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The study of the drying of Buna S.

George W. Williams
University of Louisville

Richard L. Harvin

[redacted]

UNIVERSITY OF LOUISVILLE

THE STUDY OF THE DRYING OF BUNA S

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George W. Williams
and
Richard L. Harvin

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George W. Williams

and

Richard L. Harvin

Approved by the Examining Committee.

Director W. R. Barnes

R. C. Ernst

G. C. Williams

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ABSTRACT

A study of the drying of Buna-S in crumb form (designated as GR-S) is presented in which investigations of vacuum and air drying are made. The drying characteristics are presented and the effect of drying on the quality is evaluated.

Vacuum drying is investigated using a shelf and a rotary type unit. The individual effects of temperature, vacuum, thickness of crumb layer, and size of crumb particles are studied. Data are correlated by means of drying rate curves. Comparisons of the effects of the variables are made using these curves.

Air drying is studied by the use of a shelf unit with air blowing across the crumb. Air drying also is investigated with air directed through the bed of crumb. The variables studied are: temperature, humidity, air velocity, thickness of crumb layer, size of crumb, and shrinkage of the crumb during drying.

The results are presented as drying rate curves and comparisons are made showing the effect of variables.

A study of the temperature of the rubber during drying is presented showing the trend as the moisture content changes.

The quality of the dried rubber is determined by means of an evaluation of the "gel" content. The gel content is defined as the per cent of the rubber insoluble in

benzene. The results of several studies of the effect of temperature on the formation of gel are presented.

INTRODUCTION

At the outset of the present war the United States undertook to produce synthetic elastomers to replace natural rubber supplies which were unavailable. Because of its known qualities and possibilities for replacing natural rubber in automobiles and truck tires, Buna-S rubber was chosen to be produced on a large scale. This material is a copolymer of styrene and butadiene, which resembles natural rubber in appearance as well as in processing methods and uses. At the time there was little technical information available on the production and processing of this material. The drying of the rubber was one of the many problems requiring serious attention for the successful execution of the rubber program. At the request of the Office of the Rubber Director of the War Production Board, a research project for the studying of the drying of synthetic rubber (designated as GR-S) was undertaken in the Department of Chemical Engineering of the University of Louisville. The methods, results, and conclusions of this research are presented in this thesis.

The investigation of drying was divided into several main groups and these studied separately: (a) vacuum drying, (b) air drying, (c) rotary vacuum drying, and (d) quality evaluation by gel determination.

With the investigation of the vacuum drying, the authors anticipated that it would be possible to explain more completely the drying mechanism. This anticipation was based upon the assumption that with vacuum drying procedures it would be possible to vary the total pressure as well as the temperature at which the drying would occur. In addition to these variations it was also possible to change the thickness and the bulk gravity of the cake dried. The observations of such experiments could be applied to the study and the determination of the drying mechanism.

The uniformity of the GR-S rubber was investigated because of the realization that wide variation in the material being dried would render doubtful the results of drying studies.

Air drying was studied, and the individual effect on the drying rate of temperature, humidity, particle size, air velocity, and thickness of layer dried was determined.

In the study of the drying, it was recognized as desirable to learn the effect of the various procedures on the quality of the dried product. An evaluation of the properties of the dried rubber was made by means of a determination of the gel content by a differential solubility method. Samples dried by standard plant driers (plant built to plans developed by a committee of engineers from four rubber companies) as well as by laboratory driers were investigated with respect to gel content. The effect of temperature and time of drying on the gel content was studied using the various methods of drying already stated. Other studies of gel formation were made in an effort to learn the susceptibility of the rubber to gel formation as related to the drying conditions. With such information, desirable drying conditions could be established.

Some studies were made merely to obtain background information of the drying characteristics of the GR-S rubber. By far the greater portion of the work was to establish optimum drying conditions.

All rubber used in these studies was obtained from the Louisville B. F. Goodrich Rubber Company Plant or the National Synthetic Rubber Corporation Plant. These samples were in crumb form and were obtained from the Jeffery mill immediately before the drying operation.

HISTORICAL

Early in 1942 the War Production Board started the first of the present series of research projects on subjects covering the entire field of synthetic rubber. This program was the first intensive study of this subject to receive much attention. Natural rubber previously had been available in sufficient quantities to discourage much progress in synthetic materials.

Figure 1 shows the flow sheet for the production of GR-S rubber. The process consists of mixing three parts of butadiene with one part of styrene with seven parts of soap solution to form an emulsion. Polymerization takes place in a glass lined vessel. At the proper stage, the batch is forced by its own pressure to a blowdown tank where the reaction is arrested. This material, termed Latex, is then passed to flash tanks, to remove unreacted butadiene, and then to strippers to remove the unreacted styrene. It is then pumped to a large blending tank where several batches are mixed to obtain uniformity. Latex is passed into creaming tanks where brine is added, next into a coagulation tank, and then into a soap conversion tank where, upon addition of acid, the soap in the rubber is changed to fatty acid. The coagulation occurs when the protective colloid (the soap) is converted to a fatty acid. The rubber, in crumb form is separated from the solution on an Oliver filter where it is washed by sprays. The crumb is pressed by squeeze rolls on the Oliver filter to reduce the moisture content and then taken by belt conveyor to the disintegrator from which it passes into the drier. After passing through the drier the crumb is compressed into 75 pound blocks and shipped.

One of the first projects sponsored by the War Production Board was one carried out by P. M. Lindstedt (2) in his study of GR-S drying. His first progress report covers construction of a steam cleaning device for the flight conveyors in the drier, a study of temperature lowering on the drying of the crumb, tests on a water solution of Aquarex D (sodium salts of sulfate mono-esters of higher fatty alcohols) for preventing rubber to metal adhesion in the drier, and experiments on air seal baffles for flight sections. Following this at one and two months respectively were his second and third reports, in which he made his further recommendations for a dip tank and transfer device to prevent rubber to metal adhesion. Recommended also was a steam jet for preventing fines from clogging up the flight openings. Further research (5) showed the best conditions for the operation of a Sargent double deck drier. The conditions recommended were a drying time of one hour and 25 minutes on the upper flight and 35 minutes on the lower and a uniform feed rate to produce a cake 2 inches thick. Further proposals for work included test flights of non-corrosive metals, classification of wet crumb, and study of

