STUDIES ON THE DRYING OF SUGAR PINE LUMBER

Thesis by

Wadsworth E. Pohl

In partial fulfillment of the requirements

for the degree of Master of Science.

California Institute of Technology

Pasadena, California

1930

STUDIES ON THE DRYING OF SUGAR PINE LUMBER

This thesis deals with a continuation and enlargement of the work done by Steinour[1] and Scudder[2] on the"Prevention of Brown Stain in Sugar Pine" and of Scudder's work on moisture gradients in drying wood. The reader is therefore referred directly to these two theses for a statement of their problem, the existing knowledge pertaining to it, and the facts determined by the above investigators concerning the stain and means of preventing it. The experimental equipment used, and the method of calculating results from the data obtained, has been identical in this research with that used by them. The results should therefore be quite comparable.

It was shown by Steinour that brown stain is caused by some oxidation process brought about by contact with the air. It was the experience of the Sugar Pine Lumber Company that lumber sawed from logs which had stood for any considerable time at their plant tended to stain much more than lumber sawed from logs which had stood for the same length of time in the woods, where the temperature was much lower. These observations suggested the idea that possibly a large amount of brown stain could be prevented by end-coating the freshly bucked logs, thus preventing access of air. Since sap flows most freely at the junction of the heart and sap woods and since the worst staining takes place at this junction, it was thought that by preventing the access of air at this junction the amount of staining would be reduced.

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[1]California Institute of Technology, Master's Thesis, 1926.
[2]California Institute of Technology, Master's Thesis, 1928.

In order to try out this idea a freshly bucked log was end-coated in the woods with a moisture proof paint. In order to have a check on whether or not the process was of benefit the next section of the tree was not end-coated but rolled out where the air would have free access. After standing for about a week or so at the mill these sections were sawed and the boards so obtained were used in this research.

RUN NO. 1

Schedule. The purpose of this run was to try out the schedule used by the Sugar Pine Lumber Company in their kilns for the drying of 8/4 sinker stock. The schedule used was therefore as nearly like the one used by them as conditions permitted. A considerable amount of trouble was had with the controls on the experimental kiln and in several instances the wet bulb temperature varied from that intended. The schedule is set forth graphically in the chart of Run No. 1

An initial and final steaming period at 190° dry bulb and nearly 100% humidity, each period about an hour long, was given in this run.

Condition of Lumber Used. The shipment of lumber for this run was found to contain two grades, sinker stock and a dryer stock, presumably from higher up the tree since it contained some larger knots. These boards were taken from ordinary logs which had had no special treatment. They turned out to be only 7/4 stock, so that in surfacing them 1 7/16" stock was obtained.

Run No. 1		Sinker Stock	Other Stock
Initial moisture content Percent of dry weight	Ave.	203	71
	Range	187-212	56-80
Final moisture content at middle of boards Percent of dry weight	Ave.	8.3	5.6
	Range	8.2-8.5	2.5-6.4

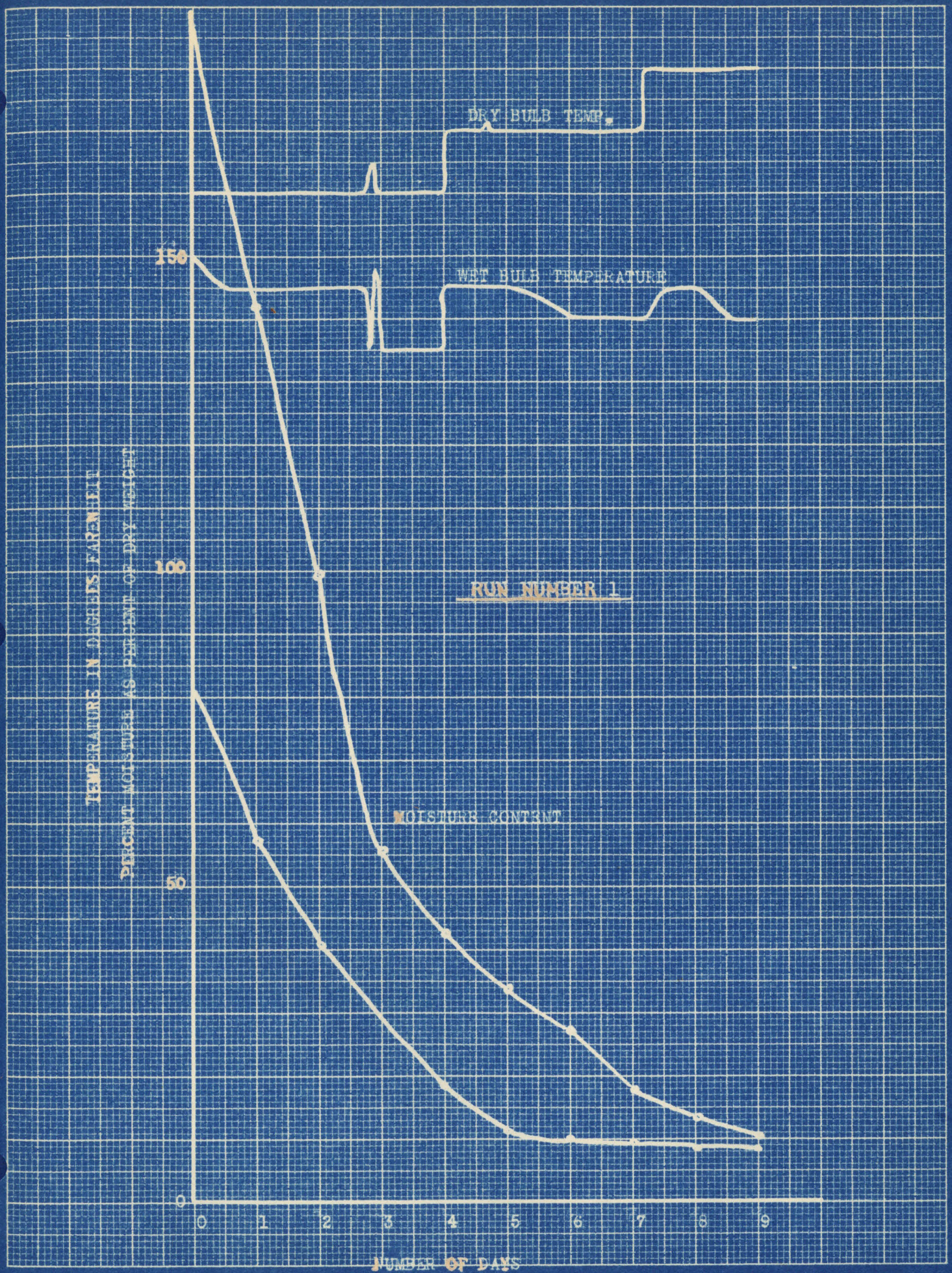

CHART NO. 1

This run left the boards in apparently good condition. They did not show appreciable binding on the saw. One out of the fourteen boards showed end-splitting. It was split back from the end about eight inches.

Staining. The stain developed in this run was quite bad, in both types of lumber. It was streaked, in both the heart and sap wood. However, the staining in this run was not nearly as bad as that in some of the boards dried by Steinour and Scudder, which they described as being very heavy and dark with stain.

Remarks. Since Run No. 1 was based on the schedule used by the Sugar Pine Lumber Company and since they report good results from it, there must have been some complicating factor in the run as carried out. It has been shown that a high temperature-high humidity treatment causes stain, and this treatment is used to develop it. The staining in this run may therefore have been caused by the initial steaming period. It does not seem probable that the fluctuations in wet bulb temperature would affect the amount of stain formed. Another possibility is that the stain developed during the two days in which the wood was in transit from the mill.

RUN NO. 2

Schedule. This schedule was also based on that used by the Sugar Pine Lumber Company. As will be seen from the chart of Run No. 2 the apparatus behaved well during this run. The initial and final steaming periods given the lumber in this run were identical with the steaming periods of run No. 1, e.g., 180° and close to 100% relative humidity. for 1 hour.

Condition of Lumber Used. The lumber used in this run was that obtained as set forth in the opening section of this report. Four boards from the end-painted log and three from the check log were used.

Run No. 2		Painted end	Check log
Initial moisture content Percent of dry Weight	Ave.	221	215
	Range	212 - 230	180-233
Final moisture content Percent of dry weight	Ave.	10.0	10.8
	Range	8.7-11.3	9.1-12.9

This run left the boards in good condition. There was little tendency to bind on the saw and there was no end-splitting.

Staining. The following is a description of the staining in the boards of this run.

Boards from end-painted log

1. Streaks of dark stain at junction of heart and sap woods, some stain in both heart and sap.
2. Sap wood very heavily stained, heart wood stain light to medium.
3. Dark stain at junction of heart and sap woods, sap wood very dark, heart wood quite clear.
4. Dark stain in sap wood, heart wood lightly stained.

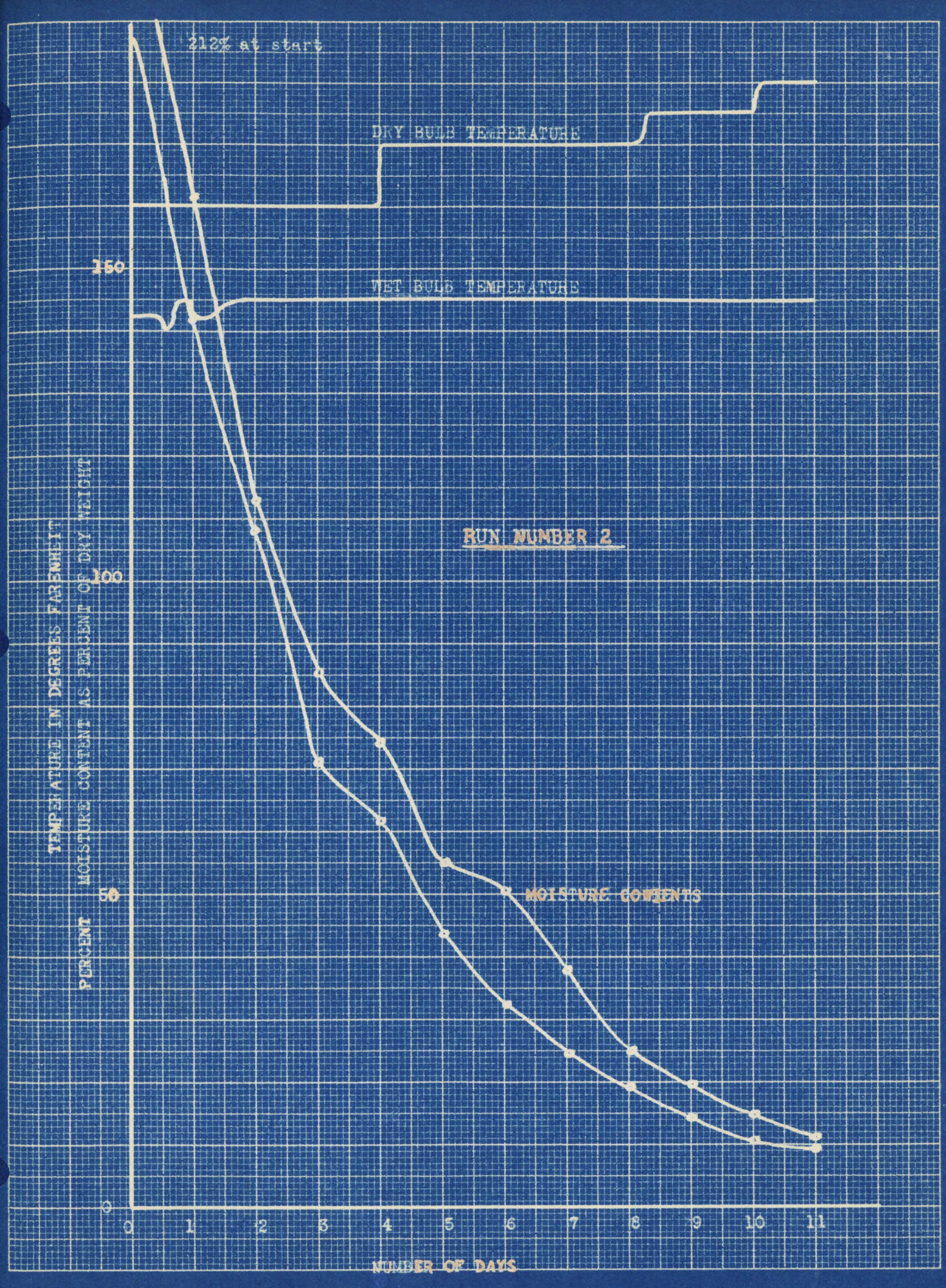

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CHART NO. 2

Boards from check log

1. Very light uniform staining all over, no streaks.

2. Deep streaks of stain running length of board.

3. Very light stain, all in heart wood; sap wood almost clear.

Remarks. The evidence obtained from this run seems to directly negate the theory that end-painting the log would prevent staining.

RUN NO. 3

Owing to some confusion at the mill the boards for this run were received almost at the same time that the boards for run No. 4 were received. They could not, therefore, be put through the kiln, but were stickered up out in the open air and allowed to air dry. After drying it was found that they were almost entirely free from stain. The boards used in this run contained several large knots, some as large as three inches across. Considering this in conjunction with their moisture content, it seems probable that these boards were not sinker stock but came from higher up in the tree.

Run No. 3

Initial moisture content Percent of dry weight	Ave. Range	85 81-89
Final moisture content Percent of dry weight	Ave. Range	13 12-15

Staining is worst in sinker stock in sugar pine, and since these boards were apparently not sinker stock and were air dried as well, it is not surprising that no stain formed.

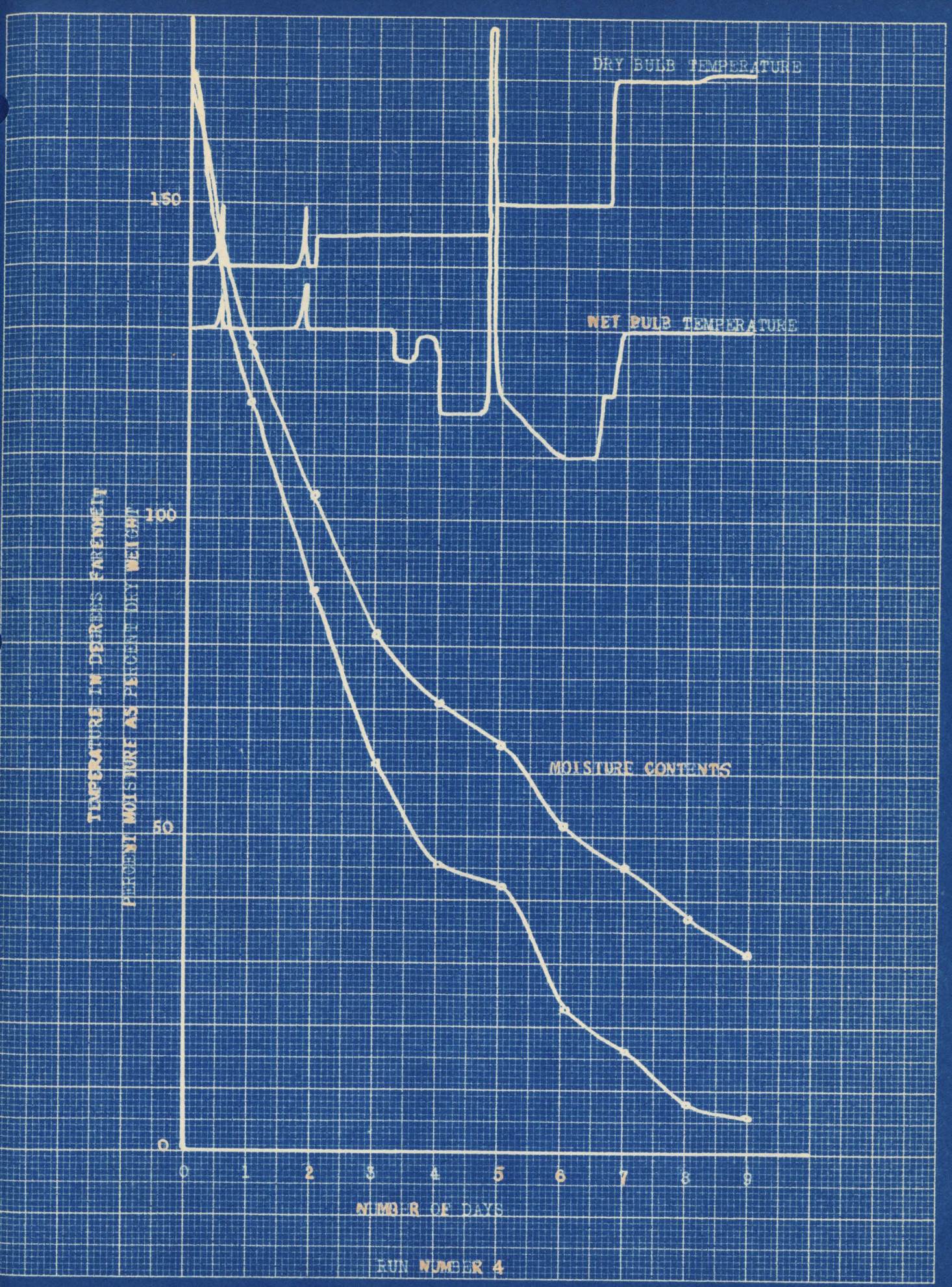
RUN NO. 4

Schedule. The schedule used in this run was at first intended to follow that of Steinour's Run No. 8. As will be seen from the chart, everything went well till the fourth day, when the controls on the wet bulb temperature began to misbehave. It was felt that possibly this lowered wet bulb temperature had caused excessive drying, so a steaming period of one hour was injected into the schedule. However, the humidity controls continued to be out of order for another two days, in spite of all that could be done for them. At the beginning of the eighth day these controls were again got into working order. Because of the continued period of low humidity, the schedule at this point was brought up to the place on Steinour's run no. 8 where the moisture content of the boards was about the same. Initial and final steaming periods similar to those of runs no. 1 and no. 2 were given to the boards of this run.

