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UNIVERSITY OF LOUISVILLE

DRYING OF SOLIDS
" "
I PRUSSIAN BLUE

A DISSERTATION
SUBMITTED TO THE FACULTY
OF THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

DEPARTMENT OF CHEMISTRY

By
ORVILLE K. SCHMIED

1933

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INTRODUCTION

The purpose of this investigation is to study the effect of varying conditions, as temperature and humidity, upon the rate of drying of solids. Commercial Prussian Blue was the solid dried. The effect of the variation of temperature and humidity on the properties of this color is included in this investigation.

Drying consists of removing or eliminating the moisture from any solid by evaporation, and is also generally understood to apply to the evaporation of solvents. For many materials drying by means of air is to be preferred. The air drying consists of passing hot air over the solid, transferring heat directly to the wet material, thereby vaporizing the water which is removed by the cooled air.

The two chief classes of driers are the atmospheric and the vacuum types. Vacuum driers are used for sensitive materials which have a decomposition temperature lower than the temperature required to dry them. By reduction of the total pressure water vapor is removed at a temperature lower than would be necessary at atmospheric pressure. For materials not requiring these

restrictions atmospheric drying is usually employed.

If the mechanical and physical problems in the drying and handling of a material indicate an atmospheric drying system, the choice lies between three types of driers (1):

1. The continuous automatic type. The material is conveyed mechanically through the drier, or from compartment to compartment, while a transverse circulation of air is usually maintained.

2. The tunnel type. The material is passed through the drier on trucks, while circulation of heated air is maintained in a direction opposite to the movement of the material. Construction permits the continuous feeding of material at one end, and removal at the opposite end.

3. The compartment type. This drier may be an entirely self-contained unit, as a dry kiln, all parts being furnished and set up in the building independent of the building construction. It also may be simply a room or compartment in the building, fitted with

coils, fan, or other drying apparatus used in the drying process.

The continuous drier is inefficient and expensive whenever it is not operated to full capacity. On the other hand, the compartment drier can be loaded during the production period and the drying can be carried on at night.

The compartment drier is not applicable where a continuous process of handling material is desired. The efficiency also tends to be lower than that of the continuous drier. The use of the compartment drier in preference to the continuous mechanically operated drier is usually advantageous whenever the period of drying exceeds five or six hours, and where production is not continuous during the twenty-four hours.

Continuous driers employ direct current or counter current drying with air. According to H. Nehbel (2) direct current drying is theoretically more efficient than counter current drying. Direct current drying must be at a higher temperature and

lower saturation than counter current, since the capacity of the dry air for taking up water is great at first, but very slow above twenty percent saturation. Thus it is uneconomical to carry the saturation further than twenty percent.

J. Dem (3) proposed increased efficiency in drying by obtaining a more intimate contact between air and material. The flights were arranged in a spiral, the satisfactory angle being about twenty degrees. A further suggestion is to introduce the air through a nozzle with spiral vanes to prevent the air from passing through in a straight line.

According to L. Buck (1) a certain limit to the speed of drying of various materials must be determined experimentally. Exceeding this speed will result in injury to the material, such as checking, cracking, curling, discoloration, warping, shrinkage, honeycombing, etc.

Prussian blue is a very permanent and powerful color made from solutions of ferrous salts with potassium ferrocyanide, with subsequent

conversion into the ferric condition. All of the blue compounds of iron and cyanogen or amorphous substances which yield colloidal solutions in pure water, thus making the pure condition extremely difficult to obtain.

The freshly prepared blue precipitates contain indefinite quantities of water, which cannot be totally removed by drying. This residual water must be regarded as constitutional, because when the substances are heated to temperatures a little over one hundred degrees Centigrade, they lose cyanogen, but not water.

When cold neutral solutions of a ferric salt and potassium ferrocyanide of equal molarity are mixed together, a precipitate of ordinary soluble Prussian blue is formed. The dry substance has the composition

When a cold solution of potassium ferrocyanide is added gradually to a cold neutral solution containing an excess of a ferrous or a

ferric salt, or when soluble Prussian blue is digested with a solution of ferric chloride, insoluble precipitates are formed. After the prolonged exposure to air involved in washing them completely, they are identical in composition and properties. The dry substance is normal ferric ferrocyanide

and usually referred to as Prussian blue.

Both the soluble and insoluble Prussian blue, just described, are ferric ferrocyanides, and not ferrous ferricyanides.

There is much controversy as to whether the ferric salt is ferricyanide or ferrocyanide. K. A. Hofmann (5) and E. Mueller (6) incline to the view that it is ferrocyanide.

Woringer (7) concludes that the constitution of insoluble Prussian blue is represented by the formula $\text{Fe Fe} (\text{Fe CN}_6)_3$.

P. F. Schmidt and B. Rassow (8) advance the opinion that Prussian blue is a ferric ferrocyanide in which a part of the Fe is replaced by K, and two mols of H_2O are in intermolecular combination. Moreover it also contains small quantities of hydrated ferric oxide in solid solution.

G. R. Lewis' (9) examination of Prussian blues by X-rays with Mo anticathode shows no diversity of crystalline structure between ferric ferrocyanide and ferrous ferrocyanide.

Various factors control the physical properties of the resultant blue. E. F. Morris (10) states that the drying of Prussian blue press cake is best carried out in a current of hot air. The resultant product is a stronger and less 'cindery' product than that obtained in a vacuum drier. The intensity of the color depends upon the concentration of acid, temperature of precipitation, amount of oxidant used, etc.

Commercial Prussian blue is a mixture of a number of ferric ferrocyanides, and consequently

varies considerably in its color and appearance. It is sold in forms of lumps, powder, and paste. All these have a deep blue color and show a bronze reflex in varying degree.

Prussian blue is used extensively as a paint pigment and in the manufacture of dyestuffs and wall paper. It is also used in the preparation of photographic color plates (11), in the printing industry (12) (13), and in the processing of rubber (14).

This investigation will include the determination, upon a semi-plant scale, of the effect of varying conditions, as temperature and humidity, upon the rate of drying and resultant color properties of Prussian blue.

THEORETICAL

The mechanism of the drying of solids has been previously investigated by Sherwood (15) and Newman (16). The drying of solids involves two mechanisms, first the diffusion through the solid to the surface, second the removal of moisture from the surface.

Quoting Sherwood (15), who has classified all drying into three types:

1. Evaporation of the liquid at the solid surface; resistance to internal diffusion of liquid small as compared with the resistance to removal of vapor from the surface.

2. Evaporation at the solid surface; resistance to internal diffusion of liquid great as compared with the resistance to removal of vapor from the surface.

3. Evaporation in the interior of the solid; resistance to internal diffusion of the liquid great as compared with the total resistance to removal of vapor.

Solids being dried under constant conditions show a constant rate period, until the

critical moisture content is reached. At this point the rate of drying begins to decrease until equilibrium moisture content is reached. This period is known as the falling rate period.

During the constant rate period water is constantly evaporated from the solid surface, while during the falling rate period the mechanism primarily depends upon diffusion to the surface.

EXPERIMENTAL

A. APPARATUS and OPERATION

The drier used in these tests was a twelve-tray "H - W" Conditioner manufactured by The Industrial Dryer Corporation, Stamford, Conn. A picture of the drier is shown in Fig. 1, while Fig. 2 is a diagramatic sketch.

Air is drawn through pipe A, Fig. 2, by the fan B. The air is then blown through the heating chamber C, which contains four sets of steam coils. It then passes under baffle wall D, into distribution chamber E. The heated air next passes through slots F, over trays in drying compartment G, and into outlet chamber H. The outgoing air either leaves through the stack J, or is recirculated by means of the damper K. Inlet damper L regulates the amount of atmospheric air which is drawn in.

The temperature of the drying air was regulated by means of steam in the coils. Valves were used to control the amount of steam required to maintain the desired temperature.

FIG. 1

"H - W" Conditioner

FIGURE 2-A

DIAGRAMATIC SKETCH OF DRIER

FRONT VIEW

FIGURE 2-B

- A-ENTERING AIR PIPE
B-FAN
C-HEATING CHAMBER
D-BAFFLE WALL
E-DISTRIBUTION CHAMBER
F-SLOTS
G-DRYING COMPARTMENT
H-OUTLET CHAMBER
U-OUTLET AIR PIPE
K-DAMPER
L-DAMPER
M-STEAM NOZZLE
N-MOTOR

DIAGRAMATIC SKETCH OF DRIER
TOP VIEW

The humidity of the incoming air was also controlled by the use of steam. The live steam was introduced directly into the path of the incoming air immediately before entrance into the fan, by means of nozzle M, Fig. 2.

A Bristol Recording Psychrometer, Fig. 3, was used as a guide in maintaining the desired conditions of temperature and humidity. The wet and dry bulbs, A, Fig. 3, were placed at the entrance to the distribution chamber E, Fig. 2, just before the air passed over the trays. The instrument itself was installed on the instrument board beside the drier. The water supply for the wet bulb was furnished by a bottle also installed on the instrument board. A constant supply of water over the wet bulb wick was necessary to obtain accurate recordings.

Temperature and humidity conditions of incoming and exhaust air were determined by means of wet and dry bulb thermometers placed at air intake and outlet, A and J, Fig. 2.

FIGURE 3

A - WET BULB THERMOMETER
A' - DRY BULB THERMOMETER
I - WATER INLET
O - WATER OUTLET
D - DRY BULB RECORDING PEN
W - WET BULB RECORDING PEN

BRISTOL RECORDING PSYCHROMETER

Air velocity readings were taken three or four times during each run. An anemometer was placed at the opening of the inlet pipe, and the reading taken in feet per minute. When recirculation of air was used, the amount of recirculation was determined from the inlet reading at that time as compared to the readings obtained when there was no recirculation.

B. MATERIAL

The material used in these tests was a standard commercial Prussian blue, furnished by the Kentucky Color and Chemical Company, Louisville, Kentucky.

The blues were prepared from ferrous sulfate with the addition of sulfuric acid and ammonium sulfate, precipitated with sodium ferrocyanide, and then oxidized by means of sodium chlorate. This oxidation was usually carried out at a temperature of sixty degrees Centigrade to a boil, although sometimes made at room temperature. The resulting color was washed free of soluble salts and acid by decantation over a period of three weeks. The sludge was finally filtered in a twenty-four inch square filter press of the plate and frame type. The press cakes were transferred directly to the trays and thence to the drier.

For each run, a total of twelve filter cakes were used, two on each of six trays, which were placed on alternate shelves in the drier.

The six empty trays were placed on the remaining shelves in order to fulfill the requirements of the design of the drier. Each wet cake weighed approximately twenty-five pounds, making a total of about three hundred pounds of color dried each run. The wet cakes as received averaged about forty-five percent moisture. Each cake was approximately twenty-two inches square, making about forty square feet for a batch of twelve trays. After experimental drying the cakes were returned to the company.

C. PRELIMINARY EXPERIMENTAL

The preliminary experimental work consisted primarily of acquiring a technique in controlling the temperature and humidity. Many difficulties had to be overcome before any actual runs could be made.