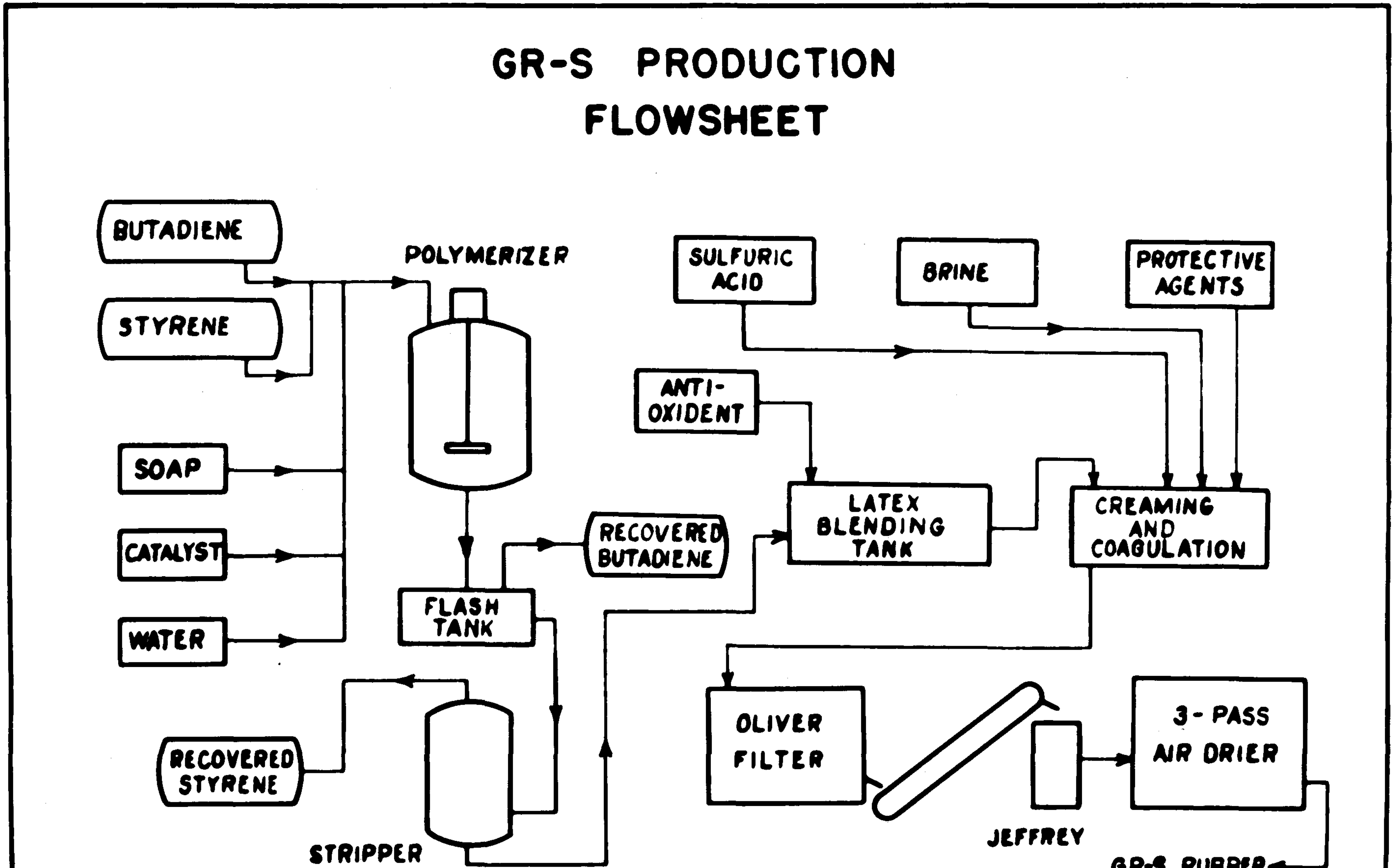

GR-S PRODUCTION
FLOWSHEET
BUTADIENE
STYRENE
POLYMERIZER
SOAP
CATALYST
WATER
FLASH TANK
RECOVERED BUTADIENE
RECOVERED STYRENE
STRIPPER
SULFURIC ACID
BRINE
PROTECTIVE AGENTS
ANTI-OXIDENT
LATEX BLENDING TANK
CREAMING AND COAGULATION
OLIVER FILTER
JEFFREY
3-PASS AIR DRIER
GR-S RUBBER

FIG. I

build-up of crumb on air seal baffles.

The problems encountered in the drying of GR-S crumb stressed the ned for fundamental facts on the characteristics of GR-S drying. This was the object of the next project brought forth. Again P. M. Lindstedt (6) was the pioneer in obtaining these data, this time on a small laboratory unit. His drier was described in his second drying report (7). He investigated the variables--humidity of circulating air, stock temperature, and air velocity. These data, along with his recommendations for further study, were reported in three progress reports to the War Production Board (6,7,8). As his investigations progressed, other factors, such as crumb size, proved to be important.

In order to obtain information that could be applied to plant operation, N. Timenes (13) experimented with a single pass drier. He investigated the same factors that Lindstedt (5) used in his studies. One investigation was on the flow of air up through the crumb, contrary to the usual downward flow. In his experimentation, Timenes found, as had Lindstedt, that the crumb would be case hardened (hardening of the outer crust) if temperatures too high and humidities too low were employed at the start of the drying.

At the same time further data were being compiled for a three pass drier as used in a standard plant. C. G. Strowe (12) of the U. S. Rubber Co. reported on air circulation, temperatures, humidities, pressure drops, and steam consumption for a three pass drier. His work, though not reported as conclusive, made it clear that further study would show that lower drying temperatures could be used with no reduction in drier capacity. Proper regulation of the flue dampers was recommended for more efficient drying. His most serious problem was the constant attention required for the feed mechanism for the drier.

Other subjects related to drying were investigated: operations preceeding and following the drying operation. There were projects on butadiene and styrene; studies of stability, density, viscosity, and heat transfer characteristics of GR-S; studies of equilibrium vapor compositions over GR-S lattices; and determinations of weight losses in packaged GR-S rubber.

In order to provide precise characterization of the GR-S polymer a method of determining the solubility of the rubber was developed. The method developed consisted of allowing the rubber to be in intimate contact with a solvent under stagnant conditions for a period of time sufficient to dissolve the soluble portion of the sample. The solution was then drained through screens with openings sufficiently small to retain the microgel. It was recognized that a very weak microgel was produced in the solution, and if it were not properly separated from the solution it would yield erratic results. The results of this determination would indicate the extent of molecular cross linkage since solubility is influenced by cross linkage and only slightly by chain length.

A method of extraction of the soluble rubber was developed by Baker and Mullen (10) of the Bell Telephone Laboratories and the results were expressed as per cent gel.

PART I.

DRYING STUDIES

THEORETICAL

Drying is defined as the removal of water from a system or structure when the amount of water present is comparatively small. The methods of drying are many and varied but by far the most important is vaporization. This involves vaporizing the water and in this form separating it from the structure of which it formed a part. If air or some other inert gas is used to carry away the water vapor formed, the process is called air drying. If the vapor is passed to a condenser, a pump being employed to maintain a pressure less than atmospheric in the apparatus, the process is called vacuum drying.

It is first necessary to consider the mechanism of evaporation of a liquid into a gas such as water into air. It must further be recognized that evaporation is a diffusional process and that between the liquid and gas phases there exists an interfacial film which offers resistance to the transfer of material between phases. The diffusion equation for transfer of material from the liquid to the vapor phase (11) is

$$N_A = \frac{DP(P_i - P_G)}{RTX\ P_{BM}} \qquad (1)$$

where N_A = mols of material transferred per unit area per unit time.

D = diffusion constant

P = total pressure

R = gas constant

T = temperature

X = effective film thickness

P_1 = partial pressure of vapor at the interface

P_G = partial pressure of the diffusing vapor in the main gas stream

P_{BM} = mean partial pressure of non-diffusing gas

Since for any one process D, P, R, and T are constant they may be grouped into one constant $\frac{DP}{RT} = K$ equation (1) becoming

$$N_A = \frac{K(P_1 - P_G)}{X \; P_{BM}} \qquad (2)$$

This states that the rate of diffusion or transfer of material between phases is proportional to the difference in pressure between that exerted by the water at temperature T and the partial pressure of the water in the gas. This difference is termed the driving force and is a function of temperature and humidity. The equation also states that the diffusion is inversely proportional to the "effective film thickness". The film thickness is dependent on temperature, air velocity, and the nature and condition of the materials involved. These dependencies then make the rate of diffusion a function of temperature, humidity, air velocity, and condition of the material.

In the study of drying of GR-S crumb, the nature and condition of the material are set within accepted limits and only the other variables will be discussed. The crumb is formed by acid coagulation of a dispersion of colloidal particles. The resulting material is quite porous and, consequently, traps much water in the voids between the minute particles. This water is termed "unbound water" and being uncombined, exerts its full vapor pressure.