Condition of Lumber Used. Fourteen boards were used in the run, half from an end-painted log, and half from the check log

Run No. 4		End-painted board	Check pieces
Initial moisture content Percent of dry weight	Ave.	155	168
	Range	130-175	165-171.5
Final moisture content Percent of dry weight	Ave.	33.8	29.2
	Range	11.5-60.5	10.2-45

The lumber from this run was not in such good condition at the end of the run as that from the two previous kiln runs. Seven out of the fourteen boards contained cracks varying from six to eight inches in length. The saw also showed some tendency to bind in cutting the moisture content strips.



KEUFFEL & ESSER CO. N.Y.

CHART NO. 3

Staining. The staining in this run was very light in most of the boards from both the painted end log and the check log. The stain, with but two exceptions, was lightly and uniformly distributed, and harmonised completely with the color of the wood. Two boards from the unpainted or check log and one from the end-painted log showed considerable staining along the junction of the heart and sap woods.

CONCLUSIONS

The results obtained from this study of the effect of end-coating of freshly bucked logs in order to exclude oxygen from the air indicate that this treatment is not beneficial in eliminating stain. Boards cut from the same logs from which the boards used in this research were obtained were put thru the kilns at Pinedale and no difference between tham and the boards from the untreated log could be seen.

PART II

A STUDY OF MOISTURE GRADIENTS IN DRYING SUGAR PINE

The general procedure in this study was the same as that used by Mr. Scudder in the work which he did on the same subject. For a detailed report on the method the reader is referred to his thesis.[1] The scheme is as follows:

Starting with a fresh board about four inches was cut from the end to eliminate possible end-drying which might have taken place thru the end-coating. Another section of three inches was then sawed off and from the center of this section a piece three inches wide was taken. The resulting block, whose dimensions were 2x2x3 inches, was then cut up in a special slicing machine into chips about 1/16 of an inch thick, until one half of the thickness of the block had been used. The chips were weighed at once to within one milligram and then dried to constant weight in an oven at about 95 degrees C$_e$ntigrade. From this dry weight the moisture content of each chip could be calculated and the moisture gradient obtained. The total weight of dry wood rather than the distance from the surface was plotted against moisture content for each chip.

This process was repeated each day for as many as five days, the freshly cut ends being coated with moisture proof paint in order to prevent end drying.

In order that as far as possible the results from the various runs should be comparable with each other, a standard schedule for all runs was used. This schedule is set forth graphically in chart 4. Owing to difficulties with the experimental kiln it was not always pos-

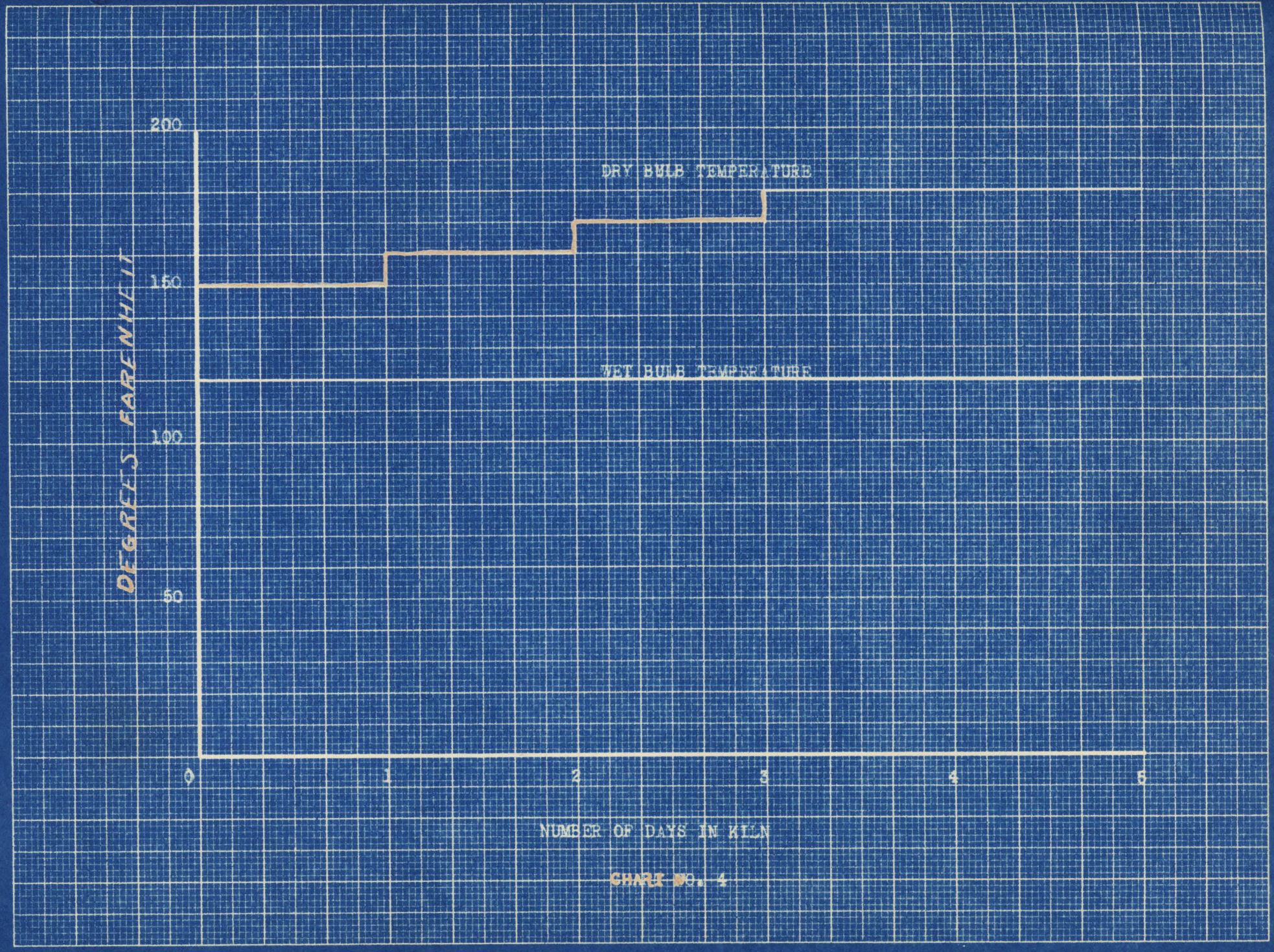

200
150
100
50
0
DEGREES FARENHEIT
DRY BULB TEMPERATURE
WET BULB TEMPERATURE
1
2
3
4
5
NUMBER OF DAYS IN KILN

CHART NO. 4

sible to maintain this schedule accurately, but digressions are noted in the discussion of the runs.

Since the grain of some of the boards used was of one type and of others of a different type it is felt that a definition of the terms radial and slash cut aw used in this thesis would be useful. This is set forth on chart 5.

Boards Number 14 and 15.

These boards were slash cut and from the air dried stock of Run No. 3. They were down to about 15% moisture before being put in the kiln. The run was of the nature of a preliminary one designed to try out the method and apparatus. The moisture gradients found are set forth graphically on chart 6. The initial gradient for board 14 was lost on account of the chips being burnt up in the drying oven.

Stock from which boards number 20-30 (incl) were obtained.

Since the mill at Pinedale closes down during the winter months it was necessary to obtain lumber before the shut-down and keep it in storage for work during the winter. The stock obtained had been partially air-dried at Pinedale. On being received here it was end painted and stickered in a highly humidified room. The humidity in this closed room was maintained at a high level by a continuous evaporation of water from a large pan on a hot-plate. This system kept these boards in fair condition for about three months. However, as was proven near the end of this period, the boards tended to dry unevenly, and some end drying was noticed in spite of a good coating of moisture proof paint on the ends. The stock was cut at the mill into five foot lengths, eighteen inches too long for use in the experimental kiln. This extra length was