The principle difficulties encountered were:

1. Variations in steam pressure.
2. Humidity control.
3. Unequal distribution of air velocity.
4. Ventilation.

It was necessary to maintain a constant air temperature throughout each run. To accomplish this a fairly constant steam pressure was necessary. Considerable difficulty was experienced due to variations in the steam pressure on the University line. During the earlier part of the work the laboratory boiler was inaccessible due to trouble with the draft. After this defect had been remedied steam was used from this source exclusively. Constant pressure regulators would be desirable for this work.

A constant humidity was also essential throughout each run. In order to reach the desired conditions it was found necessary to inject water vapor into the path of the air stream. An attempt was made to do this by means of a cold water spray, but this was impossible since saturated air at the low temperature due to the cold water was inadequate to give the desired humidity at high temperatures. To remedy this live steam was introduced instead of the cold water, thus raising the conditions of the humidified air and enabling the required humidity to be reached. Recirculation was found to give more accurate control of humidity conditions. A mechanical humidity control apparatus would be desirable for future work.

A check on the velocity of the air passing over the individual trays, and concurrently the moisture lost, showed the drier to have unequal distribution of drying air. To correct this fault two baffle plates were installed on the walls of the distribution chamber. With the installation of these plates the air was equally distributed over the trays.

During the latter hours of a high temperature run cyanogen was detected being blown from the exhaust into the room. This danger was eliminated by placing a stack to convey the exhaust gases to the outside of the building.

A number of test runs were made to eliminate all minor difficulties before the actual experimental runs were begun.

D. FINAL EXPERIMENTAL

Ten runs at different conditions of humidity and temperature were made as shown in Table I. A temperature range from 120° F to 180°F was suggested as being the limits in plant practice. The limits of humidities of the various runs was controlled in the same manner. Each run lasted for a continuous period of twenty-eight hours. Preliminary test runs determined this as the necessary drying time in order to obtain proper drying data.

Before the beginning of each run the drier was brought up to the desired conditions of temperature and humidity. At this time the loaded pans were weighed and placed in the drier. At the end of the run the pans were weighed again to determine the amount of moisture lost. The wet and dry bulb temperatures at the inlet and outlet were read at regular intervals of two hours. From this data the humidities at these points were determined. Inlet air velocity readings were taken three or four times during each run to determine the amount

TABLE I

TEMPERATURE - HUMIDITY CONDITIONS OF RUNS

Run No.	Temperature °F	Humidity %
1	120	6.3 (atmos.)
2	140	4.6 (atmos.)
3	160	6.3 (atmos.)
4	180	2.7 (atmos.)
5	140	10
6	160	10
7	180	10
8	140	15
9	160	15
10	160	20

of recirculation. The air velocity over the trays was kept constant throughout all runs. A copy of a typical psychrometer chart, which was used as a guide in controlling the temperature and humidity, is shown in Fig. 4.

In order to obtain the desired drying curves a moisture sample was taken every two hours from each of the six trays. The cakes were not of the same moisture content throughout, which made the attaining of absolute correct data impossible. Samples for any particular tray were taken as close together as possible in order to assure the best possible comparative moisture contents. During each run the samples also were taken from the same relative position in each tray.

In the early stages of the run the samples were procured by means of a half-inch cork borer; latter when the cakes became drier and harder it was necessary to remove the samples by means of a knife. Each sample constituted a complete cross-section of the cake, averaging about five grams each.

FIG. 4

TYPICAL PSYCHROMETER CHART

Copy of Chart for Run 5

Dry Bulb Temperature 140°F Wet Bulb Temperature 87°F
 Percent Humidity 10

When removed the samples were placed on watch glasses and weighed. They were then placed in an electric oven for forty-eight hours at a temperature of 70 - 80°F, after which a final weighing was made, and the percent moistures calculated. Preliminary tests showed that the above time and temperature were sufficient for drying the samples to constant weight.

At the termination of each run a larger composite sample was taken for the study of the physical properties of the color.

DRYING RESULTS

Moisture Content vs Time curves (not included) for each of the six individual trays were plotted after each run. The points which were off the general trend of these individual curves were eliminated in calculating the composite moisture content averages of the trays. These incorrect values were attributed to 'wet-spots' in the cakes and to the difficulty in always obtaining a good crosssectional sample.

In calculating the rate of drying the percent moistures at each sampling were taken from the drying curves and not from the original data. This was done to assure more correct rate of drying curves. The weights of the wet cakes at the beginnings of the runs were taken from their respective log sheets.

TABLE II

LOG SHEET

Run 1

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 4

Date: 3/10/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 3/9/33

Rx. No.: 4002

Batch Rtd.: 3/21/33

Slip No.: 155

Batch No.: 1

Drying Conditions

Date Struck: 3/6/33

Temperature: 120°F

No. Trays Dried: 20

Humidity: 6.3% (Atmos.)

Date In: 3/10/33

Inlet: Average Dry Bulb Temperature: 80°F
 Average Wet Bulb Temperature: 59°F
 Average Humidity: 26%

Outlet: Average Dry Bulb Temperature: 102°F
 Average Wet Bulb Temperature: 94°F
 Average Humidity: 71%

Average Room Temperature: 76°F

Inlet Air Velocity: 2810 ft./min.

Percent Recirculation: None

Recorded Psychrometer Chart Temperatures: Dry Bulb: 120°F
 Wet Bulb: 70°F

Pan Data

Pan No.	Wt. of Cake Before Drying lbs.	Wt. of Cake After Drying lbs.	Wt. Moisture Lost lbs.
1	48.00	29.50	18.50
2	50.00	29.00	21.00
3	49.50	30.25	19.25
4	50.75	28.75	22.00
5	50.75	30.00	20.75
6	47.50	26.75	20.75
Total	296.50	174.25	122.25

TABLE III
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 1

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	6.296	2.978	47.3
	2	4.718	2.455	52.0
	3	5.299	2.522	47.6
	4	4.021	2.222	55.3
	5	4.988	2.527	42.2
	6	5.770	2.857	49.6
			Average	<u>49.0</u>
2	1	5.134	2.428	47.3
	2	3.407	1.651	48.5
	3	4.917	2.287	46.6
	4	3.113	1.557	50.0
	5	4.219	2.082	49.3
	6	4.979	2.304	46.3
			Average	<u>48.0</u>
3	1	5.838	2.937	50.2
	2	4.455	2.294	51.5
	3	6.818	2.732	40.1
	4	4.547	2.419	53.2
	5	5.340	2.660	49.8
	6	4.709	2.108	44.8
			Average	<u>48.2</u>
4	1	5.964	2.651	44.4
	2	4.740	2.440	51.4
	3	5.590	2.497	44.7
	4	5.655	2.559	45.3
	5	4.998	2.474	49.2
	6	5.712	2.340	42.1
			Average	<u>46.2</u>
5	1	5.232	2.270	43.2
	2	5.180	2.555	49.4
	3	5.429	2.447	45.1
	4	4.809	2.098	43.7
	5	5.586	2.636	47.2
	6	5.134	1.888	36.8
			Average	<u>44.2</u>

TABLE III (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 1

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	5.307	2.125	40.1
	2	5.187	2.037	39.3
	3	5.485	2.343	42.7
	4	5.267	2.046	38.8
	5	4.887	2.165	44.3
	6	5.561	1.842	32.5
			Average	39.6
7	1	5.241	2.048	39.1
	2	5.277	2.376	45.0
	3	5.648	2.163	38.3
	4	4.928	1.948	39.5
	5	4.707	1.786	37.9
	6	6.096	1.515	24.9
			Average	37.5
8	1	7.518	2.204	29.3
	2	5.521	1.846	x33.5
	3	5.428	2.130	39.2
	4	8.238	2.568	x31.2
	5	5.243	2.088	39.9
	6	6.991	2.102	30.1
			Average	34.6
9	1	7.220	3.052	x42.3
	2	6.599	2.810	42.6
	3	6.761	2.280	33.7
	4	5.915	2.267	38.3
	5	6.367	2.408	37.8
	6	5.973	1.495	25.1
			Average	35.5
10	1	8.595	2.816	32.7
	2	5.609	2.339	41.7
	3	5.986	1.922	32.0
	4	5.886	1.712	39.1
	5	5.340	1.768	33.1
	6	4.897	1.080	22.1
			Average	35.5

TABLE III (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 1

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	5.358	1.203	22.5
	2	6.517	2.136	32.8
	3	7.933	2.794	35.2
	4	5.184	1.166	22.5
	5	8.179	2.551	30.8
	6	6.134	0.837	x13.7
			Average	28.9
12	1	5.590	1.204	35.9
	2	6.010	1.794	29.8
	3	4.282	1.402	32.7
	4	3.966	1.595	x40.2
	5	8.106	2.559	31.6
	6	4.313	0.660	15.6
			Average	29.1
13	1	6.224	1.760	28.3
	2	7.595	3.913	x51.5
	3	5.974	1.863	31.2
	4	3.428	0.308	x 9.0
	5	5.546	1.400	25.3
	6	4.156	0.848	20.4
			Average	26.3
14	1	6.415	1.860	29.0
	2	5.065	1.364	26.9
	3	5.596	1.870	30.4
	4	3.841	0.646	16.8
	5	5.632	1.610	28.6
	6	4.987	0.799	16.0
			Average	24.6
15	1	6.186	1.017	16.4
	2	5.130	0.325	x 6.3
	3	5.226	1.523	x39.1
	4	6.813	1.790	26.3
	5	6.502	1.999	34.2
	6	5.855	0.395	6.7
			Average	20.9

x Value omitted in average.

DRYING CURVE I

TEMP 120°F - HUM 63%

RUN 1

TABLE IV
RATE OF DRYING
Run 2

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O/ 100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	49.0	297	152	145		95.4	
2	48.4	295	152	143	2	94.0	.0233
3	47.3	289	152	137	6	90.1	.0697
4	45.8	281	152	129	8	84.8	.0930
5	43.6	270	152	118	11	77.6	.1279
6	41.0	257	152	105	13	69.0	.1512
7	38.0	245	152	93	12	61.2	.1395
8	34.5	232	152	80	13	52.6	.1512
9	34.2	231	152	79	1	51.9	.0116
10	33.7	229	152	77	2	50.7	.0233
11	30.5	219	152	67	10	44.1	.1163
12	27.8	210	152	58	9	38.2	.1048
13	25.8	205	152	53	5	34.8	.0582
14	23.4	198	152	46	7	30.3	.0814
15	21.7	194	152	42	4	27.6	.0465

RATE OF DRYING CURVE II

TEMP. 120°F

HUM. 6.3%

RUN 1

H₂O EVAP / Hr. / Sq. Ft.

0.250

0.200

0.150

0.100

0.050

0.000

10

20

30

40

50

60

70

80

90

H₂O / 100 # DRY SOLID

(d)

(b)

(c)

(a)

The drying conditions for Run 1 were a constant temperature of 120°F and a humidity of approximately 6% (atmospheric). The supply of air was taken at room conditions without recirculation or impregnation with steam.

