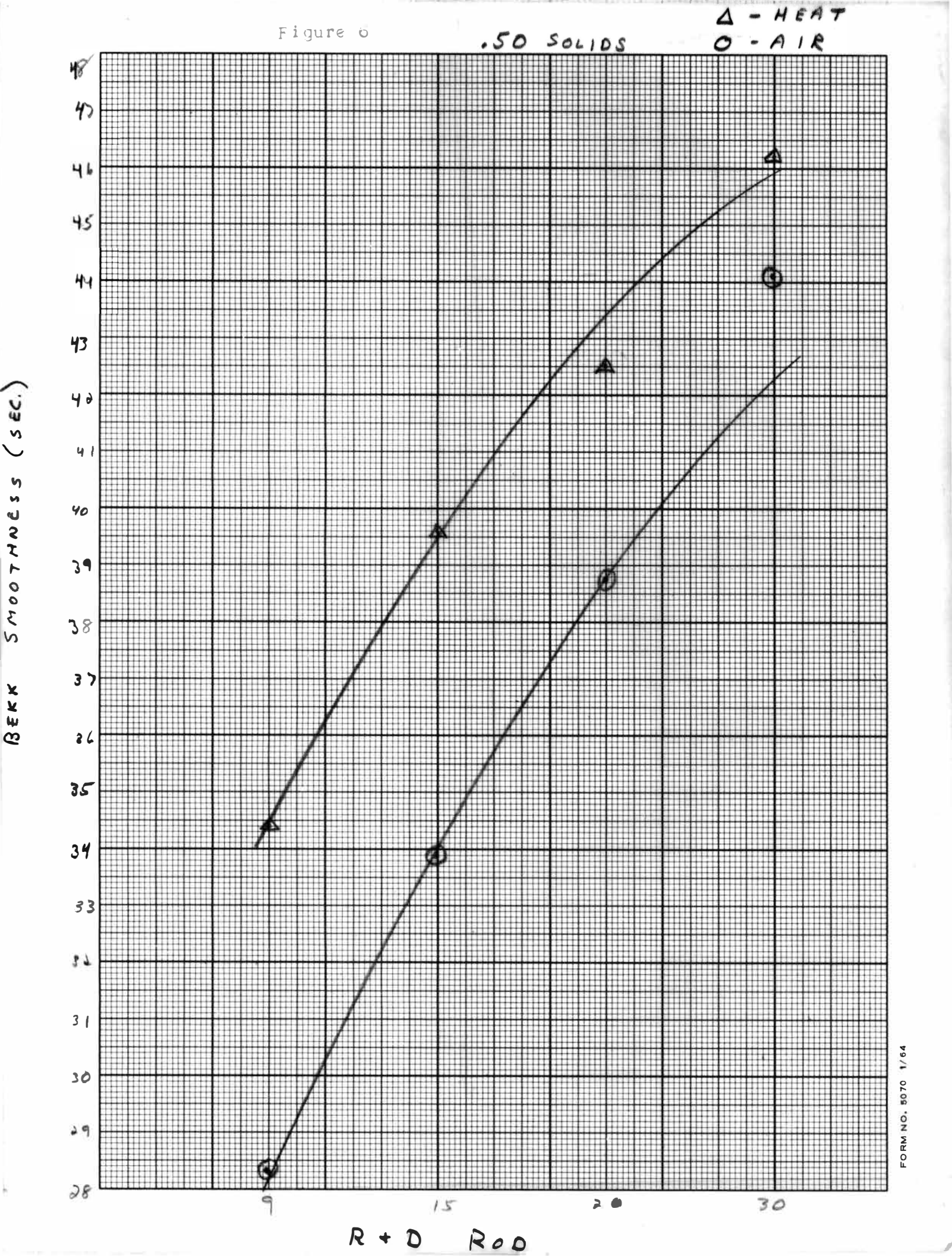