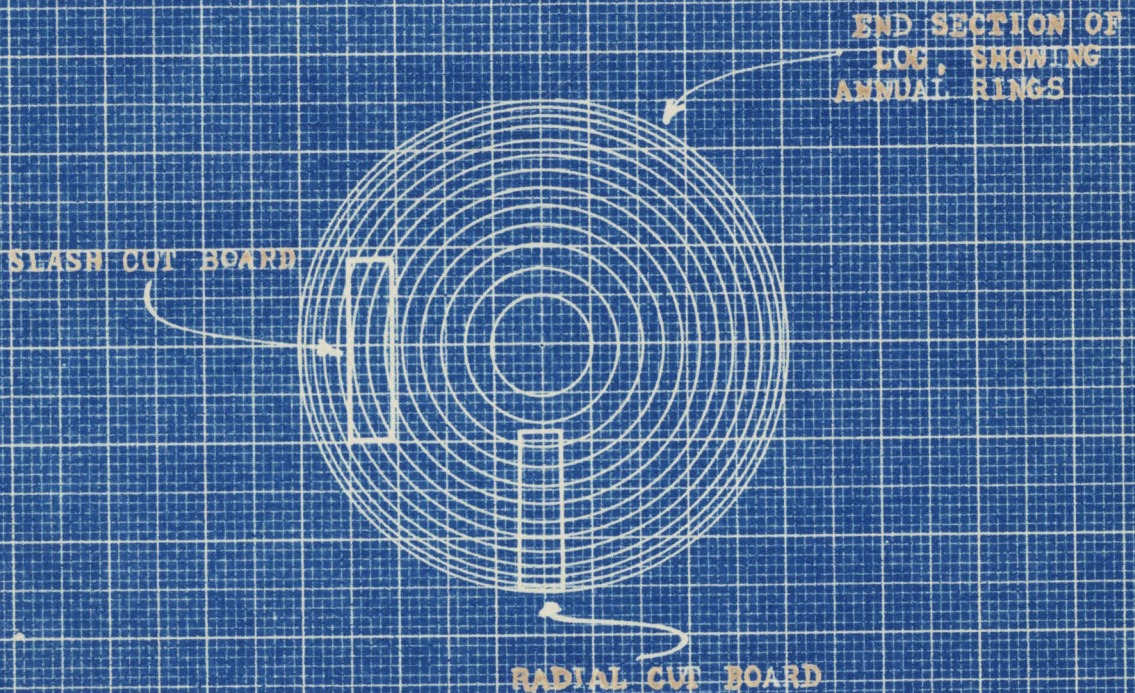


CHART NUMBER 5

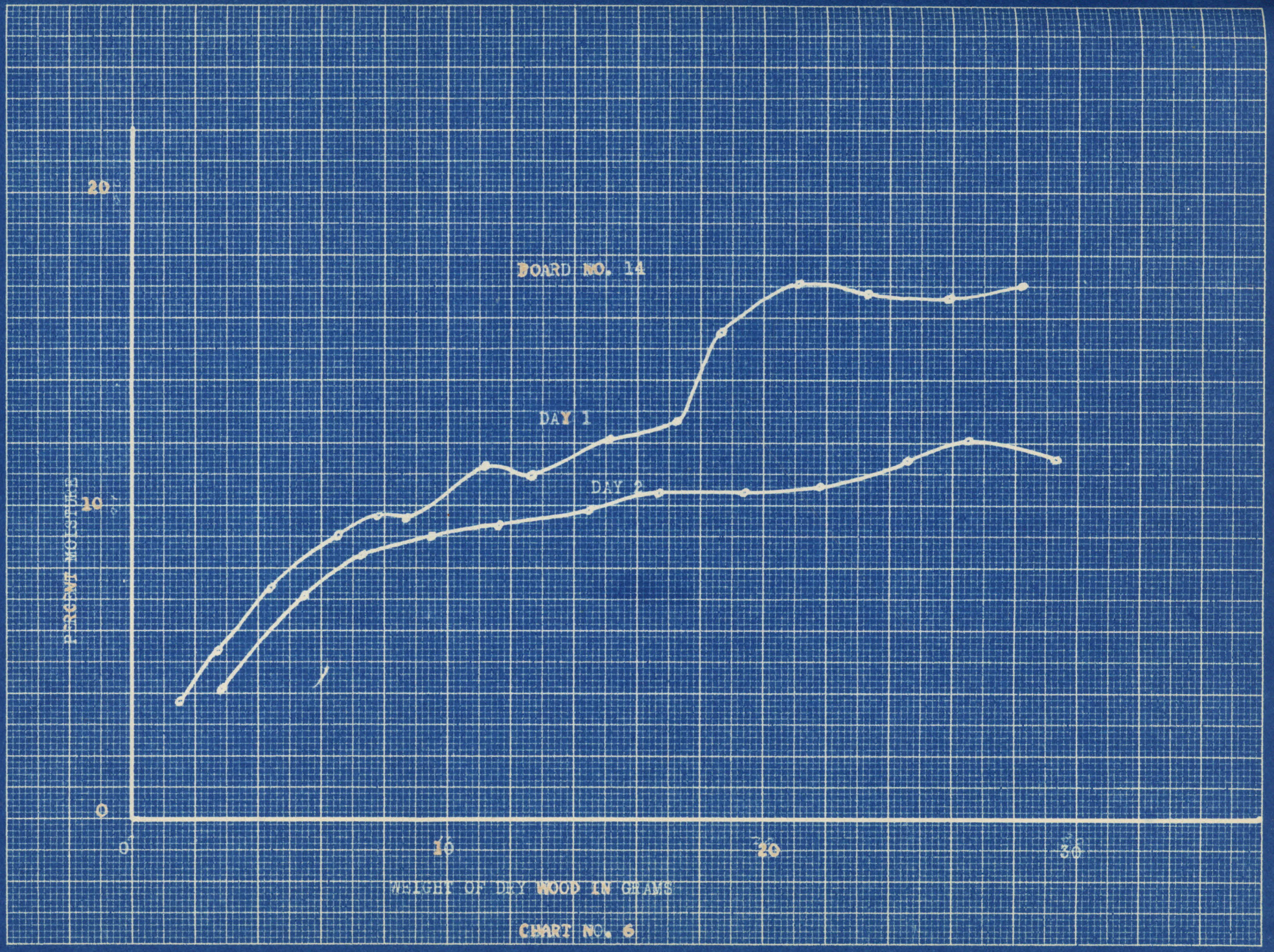


CHART NO. 6

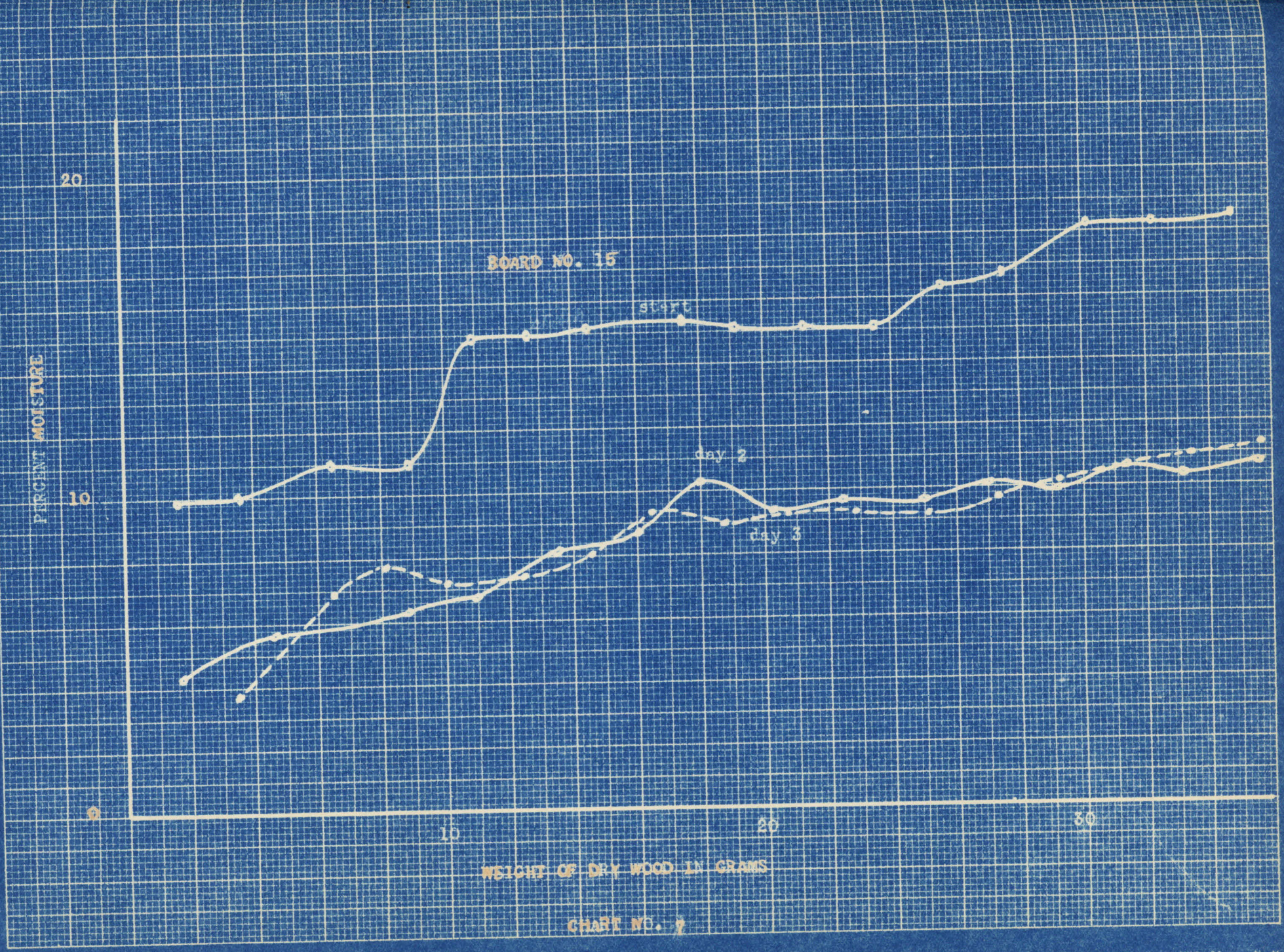


CHART NO. 7

cut off and discarded before the board was used, in order to eliminate as far as possible end drying which might have taken place even thru the end coatings.

Board Number 20.

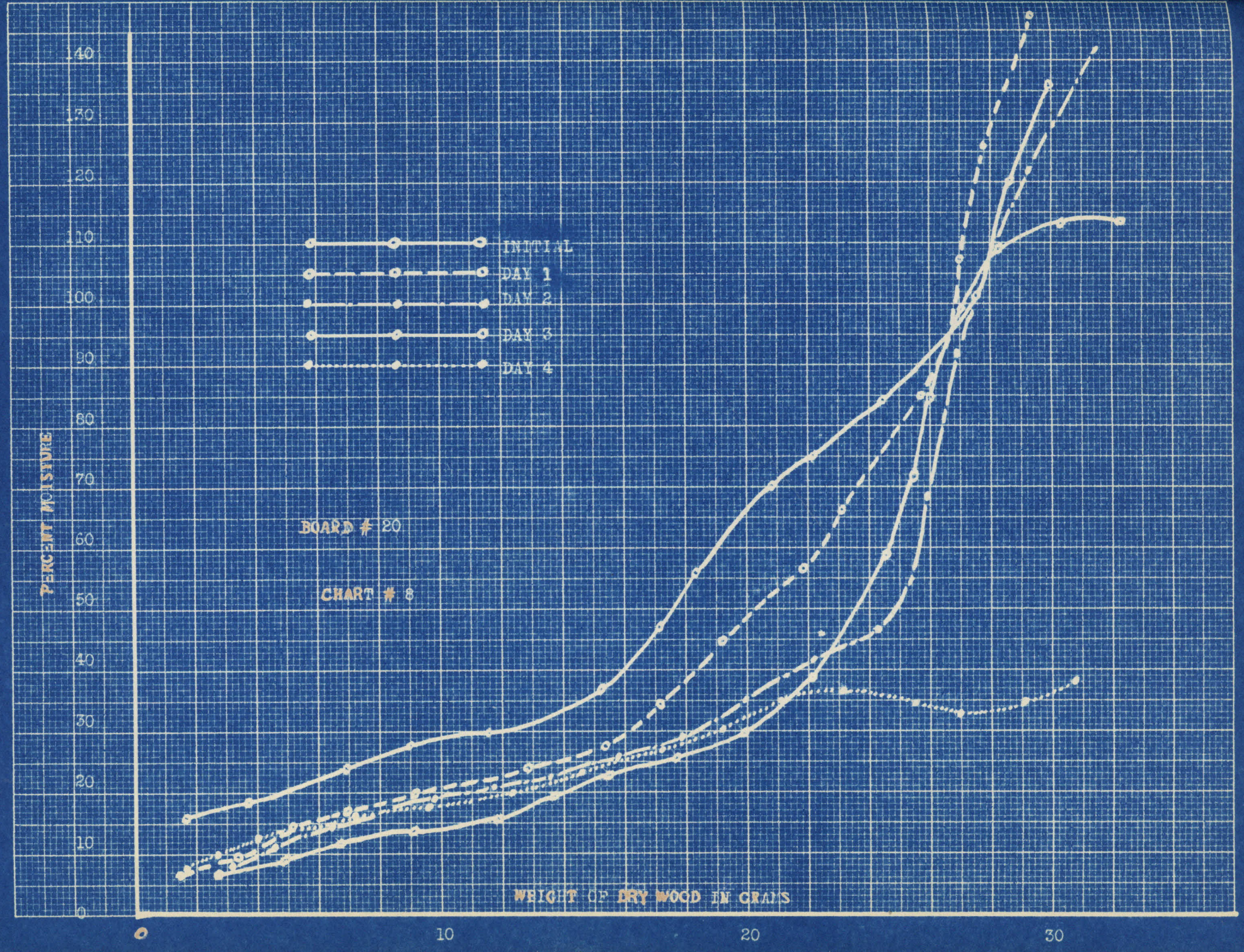
The curve for the initial moisture gradient in this board shows clearly the effect of having been partially air-dried at Pinedale. It was comparatively dry in from the surface for some distance and then quite suddenly was found to be very wet. The curves for days 1 and 2 show that drying was slowly proceeding, which is in accord with the mild schedule to which the board was being subjected. As the severity of the treatment was increased on days 3 and 4 the moisture content at the center of the board was seen to fall rapidly. This board was slash cut.

Board Number 21.

The initial moisture gradient curve for this board shows a fairly uniform gradient. The curve for day 1 indicates that drying was taking place near the surface of the board. The fact that the moisture content at the middle of the board was greater on day 1 than it was initially is probably due to variation in the wood structure from place to place. On days 2 and 3 the dry bulb temperature was left constant at 160°, which resulted in little or no drying taking place on day 3. Days 4 and 5 show uniform drying thruout the board. This board was radial cut.

Board Number 21 A.

The initial moisture content of this board was somewhat below 20%. After two days of treatment under the standard schedule it was found to be below 10% moisture. This board was slash cut.


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
PERCENT MOISTURE
INITIAL
DAY 1
DAY 2
DAY 3
DAY 4
BOARD # 20
CHART # 8
WEIGHT OF DRY WOOD IN GRAMS
0
10
20
30

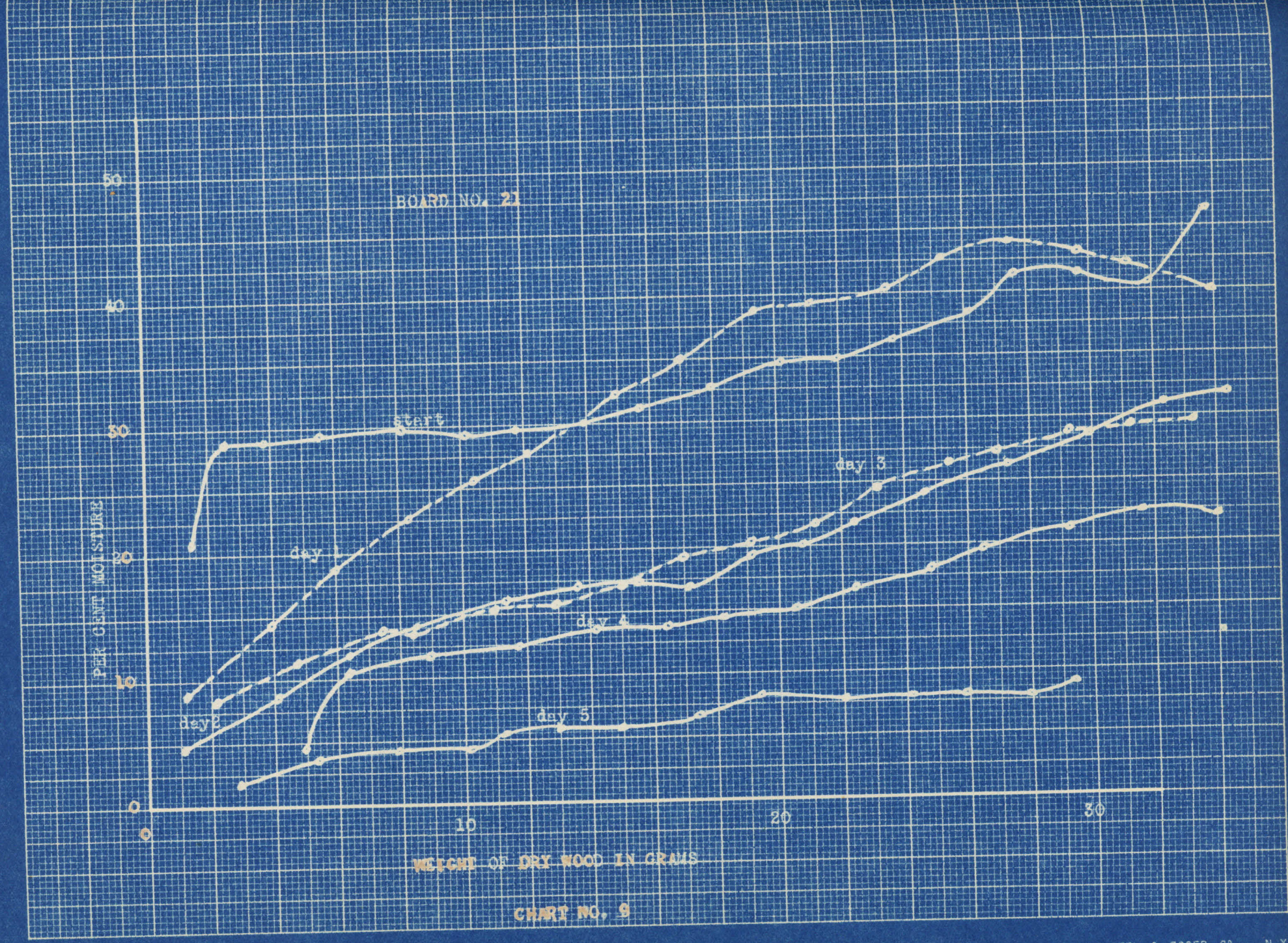


CHART NO. 9

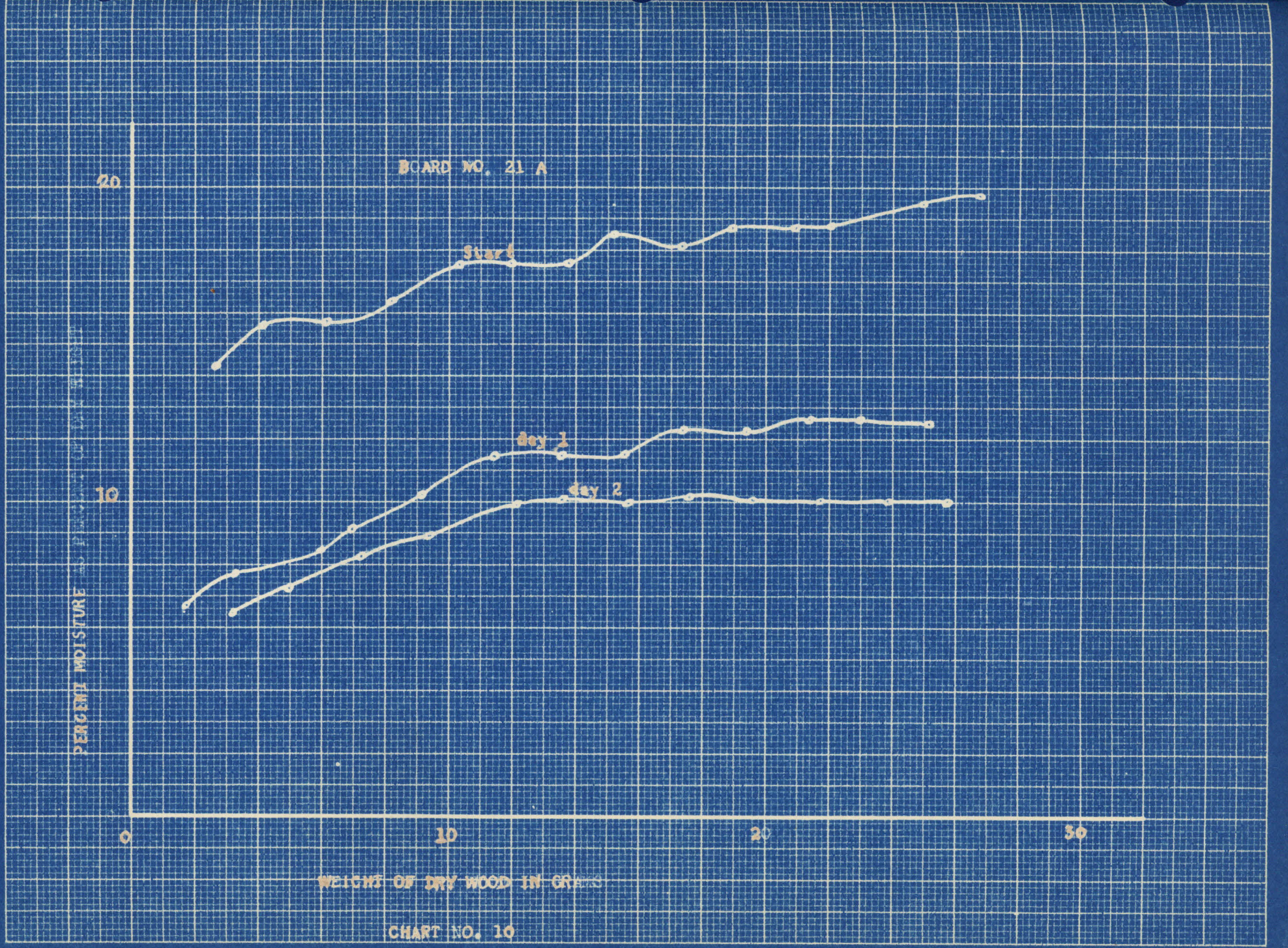


CHART NO. 10

Board Number 22.