The transfer of moisture from the interior of a single crumb particle into the drying medium surrounding it involves two steps: first, the transfer of the moisture as either liquid or vapor through the particle to the surface; and second, the transfer of water vapor from the surface of the particle into the main stream of the drying air.

Consider a wet crumb particle in a drying medium. It is assumed that the temperature of the crumb is less than the temperature of the drying medium. This being true, sensible heat is immediately transferred to the wet crumb resulting in an increased temperature and vapor pressure of the water. The driving force is then increased to a value such that diffusion will take place through the air film. The concentration of water at the surface is thus lowered causing diffusion of water through the particle to the surface.

It is possible that, for a time, liquid moisture will diffuse to the surface at a rate equal to that of the evaporation from the surface. If this process occurs the evaporation and liquid diffusion attain an equilibrium, and the temperature of the particle will approach the wet bulb temperature of the medium. This period of drying is called the "constant rate" period. As the moisture content of the particle is diminished, a point is reached at which the power of the particle to deliver moisture to the surface becomes less than that of the medium to evaporate such water. This causes the plane of vaporization to move from the surface to the interior of the particle. This plane approaches the center of the particle as the drying progresses. Once the plane of vaporization starts to move toward the interior, the drying rate begins to diminish, and the "falling rate" period begins. Drying ends when the driving force becomes too small to cause diffusion. This discontinuance occurs when the vapor pressure of the water in the particle is approximately equal to the partial pressure in the medium.

Consider the drying mechanism for a layer of crumb particles two inches deep. Assume that the drying medium is hot air under reduced pressure. Here the partial pressure of the water in the air is reduced; therefore the driving force is effectively increased. Evaporation takes place at the surface of the layer, and diffusion of the liquid begins in the crumb when particles which are at the surface are in contact with the medium. As the evaporation proceeds, the surface is dried since very little liquid water is brought by diffusion to the surface because of the definite particle nature of the crumb and the many voids thus produced (i.e. large quantities of liquid probably do not diffuse through voids between particles). Therefore, drying proceeds under the surface only as the temperature plane moves inward. The drying rate of the individual particles would be increased by reduced pressure although that of the whole may or may not. This rate would depend upon the speed with which the temperature of the whole layer was increased as well as the magnitude of the increased rate because of reduced pressure. With this type of drying, the rate is increased by increasing temperature and vacuum. It is ordinarily possible to effect drying of materials under reduced pressure at lower temperatures than with other methods. This factor is important depending upon the nature of the material. With rotary vacuum drying, each crumb particle is subjected to the direct heating effect of the medium and the rate of drying therefore would be increased by a consequent increase of evaporation area and by reduced pressure for the particle, as well as the entire mass. Under similar temperature and pressure conditions the drying rate produced with rotary drying is greater than with shelf drying.

Suppose, instead of reduced pressure, the heating medium be changed to hot air at atmospheric pressure blown across the surface of the crumb layer, other conditions the same. Since the total pressure is greater in this case than with vacuum drying, the partial pressure of the water vapor in the air when saturation is not attained is likewise greater, and the effective pressure gradient is decreased. However, the coefficient K, in equation (2) is a film coefficient for diffusion dependent on the film thickness. Any influence that tends to change the film thickness will cause some change in the coefficient. For example, if the film thickness is halved, the coefficient K will be doubled as will the mols of material transferred, N_A. It has been shown that air velocity has a marked effect on this film thickness. The coefficient K and likewise the heat transfer coefficient vary as the 0.8 power of the air velocity. This is equivalent to increasing the rate of drying during the constant rate period in direct proportion to the increase in these film coefficients. During the falling rate period, however, the air film resistance is only a part of the total resistance to both diffusion and flow of heat, so that as the zone of vaporization penetrates more deeply into the solid, the improvement in the air film coefficient becomes of less and less relative importance. If the wet bulb temperature of the air and its velocity are fixed, but the humidity of the air is varied, the effect is to vary the partial pressure (P_G) and to vary the gradient driving force ($P_i - P_G$) proportionately.

With this type drying, as in vacuum drying, the evaporation is carried on at the surface of the layer first.

As the drying proceeds the temperature plane and evaporating plane move inward thus causing diffusion and heat transfer to be carried out through the entire thickness of the layer up to the end of the drying.

Recalling that a layer of GR-S crumb contains many voids through which liquid diffusion is slight or impossible, it is evident that the drying rate is hampered where evaporation is from the surface of the layer. It is also to be noted that the drying of a single crumb particle would be more rapid than the drying of a layer. This circumstance, of course, is due to the fact that heat is supplied directly to all surfaces of the particle and more area of diffusion is possible. Further, with more air sweeping across the surface, the driving force would be greatly increased according to the foregoing discussion.

If the conditions remain unchanged but the direction of air flow be changed so that air passes through the crumb layer, the situation approaches the drying of a particle.

Every particle is in contact with the hot air and is heated to the wet bulb temperature rapidly. The heat transfer in this case is only across an air film where the coefficient is less than that through the crumb. The air, circulating around each particle carries away the vapor as it forms and thus maintains the maximum pressure gradient. In the previously mentioned drying methods both heat and vapor had to be transmitted through the layer. Furthermore the improvement in the air film coefficients caused by increased air velocity retains its importance throughout the drying operation. The drying rate is increased by the air going through the layer for these reasons: (a) drying is effected on all the particles from the start; (b) liquid diffusion and heat transfer area are increased greatly; (c) the distance the liquid must diffuse to the evaporating surface is decreased to the effective radius of the particle; and (d) the distance sensible heat must be transferred is likewise shortened.

Graphical plots of the drying rates of a material may be derived from the plots of moisture content-time data taken during drying. The slopes are tabulated with the corresponding moisture contents, the data may be plotted to give the drying rate curve. The tangents are determined from the normals to the curve which can be constructed accurately. Two glass rods when placed across the curve, produce a straight line when looking down upon them only when they are parallel to the normal. Thus by rolling away one rod the normal may be drawn using the remaining rod as a straight edge.

ANALYTICAL PROCEDURE

The procedures used in the analytical work are for the most part standard procedures with modifications, where necessary, to make them applicable to the study.

The following analyses were made on the crumb as received:

1. Moisture content (initial moisture content as well as moisture content during drying)

2. Salt content (calculated from chloride determinations as NaCl)

3. Fatty acid content (calculated as myristic acid)

4. True specific gravity

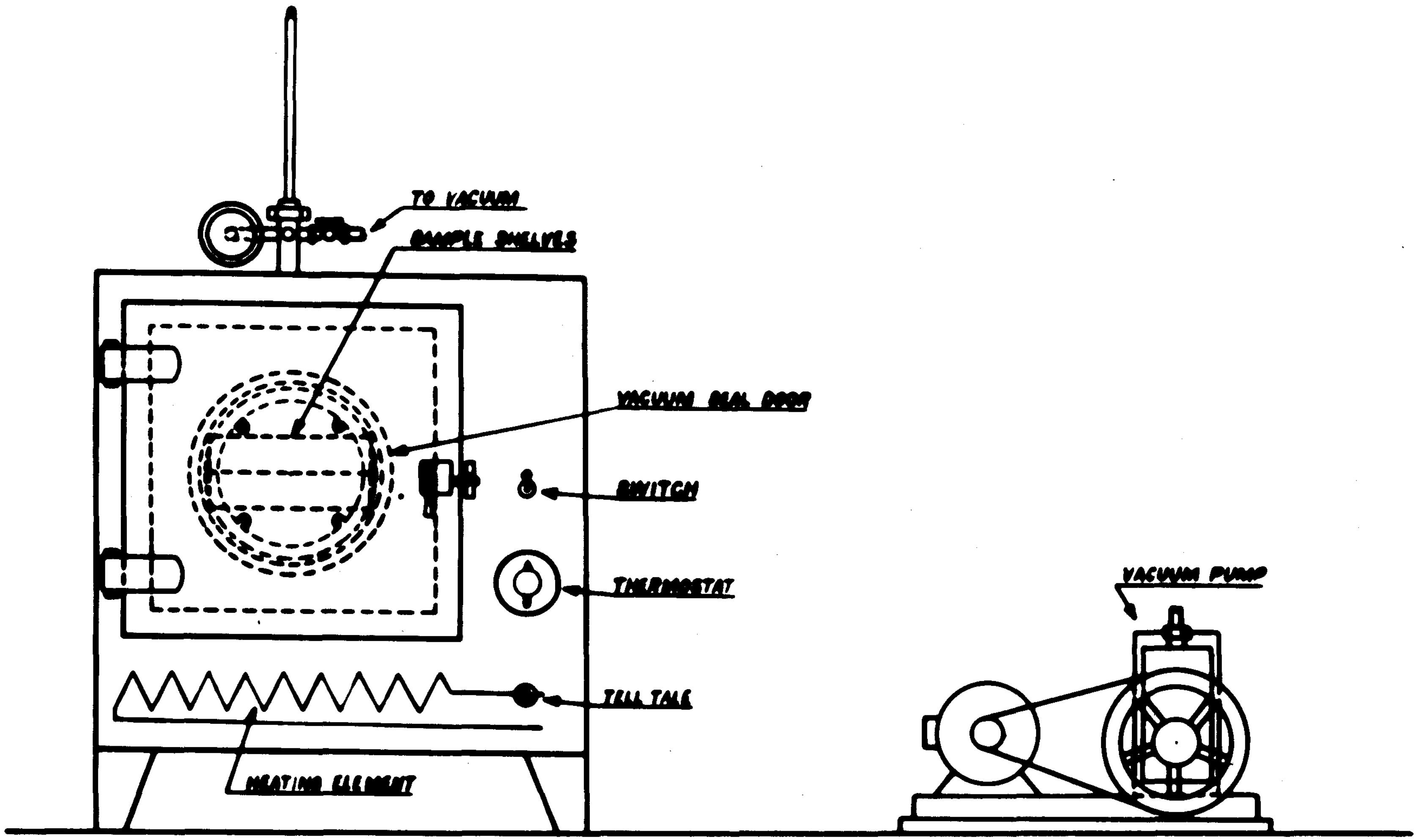
5. Bulk specific gravity.

In the vacuum drying study, the moisture content of the crumb as drying proceeds was determined by weighing in a 50 ml. tared weighing bottle, the samples of crumb, taken periodically and placing the bottle, with top removed, into a laboratory vacuum over (see Figure 2). The oven was adjusted to approximately 70°C. and 27 inches of mercury vacuum. The samples to be dried were allowed to remain in the oven at these conditions for a minimum of three hours or until constant weight was obtained. Under these circumstances, consistent results were obtained rapidly without subjecting the crumb to thermal conditions that would change its structure materially. The difference between the weights before and after the drying represented the water lost. Moisture content was calculated by dividing the water lost on drying by the final weight (dry weight). This gave units of pounds of water per pound of dry material.

The moisture content for the rotary vacuum drier runs was obtained by blowing heated air across the samples which were secured in tared half pint mason jars.

For the air drying with air across the cake, the initial moisture content of the total amount run was determined. The initial sample was placed in a tared weighing bottle and weighed wet. It was then dried and reweighed. The bottle tare weight was subtracted from the total wet and total dry weight to obtain wet and dry sample weights. The difference of sample wet weight and sample dry weight was the water lost during drying. The moisture content, expressed as pounds of water per pound of dry material, was calculated by dividing the water lost during drying by the dry sample weight.

The total sample, in a tared plastic box, was weighed at the beginning of the run and at 30 minute intervals until the sample reached constant weight. The dry weight of the total sample was obtained by first, subtracting the container tare weight from the initial total wet weight, and then dividing this difference by one plus the predetermined initial moisture content. The periodic



SCALE 1/2" = 1"

FIG. 2 LABORATORY VACUUM DRIER

weighings were used to determine the moisture content at that particular time by subtracting the total weight of dry material from the weight of wet crumb at each interval. This difference was the amount of water still in the crumb sample, and divided by the total dry weight, was the moisture content in the proper units.

The method for the moisture content determinations with air through the cake was similar to that for drying with air across the cake in that they both were computed using the entire sample. The sample was placed in the screen bottom drying tray and an initial weighing taken (see EXPERIMENTAL OF AIR DRYING--AIR THROUGH THE CRUMB LAYER). Weighings were then taken at small time intervals until the rubber was dry, indicated by constant weight readings. This final total dry weight, subtracted from the periodic weighings, gave the amount of water still present at that weighing. These differences, divided by the sample dry weight, (difference between the total dry weight and the container tare weight) were moisture contents in pounds of water per pound of dry material.

In the determination of the salt (NaCl) content, a sample (approximately 5 GM.) of the wet crumb was weighed out and placed in a 125 ml. erlenmeyer flask. The crumb was covered with ethyl alcohol and allowed to stand 30 minutes. The samples were titrated with O.IN silver nitrate solution to potassium chromate end-point. The salt content was calculated as sodium chloride.

For the fatty acid determination, a sample of the wet crumb (approximately 5 GM.) was weighed out, placed in a 125 ml. erlenmeyer flask. The crumb was covered with ethyl alcohol and after standing for 30 minutes was titrated with 0.IN sodium hydroxide solution to phenolphthalein end-point. The results were calculated as myristic acid.

The true specific gravity was determined by weighing a selected sample (1 to 2 GM.) of the wet crumb into a tared 50 ml. specific gravity bottle. Individual particles of crumb about 1/8 in. in diameter were used. To this bottle containing the crumb was added approximately 25 ml. of distilled water. The bottle was then placed in a vacuum dessicator and subjected to as low a total pressure as obtainable with a laboratory aspirator. This operation was conducted at room temperature for 1 to 1½ hours. Then the bottle was completely filled with distilled water, the top inserted, and the filled bottle weighed. From the difference in weights the true specific gravity was calculated on the basis of the density of the water equal to one.

The bulk specific gravity was calculated from the weight and volume of the sample used in the drying experiments. The weight per cubic foot of the crumb was calculated, and this value was divided by the density of water in appropriate units.

With the exception of the moisture content determinations made on the crumb during the drying experiments, all analyses were made on the crumb as received.

VACUUM DRYING

APPARATUS

The vacuum drying study of the GR-S crumb was initially carried out in a small laboratory cabinet type vacuum dryer (see Figure 2). The dryer was electrically heated and thermostatically controlled. The temperature range was up to about 300°C., and the vacuum, at continuous operation of the pump, was about 29.0 inches of mercury. In order to obtain the proper vacuum, either air could be bled into the system or the oven could be exhausted to the proper vacuum and then the valves closed. Both systems had their difficulties; the former was hard to adjust, and the latter tended to fall off. The small vacuum pump of the oil submerged type was belt driven by a small motor. The oven and the pump were connected through a catch all, consisting of a standard vacuum bottle. The size of the oven limited the sample to about 10-20 GM.

Later studies were carried out in a semi-commercial cabinet type drier (see Figure 3). The drier accommodated galvanized iron trays 20 inches square by 1 inch deep. The shelves were steam heated and spaced so closely (2 3/8 inches) that heating was produced by radiation as well as conduction through the entire area of the bottom of the tray. The temperature was controlled by the steam pressure varying from 0 to 50 psi. gage within the shelves. The temperatures of two shelves and of the top, middle, and bottom of the "cake" of rubber crumb were obtained by copper-constantan thermocouples in conjunction with a direct reading Leeds and Northrop potentiometer. The temperature of the air space was obtained by a thermometer through an opening in the center of the door. The vacuum pump was a rotary, sliding vane type pump connected to the drier through a water cooled condenser and was capable of exhausting to 29 inches of mercury.