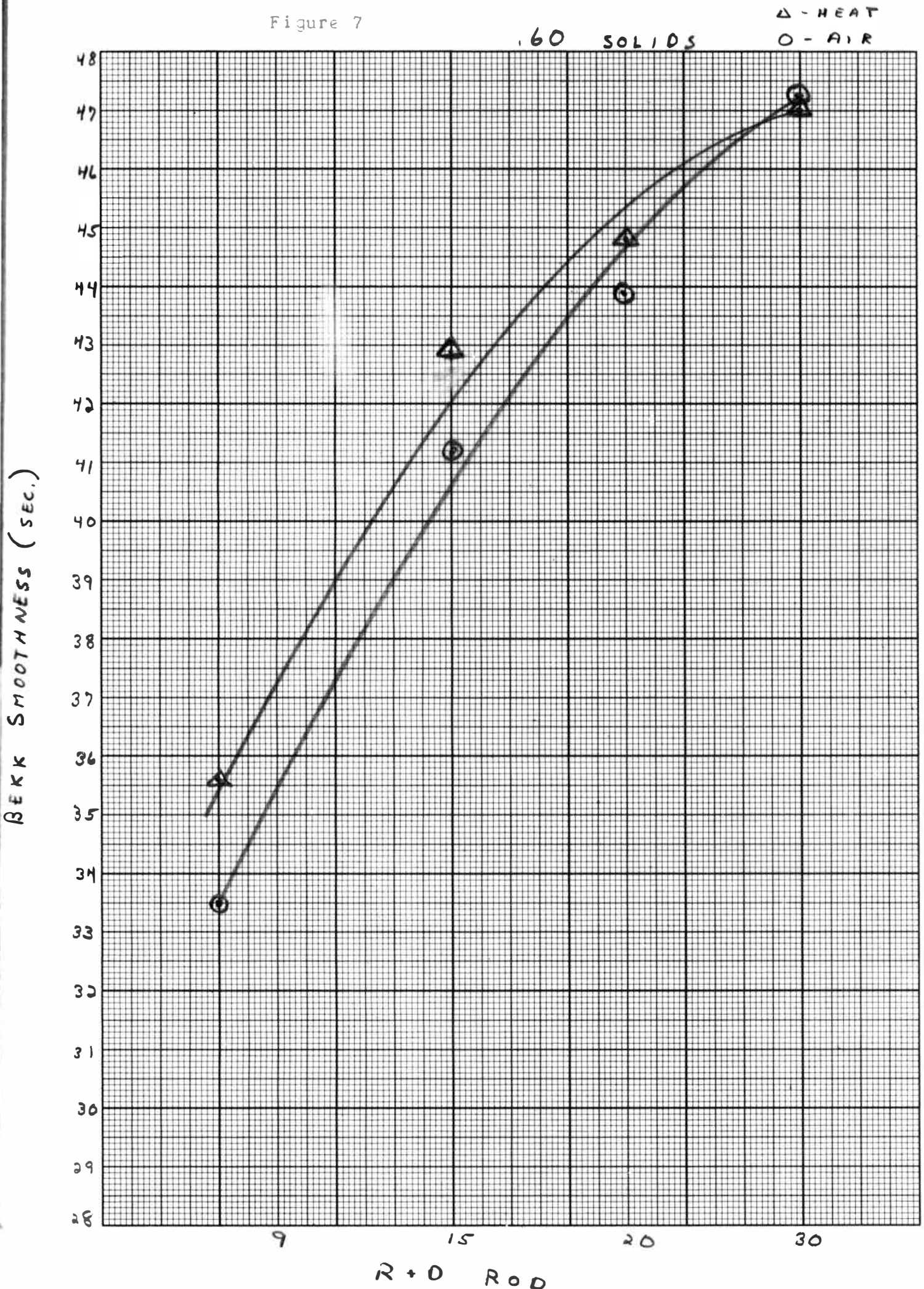