This board was run on the same schedule as 21 A. The initial gradient was probably obtained from chips from the other side of the board than that supplying the chips on the following days. This would indicate that drying tended to take place chiefly from one side of the board, and made it appear desirable to label the board so that the chips for the moisture gradient determination would always be taken from the same side of the drying board. Previously it had been assumed that the two sides of the board were equal. This board was slash cut.

Board Number 23.

Part of the grain in this board was particularly bad for moisture gradient determinations. The grain in the section from which the chips for day 1 were obtained was twisted and distorted so that probably extraordinary drying effects were obtained. Otherwise the curves show a reasonable drying rate. This board was radial cut.

Board Number 24.

The extraordinary moisture gradients obtained from this board are probably largely due to the fact that a wide strip of sap wood was present on one side of the board. It is known that sap flows most easily at the junction of the heart and sap woods and if the junction came closer to the portion from which the gradients were determined in some cases it is not peculiar that an extraordinary drying effect took place. This board was radial cut.

Boards Number 25 and 26.

The moisture content of these boards was below 20% at the start of the run. On a mild schedule (the start of the standard schedule) they did not show appreciably drying after the first day. These boards were radial cut.

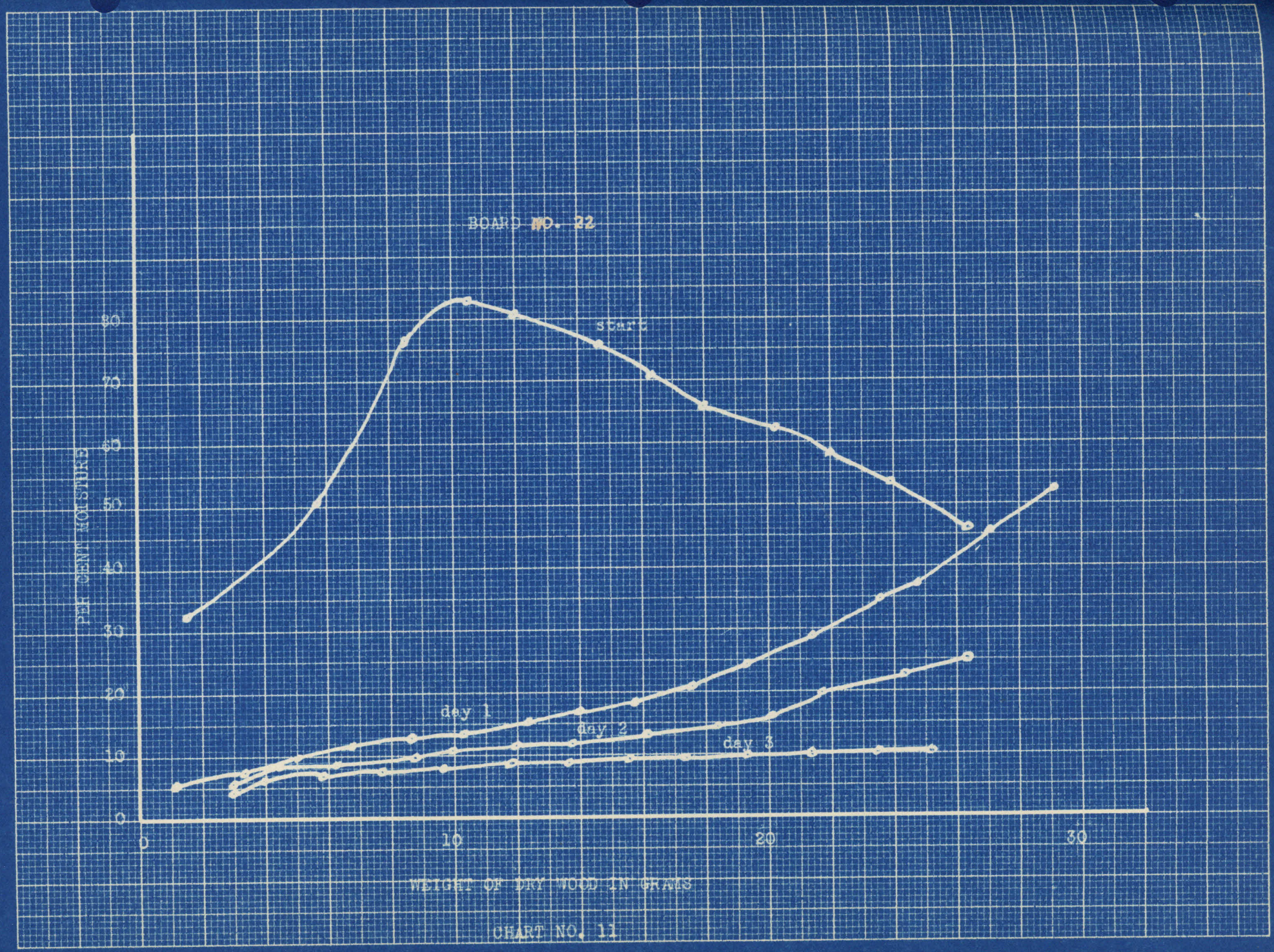


CHART NO. 11

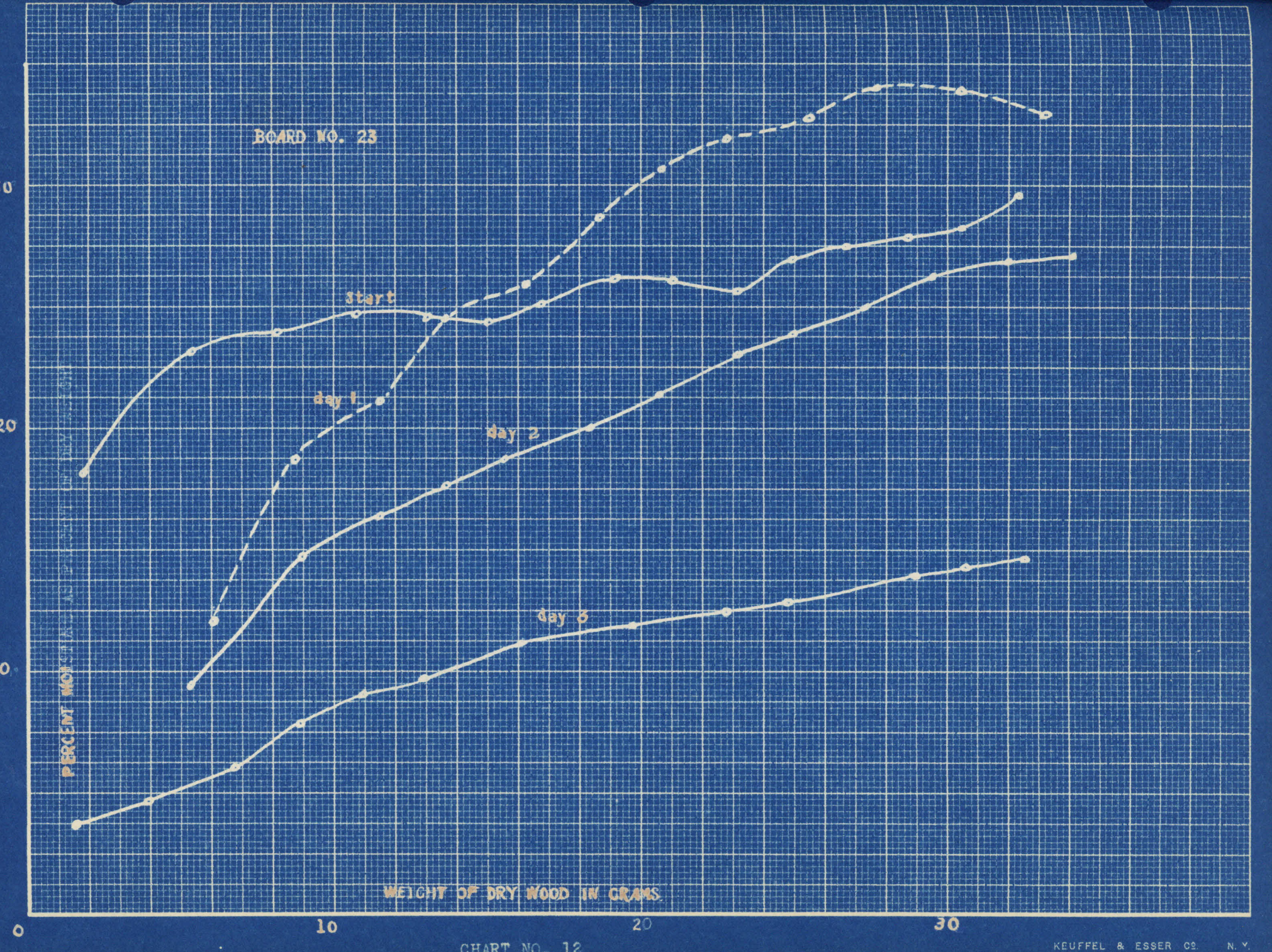
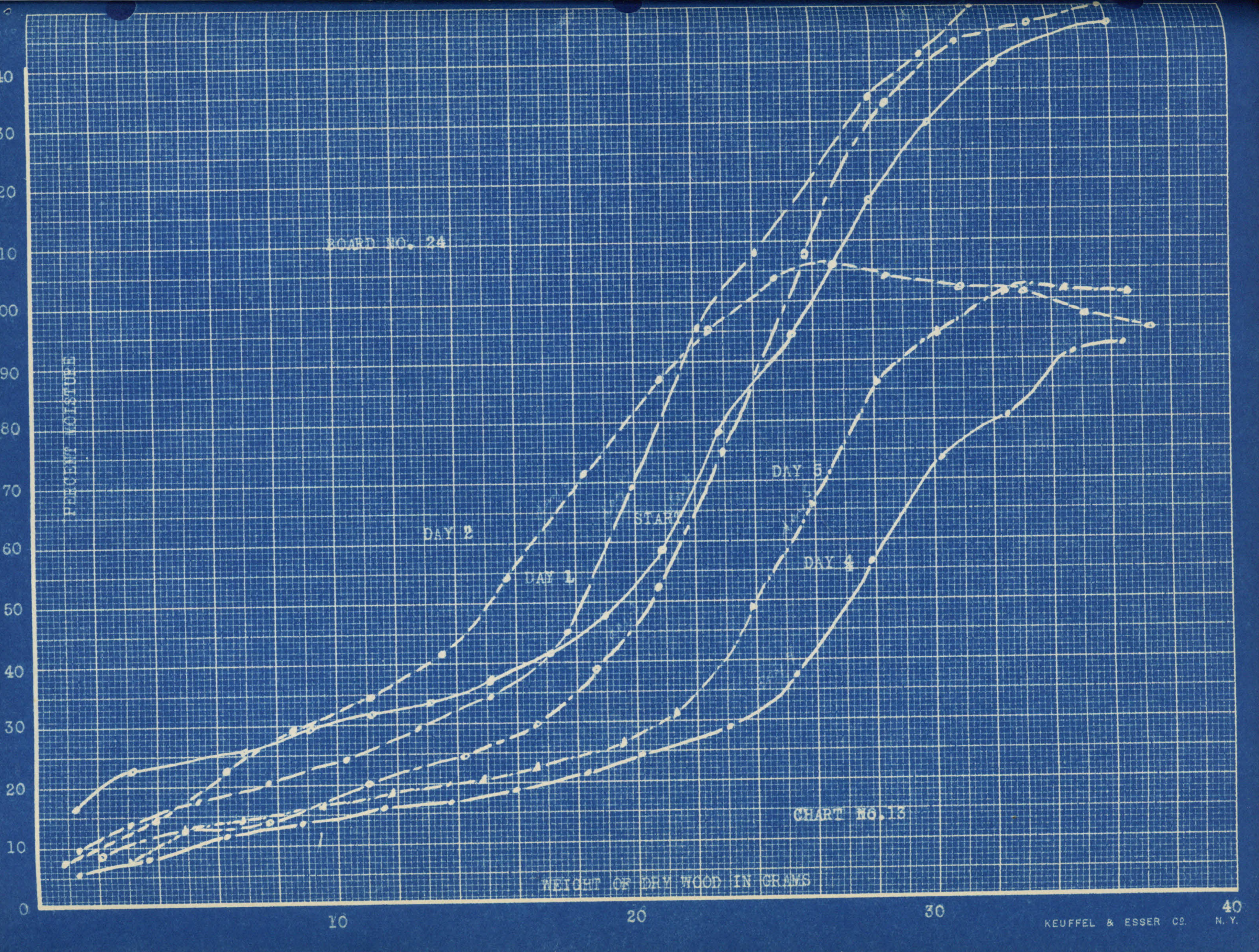
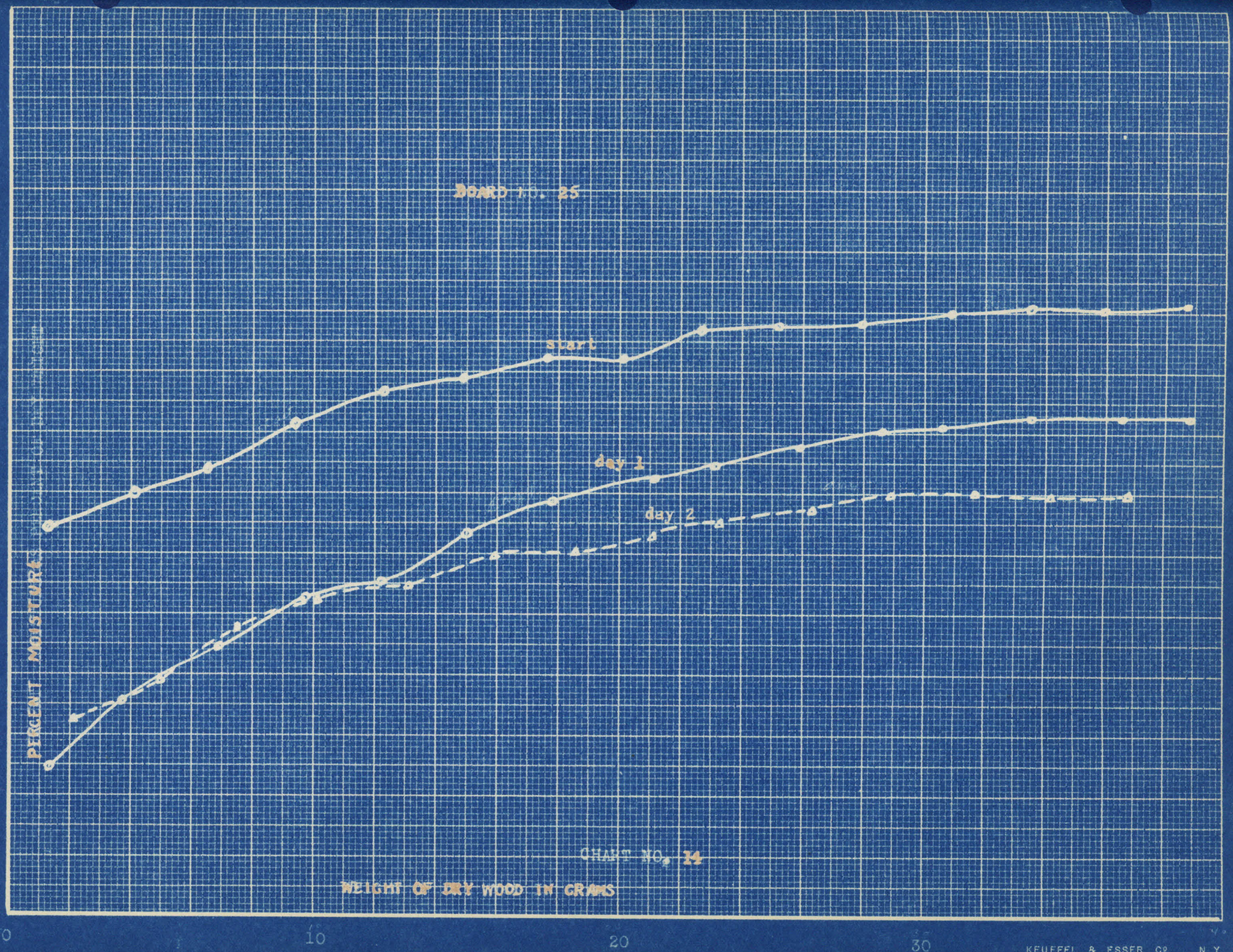


CHART NO. 12

KEUFFEL & ESSER Co. N.Y.