The drying curve as shown in Curve I indicates a continual decrease in the percentage moisture during the first fourteen hours. In the next four hours there is a very small decrease in moisture content. From this point the decrease again becomes rapid, but gradually lessens as the run nears completion.

The rate of drying curve as shown in Curve II indicates a gradual increase in the rate of drying (a to b) during the first fourteen hours. In the next four hours (b to c) the rate of drying is very low. In the following two hours (c to d) the rate of drying again becomes rapid, but from this point decreases steadily during the remainder of the run.

TABLE V

LOG SHEET

Run 2

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 5

Date: 3/15/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 3/14/33

Rx. No.: 4002

Batch Rtd.: 3/21/33

Slip No.:

Batch No.: 4

Drying Conditions

Date Struck: 3/9/33

No. Trays Dried: 20

Date In: 3/14/33

Temperature: 140°F

Humidity: 4.6% (Atmos.)

Inlet: Average Dry Bulb Temperature: 78°F

Average Wet Bulb Temperature: 60°F

Average Humidity: 33%

Outlet: Average Dry Bulb Temperature: 117°F

Average Wet Bulb Temperature: 106°F

Average Humidity: 67%

Average Room Temperature: 77°F

Inlet Air Velocity: 2900 ft./min.

Percent Recirculation: None

Recorded Psychrometer Chart Temperatures: Dry Bulb: 140°F
Wet Bulb: 78°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. Moisture Lost lbs.
1	49.00	27.75	21.25
2	51.50	28.25	23.25
3	50.50	28.75	21.75
4	50.50	26.50	24.00
5	51.75	28.25	23.50
6	49.00	26.75	22.25
Total	302.25	166.25	136.00

TABLE VI
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 2

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	5.388	2.542	47.1
	2	5.887	2.910	49.4
	3	4.584	2.153	46.9
	4	5.312	2.726	51.3
	5	6.023	2.911	48.3
	6	6.313	2.978	47.2
			Average	<u>48.4</u>
2	1	5.529	2.341	42.3
	2	4.938	2.480	x58.3
	3	5.698	2.638	46.3
	4	5.416	2.642	48.8
	5	5.523	2.749	49.8
	6	5.734	2.608	45.6
			Average	<u>46.6</u>
3	1	5.781	2.398	41.5
	2	5.778	2.812	48.7
	3	4.619	2.066	44.9
	4	5.701	2.612	45.8
	5	5.117	2.400	47.8
	6	5.348	2.393	44.7
			Average	<u>45.6</u>
4	1	5.168	1.867	35.1
	2	4.995	2.272	45.4
	3	5.523	2.331	42.2
	4	5.049	2.113	41.8
	5	5.353	2.413	45.1
	6	4.848	1.851	38.3
			Average	<u>41.3</u>
5	1	5.654	1.804	31.9
	2	5.760	2.515	43.7
	3	5.630	2.256	40.2
	4	4.529	1.826	40.3
	5	5.713	2.348	41.2
	6	5.498	1.817	33.0
			Average	<u>38.4</u>

x Value omitted in average.

TABLE VI (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 2

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	4.024	1.203	30.0
	2	5.823	2.324	39.9
	3	4.256	1.463	34.4
	4	4.493	1.586	35.2
	5	5.927	2.268	38.3
	6	5.588	1.672	29.9
			Average	<u>34.6</u>
7	1	5.395	1.531	28.3
	2	6.301	2.191	34.7
	3	6.239	1.842	29.5
	4	6.492	2.250	34.7
	5	7.608	2.049	27.0
	6	7.378	1.648	22.3
			Average	<u>29.4</u>
8	1	7.176	1.736	24.2
	2	8.939	3.037	34.0
	3	5.323	1.844	34.7
	4	5.347	1.199	22.4
	5	5.957	1.822	30.6
	6	5.080	0.955	18.8
			Average	<u>27.5</u>
9	1	5.712	1.102	19.1
	2	6.296	2.152	34.2
	3	5.895	1.613	28.7
	4	5.057	1.666	23.3
	5	6.186	1.773	28.7
	6	Lost		
			Average	<u>26.8</u>
10	1	6.203	1.282	20.7
	2	6.297	1.039	16.5
	3	4.744	0.784	16.5
	4	6.090	0.837	13.7
	5	7.541	2.314	30.6
	6	5.495	0.793	14.4
			Average	<u>19.6</u>

TABLE VI (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 2

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	5.990	0.719	12.0
	2	5.795	0.713	12.6
	3	5.697	1.046	18.4
	4	66.24	0.698	10.6
	5	5.174	1.238	23.9
	6	Lost		
			Average	<u>15.5</u>
12	1	5.258	0.284	x 5.4
	2	4.439	0.274	6.2
	3	5.858	0.880	15.1
	4	6.026	0.612	10.1
	5	4.891	0.917	18.8
	6	4.824	0.587	<u>12.1</u>
			Average	<u>12.5</u>
13	1	4.004	0.064	x 1.6
	2	5.893	0.779	13.2
	3	5.639	0.553	9.8
	4	4.047	0.083	2.0
	5	5.606	0.496	8.8
	6	5.675	0.343	<u>6.0</u>
			Average	<u>7.8</u>
14	1	5.543	0.652	11.8
	2	4.911	0.548	11.2
	3	5.558	0.572	10.6
	4	4.931	0.110	2.2
	5	4.779	0.090	1.9
	6	5.054	0.657	<u>13.0</u>
			Average	<u>8.5</u>
15	1	4.584	0.544	12.1
	2	4.397	0.099	2.3
	3	5.558	0.284	5.1
	4	4.468	0.640	14.3
	5	5.046	0.431	8.5
	6	4.268	0.435	<u>10.2</u>
			Average	<u>8.8</u>

x Value omitted in average.

DRYING CURVE III

TEMP. 140°F - HUM. 4.6%

RUN 2

PERCENT MOISTURE

TIME IN HOURS

TABLE VII
RATE OF DRYING
Run 2

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O/ 100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	48.4	302	156	146		93.5	
2	46.8	294	156	138	8	88.5	.0930
3	44.7	282	156	126	12	80.7	.1398
4	42.0	269	156	113	13	72.4	.1512
5	38.5	254	156	98	15	62.8	.1754
6	34.6	239	156	83	15	53.2	.1754
7	29.8	220	156	64	19	41.0	.2210
8	27.5	215	156	59	5	38.8	.0582
9	26.8	213	156	57	2	36.5	.0233
10	20.0	195	156	39	18	25.0	.2095
11	15.5	185	156	29	10	18.6	.1163
12	12.0	177	156	21	8	13.5	.0930
13	9.3	172	156	16	5	10.3	.0582
14	8.0	170	156	14	2	9.0	.0233
15	7.7	169	156	13	1	8.3	.0116

RATE OF DRYING CURVE IV

TEMP 140°F HUM. 4.6%

RUN 2

H₂O EVAP./HR./SQ. FT.

0.250

0.200

0.150

0.100

0.050

0.000

0

10

20

30

40

50

60

70

80

H₂O/100 # DRY SOLID

(d)

(b)

(c)

(a)

The drying conditions for Run 2 were a constant temperature of 140°F and a humidity of approximately 5% (atmospheric). The supply of air was taken at room conditions without recirculation or impregnation with steam.

The drying curve as shown in Curve III indicates a continual decrease in the percentage moisture during the first thirteen hours. In the next three hours there is a very small decrease in moisture content. From this point the decrease again becomes rapid, but gradually lessens until at the finish of the run the moisture content is almost constant.

The rate of drying curve as shown in Curve IV indicates a gradual increase in the rate of drying (a to b) during the first twelve hours. In the next four hours (b to c) the rate of drying is very low. In the following two hours (c to d) the rate of drying again becomes rapid, but from this point decreases steadily during the remainder of the run.

TABLE VIII

LOG SHEET

Run 3

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 6

Date: 3/22/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 3/21/33

Rx. No.: 4002

Batch Rtd.: 3/28/33

Slip No.: 155

Batch No.: 7

Drying Conditions

Date Struck: 3/14/33

Temperature: 160°F

No. Trays Dried: 20

Humidity: 6.3% (Atmos.)

Date In: 3/21/33

Inlet: Average Dry Bulb Temperature: 82°F

Average Wet Bulb Temperature: 65°F

Average Humidity: 39%

Outlet: Average Dry Bulb Temperature: 137°F

Average Wet Bulb Temperature: 120°F

Average Humidity: 57%

Average Room Temperature: 81°F

Inlet Air Velocity: 2800 ft./min.

Percent Recirculation: None

Recorded Psychrometer Chart Temperatures: Dry Bulb: 160°F

Wet Bulb: 93°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. Moisture Lost lbs.
1	51.25	29.00	22.25
2	52.00	28.50	23.50
3	50.00	27.00	23.00
4	51.25	27.50	23.75
5	51.50	28.50	23.00
6	50.00	27.00	23.00
Total	306.00	167.50	138.50

TABLE IX
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 3

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	5.726	2.737	47.8
	2	6.221	2.983	47.9
	3	5.754	2.860	49.7
	4	5.813	2.974	51.2
	5	6.095	3.082	50.6
	6	6.664	3.106	46.7
			Average	<u>49.0</u>
2	1	4.954	2.179	43.9
	2	5.776	2.788	48.3
	3	5.640	2.600	46.0
	4	6.039	2.785	46.1
	5	4.881	2.341	47.9
	6	5.195	2.365	45.5
			Average	<u>46.3</u>
3	1	4.504	1.816	40.3
	2	6.024	2.603	43.2
	3	5.215	1.945	37.4
	4	6.903	3.494	50.6
	5	5.676	2.546	44.8
	6	6.509	2.774	42.7
			Average	<u>43.2</u>
4	1	4.437	1.545	34.8
	2	5.246	2.016	38.5
	3	5.054	2.231	44.2
	4	5.407	2.209	40.9
	5	5.628	2.441	43.4
	6	6.113	2.523	41.2
			Average	<u>40.5</u>
5	1	6.767	2.201	32.5
	2	5.522	2.114	38.3
	3	7.436	2.764	37.1
	4	4.604	1.698	36.9
	5	5.725	2.443	42.7
	6	6.790	2.594	38.2
			Average	<u>37.6</u>

TABLE IX (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 3

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	5.419	1.397	25.8
	2	5.995	1.628	27.2
	3	6.608	1.995	30.3
	4	8.431	2.715	32.2
	5	7.016	2.420	34.5
	6	4.421	1.031	x23.3
			Average	<u>30.0</u>
7	1	3.702	0.763	20.7
	2	5.148	1.512	29.4
	3	6.771	1.713	25.6
	4	5.319	1.386	26.1
	5	7.066	2.585	36.6
	6	6.154	1.907	31.0
			Average	<u>28.2</u>
8	1	4.638	0.820	17.7
	2	6.282	1.705	27.1
	3	6.390	1.883	29.5
	4	6.548	1.476	22.9
	5	6.067	2.083	34.3
	6	5.783	1.649	28.5
			Average	<u>26.6</u>
9	1	5.130	0.724	14.1
	2	6.086	1.629	26.8
	3	5.742	0.910	15.9
	4	4.207	0.469	11.2
	5	5.760	2.132	31.5
	6	5.297	1.290	24.3
			Average	<u>20.6</u>
10	1	3.937	0.490	12.5
	2	5.381	0.787	14.7
	3	4.336	0.582	13.4
	4	4.567	0.603	13.2
	5	5.352	0.919	17.2
	6	3.412	0.445	13.0
			Average	<u>14.0</u>

x Value omitted in average.