To obtain a more nearly complete view of vacuum drying, a small commercial rotary vacuum drier (see Figure 4) was operated under several conditions. This dryer consisted of a horizontal cylinder, equipped with steam tubes, capable of rotation about its horizontal longitudinal axis. The drum of the dryer was rotated in one direction for 360°, then in the opposite direction for 360° at the rate of 2 rpm. The vacuum was applied through a water cooled condenser by means of a Nash Hytor, pulling a maximum of 29.0 inches of mercury. The desired vacuum was maintained by continuous use of the pump, with continuous bleeding of air at the drainage of the condenser. The material to be dried was charged through a port in the side of the drum. Although the maximum steam pressure was only 5 psi. gage, the apparatus was so installed that a vacuum could be applied to the steam chest to give lower temperatures.

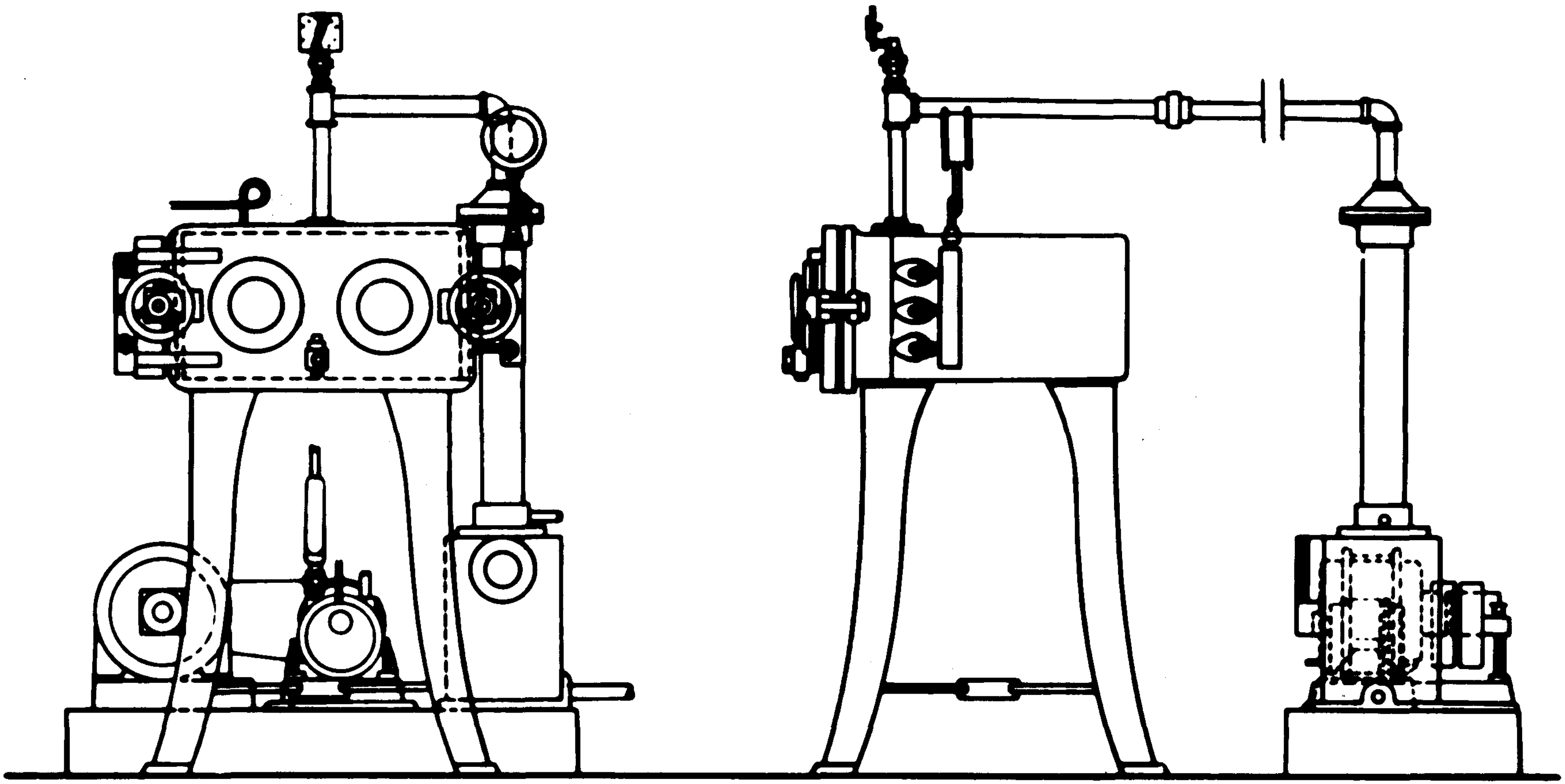


FIG. 3 VACUUM DRIER

SCALE 3/4" = 1'

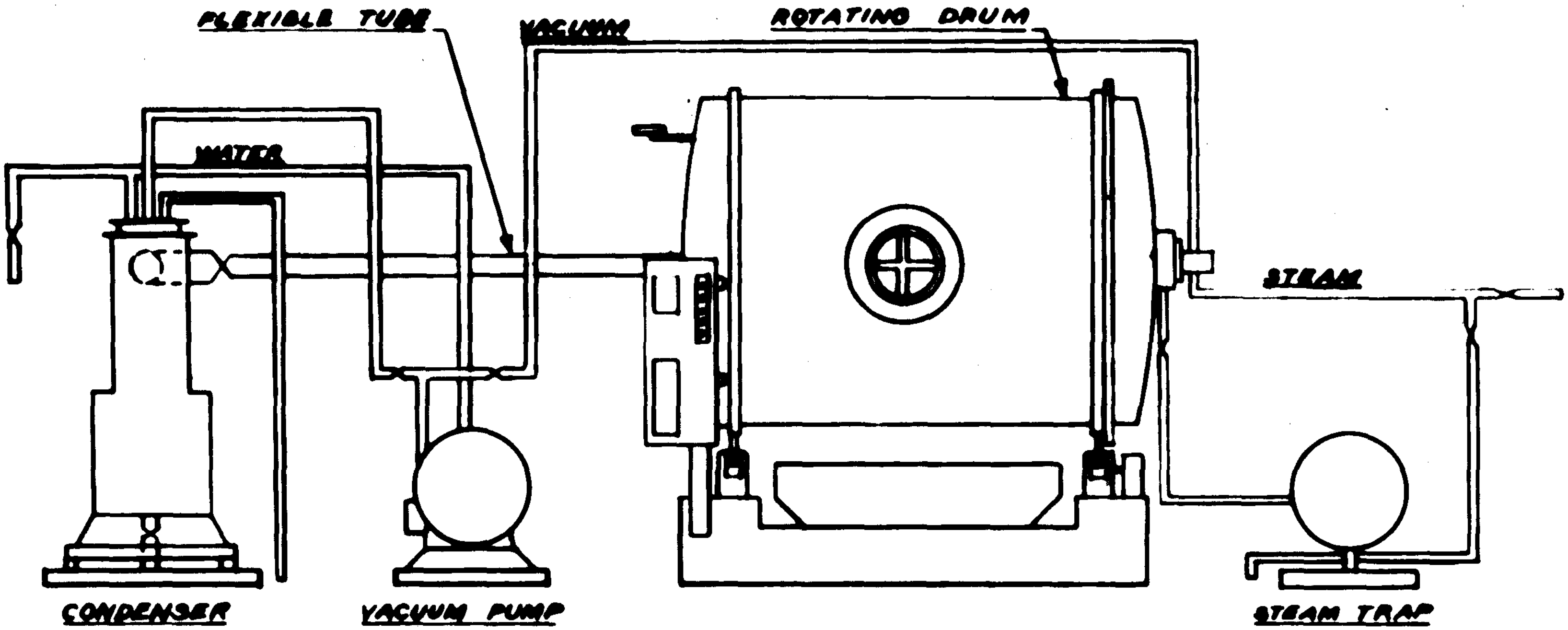


FIG. 4 ROTARY VACUUM DRIER

PROCEDURE

SHELF DRIER

The crumb to be dried was crumbled so that a uniform depth could be obtained, and placed in a tray. The trays were placed in the vacuum drier and thermocouples inserted in the cake at top, middle, and bottom. The proper conditions were secured and samples were taken at half hour intervals. These samples, along with an initial sample of crumb as received, were weighed, dried, and reweighed to obtain data for moisture content-time curves. Just preceding each sampling to avoid errors the vacuum, steam pressure, and temperatures were read.