BOARD NO. 24
DAY 2
DAY 1
START
DAY 5
DAY 4
CHART NO. 13
PERCENT MOISTURE
WEIGHT OF DRY WOOD IN GRAMS
0
10
20
30
40
50
60
70
80
90
00
10
20
30
40
10
20
30
KEUFFEL & ESSER CO. N.Y.


BOARD NO. 25
start
day 1
day 2
PERCENT MOISTURE
20
10
0
10
20
30
CHART NO. 14
WEIGHT OF DRY WOOD IN GRAMS
KEUFFEL & ESSER Co. N.Y.

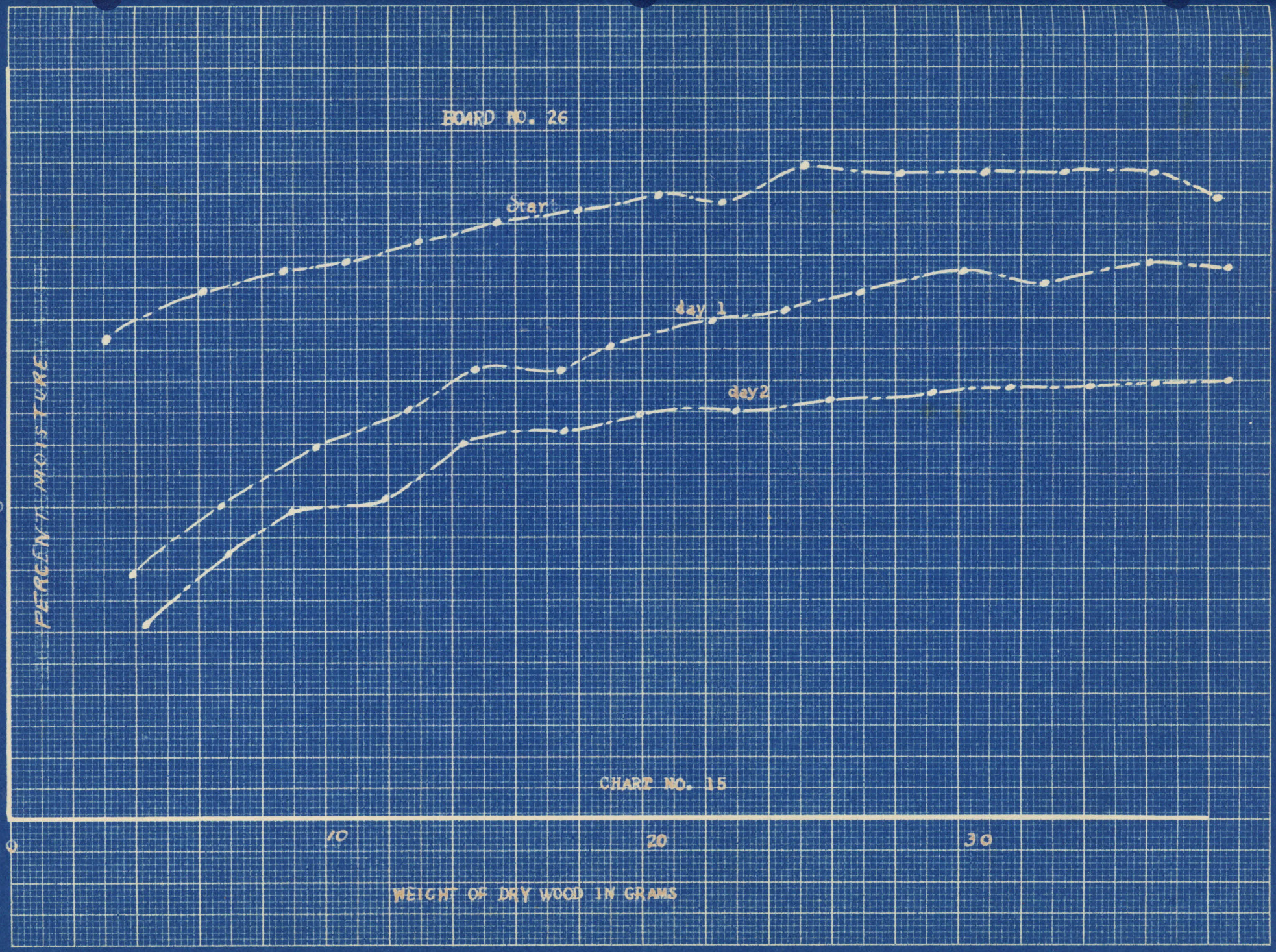


CHART NO. 15

Board Number 27.

The initial moisture gradient in this board shows clearly the effect of having been stored for a considerable period of time. All of the subsequent curves show that drying was taking place thruout the board at a fairly uniform rate. During the last two days of the schedule drying was more rapid towards the center of the board. This board was radial cut.

Board Number 28.

This board was slash cut. With the exception of the initial curve the curves for this board show a more or less uniform drying rate thruout the thickness of the board. The fact that the initial curve falls below that for day 1 is probably accounted for by end drying thru the end coating.

Board Number 29.

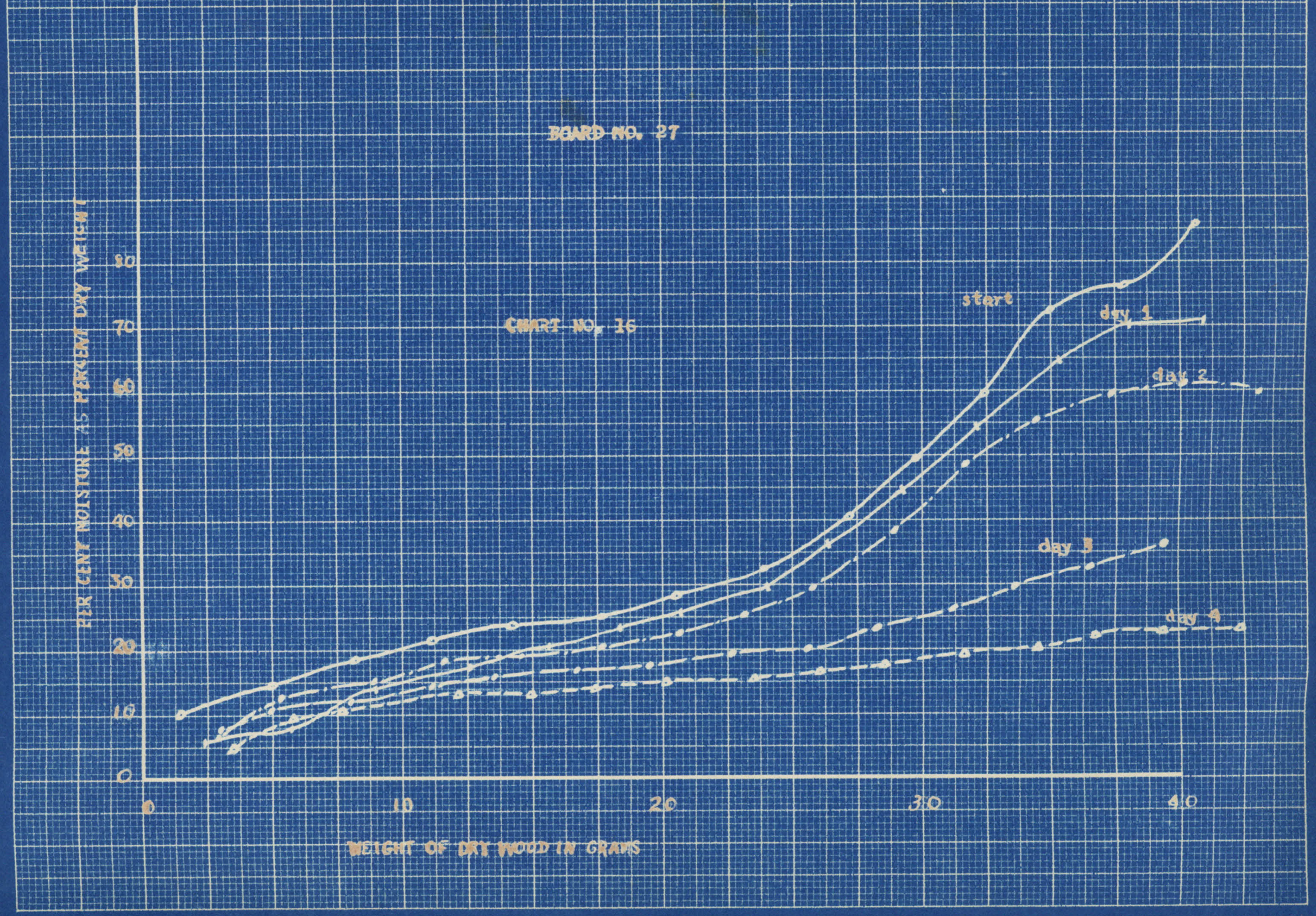
This board was found to be too dry to give worthwhile results and was discarded after taking the initial moisture gradient.

Board Number 30.

In this board the chips were taken as far thru the block as the chipping machine would permit. About 79% of the block was used. The phenomenon of an increasing moisture content at the center of the board on days 1 and 2 was thot to require explanation. Since the board had been in storage for nearly three months it was thought probable that it had dried back from the ends. This theory was tested out by taking the last wet board in storage, ripping two parallel strips lengthwise from the center of the board and taking the moisture content along these strips every six inches. The results of these tests are set forth

BOARD NO. 27

CHART NO. 16



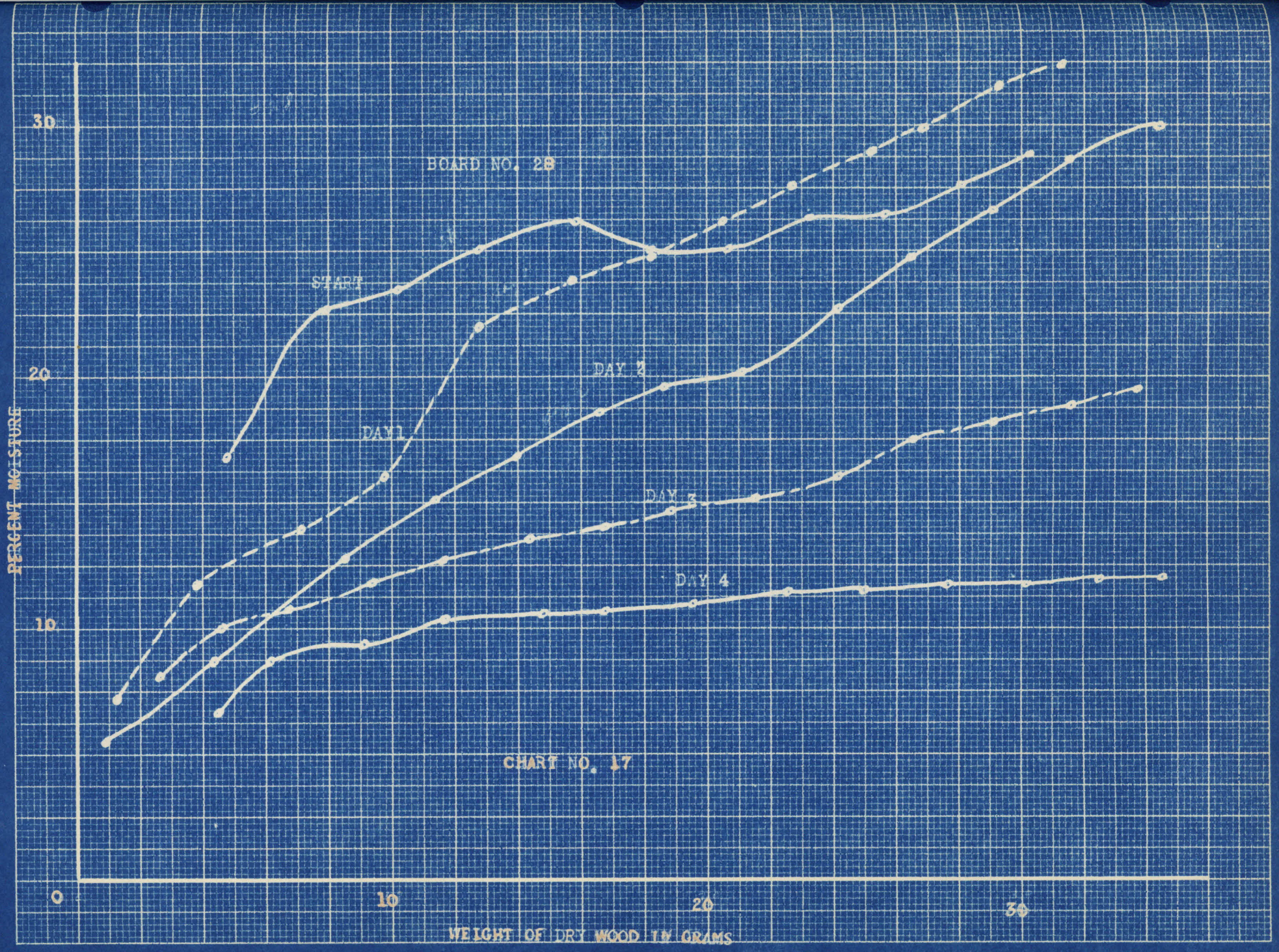

BOARD NO. 28
START
DAY 1
DAY 2
DAY 3
DAY 4
30
20
10
0
10
20
30
PERCENT MOISTURE
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 17

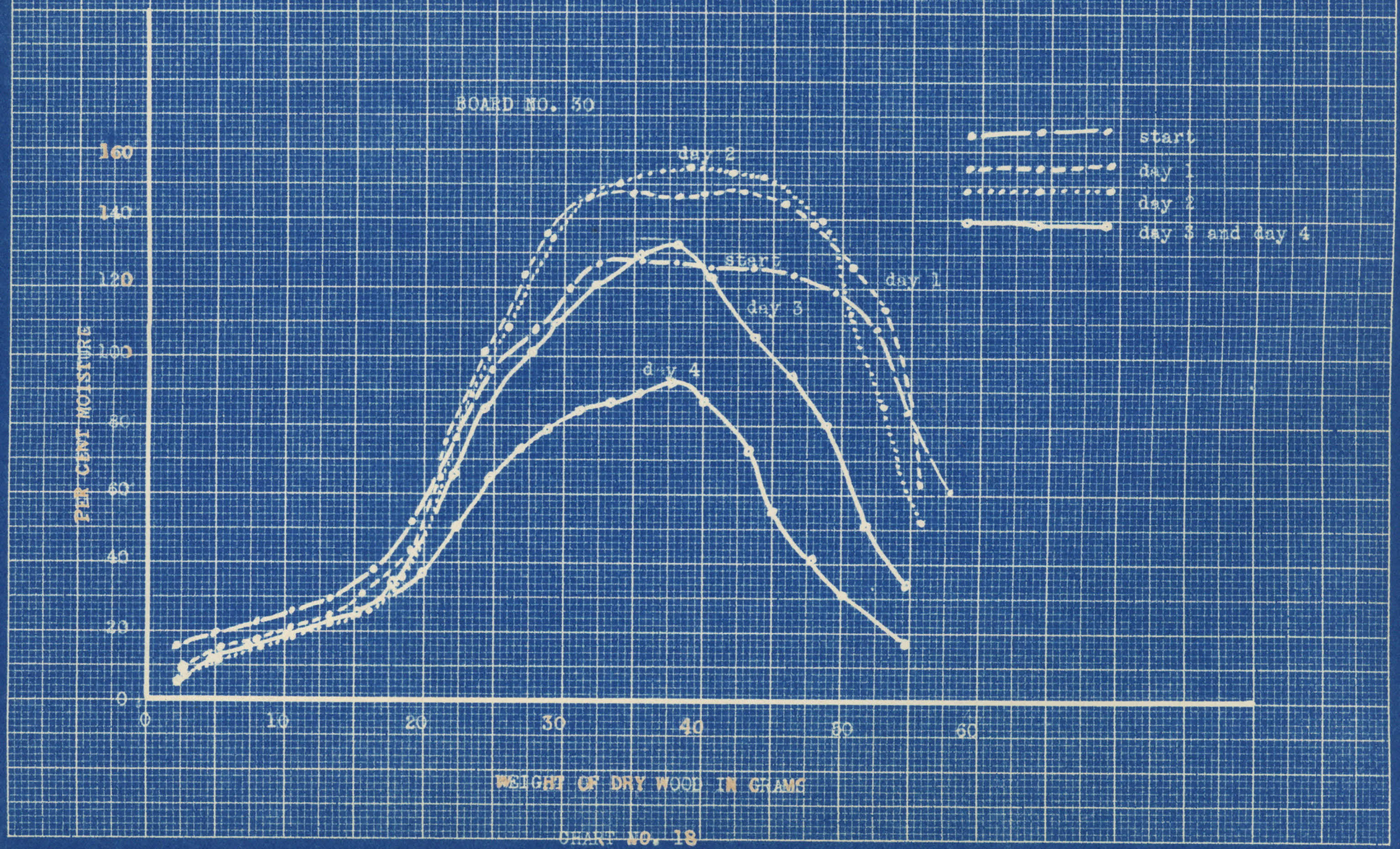


CHART NO. 18

graphically in chart no. 19. It is clear, from a consideration of these curves that a very considerable moisture gradient existed along the length of the board. This would account for the results of Boards number 20, 21, 22, 24, 28 and shows that the method of sampling a board under treatment at different locations along its length on successive days leads to uncertain results, particularly when the stock has been partially dried previously.