TABLE IX (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 3

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	3.782	0.412	10.9
	2	4.495	0.420	9.4
	3	4.287	0.491	11.4
	4	4.052	0.431	10.6
	5	5.440	0.947	17.4
	6	5.095	0.817	16.0
			Average	<u>12.6</u>
12	1	4.459	0.628	14.1
	2	2.766	0.244	8.1
	3	5.142	0.440	8.6
	4	3.876	0.401	10.3
	5	4.812	1.389	x28.9
	6	5.261	0.723	13.8
			Average	<u>11.0</u>
13	1	3.781	0.334	8.8
	2	3.735	0.104	2.8
	3	3.750	0.413	11.0
	4	4.199	0.529	12.6
	5	3.654	0.426	11.6
	6	4.078	0.424	10.4
			Average	<u>9.5</u>
14	1	4.462	0.322	7.2
	2	5.770	0.431	7.5
	3	6.563	0.836	12.7
	4	5.306	0.656	12.4
	5	3.789	0.172	4.5
	6	4.819	0.096	2.0
			Average	<u>7.4</u>
15	1	2.855	0.319	11.2
	2	3.433	0.415	12.1
	3	5.077	0.489	9.7
	4	5.566	0.453	8.1
	5	5.330	0.512	9.6
	6	4.530	0.369	8.1
			Average	<u>9.8</u>

x Value omitted in average.

DRYING CURVE V

TEMP. 160°F - HUM. 6.3%

RUN 3

TABLE X
RATE OF DRYING

Run 3

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O/ 100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	49.7	306	157	149		94.8	
2	46.4	293	157	136	13	86.7	.1512
3	43.9	280	157	123	13	78.3	.1512
4	40.7	265	157	108	15	68.8	.1754
5	37.3	251	157	94	14	59.8	.1630
6	30.0	224	157	67	27	42.7	.3240
7	28.2	219	157	62	5	39.5	.0582
8	26.6	214	157	57	5	36.3	.0582
9	19.3	195	157	38	19	24.2	.2210
10	15.3	185	157	28	10	17.8	.1163
11	12.5	179	157	22	6	14.0	.0698
12	10.7	176	157	19	3	12.1	.0349
13	9.3	172	157	15	4	9.5	.0465
14	8.5	171	157	14	1	8.9	.0116
15	8.0	170	157	13	1	8.3	.0116

RATE OF DRYING CURVE VI

TEMP 160°F

HUM. 63%

RUN 3

The drying conditions for Run 3 were a constant temperature of 160°F and a humidity of approximately 6% (atmospheric). The supply of air was taken at room conditions without recirculation or impregnation with steam.

The drying curve as shown in Curve V indicates a continual decrease in the percentage moisture during the first ten hours. In the next four hours there is a very small decrease in moisture content. From this point the decrease again becomes rapid, but gradually lessens until at the finish of the run the moisture content is almost constant.

The rate of drying curve as shown in Curve VI indicates a constant rate during the first eight hours (a to b). In the next two hours (b to c) the rate of drying shows a considerable increase. The following four hours (c to d) show a very low rate. During the next two hours (d to e) the rate of drying again becomes rapid, but from this point decreases steadily during the remainder of the run.

TABLE XI

LOG SHEET

Run 4

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 3

Date: 3/8/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 3/7/33

Rx. No.: 4002

Batch Rtd.: 3/14/33

Slip No.: 115

Batch No.: 4

Drying Conditions

Date Struck: 2/21/33

No. Trays Dried: 20

Temperature: 180°F

Date In: 3/7/33

Humidity: 2.7% (Atmos.)

Inlet: Average Dry Bulb Temperature: 83°F

Average Wet Bulb Temperature: 66°F

Average Humidity: 39%

Outlet: Average Dry Bulb Temperature: 152°F

Average Wet Bulb Temperature: 132°F

Average Humidity: 56%

Average Room Temperature: 81°F

Inlet Air Velocity: 2800 ft./min.

Recirculation: None

Recorded Psychrometer Chart Temperatures: Dry Bulb: 180°F

Wet Bulb: 95°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. Moisture Lost lbs.
1	46.75	26.50	20.25
2	51.75	31.50	20.25
3	50.25	29.50	20.75
4	49.25	29.00	20.25
5	53.00	32.50	20.50
6	50.50	29.75	20.75
Total	301.50	178.75	122.75

TABLE XII
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 4

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	5.260	2.517	47.8
	2	Lost		
	3	5.637	2.980	52.8
	4	5.538	2.937	53.0
	5	6.176	3.327	52.9
	6	6.015	2.995	49.9
			Average	<u>51.3</u>
2	1	5.177	2.372	45.7
	2	5.342	2.704	50.6
	3	5.638	2.744	48.6
	4	4.278	1.953	45.7
	5	4.921	2.454	49.8
	6	5.532	2.690	48.7
			Average	<u>48.2</u>
3	1	5.034	2.154	42.7
	2	5.595	2.782	49.7
	3	5.802	2.754	47.4
	4	5.337	2.223	41.6
	5	4.505	2.263	50.1
	6	5.533	2.297	41.6
			Average	<u>45.6</u>
4	1	5.502	1.750	31.6
	2	5.629	2.371	40.3
	3	4.555	1.999	43.9
	4	4.534	1.633	35.9
	5	4.207	2.044	47.7
	6	4.652	1.815	39.0
			Average	<u>39.7</u>
5	1	5.617	1.552	27.6
	2	5.433	1.965	36.1
	3	4.449	1.669	37.5
	4	5.921	1.910	32.3
	5	3.872	1.647	42.6
	6	4.503	1.691	37.5
			Average	<u>35.6</u>

TABLE XII (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 4

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	3.516	0.612	17.8
	2	6.910	2.123	30.7
	3	5.939	1.854	31.1
	4	6.116	1.730	28.3
	5	4.429	1.576	35.6
	6	7.612	2.408	31.7
			Average	<u>29.2</u>
7	1	6.241	0.619	9.9
	2	6.677	0.767	x11.9
	3	5.902	1.535	25.9
	4	4.230	0.299	x 7.1
	5	5.714	1.667	29.3
	6	5.654	0.936	16.5
			Average	<u>20.4</u>
8	1	4.236	0.552	13.0
	2	5.005	1.099	22.0
	3	5.061	1.294	25.5
	4	4.299	0.704	16.4
	5	6.600	1.869	28.3
	6	5.369	0.954	17.8
			Average	<u>20.5</u>
9	1	5.304	0.629	11.9
	2	5.556	1.042	18.7
	3	7.522	2.105	28.0
	4	7.537	1.598	21.2
	5	9.740	2.740	28.2
	6	7.230	1.484	20.5
			Average	<u>21.4</u>
10	1	3.892	0.442	11.4
	2	5.426	0.442	8.1
	3	7.173	1.202	16.5
	4	6.429	1.199	x35.1
	5	5.450	0.748	8.9
	6	6.016	1.309	21.8
			Average	<u>13.3</u>

x Value omitted in average.

TABLE XII (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 4

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	5.242	0.395	11.5
	2	6.191	1.213	19.5
	3	5.384	0.998	18.5
	4	5.505	0.825	15.0
	5	5.775	1.526	x26.3
	6	4.169	0.551	13.3
			Average	<u>14.7</u>

x Value omitted in average.

DRYING CURVE VII

TEMP 180°F - HUM. 2.7%

RUN 4

PERCENT MOISTURE

TIME IN HOURS

TABLE XIII
RATE OF DRYING ,

Run 4

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O/ 100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	51.3	302	147	155		105.4	
2	48.6	286	147	139	16	94.5	.1861
3	45.3	269	147	122	17	82.9	.1979
4	42.9	257	147	110	12	74.8	.1398
5	35.7	228	147	81	29	55.1	.3370
6	28.8	207	147	60	21	40.8	.2450
7	20.4	185	147	38	22	25.8	.2580
8	20.4	185	147	38	0	25.8	.0000

RATE OF DRYING CURVE VIII

TEMP 180°F HUM. 2.7%

RUN 4

#H₂O EVAP./HR./SQ. FT.

0.250

0.200

0.150

0.100

0.050

0.000

(b)

(c)

(a)

#H₂O/100# DRY SOLID

The drying conditions for Run 4 were a constant temperature of 180°F and a humidity of approximately 3% (atmospheric). The supply of air was taken at room conditions without recirculation or impregnation with steam.

The drying curve as shown in Curve VII indicates a rapid decrease in the percentage moisture during the first twelve hours. The decrease during the next two hours was negligible.

The rate of drying curve as shown in Curve VIII indicates a gradual increase in the rate of drying (a to b) during the first twelve hours. In the next two hours (b to c) the rate of drying drops to zero.

This run was terminated at the end of twenty hours when considerable case-hardening of the cakes made the securing of accurate samples impossible. This case-hardening was believed due to the high temperature and low humidity of the drying air. These conditions are considered improper for the drying of commercial Prussian blue.

TABLE XIV

LOG SHEET

Run 5

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 9

Date: 4/21/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 4/21/33

Rx. No.: 4002

Batch Rtd.: 4/24/33

Slip No.: 189

Batch No.: 6

Drying Conditions

Date Struck: 4/12/33

No. Trays Dried: 20

Temperature: 140°F

Date In: 4/21/33

Humidity: 10%

Inlet: Average Dry Bulb Temperature: 80°F
 Average Wet Bulb Temperature: 64°F
 Average Humidity: 40%

Outlet: Average Dry Bulb Temperature: 122°F
 Average Wet Bulb Temperature: 112°F
 Average Humidity: 70%

Average Room Temperature: 78°F

Inlet Air Velocity: 1550 ft./min.