In some early runs on thickness of cake and bulk specific gravity, the amount of material run was so small that thermocouples could not be used. In these instances the temperature designation was that of the air space above the crumb. For these small trays, moisture content-time data were obtained by weighing the entire tray on an analytical balance every half hour. Final dry weight was subtracted from each weighing to find the amount of water present at that time.

For each run, when the drier of Figure 3 was used the tray was tared and weighed full of rubber just before placing it in the oven. It was weighed again at the completion of the run.

The cake was examined after the run to determine the amount and manner of drying as shown by the crumb color, manner of shrinkage, tackiness, and any other conditions brought about by the temperature and vacuum.

A larger sample--about 75-100 GM.--of the dried rubber was saved from each run for gel content determinations.

ROTARY DRIER

In operating the rotary drier, approximately 20 pounds of GR-S crumb, as received, was placed in the drum. Previously the drum had been brought to operating conditions using 5 psi. gage steam. Rotation was started and the proper vacuum adjusted. Samples for moisture content determinations were secured at half hour intervals. The crumb was immediately placed in a tared air tight mason jar. The moisture content of each sample was determined by the air drying method described in the analytical procedure.

RESULTS

The vacuum data for the curves in this section are presented in tabular form in the appendix. In each table the wet weight is secured by subtracting the bottle tare weight from the total wet weight; the dry weight, by subtracting the tare weight from the total dry weight. The difference between the wet sample weight and the dry sample weight gives the amount of water lost from the sample. The moisture content expressed as pounds of water per pound of dry material is calculated by dividing the water lost by the dry weight.

The data for the drying rate curves were obtained from the moisture content curves. This was done by drawing normals to these curves at regular moisture content intervals and evaluating the slope of these lines. The tangents of the curves were evaluated from these normals giving the drying rate as pounds of water per pound of dry material per hour for the whole cake. To obtain the rate as pounds of water per square foot per hour the rate was multiplied by the total weight and divided by the cake area.

The first investigation was a series of runs at different vacuums varying the temperatures at each vacuum. The vacuums were 10, 15, 20, and 25 inches of mercury with a temperature spread sufficient to cover plant drier temperatures (160°F. to 200°F.). These data were first plotted showing the effect of variation of temperature on the drying rate, with the vacuum held constant (see Figures 5, 9, 15, and 21). The temperature rise for the top, bottom, and middle of the cake during drying was plotted for each run. In order to show the effect of vacuum, the curves were grouped for small temperature ranges. These were 54-58, 60-67, and 70-83 degrees C. (see Figures 26, 28, and 30). The drying rate curves are compared in the same way.

The next investigations were the determinations of the relation of bulk specific gravity and cake thickness to the drying rate. Since all these runs were made simultaneously, the variations within the drier were negligible and both temperature and vacuum were constant. All data were plotted on the same axes for moisture content-time representation. In order to show the effect of bulk gravity and cake thickness, the drying rates for each variable were plotted separately (see Figures 33 and 34).

The various data for the rotary drier were computed as for the shelf drier. Because of the limited range of temperatures available, runs were carried out at 5 psi. gage steam pressure. The vacuums used, as shown in Figures 35, were 10, 18, 23, and 29 inches of mercury.

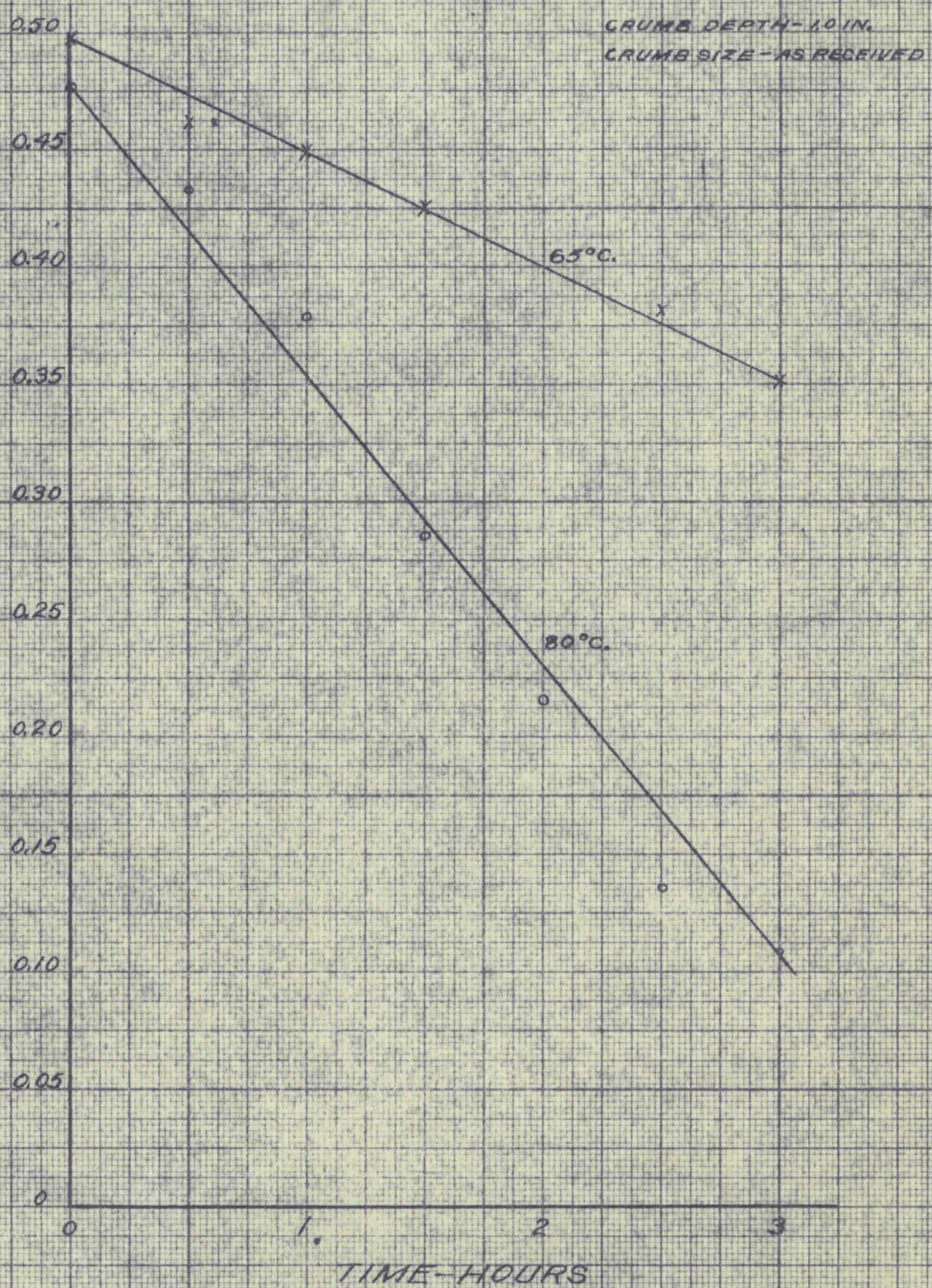


FIG. 5 MOISTURE CONTENT-TIME CURVES.
EFFECT OF TEMPERATURE AT 10 IN. HG. VACUUM.