Having reached this conclusion and having used up the last board on hand with a reasonably high moisture content, it was decided to try out a different procedure in an attempt to obviate the difficulty.

Owing to various factors it was not possible to obtain a fresh supply of green lumber.

This suggested the possibility of studying the moisture gradients in wood which had been water soaked. It was thought that if blocks of wood suitable in size for cutting in the chipping machine were water soaked and then coated with moisture proof paint that it would be possible to use adjacent blocks from wood which was particularly uniform and straight grained. Such a scheme would eliminate to a great degree the difficulties of comparing the moisture gradients in blocks which came from widely separated parts of a board.

With this in view several preliminary experiments were carried out, with the object of determining whether the moisture proof paint available was really sufficiently water proof to be used for such a purpose. This was determined in the following manner: Blocks of wood were thoroly soaked up with water and two adjacent sections cut from the center of each. One of each pair was coated completely with the moisture proof paint and the other was used as a sample for determining in-

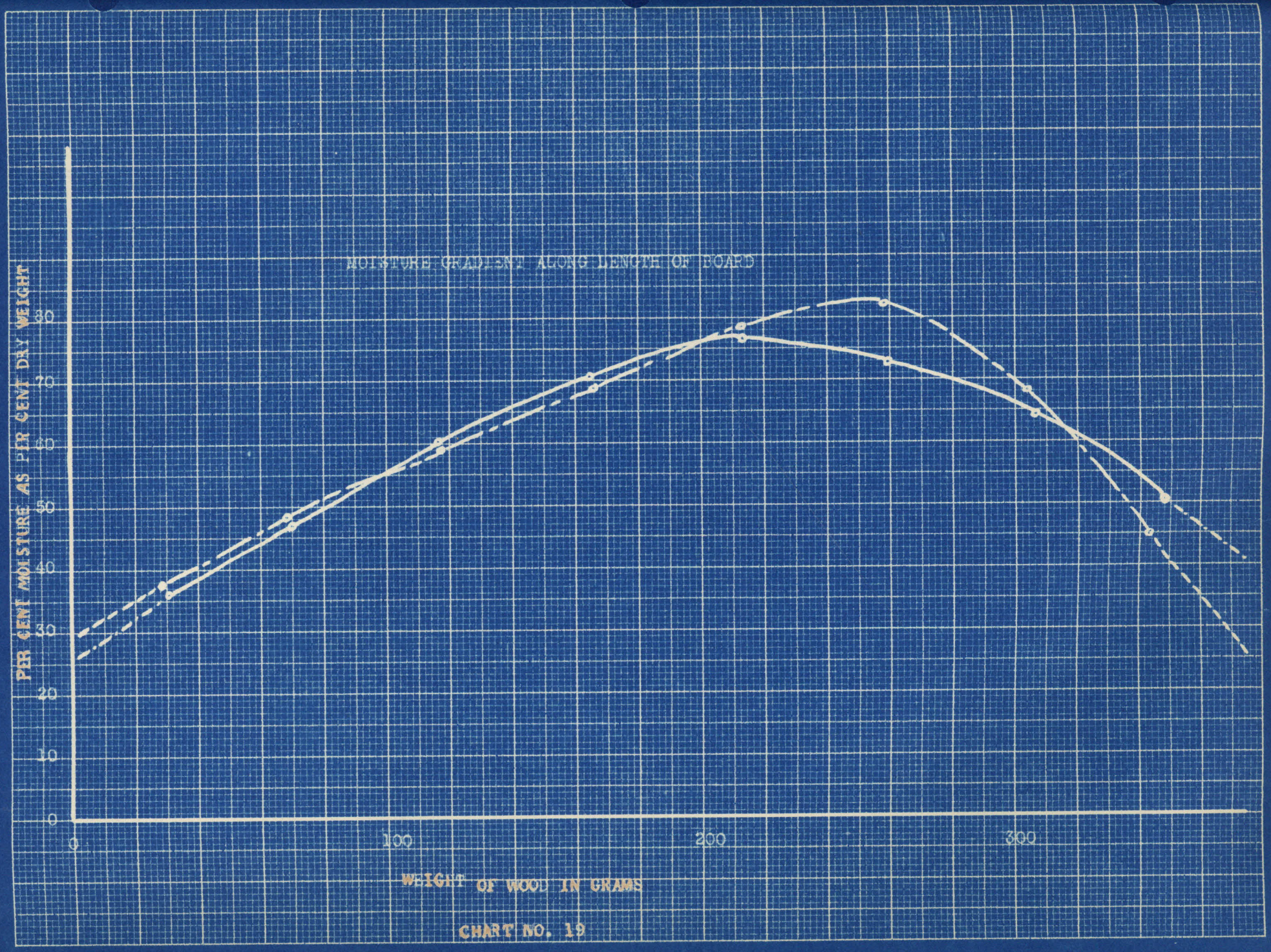


CHART NO. 19

initial moisture content. The coated blocks were then treated in various ways. It was found that if the paint was allowed to air dry for about forty-eight hours it would then stand treatment in the oven at ordinary dry kiln temperatures without leakage. The moisture contents of the painted section and the check section were then found to agree within 1%.

Chart Number 20.

In order to try out the method a tiral run was made. Several blocks were soaked up and painted according to the method worked out. The paint was then removed from one face of each block, in order to permit drying from that face. The blocks were then placed in the kiln and run under the standard schedule as set forth in chart 4. The results of this preliminary run, which was on blocks which dried from that surface which corresponded to the face of a slash cut board, are set forth graphically in chart 20.

Charts Number 21 and 22.

The blocks whose moisture gradients are plotted in these two charts were cut from adjacent positions from a single selected piece of lumber. This system was used on all subsequent runs. The blocks were allowed to dry from that surface corresponding to the face of a slash cut board. The two sets of data plotted in these charts were obtained simultaneously and should therefore check each other. This is seen to be approximately the case.

Chart Number 23.

The drying rates obtained from the previous run were so great that it was felt to be necessary to devise a new and milder schedule in order to follow the process more exactly. This new schedule is set forth on chart 23.

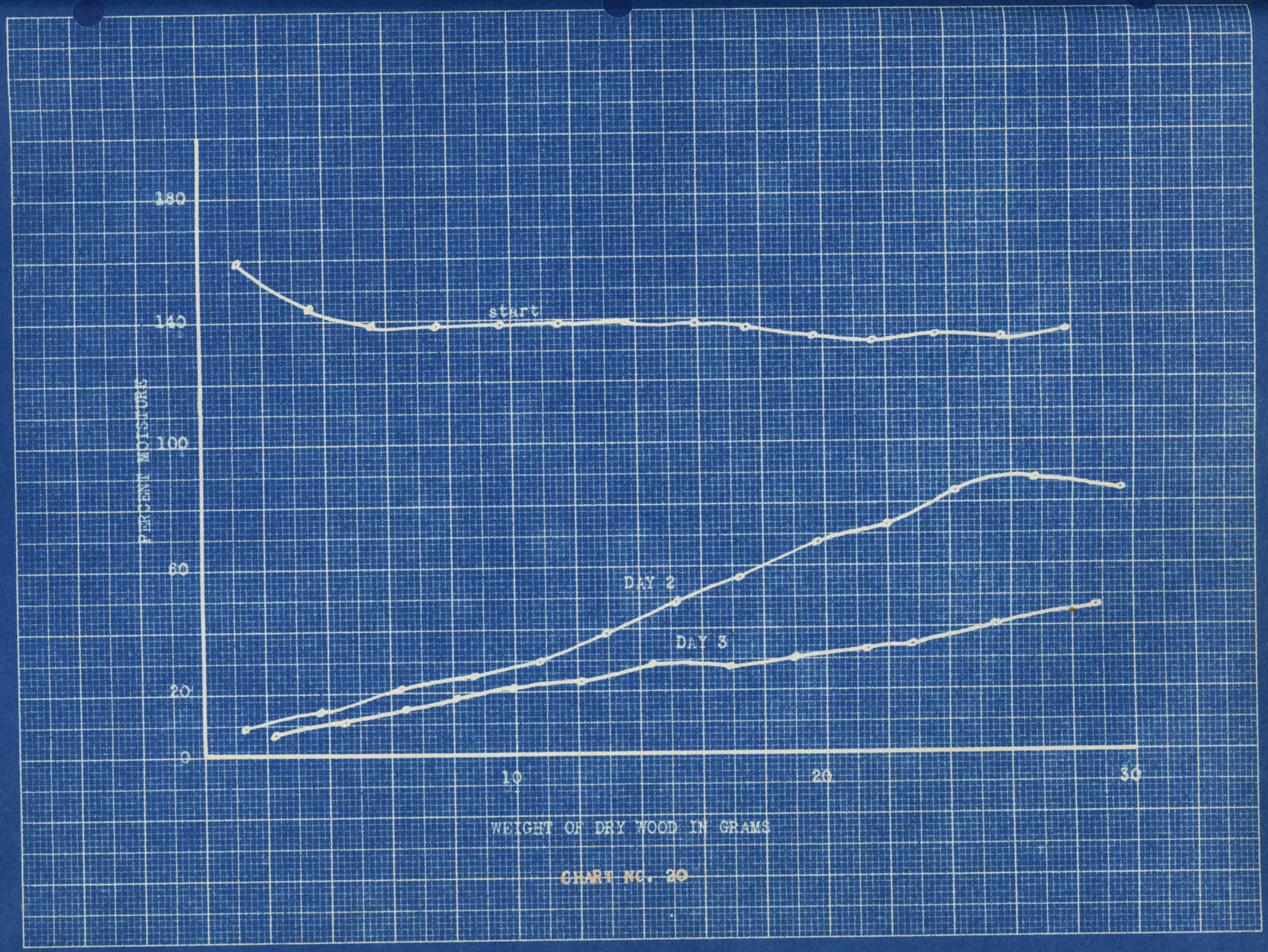

180
140
100
60
20
0
PERCENT MOISTURE
start
DAY 2
DAY 3
10
20
30
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 20

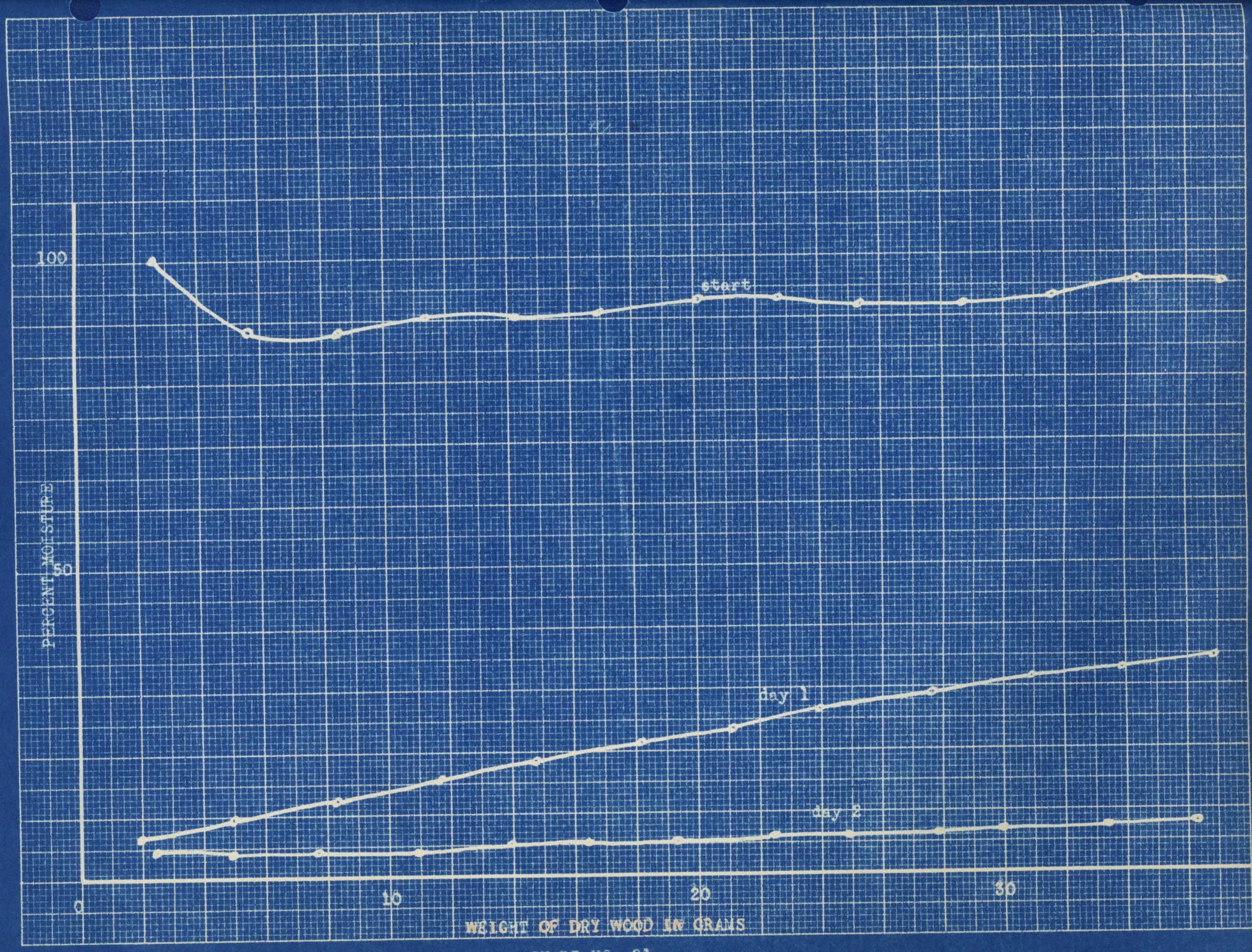

100
50
0
10
20
30
start
day 1
day 2
PERCENT MOISTURE
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 21