Percent Recirculation: 54

Recorded Psychrometer Chart Temperatures: Dry Bulb: 140°F
 Wet Bulb: 87°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. Moisture Lost lbs.
1	51.50	27.00	24.50
2	38.00	21.75	16.50
3	51.00	29.25	21.75
4	49.75	28.00	21.75
5	48.50	28.50	20.00
6	46.00	28.00	18.00
Total	284.75	162.50	122.25

TABLE XV
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 5

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	4.429	2.329	52.6
	2	6.018	2.707	44.9
	3	5.876	2.751	46.7
	4	5.541	2.721	49.2
	5	6.201	2.893	46.6
	6	5.715	2.475	43.3
			Average	<u>47.2</u>
2	1	4.959	2.576	51.9
	2	5.463	2.345	42.9
	3	6.022	2.625	43.6
	4	5.748	2.578	44.8
	5	5.715	2.565	44.9
	6	5.908	2.388	40.5
			Average	<u>44.8</u>
3	1	5.075	2.611	51.4
	2	5.663	2.250	39.8
	3	5.842	2.370	40.6
	4	5.159	2.193	42.5
	5	5.571	2.298	41.2
	6	5.271	1.845	35.0
			Average	<u>41.8</u>
4	1	5.182	2.586	49.9
	2	4.934	1.452	36.0
	3	6.241	2.307	37.0
	4	3.592	1.358	37.8
	5	4.204	1.589	37.8
	6	5.308	1.733	32.9
			Average	<u>39.6</u>
5	1	4.965	2.358	47.5
	2	5.385	1.742	32.3
	3	6.326	2.124	33.6
	4	6.218	1.987	32.3
	5	4.381	0.840	x19.2
	6	4.382	1.436	29.7
			Average	<u>35.1</u>

x Value omitted in average.

TABLE XV (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 5

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	4.955	2.148	43.4
	2	6.012	2.102	35.0
	3	6.017	2.127	35.5
	4	6.535	1.978	30.3
	5	5.087	1.764	34.7
	6	6.454	1.823	28.3
			Average	34.5
7	1	5.554	2.323	41.8
	2	5.737	1.838	32.1
	3	6.539	2.189	33.5
	4	4.736	1.270	26.9
	5	6.892	2.101	31.5
	6	4.776	0.906	19.0
			Average	30.6
8	1	4.434	1.863	42.1
	2	8.229	2.594	31.6
	3	5.710	1.769	31.0
	4	5.689	0.925	16.2
	5	5.759	1.531	26.6
	6	6.059	1.346	22.2
			Average	28.3
9	1	4.620	1.637	35.4
	2	4.344	0.738	17.0
	3	6.356	0.697	x11.0
	4	5.452	0.916	16.8
	5	6.474	1.509	23.3
	6	4.732	0.531	x11.2
			Average	23.1
10	1	5.683	1.951	34.4
	2	5.321	0.669	12.6
	3	3.988	0.613	15.4
	4	5.097	0.498	9.8
	5	4.934	1.134	23.0
	6	6.238	1.119	17.9
			Average	18.9

x Value omitted in average.

TABLE XV (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 5

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	5.436	1.222	22.3
	2	4.513	0.712	15.8
	3	4.086	0.427	10.5
	4	4.278	0.339	7.9
	5	4.961	4.079	9.7
	6	3.560	0.409	11.1
			Average	<u>12.9</u>
12	1	6.104	1.529	25.1
	2	5.704	0.703	12.3
	3	4.544	0.330	7.3
	4	4.744	0.375	7.9
	5	4.768	0.249	5.2
	6	3.693	0.138	3.7
			Average	<u>10.3</u>
13	1	4.552	0.446	9.8
	2	4.977	0.050	x 1.0
	3	5.195	0.238	4.6
	4	4.305	0.036	0.8
	5	3.607	0.213	5.9
	6	4.069	0.036	0.9
			Average	<u>4.4</u>
14	1	5.269	1.006	x19.1
	2	3.547	0.356	10.0
	3	5.645	0.767	13.6
	4	3.610	0.048	1.3
	5	5.370	0.724	13.5
	6	5.144	0.424	8.2
			Average	<u>9.3</u>
15	1	4.912	0.610	12.4
	2	5.103	0.601	12.2
	3	4.832	0.432	8.9
	4	4.912	0.382	7.8
	5	3.924	0.386	9.9
	6	4.702	0.059	1.3
			Average	<u>8.8</u>

x Value omitted in average.

DRYING CURVE IX

TEMP 140°F - HUM. 10%

RUN 5

TABLE XVI
RATE OF DRYING
Run 5

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O /100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	47.2	285	151	134		88.7	
2	45.3	276	151	125	9	82.8	.1047
3	42.7	263	151	112	13	74.2	.1512
4	38.8	247	151	96	16	63.6	.1861
5	35.1	233	151	82	14	54.3	.1630
6	34.5	231	151	80	2	53.0	.0233
7	31.2	219	151	68	12	45.0	.1398
8	27.5	209	151	58	10	38.4	.1163
9	23.1	196	151	45	13	29.8	.1512
10	18.4	185	151	34	11	22.5	.1280
11	13.7	175	151	24	10	18.9	.1163
12	10.8	169	151	18	6	11.9	.0698
13	9.5	167	151	16	2	10.6	.0233
14	8.8	166	151	15	1	9.9	.0116
15	8.8	166	151	15	0	9.9	.0000

RATE OF DRYING CURVE X

TEMP 140°F HUM. 10%

RUN 5

The drying conditions for Run 5 were a constant temperature of 140°F and a humidity of 10%. The drying air was 54% recirculated and impregnated with steam to the desired humidity.

The drying curve as shown in Curve IX indicates a continual decrease in the percentage moisture during the first eight hours. In the next two hours there is a very small decrease in moisture content. From this point the decrease again becomes rapid, but gradually lessens until at the finish of the run the moisture content is almost constant.

The rate of drying curve as shown in Curve X indicates a gradual increase in the rate of drying (a to b) during the first six hours. In the next two hours (b to c) the rate of drying begins to decrease, and in the following two hours (c to d) becomes very low. During the next two hours (d to e) the drying rate again becomes rapid. It remains fairly constant for the following eight hours (e to f), but from this point decreases steadily during the remainder of the run.

TABLE XVII

LOG SHEET

Run 6

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 7

Date: 4/12/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 4/11/33

Rx. No.: 4002

Batch Rtd.: 4/13/33

Slip No.: 189

Batch No.: 2

Drying Conditions

Date Struck: 4/5/33

No. Trays Dried: 20

Temperature: 160°F

Date In: 4/11/33

Humidity: 10%

Inlet: Average Dry Bulb Temperature: 81°F

Average Wet Bulb Temperature: 62°F

Average Humidity: 32%

Outlet: Average Dry Bulb Temperature: 141°F

Average Wet Bulb Temperature: 124°F

Average Humidity: 62%

Average Room Temperature: 79°F

Inlet Air Velocity: 660 ft./min.

Percent Recirculation: 76

Recorded Psychrometer Chart Temperatures: Dry Bulb: 160°F

Wet Bulb: 101°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. Moisture Lost lbs.
1	51.25	31.00	20.25
2	52.00	30.50	21.50
3	51.00	29.50	21.50
4	53.00	30.50	22.50
5	53.75	31.25	22.50
6	48.50	27.50	21.00
Total	309.50	180.25	129.25

TABLE XVIII
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 6

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	5.290	2.273	42.9
	2	6.373	2.743	43.0
	3	6.214	2.732	43.9
	4	5.966	2.735	45.8
	5	5.451	2.277	41.8
	6	5.966	2.525	42.3
			Average	43.3
2	1	5.454	2.257	41.3
	2	5.204	2.149	41.3
	3	5.405	2.191	40.5
	4	5.763	2.331	40.4
	5	5.207	2.204	42.3
	6	5.466	2.218	40.6
			Average	41.1
3	1	5.176	1.953	37.7
	2	5.816	2.215	38.1
	3	5.816	2.149	36.5
	4	5.624	1.998	35.5
	5	5.326	2.074	38.6
	6	5.558	2.055	37.0
			Average	37.4
4	1	4.777	1.629	34.1
	2	8.320	3.002	36.1
	3	8.426	2.717	32.3
	4	7.425	2.352	31.7
	5	6.902	2.369	34.3
	6	7.628	2.435	31.9
			Average	33.4
5	1	4.653	1.336	28.7
	2	7.279	2.227	30.6
	3	6.032	1.734	28.8
	4	5.341	1.426	26.8
	5	6.010	1.770	29.7
	6	6.972	1.837	26.4
			Average	28.5

TABLE XVIII (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 6

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	5.384	1.448	26.9
	2	8.999	1.949	21.7
	3	6.538	1.319	20.2
	4	7.627	1.485	19.5
	5	7.329	1.847	25.2
	6	5.838	1.115	19.2
			Average	<u>22.1</u>
7	1	8.234	2.155	26.2
	2	8.574	2.124	24.7
	3	4.851	0.838	17.5
	4	7.145	1.360	19.1
	5	7.229	1.729	23.9
	6	7.373	1.438	19.5
			Average	<u>21.8</u>
8	1	3.874	0.606	15.7
	2	2.753	0.314	x11.4
	3	4.652	0.772	16.9
	4	4.403	0.577	13.1
	5	4.211	0.748	17.8
	6	4.095	0.924	22.6
			Average	<u>17.1</u>
9	1	3.609	0.405	11.2
	2	3.763	0.643	17.1
	3	4.127	0.510	12.3
	4	4.072	0.336	8.3
	5	4.342	0.817	18.8
	6	4.124	0.940	22.6
			Average	<u>15.0</u>
10	1	3.716	0.383	10.3
	2	4.137	0.541	13.0
	3	4.241	0.428	10.1
	4	4.820	0.452	9.4
	5	5.264	0.796	14.9
	6	4.980	0.946	19.0
			Average	<u>12.8</u>

x Value omitted in average.

TABLE XVIII (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 6

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	6.578	0.859	13.0
	2	4.981	0.105	2.1
	3	6.002	0.892	14.8
	4	3.938	0.482	12.2
	5	5.913	0.765	12.9
	6	6.165	0.562	9.1
			Average	<u>10.7</u>
12	1	4.702	0.082	x 1.8
	2	4.880	0.075	1.5
	3	5.629	0.645	11.4
	4	6.184	0.501	8.1
	5	3.529	0.052	x 1.5
	6	4.555	0.268	6.1
			Average	<u>6.9</u>
13	1	2.975	0.147	4.9
	2	3.901	0.220	5.6
	3	4.805	0.232	4.8
	4	4.534	0.370	8.2
	5	3.019	0.219	7.3
	6	5.674	0.654	x 11.5
			Average	<u>6.1</u>
14	1	5.124	0.287	5.6
	2	4.349	0.079	1.8
	3	3.649	0.055	1.5
	4	4.290	0.076	1.8
	5	4.777	0.070	1.5
	6	3.737	0.058	1.6
			Average	<u>2.3</u>
15	1	3.358	0.060	1.8
	2	3.855	0.069	1.8
	3	7.361	0.704	x 9.6
	4	4.142	0.083	2.0
	5	4.876	0.144	3.0
	6	4.310	0.084	1.9
			Average	<u>2.1</u>

x Value omitted in average.