.60 SOLIDS
○ AIR DRIED
△ OVEN DRIED
HUNTER GLOSS (CALENDERED SHEETS)
77
76
75
74
73
72
71
70
69
68
67
66
65
9
15
20
30
R + D ROD

Figure 6



FORM NO. 5070 1/64

Figure 7



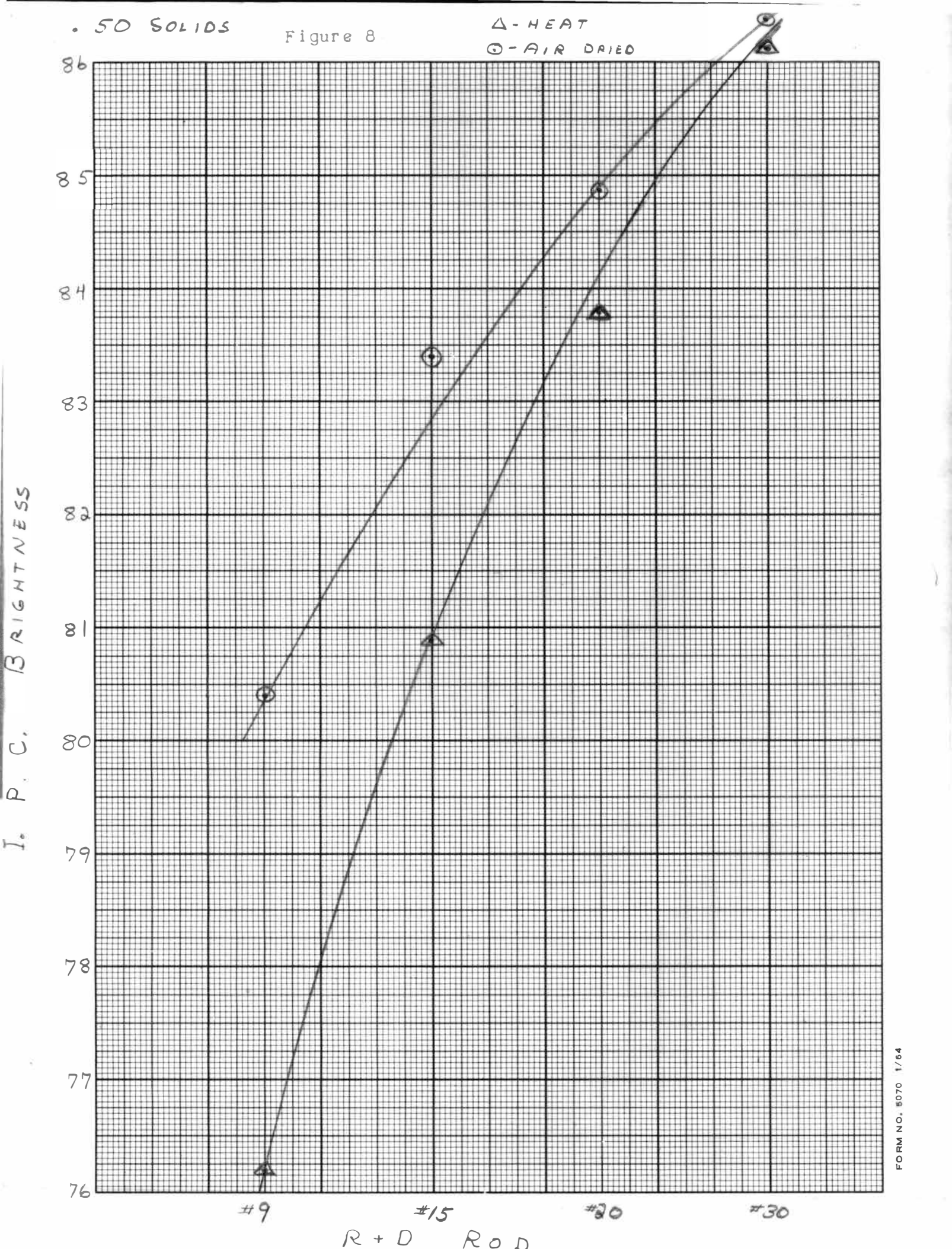
FORM NO. 5070 1/64

.50 SOLIDS

Figure 8

Δ - HEAT

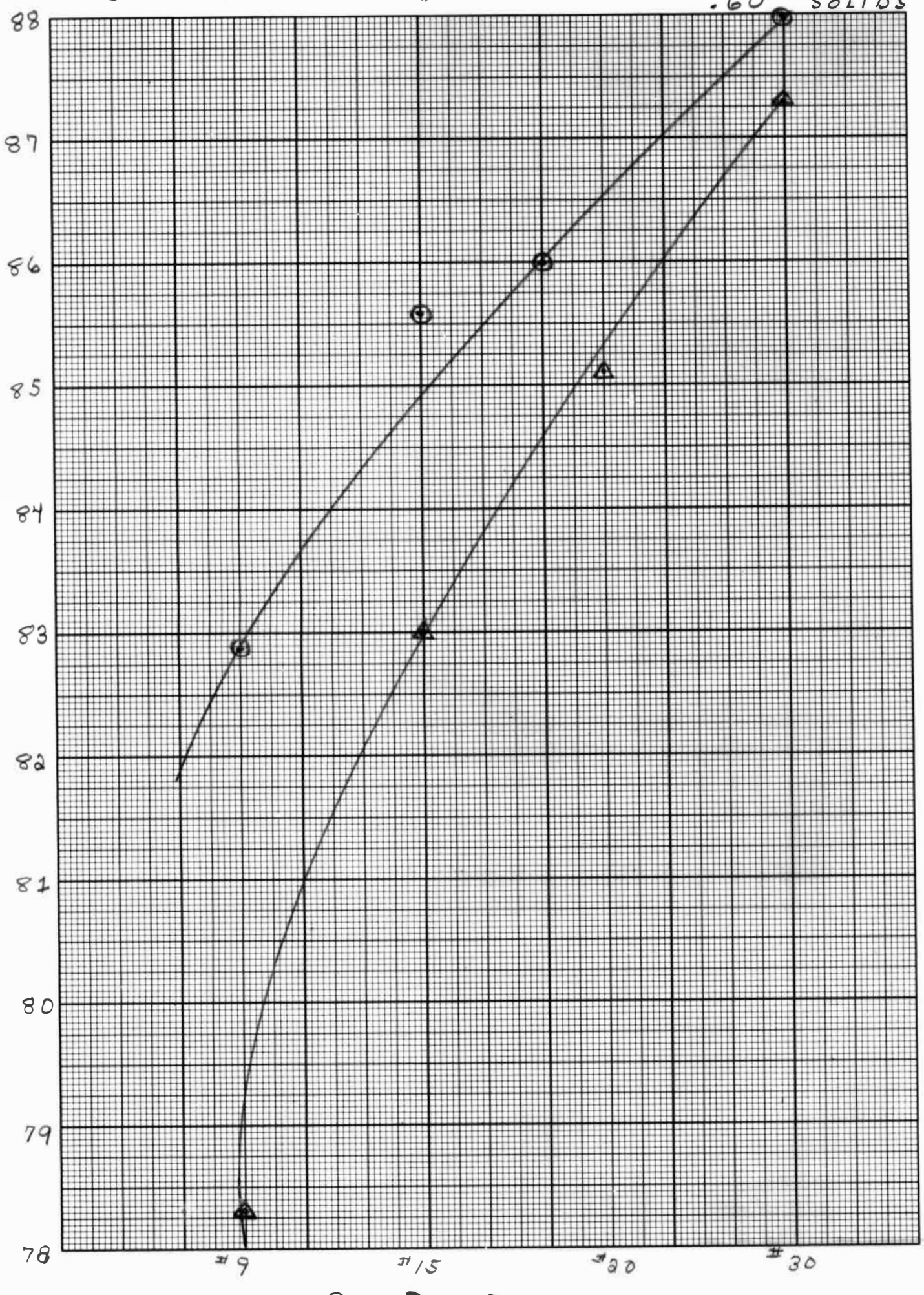
⊙ - AIR DRIED