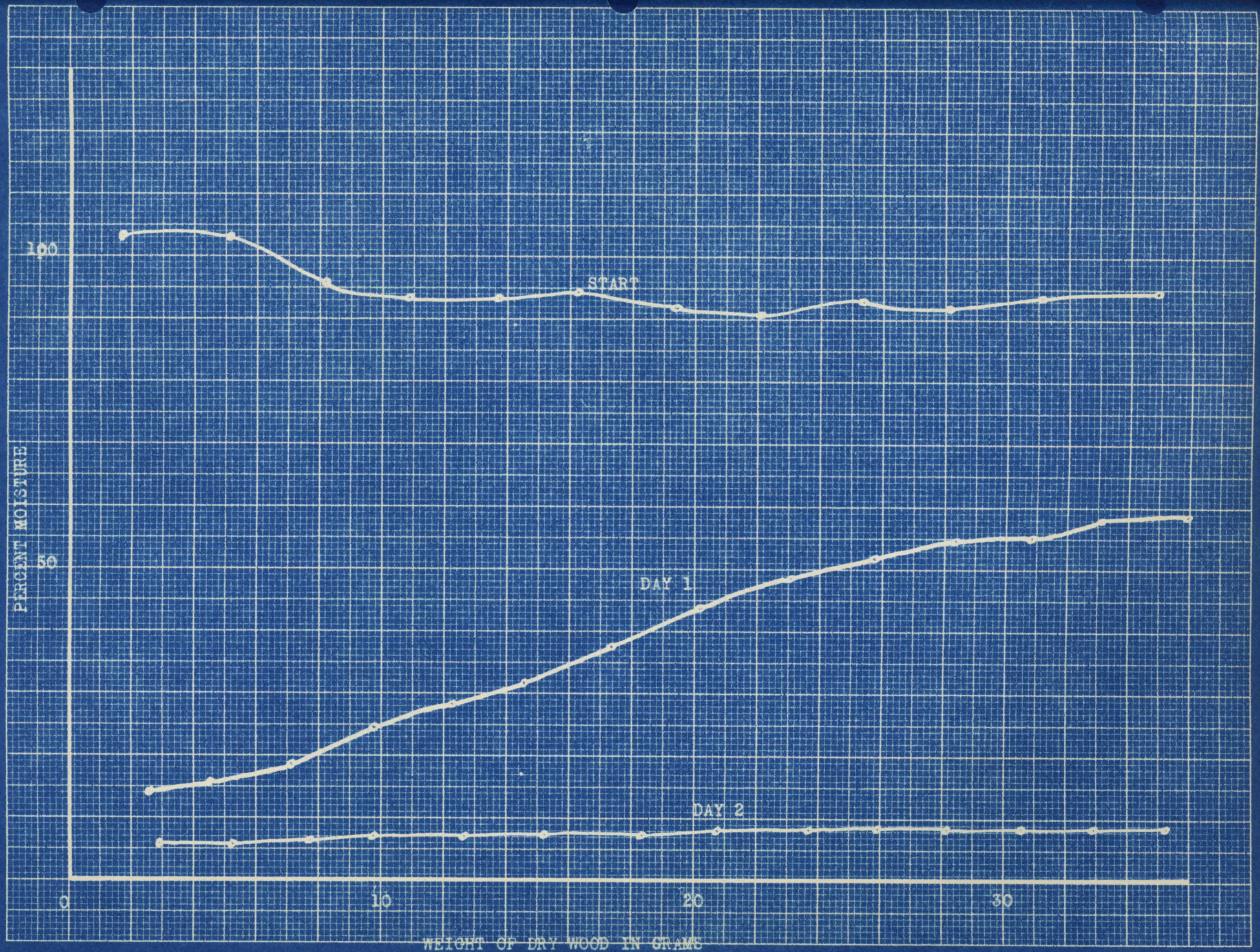

100
50
0
10
20
30
PERCENT MOISTURE
WEIGHT OF DRY WOOD IN GRAMS
START
DAY 1
DAY 2

CHART NO. 22

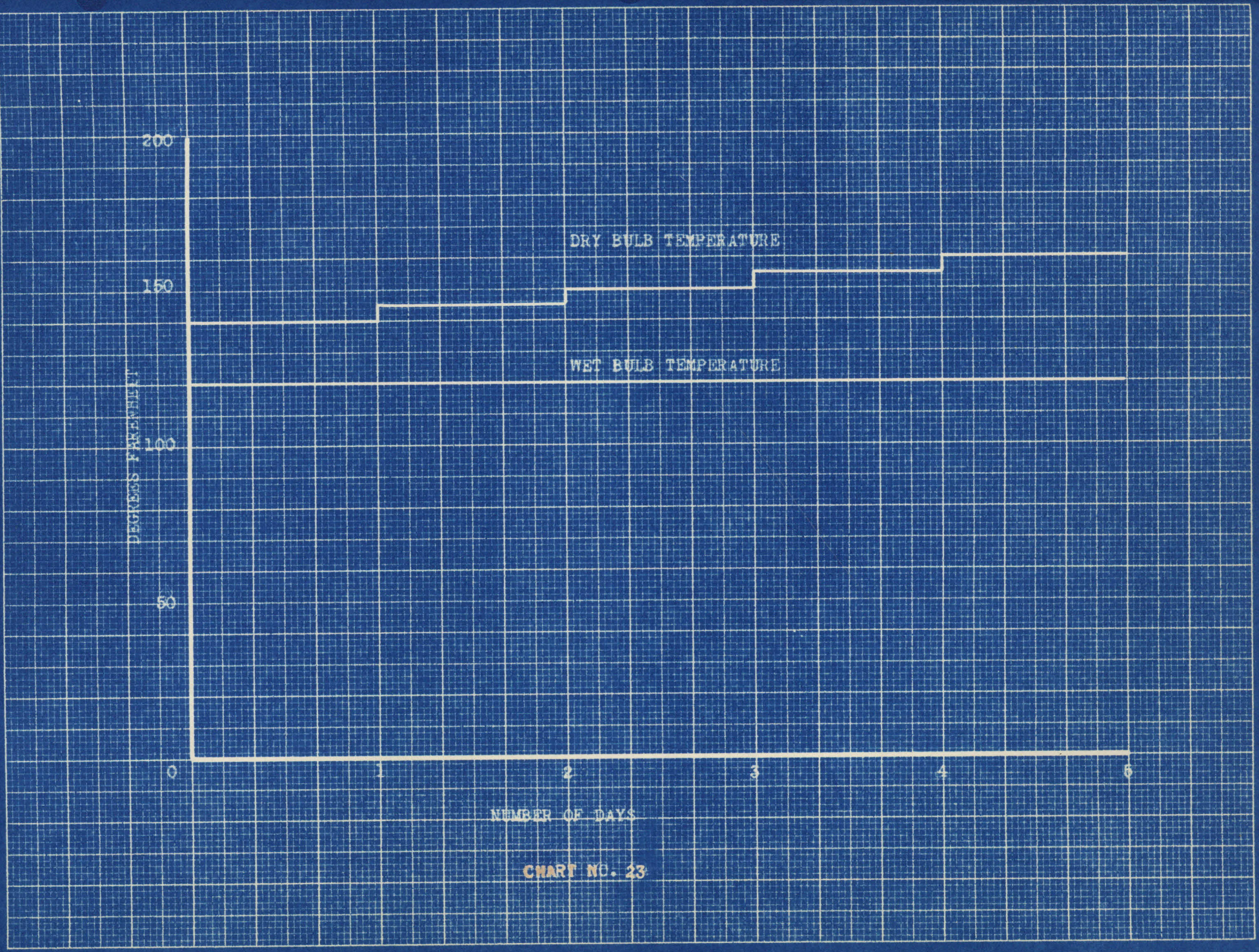

200
150
100
50
0
DEGREES FAHRENHEIT
DRY BULB TEMPERATURE
WET BULB TEMPERATURE
1
2
3
4
5
NUMBER OF DAYS

CHART NO. 23

Charts Number 24 and 25.

The blocks whose moisture gradients are plotted on these charts were run simultaneously as checks on each other. The drying face in this case corresponded to that of a radial cut board. The drying in the case of a radial cut board appears to take place back from the surface. The boundary between wet and dry wood is well defined at first and is seen to move back towards the center of the board as the drying proceeds.

Charts Number 26 and 27.

The drying faces on these blocks corresponded to those of slash cut boards. A comparison of the types of curves for slash cut lumber obtained in this run with those of the previous run on radial cut lumber shows a marked difference in the type of drying taking place. This difference is probably largely due to the action of the medullary rays in the slash cut board. These rays form pores which conduct the water with considerable ease to the surface. Thus the drying in the slash cut board is faster than in the radial cut board. Owing to an accident in the drying kiln the block which was to have been used for the determination of the moisture gradient for day 3 on chart 27 was lost.

Charts Number 28 and 29.

In this run an attempt was made to measure any temperature gradient which might exist within the block. This was done by inserting, at various depths from the drying surface, copper-constantan thermo-couples. However, no measurable temperature difference could be detected

The drying surfaces on these blocks corresponded to those of radial cut boards. These blocks did not take up water well as is seen by the fact that their initial moisture content was only slightly above 50%. An extraordinary amount of pitch was found in the vessel in which the soaking took place hence it is probable that this inability to take up water was due to an excessive pitch content.

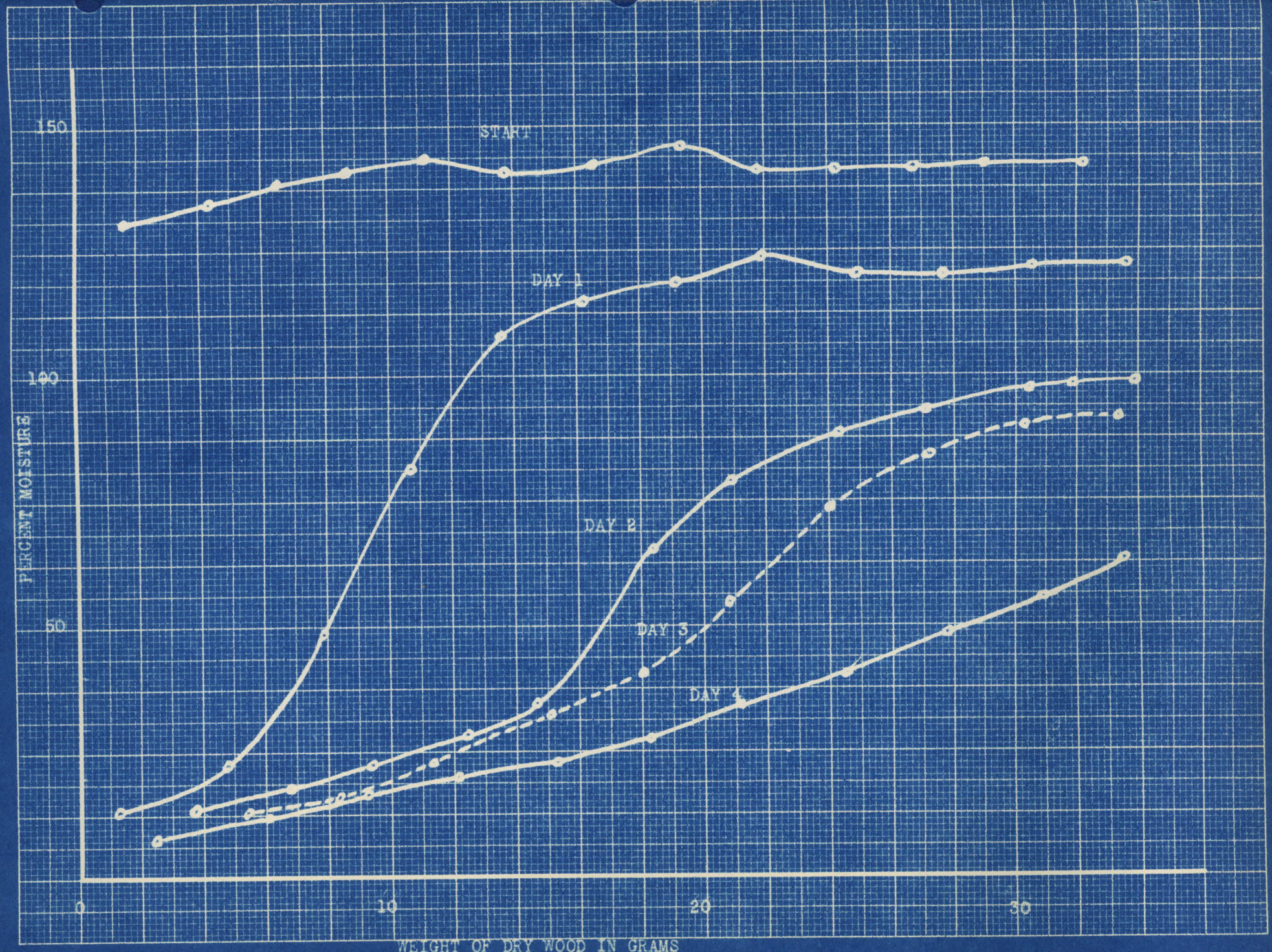

150
100
50
0
10
20
30
START
DAY 1
DAY 2
DAY 3
DAY 4
PERCENT MOISTURE
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 24

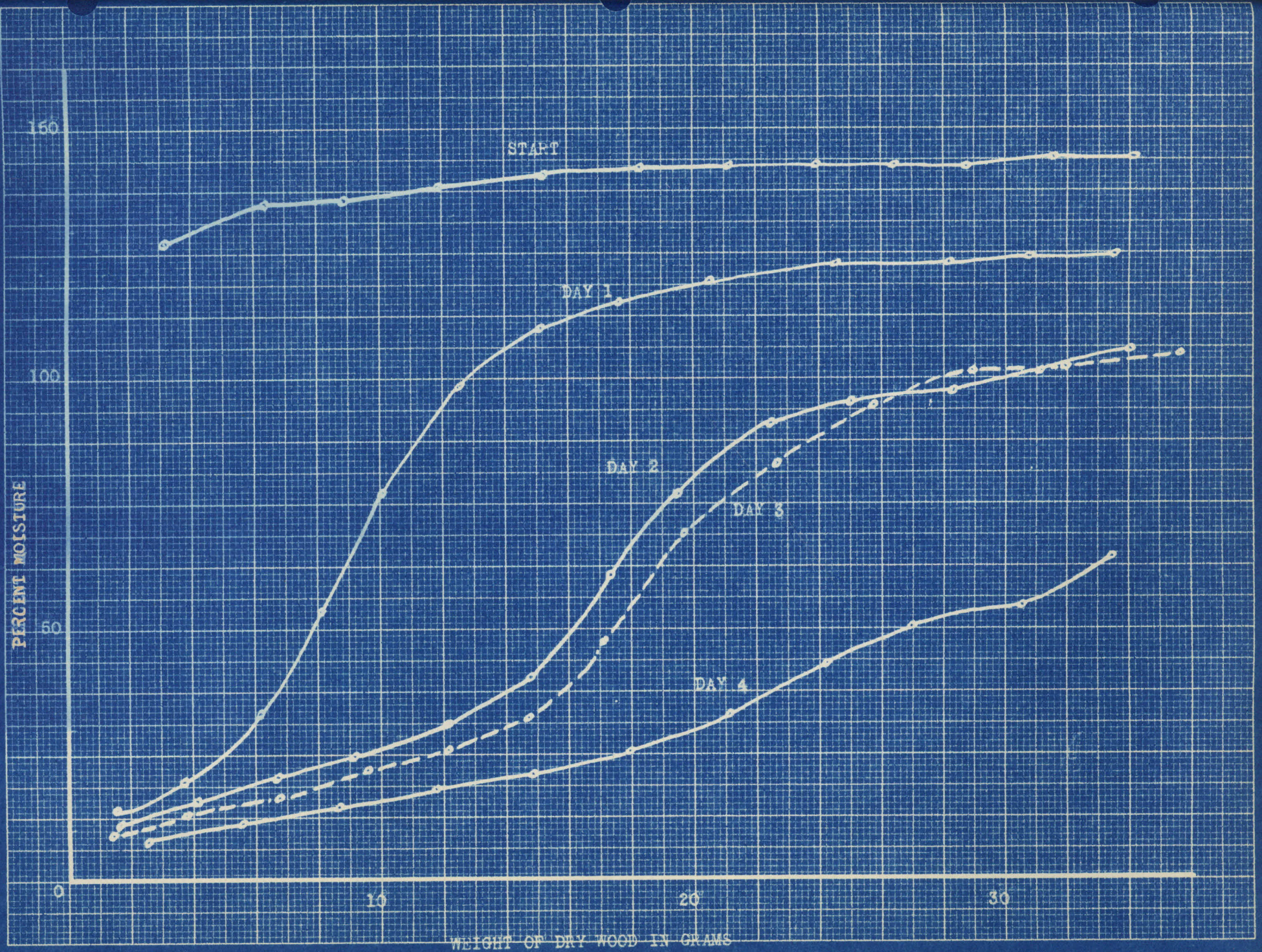

150
100
50
0
PERCENT MOISTURE
START
DAY 1
DAY 2
DAY 3
DAY 4
10
20
30
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 25