DRYING CURVE XI

TEMP. 160°F - HUM. 10%

RUN 6

TABLE XIX
RATE OF DRYING
Run 6

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O /100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	43.3	310	176	134		76.1	
2	41.0	298	176	122	12	69.3	.1398
3	37.8	283	176	107	15	60.8	.1754
4	33.7	265	176	89	18	50.6	.2095
5	28.5	246	176	70	19	39.8	.2210
6	22.0	226	176	50	20	28.4	.2327
7	21.8	225	176	49	1	27.8	.0116
8	18.0	215	176	39	10	22.2	.1163
9	14.5	206	176	30	9	17.0	.1047
10	11.7	199	176	23	7	13.1	.0794
11	9.2	194	176	18	5	10.2	.0582
12	7.0	189	176	13	5	7.4	.0582
13	5.2	186	176	10	3	5.7	.0349
14	3.7	183	176	7	3	4.0	.0349
15	2.5	180	176	4	3	2.3	.0349

RATE OF DRYING CURVE XII

TEMP 160°F

HUM 10%

RUN 6

The drying conditions for Run 6 were a constant temperature of 160°F and a humidity of 10%. The drying air was 76% recirculated and impregnated with steam to the desired humidity.

The drying curve as shown in Curve XI indicates a continual decrease in the percentage moisture during the first ten hours. In the next two hours there is a very small decrease in moisture content. From this point the decrease again becomes rapid, but gradually lessens as the run nears completion.

The rate of drying curve as shown in Curve XII indicates a gradual increase in the rate of drying (a to b) during the first ten hours. In the next two hours (b to c) the rate of drying is very low. In the following two hours (c to d) the rate of drying again becomes rapid, but from this point decreases steadily during the next ten hours (d to e), and then remains constant for the rest of the run.

TABLE XX

LOG SHEET

Run 7

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 11

Date: 5/3/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 5/2/33

Rx. No.: 4002

Batch Rtd.: 5/9/33

Slip No.: 189

Batch No.: 12

Drying Conditions

Date Struck: 4/26/33

No. Trays Dried: 20

Temperature: 180°F

Date In: 5/2/33

Humidity: 10%

Inlet: Average Dry Bulb Temperature: 80°F
 Average Wet Bulb Temperature: 65°F
 Average Humidity: 44%

Outlet: Average Dry Bulb Temperature: 156°F
 Average Wet Bulb Temperature: 136°F
 Average Humidity: 57%

Average Room Temperature: 78°F

Inlet Air Velocity: 740 ft./min.

Percent Recirculation: 74

Recorded Psychrometer Chart Temperatures: Dry Bulb: 180°F
 Wet Bulb: 120°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. Moisture Lost lbs.
1	53.00	31.00	22.00
2	53.00	31.25	21.75
3	54.00	31.50	22.50
4	53.00	31.00	22.00
5	53.00	31.00	22.00
6	52.00	30.00	22.00
Total	318.00	185.75	132.25

TABLE XXI
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 7

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	6.480	2.818	43.5
	2	5.669	2.450	43.2
	3	6.470	2.906	45.0
	4	5.314	2.436	45.8
	5	6.024	2.707	45.0
	6	6.012	2.621	43.7
			Average	<u>43.5</u>
2	1	4.948	1.322	x26.8
	2	7.291	3.830	x52.5
	3	6.284	2.642	42.0
	4	5.761	2.336	40.6
	5	6.158	2.636	42.8
	6	5.942	2.537	42.7
			Average	<u>42.0</u>
3	1	6.246	2.407	38.5
	2	6.106	2.368	38.9
	3	5.848	2.258	39.2
	4	6.241	2.328	37.3
	5	6.266	2.572	41.0
	6	5.777	2.120	36.8
			Average	<u>38.6</u>
4	1	5.970	2.084	34.9
	2	4.933	1.723	34.9
	3	5.136	1.728	33.6
	4	4.825	1.545	32.0
	5	5.765	2.195	38.1
	6	4.581	1.631	35.6
			Average	<u>34.8</u>
5	1	5.935	1.802	30.4
	2	4.226	1.355	32.1
	3	4.983	1.560	32.1
	4	6.314	1.638	26.0
	5	6.840	2.201	32.2
	6	6.271	1.791	28.6
			Average	<u>30.2</u>

x Value omitted in average.

TABLE XXI (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 7

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	8.140	2.134	26.2
	2	7.985	2.184	27.4
	3	5.592	1.190	21.3
	4	6.438	1.584	24.6
	5	7.749	2.460	31.7
	6	6.215	1.105	x17.8
			Average	26.2
7	1	7.347	1.864	25.4
	2	6.682	1.711	25.6
	3	6.945	1.761	25.4
	4	5.913	1.318	22.3
	5	7.230	2.324	30.0
	6	7.156	1.877	26.3
			Average	25.8
8	1	5.304	0.801	15.1
	2	6.678	1.528	22.9
	3	5.421	1.090	20.1
	4	5.522	0.869	15.8
	5	5.868	1.729	29.5
	6	6.242	1.463	23.4
			Average	21.1
9	1	4.018	0.423	10.6
	2	5.078	0.918	18.1
	3	6.281	1.248	19.9
	4	6.238	0.876	14.0
	5	7.187	1.980	27.5
	6	7.243	1.176	16.2
			Average	17.7
10	1	6.491	1.167	x18.0
	2	6.136	0.858	14.0
	3	5.662	0.386	x 6.8
	4	5.737	1.090	19.1
	5	4.788	0.812	14.0
	6	5.720	0.667	11.7
			Average	14.7

x Value omitted in average.

TABLE XXI (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 7

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	3.658	0.385	10.3
	2	5.018	0.719	14.3
	3	4.793	0.552	11.5
	4	4.189	0.442	10.5
	5	5.099	1.139	x22.3
	6	5.444	1.095	20.1
			Average	<u>13.3</u>
12	1	2.960	0.225	7.6
	2	4.581	0.450	10.5
	3	3.812	0.227	6.0
	4	4.250	0.249	5.9
	5	5.137	0.808	15.7
	6	4.340	0.818	18.6
			Average	<u>10.6</u>
13	1	5.520	0.478	8.7
	2	5.681	0.165	2.9
	3	3.328	0.282	8.5
	4	5.242	0.560	10.7
	5	5.078	0.807	15.9
	6	4.212	0.344	8.2
			Average	<u>9.2</u>
14	1	6.513	0.513	7.9
	2	5.943	0.666	x11.2
	3	6.565	0.874	13.3
	4	5.442	0.084	1.5
	5	5.151	0.613	11.9
	6	5.955	0.846	x14.2
			Average	<u>8.7</u>
15	1	4.342	0.069	1.6
	2	5.846	0.110	1.9
	3	5.370	0.255	4.8
	4	4.574	0.064	1.4
	5	6.400	0.786	12.3
	6	4.382	0.356	8.1
			Average	<u>6.7</u>

x Value omitted in average.

DRYING CURVE XIII

TEMP. 180°F - HUM. 10%

RUN 7

PERCENT MOISTURE

TIME IN HOURS

TABLE XXII
RATE OF DRYING
Run 7

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O /100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	43.5	318	180	138		76.7	
2	41.3	306	180	126	12	70.0	.1398
3	38.6	293	180	113	13	62.8	.1512
4	35.0	277	180	97	16	53.8	.1861
5	31.0	261	180	81	16	45.0	.1861
6	26.2	244	180	64	17	35.6	.1979
7	25.8	243	180	63	1	35.0	.0116
8	21.3	229	180	49	14	27.2	.1630
9	17.8	219	180	39	10	21.7	.1163
10	15.0	212	180	32	7	17.8	.0794
11	12.7	206	180	26	6	14.4	.0698
12	10.7	202	180	22	4	12.2	.0465
13	9.2	198	180	18	4	10.0	.0465
14	8.1	196	180	16	2	8.9	.0233
15	7.2	194	180	14	2	7.8	.0233

RATE OF DRYING CURVE XIV

TEMP 180°F

HUM. 10%

RUN 7

H₂O EVAP./HR./SQ. FT.

0.250

0.200

0.150

0.100

0.050

0.000

0

10

20

30

40

50

60

70

80

H₂O / 100 # DRY SOLID

The drying conditions for Run 7 were a constant temperature of 180°F and a humidity of 10%. The drying air was 74% recirculated and impregnated with steam to the desired humidity.

The drying curve as shown in Curve XIII indicates a continual decrease in the percentage moisture during the first ten hours. In the next two hours there is a very small decrease in moisture content. From this point the decrease again becomes rapid, but gradually lessens as the run nears completion.

The rate of drying curve as shown in Curve XIV indicates a gradual increase in the rate of drying during the first ten hours (a to b). In the next two hours (b to c) the rate of drying is very low. In the following two hours (c to d) the drying rate again becomes rapid, but from this point decreases steadily during the remainder of the run.

TABLE XXIII

LOG SHEET

Run 8

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 10

Date: 4/26/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 4/26/33

Rx. No.: 4002

Batch Rtd.: 5/2/33

Slip No.: 189

Batch No.: 9

Drying Conditions

Date Struck: 4/18/33

No. Trays Dried: 20

Temperature: 140°F

Date In: 4/26/33

Humidity: 15%

Inlet: Average Dry Bulb Temperature: 77°F
 Average Wet Bulb Temperature: 61°F
 Average Humidity: 38%

Outlet: Average Dry Bulb Temperature: 123°F
 Average Wet Bulb Temperature: 109°F
 Average Humidity: 63%

Average Room Temperature: 75°F

Inlet Air Velocity: 1270 ft./min.

Percent Recirculation: 55

Recorded Psychrometer Chart Temperatures: Dry Bulb: 140°F
 Wet Bulb: 93°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. of Moisture Lost lbs.
1	52.00	31.50	20.50
2	52.50	31.50	21.00
3	53.25	32.50	20.75
4	51.00	31.00	20.00
5	54.00	34.00	20.00
6	51.00	30.50	20.50
Total	313.75	191.00	122.75

TABLE XXIV

MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 8

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	6.362	3.163	49.8
	2	5.644	3.473	x61.6
	3	5.475	2.526	46.2
	4	5.680	2.678	47.1
	5	6.148	2.829	46.1
	6	6.292	2.904	46.2
			Average	47.1
2	1	5.877	2.659	45.2
	2	5.578	2.398	42.9
	3	5.632	2.433	43.2
	4	5.888	2.485	42.3
	5	5.883	2.604	44.3
	6	6.035	2.602	43.2
			Average	43.5
3	1	6.177	2.674	43.3
	2	4.414	1.724	39.1
	3	4.760	1.934	40.7
	4	5.595	2.229	39.8
	5	5.499	2.371	43.1
	6	6.016	2.495	41.5
			Average	41.3
4	1	5.180	2.263	44.6
	2	4.873	1.856	38.1
	3	5.201	2.014	38.7
	4	4.550	1.677	37.8
	5	5.473	2.278	41.7
	6	4.916	1.840	37.4
			Average	39.7
5	1	4.129	1.702	41.2
	2	4.400	2.534	x57.6
	3	3.398	1.143	33.7
	4	5.069	1.715	33.8
	5	5.202	2.005	38.6
	6	5.696	1.945	34.2
			Average	36.3

x Value omitted in average.