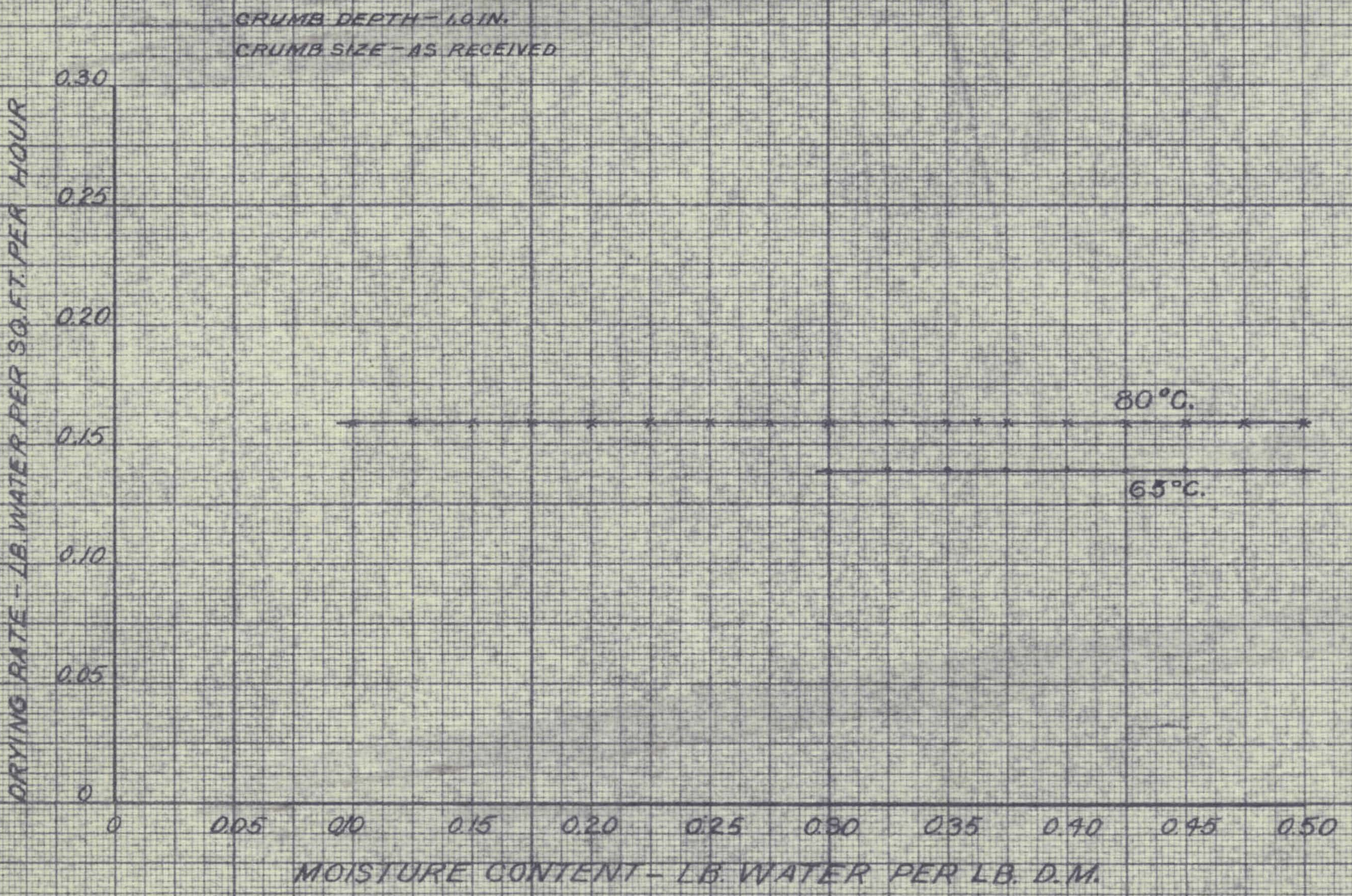


FIG. 6 DRYING RATE CURVES.
EFFECT OF TEMPERATURE AT 10 IN. HG. VACUUM.

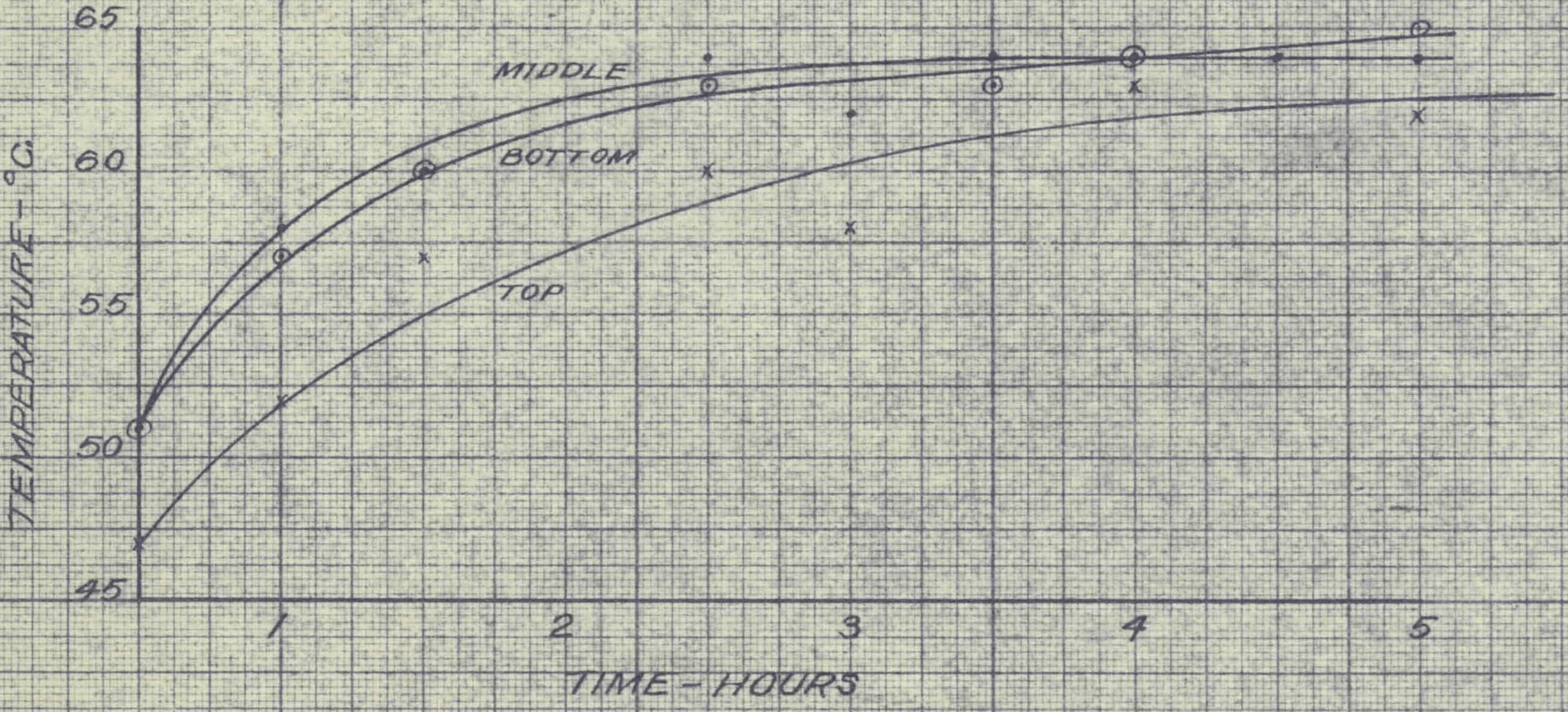


FIG. 7 TEMPERATURE-TIME CURVES FOR 10 IN. HG. VACUUM AT 65 °C.