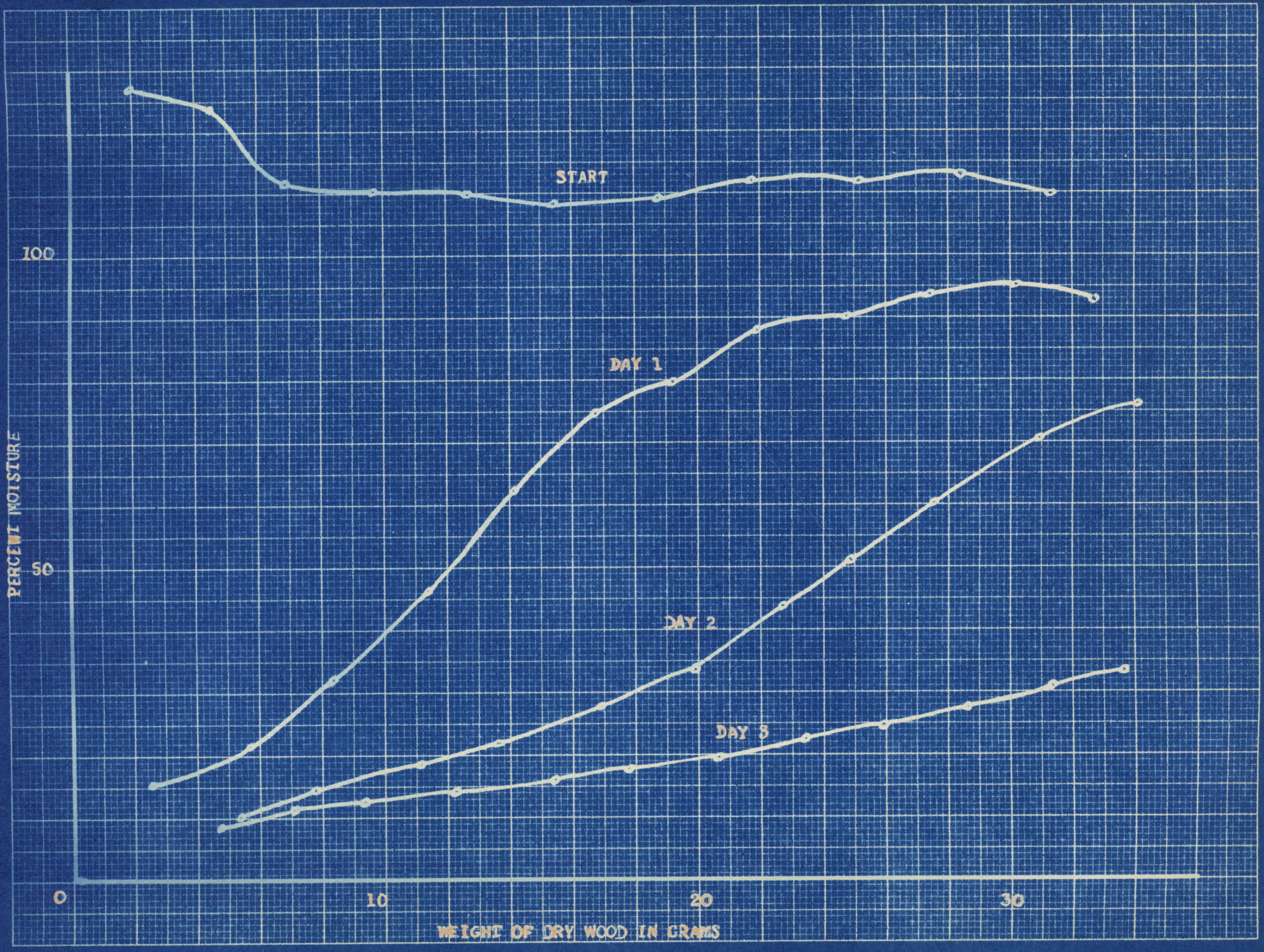

START
DAY 1
DAY 2
DAY 3
100
50
0
PERCENT MOISTURE
10
20
30
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 26

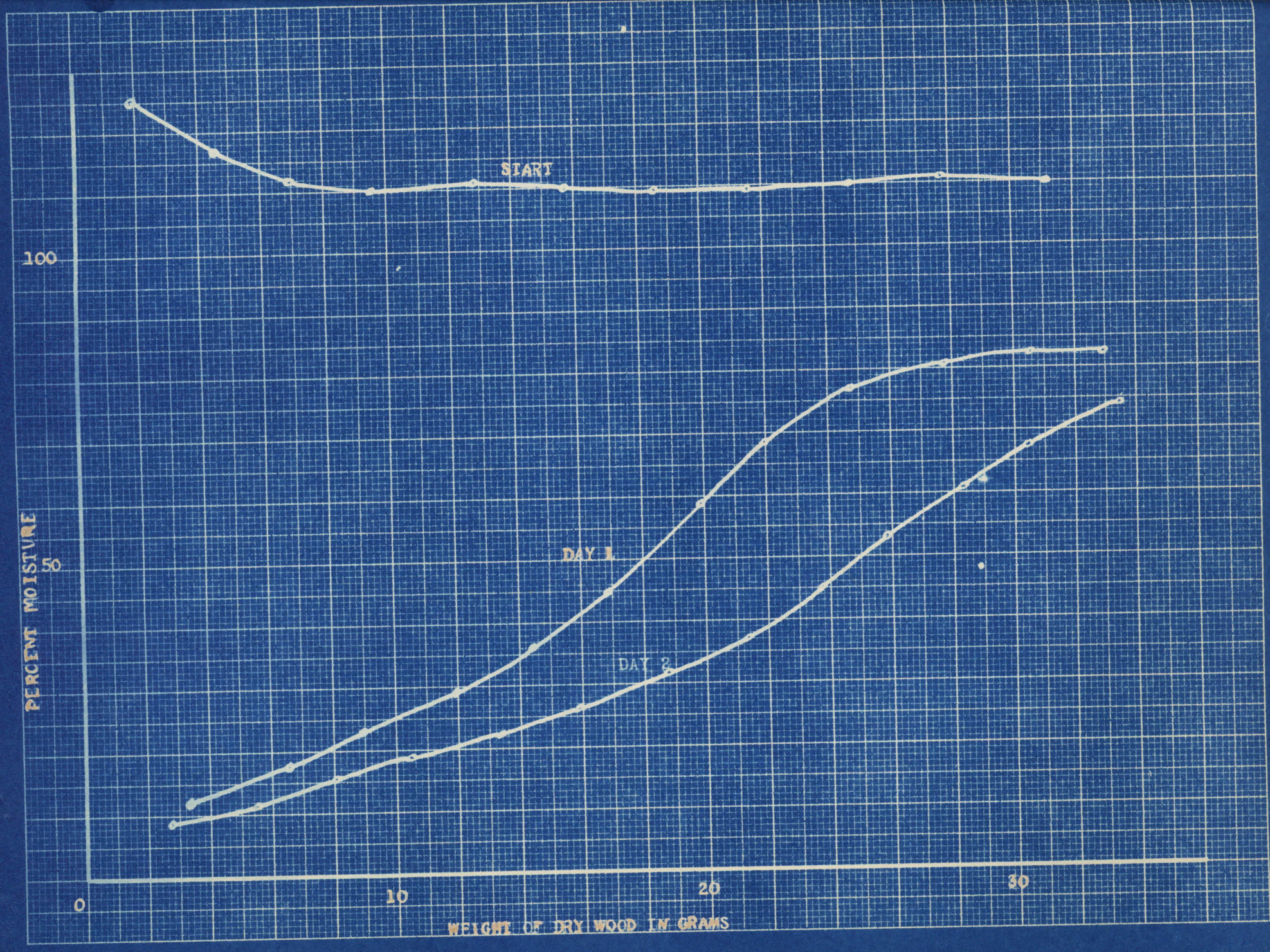

START
DAY 1
DAY 2
100
50
0
10
20
30
PERCENT MOISTURE
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 27

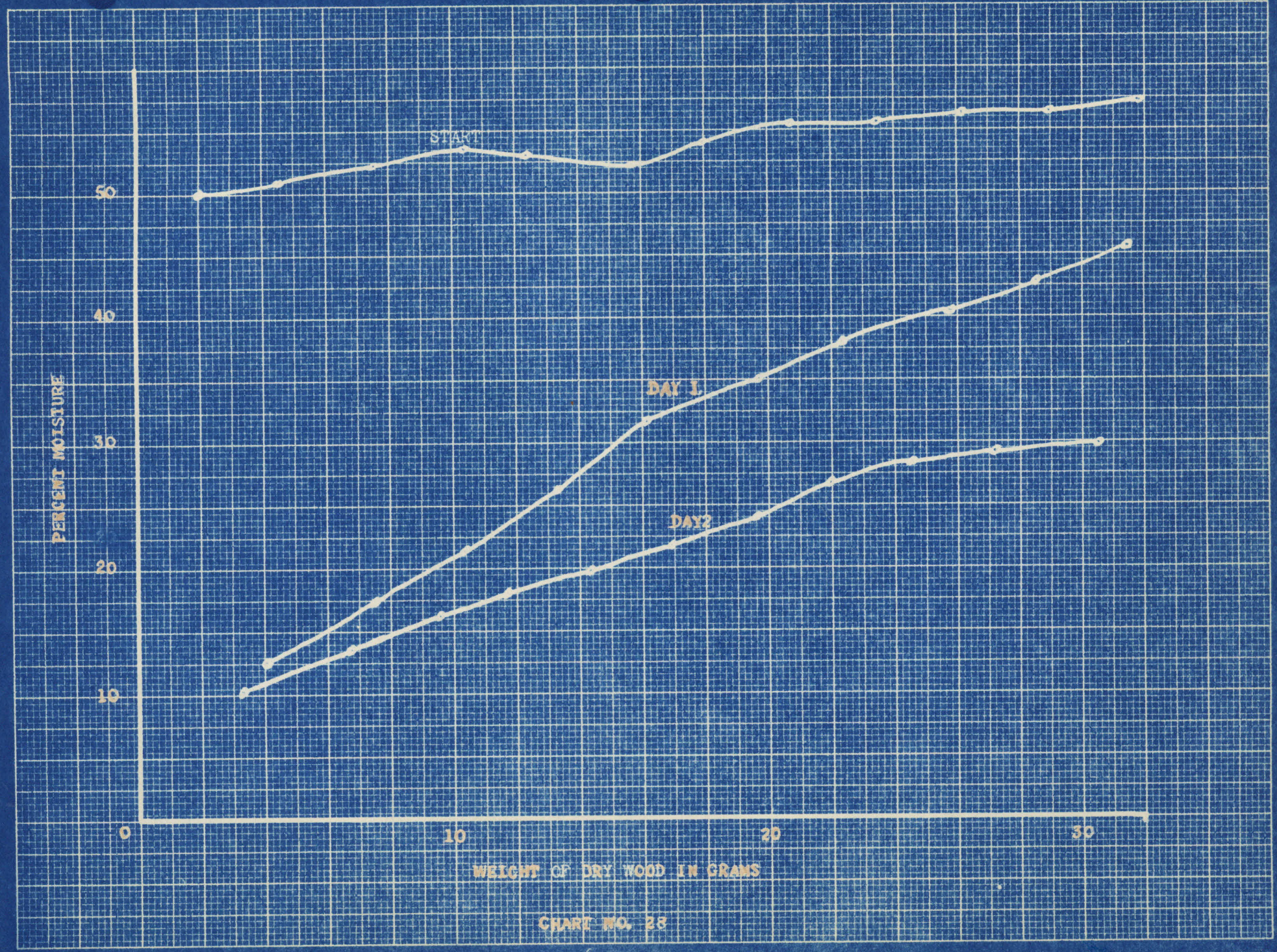

START
DAY 1
DAY 2
50
40
30
20
10
0
10
20
30
PERCENT MOISTURE
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 28

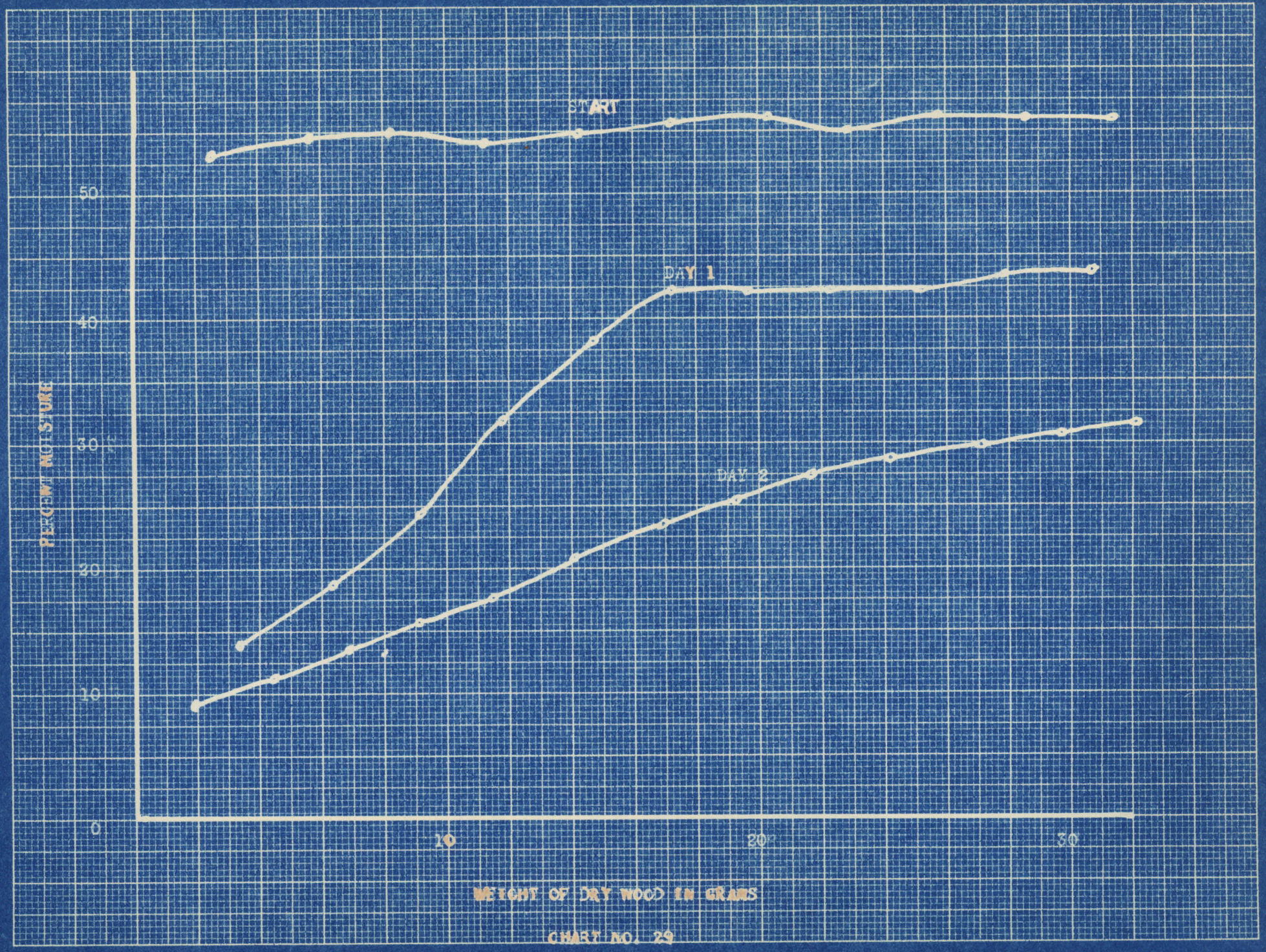

START
DAY 1
DAY 2
50
40
30
20
10
0
10
20
30
PERCENT MOISTURE
WEIGHT OF DRY WOOD IN GRAMS

CHART NO. 29

CONCLUSIONS

From the results obtained in this research it appears that the moisture gradients as obtained from samples from different sections of a board cannot be satisfactorily compared with one another on account of variations in wood structure and consequent differences in drying rates. This difference becomes more pronounced if the wood has been previously dried to any extent.

In order to eliminate as far as possible this difficulty a system of using blocks coated with moisture proof paint and cut from adjacent positions in selected stock was developed. However, no green lumber was available for these blocks and water soaked wood had to be used. Since wood is apparently an irreversible colloid, the use of water soaked wood gives data on the movement of free water only. Further work should therefore be carried on under this new method to determine the moisture gradients in fresh green lumber as it is dried.

Water soaked wood resists attempts to case harden it but this method of using painted blocks offers an excellent method of studying the case hardening of fresh lumber.

A marked difference, both as to rate and type of drying, has been shown for slash and radial cut lumber. No temperature gradient was found in the water soaked, drying wood, whereas Scudder reported a difference of about five degrees between the outside and center of a drying piece of fresh wood. The investigation of the temperature gradient in drying fresh lumber would therefore offer an interesting field for further work.

ACKNOWLEDGEMENT

The writer wishes to express his appreciation to Dr. William N. Lacey for his many helpful suggestions while directing this research, and to Mr. Arthur H. Fleming and Mr. James Clifford of the Sugar Pine Lumber Company for their interest and cooperation in obtaining the necessary lumber.

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