TABLE XXIV (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 8

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	3.249	1.208	37.1
	2	5.789	1.750	30.3
	3	3.614	1.115	30.7
	4	6.740	2.093	31.0
	5	6.454	2.404	37.3
	6	5.626	1.850	32.9
			Average	33.2
7	1	5.667	1.855	32.7
	2	5.312	1.692	31.9
	3	5.967	1.925	32.3
	4	5.896	1.617	27.4
	5	5.397	1.854	34.4
	6	6.811	2.075	30.4
			Average	31.5
8	1	6.881	2.119	30.8
	2	5.678	1.009	x17.8
	3	6.030	1.445	24.0
	4	5.812	1.375	23.7
	5	6.745	2.175	32.2
	6	6.284	2.098	33.4
			Average	28.8
9	1	6.536	1.888	28.9
	2	4.866	1.535	31.5
	3	5.826	1.460	25.0
	4	4.148	0.764	18.4
	5	6.608	1.924	29.1
	6	5.401	1.743	32.3
			Average	27.5
10	1	5.007	1.241	24.8
	2	6.141	1.469	23.9
	3	4.971	0.769	15.5
	4	4.686	0.766	16.3
	5	5.629	1.495	26.6
	6	5.632	1.135	x20.2
			Average	21.4

x Value omitted in average.

TABLE XXIV (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 8

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	6.529	1.520	23.3
	2	4.953	0.604	12.2
	3	5.336	0.945	17.7
	4	5.586	0.880	15.8
	5	4.704	1.242	26.4
	6	5.948	1.676	28.2
			Average	<u>20.6</u>
12	1	6.452	1.121	17.4
	2	6.091	0.680	11.2
	3	4.359	0.127	x 2.9
	4	6.726	1.080	16.1
	5	5.999	1.406	23.4
	6	4.581	1.006	22.0
			Average	<u>18.0</u>
13	1	4.350	0.472	10.8
	2	4.795	0.549	11.7
	3	3.135	0.448	14.3
	4	4.777	0.397	8.3
	5	5.026	1.014	20.2
	6	6.221	1.428	22.9
			Average	<u>13.7</u>
14	1	5.101	0.623	12.2
	2	4.562	0.569	12.5
	3	4.511	0.347	7.7
	4	3.023	0.252	8.3
	5	4.725	0.587	12.4
	6	5.610	1.039	18.5
			Average	<u>11.9</u>
15	1	6.108	1.288	21.0
	2	4.109	0.444	10.8
	3	3.074	0.103	3.3
	4	4.324	0.535	12.4
	5	4.470	0.249	5.6
	6	5.201	0.568	10.9
			Average	<u>10.7</u>

x Value omitted in average.

DRYING CURVE XV

TEMP. 140°F - HUM. 15%

RUN 8

TABLE XXV
RATE OF DRYING
Run 8

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O /100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	46.7	314	169	145		85.6	
2	44.1	302	169	133	12	78.7	.1398
3	41.4	288	169	119	14	70.4	.1630
4	39.0	277	169	108	11	63.9	.1280
5	36.5	266	169	97	11	57.4	.1280
6	34.0	256	169	87	10	51.4	.1163
7	31.5	247	169	78	9	46.1	.1047
8	28.9	238	169	69	9	40.8	.1047
9	27.5	233	169	64	5	37.9	.0582
10	21.5	215	169	46	18	27.2	.2095
11	20.5	213	169	44	2	26.0	.0233
12	16.6	203	169	34	10	20.1	.1163
13	14.1	197	169	28	6	16.6	.0698
14	12.2	192	169	23	5	13.6	.0582
15	10.8	189	169	20	3	11.8	.0349

RATE OF DRYING CURVE XVI

TEMP. 140°F

HUM. 15%

RUN 8

The drying conditions for Run 8 were a constant temperature of 140°F and a humidity of 15%. The drying air was 55% recirculated and impregnated with steam to the desired humidity.

The drying curve as shown in Curve XV indicates a steady decrease in moisture content during the first fourteen hours. In the next six hours the decrease in percentage moisture is irregular. For the remainder of the run there is a gradual decrease in the moisture content.

The rate of drying curve as shown in Curve XVI indicates a slowly decreasing rate during the first fourteen hours (a to b). In the next six hours (b to c) the drying rate decreases, increases, and rapidly decreases again. In the following two hours (c to d) the rate of drying again becomes rapid, but from this point decreases steadily during the remainder of the run.

TABLE XXVI

LOG SHEET

Run 9

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 8

Date: 4/14/33

Plant Record Data

Laboratory Data

Name: Bronze Blue
 Rx. No.: 4002
 Slip No.: 189
 Batch No.: 4
 Date Struck: 4/6/33
 No. Trays Dried: 20
 Date In: 4/13/33

Batch Recd.: 4/13/33
 Batch Rtd.: 4/18/33

Drying Conditions

Temperature: 160°F
 Humidity: 15%

Inlet: Average Dry Bulb Temperature: 83°F
 Average Wet Bulb Temperature: 68°F
 Average Humidity: 45%

Outlet: Average Dry Bulb Temperature: 141°F
 Average Wet Bulb Temperature: 126°F
 Average Humidity: 65%

Average Room Temperature: 81°F
 Inlet Air Velocity: 650 ft./min.
 Percent Recirculation: 77

Recorded Psychrometer Chart Temperatures: Dry Bulb: 160°F
 Wet Bulb: 108°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. Moisture Lost lbs.
1	52.00	31.50	20.50
2	52.25	30.00	22.25
3	53.50	30.00	23.50
4	51.50	29.25	22.25
5	50.50	29.75	20.75
6	52.50	30.00	22.50
Total	312.25	180.50	131.75

TABLE XXVII
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 9

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	6.578	2.938	44.7
	2	5.610	2.586	46.1
	3	5.574	2.639	47.3
	4	4.952	2.427	49.1
	5	5.557	2.496	44.9
	6	6.004	2.786	46.3
			Average	<u>46.4</u>
2	1	6.195	2.674	43.2
	2	5.304	2.341	44.2
	3	5.561	2.579	46.4
	4	5.880	2.684	45.6
	5	5.480	2.267	41.3
	6	5.942	2.745	46.2
			Average	<u>44.5</u>
3	1	6.204	2.595	41.8
	2	5.641	2.503	44.3
	3	5.868	2.623	46.6
	4	5.886	2.390	40.7
	5	5.422	2.238	41.3
	6	6.094	2.669	43.8
			Average	<u>41.1</u>
4	1	5.553	2.175	39.2
	2	6.016	2.557	42.5
	3	5.879	2.449	41.7
	4	5.643	2.062	36.5
	5	5.238	1.986	37.9
	6	5.463	2.185	39.9
			Average	<u>39.6</u>
5	1	5.834	2.084	35.7
	2	5.150	1.958	38.0
	3	5.633	2.164	38.4
	4	4.645	1.495	32.2
	5	5.259	1.844	35.1
	6	5.416	1.889	34.9
			Average	<u>35.7</u>

TABLE XXVII (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 9

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	5.705	1.924	33.7
	2	5.341	1.942	36.3
	3	5.473	2.096	38.3
	4	4.981	1.350	27.1
	5	5.638	1.966	34.9
	6	4.998	1.571	31.5
			Average	33.6
7	1	7.420	2.123	28.6
	2	5.537	1.277	23.1
	3	6.930	1.924	27.7
	4	6.223	1.222	19.7
	5	6.475	1.523	23.5
	6	5.865	1.456	24.8
			Average	24.6
8	1	6.826	1.867	27.3
	2	5.366	1.492	27.8
	3	6.633	1.618	24.4
	4	6.347	1.335	21.1
	5	5.037	2.315	x46.0
	6	5.316	0.789	14.9
			Average	23.1
9	1	5.246	1.230	23.5
	2	3.442	1.140	x33.1
	3	6.151	1.381	22.5
	4	4.714	0.866	18.4
	5	4.165	0.659	16.2
	6	6.067	1.354	22.3
			Average	20.8
10	1	5.089	0.562	11.0
	2	5.735	1.178	20.6
	3	5.699	0.910	16.0
	4	5.261	0.603	11.4
	5	5.203	0.583	11.2
	6	4.991	0.760	15.2
			Average	14.2

x Value omitted in average.

TABLE XXVII (Cont.)
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 9

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	6.113	0.796	13.0
	2	6.699	1.123	16.8
	3	6.120	0.761	12.4
	4	3.978	0.055	x 1.4
	5	4.078	0.458	11.2
	6	4.480	0.712	16.0
			Average	13.9
12	1	4.126	0.365	8.9
	2	6.957	1.554	x22.3
	3	6.470	1.544	x23.9
	4	4.661	0.483	10.4
	5	3.354	0.472	14.1
	6	7.465	1.218	16.3
			Average	12.4
13	1	5.471	0.673	12.3
	2	4.915	1.137	x23.2
	3	6.222	0.936	15.0
	4	4.709	0.655	13.9
	5	3.858	0.323	8.4
	6	6.059	0.897	14.8
			Average	12.5
14	1	3.286	0.312	9.5
	2	3.797	0.063	x 1.7
	3	3.907	0.236	6.0
	4	4.290	0.068	x 1.6
	5	5.423	0.598	11.0
	6	5.702	0.560	9.8
			Average	9.1
15	1	4.842	0.446	9.2
	2	5.321	0.918	x17.3
	3	5.212	0.068	x 1.3
	4	5.586	0.633	11.3
	5	3.956	0.434	11.0
	6	3.602	0.057	x 1.5
			Average	10.5

x Value omitted in average.

DRYING CURVE XVII

TEMP. 160°F - HUM. 15%

RUN 9

PERCENT MOISTURE

TIME IN HOURS

TABLE XXVIII
RATE OF DRYING
Run 9

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O /100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	46.4	312	167	145		86.8	
2	44.4	301	167	134	11	79.3	.1280
3	42.1	288	167	121	13	72.4	.1512
4	39.4	275	167	108	13	64.7	.1512
5	35.9	261	167	94	14	56.2	.1630
6	31.0	242	167	76	19	44.9	.2210
7	24.5	221	167	54	21	32.3	.2450
8	22.7	216	167	49	5	29.3	.0582
9	20.6	210	167	43	6	25.7	.0698
10	16.6	200	167	33	10	19.8	.1163
11	13.8	194	167	27	6	16.2	.0698
12	12.0	191	167	24	3	14.4	.0349
13	10.8	188	167	21	3	12.6	.0349
14	9.9	186	167	19	2	11.4	.0233
15	9.7	185	167	18	1	10.8	.0116

RATE OF DRYING CURVE XVIII

TEMP 160°F

HUM. 15%

RUN 9

#H₂O EVAP./HR./SQ. FT.

0.250

0.200

0.150

0.100

0.050

0.000

(d)

(b)

(c)

(a)

#H₂O/100# DRY SOLID

The drying conditions for Run 9 were a constant temperature of 160°F and a humidity of 15%. The drying air was 77% recirculated and impregnated with steam to the desired humidity.

The drying curve as shown in Curve XVII indicates a continual decrease in the percentage moisture during the first twelve hours. In the next four hours there is a small decrease in moisture content. From this point the decrease again becomes rapid, but gradually lessens until at the finish of the run the moisture content is almost constant.