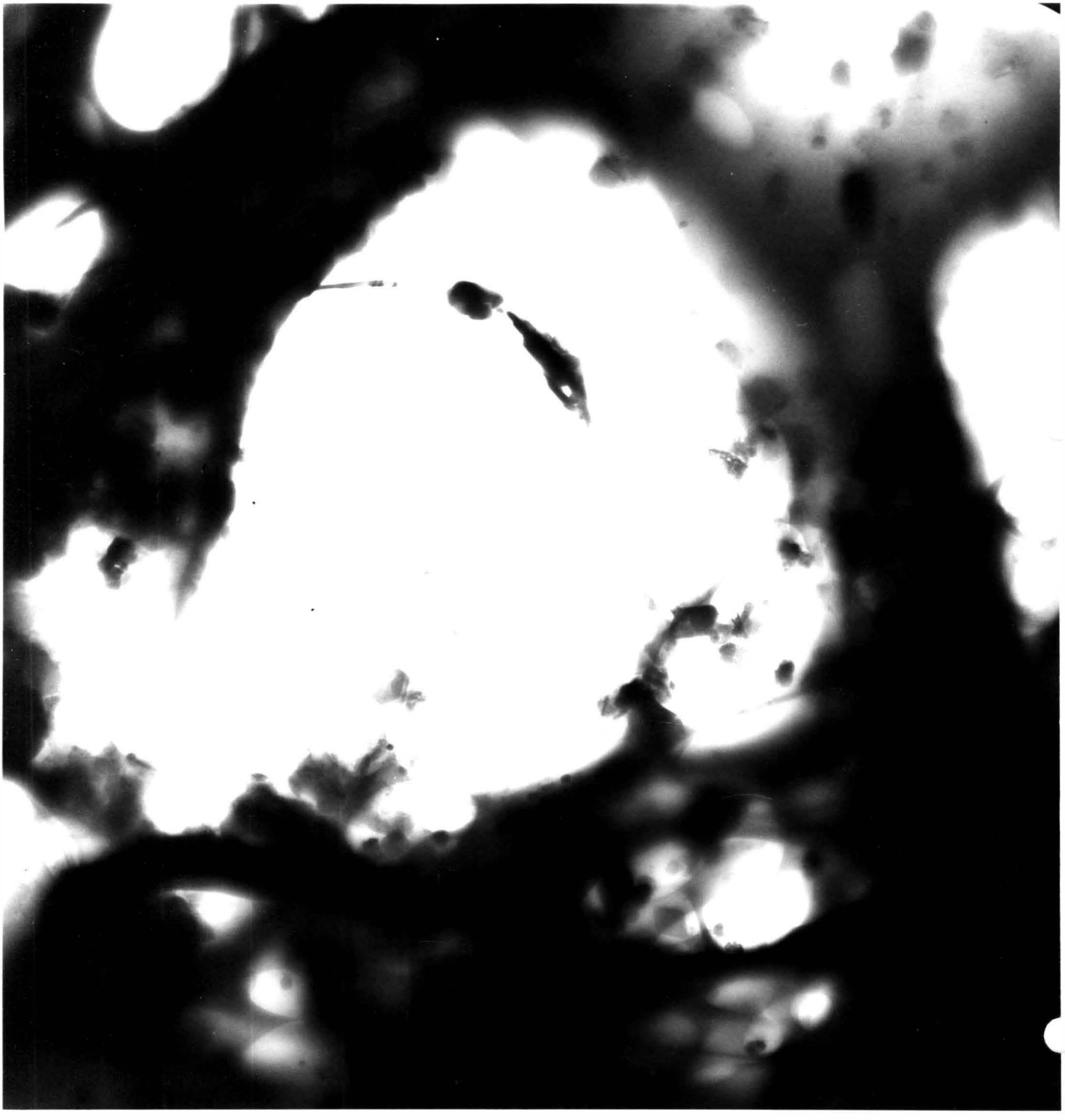
FORM NO. 5070 1/64

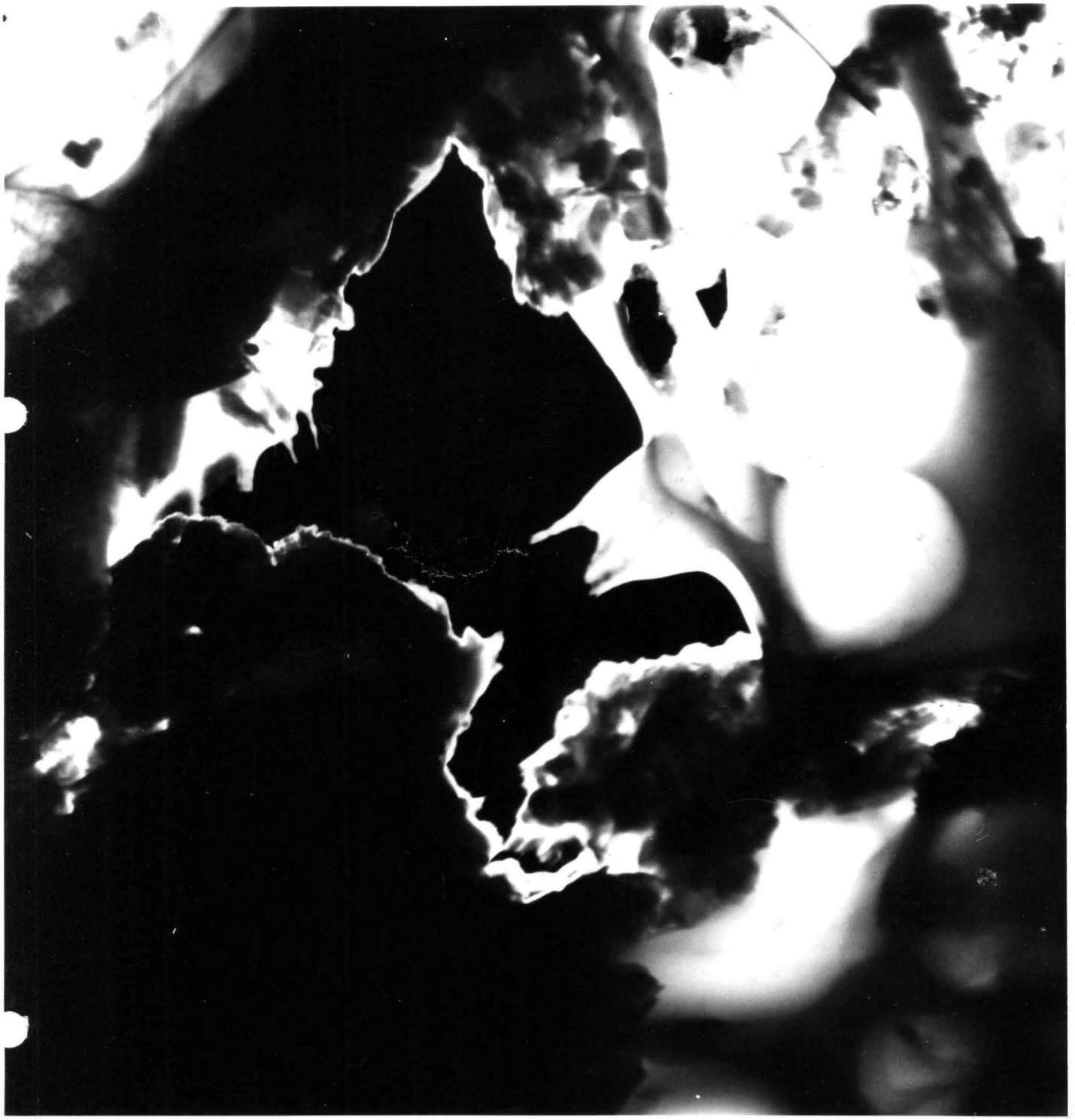
Δ - HEAT DRIED
○ - AIR DRIED

Figure 9



FORM NO. 5070 1/64





IV. Discussion of Results and Graphs:

A. Physical Data Interpretation

As the rod number or coat weight increased, the brightness, gloss and smoothnes were shown to increase also. As the sheets were heat dried a decrease in brightness was noted as well as an increase in gloss and smoothness. Apparently, as the wet coating was being hot air dried, the viscosity of latex was reduced sufficiently so as to enable the latex to migrate towards the top of the sheet or the heat source in the same fashion as the liquid water (I). This phenomena was seen more readily in the mobile fifty percent solids coatings than in the immobile sixty percent solids coating. Thus as the latex concentration on the surface was increased by the heat source, a decrease in brightness and an increase in gloss and smoothness was observed.