The rate of drying curve as shown in Curve XVIII indicates a steady increase in the rate of drying during the first ten hours (a to b). In the next four hours (b to c) the rate of drying is very low. In the following two hours (c to d) the rate of drying increases slightly, then from this point decreases steadily during the remainder of the run.

TABLE XXIX

LOG SHEET

Run 10

Department of Chemical Engineering

Graduate School

University of Louisville

DRYING OF PRUSSIAN BLUE

Psychrometer Chart No. 12

Date: 5/12/33

Plant Record Data

Laboratory Data

Name: Bronze Blue

Batch Recd.: 5/12/33

Rx. No. 4002

Batch Rtd.: 5/16/33

Slip No.: 235

Batch No.: 1

Drying Conditions

Date Struck: 5/1/33

No. Trays Dried: 20

Temperature: 160°F

Date In: 5/11/33

Humidity: 20%

Inlet: Average Dry Bulb Temperature: 81°F

Average Wet Bulb Temperature: 71°F

Average Humidity: 61%

Outlet: Average Dry Bulb Temperature: 141°F

Average Wet Bulb Temperature: 126°F

Average Humidity: 64%

Average Room Temperature: 80°F

Inlet Air Velocity: 820 ft./min.

Percent Recirculation: 71

Recorded Psychrometer Chart Temperatures: Dry Bulb: 160°F
Wet Bulb: 115°F

Pan Data

Pan No.	Wt. of Cakes Before Drying lbs.	Wt. of Cakes After Drying lbs.	Wt. Moisture Lost lbs.
1	53.75	34.00	19.75
2	55.00	34.25	20.75
3	54.00	32.25	21.75
4	54.00	32.50	21.50
5	53.25	33.00	20.25
6	54.50	33.75	20.75
Total	324.50	199.75	124.75

TABLE XXX
MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 10

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
1	1	6.002	2.596	43.3
	2	5.674	2.480	43.7
	3	5.507	2.522	45.8
	4	5.437	2.559	47.1
	5	6.155	2.860	46.5
	6	6.274	2.827	45.1
			Average	<u>45.3</u>
2	1	5.548	2.309	41.7
	2	5.597	2.370	42.3
	3	5.452	2.430	44.6
	4	5.674	2.552	44.3
	5	6.230	2.794	44.9
	6	6.293	2.667	42.3
			Average	<u>43.4</u>
3	1	5.508	2.201	40.0
	2	5.809	2.374	40.9
	3	5.330	2.155	40.5
	4	5.871	2.461	41.8
	5	5.381	2.268	42.2
	6	5.787	2.401	41.4
			Average	<u>41.5</u>
4	1	4.607	1.790	38.9
	2	4.907	1.886	38.4
	3	5.420	2.222	41.0
	4	4.852	1.836	37.8
	5	5.331	2.165	40.6
	6	5.857	2.228	38.1
			Average	<u>39.1</u>
5	1	4.483	1.644	36.7
	2	4.838	1.727	35.7
	3	4.532	1.575	34.8
	4	4.758	1.907	40.1
	5	4.614	1.752	38.0
	6	5.093	1.865	36.7
			Average	<u>37.0</u>

TABLE XXX (Cont.)
 MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 10

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
6	1	5.472	1.802	32.9
	2	8.114	2.736	33.7
	3	7.538	2.574	34.2
	4	5.971	2.236	37.5
	5	4.410	1.561	35.4
	6	9.565	3.320	34.7
			Average	<u>34.7</u>
7	1	5.362	1.807	33.7
	2	6.071	1.865	30.7
	3	5.081	1.592	31.3
	4	4.276	1.444	33.8
	5	5.312	1.834	34.5
	6	6.804	2.033	29.8
			Average	<u>32.3</u>
8	1	4.562	2.409	x53.0
	2	6.522	1.838	28.2
	3	5.946	1.705	28.6
	4	6.747	2.088	30.9
	5	6.476	2.077	32.1
	6	4.709	1.432	30.4
			Average	<u>30.0</u>
9	1	6.574	1.614	24.8
	2	5.695	1.811	31.8
	3	5.373	1.115	20.8
	4	7.282	2.084	28.5
	5	7.270	2.195	30.2
	6	7.304	1.829	25.0
			Average	<u>26.9</u>
10	1	4.018	0.774	19.3
	2	6.480	1.231	19.0
	3	4.001	0.612	15.3
	4	6.722	1.414	21.0
	5	6.804	1.956	28.7
	6	4.319	0.690	x16.0
			Average	<u>20.6</u>

x Value omitted in average.

TABLE XXX (Cont.)

MOISTURE CONTENTS OF INDIVIDUAL TRAYS

Run 10

Sample No.	Tray No.	Wt. Wet Sample gms.	Moisture Lost gms.	Percent Moisture
11	1	3.836	0.582	15.2
	2	5.804	1.053	18.3
	3	5.109	0.564	11.0
	4	4.738	0.931	19.6
	5	7.036	2.163	30.8
	6	7.700	2.152	27.9
			Average	20.5
12	1	4.024	0.612	15.3
	2	5.006	0.991	19.8
	3	5.318	1.098	20.7
	4	5.189	1.031	19.8
	5	5.831	1.669	28.7
	6	5.068	0.956	18.9
			Average	20.5
13	1	4.864	0.567	11.7
	2	4.271	0.605	14.3
	3	5.388	1.039	19.3
	4	5.243	1.018	19.5
	5	6.308	1.858	29.5
	6	5.992	1.662	27.7
			Average	18.9
14	1	3.596	0.391	10.9
	2	5.694	0.790	13.9
	3	6.002	1.292	21.5
	4	6.652	1.535	23.1
	5	5.721	1.554	27.1
	6	4.784	0.554	11.6
			Average	18.0
15	1	5.020	0.236	x 4.7
	2	5.253	0.491	9.3
	3	6.189	1.083	17.5
	4	5.033	0.879	17.5
	5	5.158	0.978	19.0
	6	6.154	1.036	16.8
			Average	16.0

DRYING CURVE XIX

TEMP. 160°F - HUM. 20%

RUN 10

TABLE XXXI
RATE OF DRYING
Run 10

Sample No.	Percent Moisture (From Curve)	Wt. Wet Cake lbs.	Wt. Dry Cake lbs.	Moisture Present lbs.	Moisture Lost lbs.	Lbs. H ₂ O /100 lbs. Dry Solid	Lbs. H ₂ O Evaporated /hr./sq.ft.
1	45.3	325	178	147		83.1	
2	43.4	315	178	137	10	76.9	.1163
3	41.6	305	178	127	10	71.3	.1163
4	39.4	294	178	116	11	65.1	.1280
5	37.2	283	178	105	11	58.9	.1280
6	34.7	273	178	95	10	53.3	.1163
7	32.3	263	178	85	10	47.7	.1163
8	29.8	254	178	76	9	42.6	.1047
9	26.8	243	178	65	11	36.5	.1280
10	20.7	225	178	47	18	26.4	.2095
11	20.6	224	178	46	1	25.8	.0116
12	20.3	223	178	45	1	25.2	.0116
13	19.5	221	178	43	2	24.2	.0233
14	18.3	218	178	40	3	22.5	.0349
15	16.1	212	178	34	6	19.1	.0698

RATE OF DRYING CURVE XX

TEMP 160°F

HUM. 20%

RUN 10

The drying conditions for Run 10 were a constant temperature of 160°F and a humidity of 20%. The drying air was 71% recirculated and impregnated with steam to the desired humidity.

The drying curve as shown in Curve XIX indicates a steady decrease in moisture content during the first fourteen hours, and in the following four hours the decrease becomes more rapid. In the next two hours the decrease is very small, after which the moisture content decreases more rapidly.

The rate of drying curve as shown in Curve XX indicates a constant rate of drying during the first sixteen hours (a to b). In the next two hours (b to c) the drying rate increases slightly, and then in the following four hours (c to d) is very low. For the remainder of the run the drying rate tends to increase.

COLOR RESULTS

At the completion of each run a composite sample was taken from all trays, and color tests upon each were made. The samples were compared with Kentucky Color and Chemical Company's standard 4012 blue as to mass tone, strength, tint, hardness, and oil adsorption. The sample from Run 1 is listed as Sample 1, Run 2, Sample 2, etc.

Mass tones were determined as follows:

1/2 gram color

15 drops linseed oil (bleached)

Rubbed 4 x 50 strokes.

Mass tones on Samples 1, 2, 3, 7, and 9 were satisfactory as compared to the standard. Samples 4, 5, and 6 had a purple appearance as compared to the standard, while Sample 8 was very black and Sample 10 quite red.

A strength test was run as follows:

20 mg. color

1.0 mg. ZnO

15 drops linseed oil (bleached)

Rubbed 3 x 75 strokes.

Table XXXII lists the comparative tints and strengths of the samples.

All the samples were of equal hardness. The oil adsorption was the same for all except Sample 8, which was lower than the rest.

TABLE XXXII

TINTS AND STRENGTHS OF SAMPLES COMPARED
TO STANDARD 4012 BLUE

Sample No.	Strength	Tint
1	20% weak	O.K.
2	8% weak	O.K.
3	4% weak	O.K.
4	2% strong	O.K.
5	O.K.	O.K.
6	4% weak	redder
7	2% weak	trace green
8	1% weak	trace green
9	2% weak	trace red
10	3% weak	O.K.

SUMMARY

Examination of the drying and drying rate curves shows the same general characteristics in each run. In each case a gradual increase in the rate of drying during approximately the first third of the run is followed by a sharp decrease and then a rapid increase over a short time interval. This is followed by a gradual decrease in the drying rate for the remainder of the run.

The chemistry of Prussian blue is not at all complete. The structural formulas proposed have not been entirely satisfactory. Also no information is available as to the physical characteristics of the solid.

There are evidently several factors, both physical and chemical, involved in the explanation of what takes place during the drying. The mechanism of drying may possibly involve:

1. The first period of gradually increasing or constant rate of drying, during which the drying rate is governed by evaporation of water from the surface of the solid rather than by diffusion of moisture from the interior of the solid.

2. The second period of very low rate of drying, during which a change in the chemical and physical properties of the solid govern the drying rate.
3. The third period of steadily decreasing rate of drying, during which diffusion of the liquid to the surface of the solid controls the drying rate rather than evaporation at the surface.

A further study of the physical and chemical changes during the second period is being made in this laboratory along with the thermal decomposition of Prussian blue.

The results of these experiments show that drying conditions of a temperature between 140 and 160°F and a humidity between 5 and 15% are the best of those investigated for the drying of Prussian blue. These conditions also give a blue which compares favorably with the standard.

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VITA

Orville K. Schmied was born in Louisville, Kentucky, May 24, 1910. He attended the public school in Louisville and was graduated from the duPont Manual Training High School in 1928. He received the degree of Bachelor of Science in Chemical Engineering from the University of Louisville in June 1932. A scholarship awarded by the Oil, Paint and Varnish Club of Louisville enabled him to enter the Graduate School of the University of Louisville. He received the degree of Master of Science from this institution in June, 1933.