From the graphs, the binder (latex) distribution of all coatings, air dried at a slow rate, was of the fashion that more of the latex migrated away from the surface of the sheet and probably into the hydrophilic base stock along with the water being drawn into the substrate by capillary action. Thus, a higher brightness, a lower gloss, and a lower smoothness were obtained as compared to the heat dried sheets.

Also from the graphs, there appeared to be more overall latex migration tendencies in the fifty percent solids coatings than in the sixty percent solids coatings; as the breadth or difference between the curves of the lower percent solids coatings were generally much greater than the narrow breadths of the higher percent solids coatings. It was observed that often there was little difference noted between the heat dried and air dried sheets as one aproached the number thirty R. and D. rod: generally, the graphs tapered off at this point.

B. Optometric Analysis (discussion)

The first series of microtomed cross sections were observed through the Paper Technology microscope with a magnification of 1200 with the aid of an oil immersion lens and high intensity polarized light. In general, no conclusions could be drawn from these observations concerning the distribution of latex particles. Even at these magnifications and under these intense light sources, the latex particles could not be distinguished quantitatively, mainly due to the high density of the pigment coating strata and the extremely small particles size of the latex units. On the whole, good profiles of the coating surface as such could be observed quite well under these conditions.

Next, the first series of microtomed cross sections photographed under transmitted light with New Jersey Zinc's electron microscope were examined thoroughly. The magnification used was 17000 which appeared to be too great for the purpose of observing cross sections. Nothing conclusive could be drawn about the latex migration tendencies. Visually one could not distinguish the latex particles among the dense network of fibers, pigment, and voids.

V. Conclusions:

Concluding from the physical testing observations, it can be said that to obtain the optimum smoothness, gloss, and brightness in a sheet the rate of drying and type of drying conditions must be controlled accordingly. It appears that in designing a coating drying apparatus, a prior cool air dryer section before the final, forced heated air section would give a well oriented adhesive distribution in the sheet as well as give near optimum surface properties of brightness, smoothness, uniformity, printability, gloss, and calendered gloss.

I would like to offer my sincere appreciation to Dr. R.A. Diehm, for his extensive help and guidance throughout the past two semesters.

Andrew M. Sukas

VI. Bibliography

1. Heiser, E.J. and Cullen, D.W., "Effects of Drying Rates on Rates on Adhesive Redistribution and Coated Paper Properties, Tappi, Vol. 48, No.-85, (August, 1965)

2. Rappen, J. Wayen, Tappi Vol.34, No.2:324-335 (July, 1951)

3. Casey, J.P. and Libby, C.E., Paper Trade Journal,127, No. 25: 83-90; No. 26:35-41 (December 16,23, 1948)

4. Singleterry, C.R. Paper Trade Journal 113, No. 16, 37-40, (October 30, 1941)

5. Eames, A.C., Tappi, 43, No.1: 2-10 (January, 1960)

6. Rowland, B.W., Paper Trade Journal 111, No.16:41-46 (October 17, 1940)

7. Livingston, L.H. Thesis, W.M.U., 1966, "The Effect of Drying conditions on the Surface Properites of a Commercial Coating".

8. Davidson, Gleen, Paper Trade Journal, 110 No.24:30-32, (June 13, 1940)

9. Dobb, R.M.K. and Lowe, D.U., Pheology No.2:158 (January 1930)

10. Cobb, R.M. Journal Rheology, 158-166, (1930); Paper Industry 12: 753 (July, 1930)