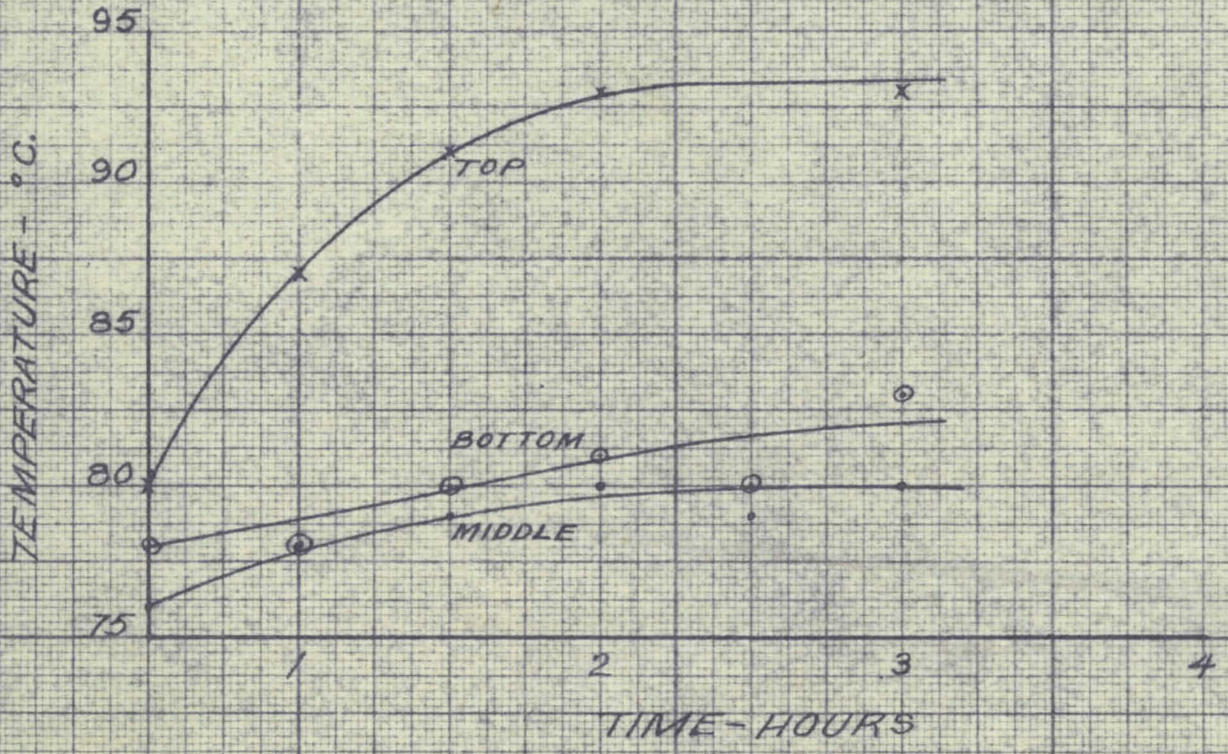


FIG. 8 TEMPERATURE-TIME CURVES FOR 10 IN. HG. VACUUM AT 83°C.

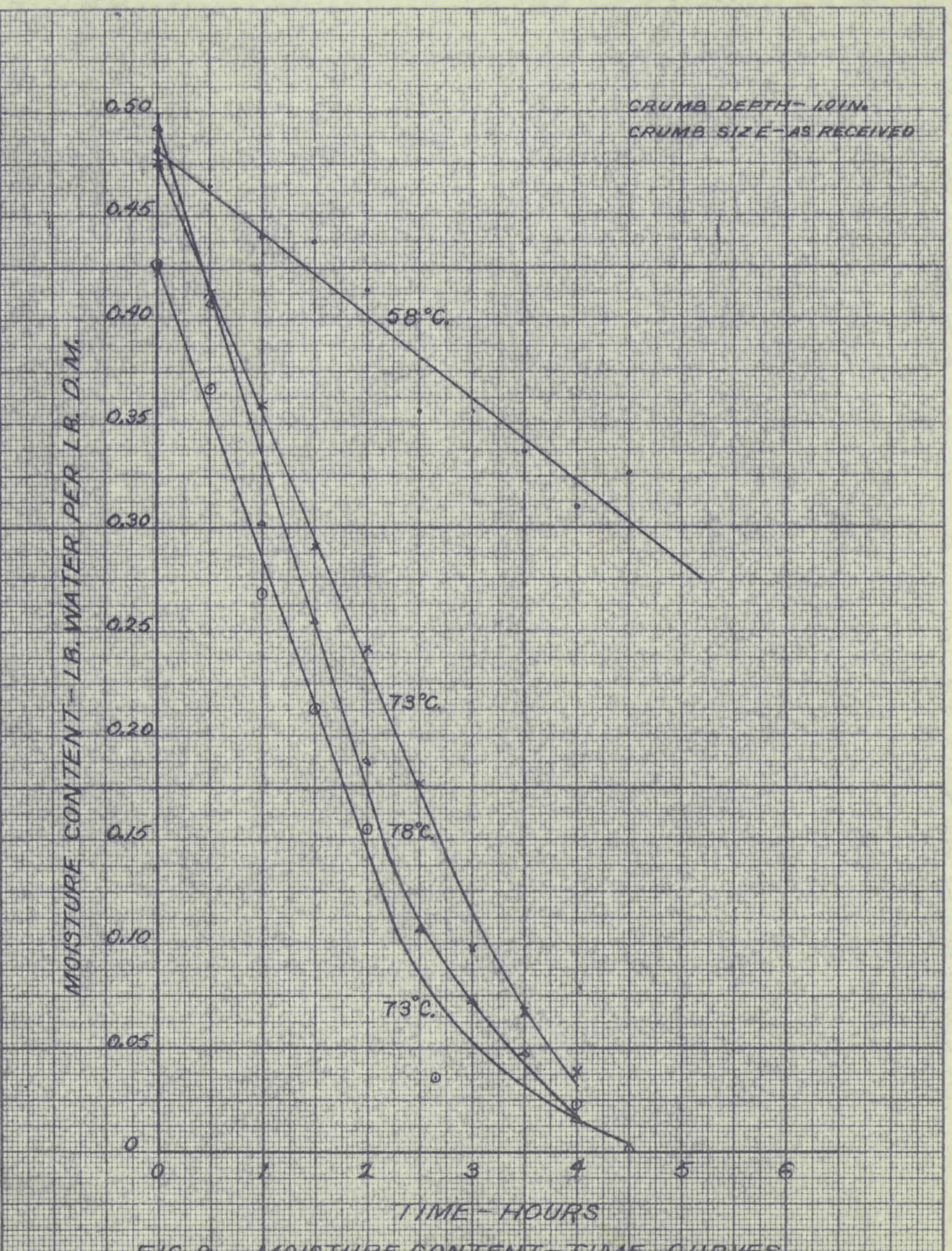


FIG. 9 MOISTURE CONTENT-TIME CURVES.
EFFECT OF TEMPERATURE AT 15 IN. HG. VACUUM.

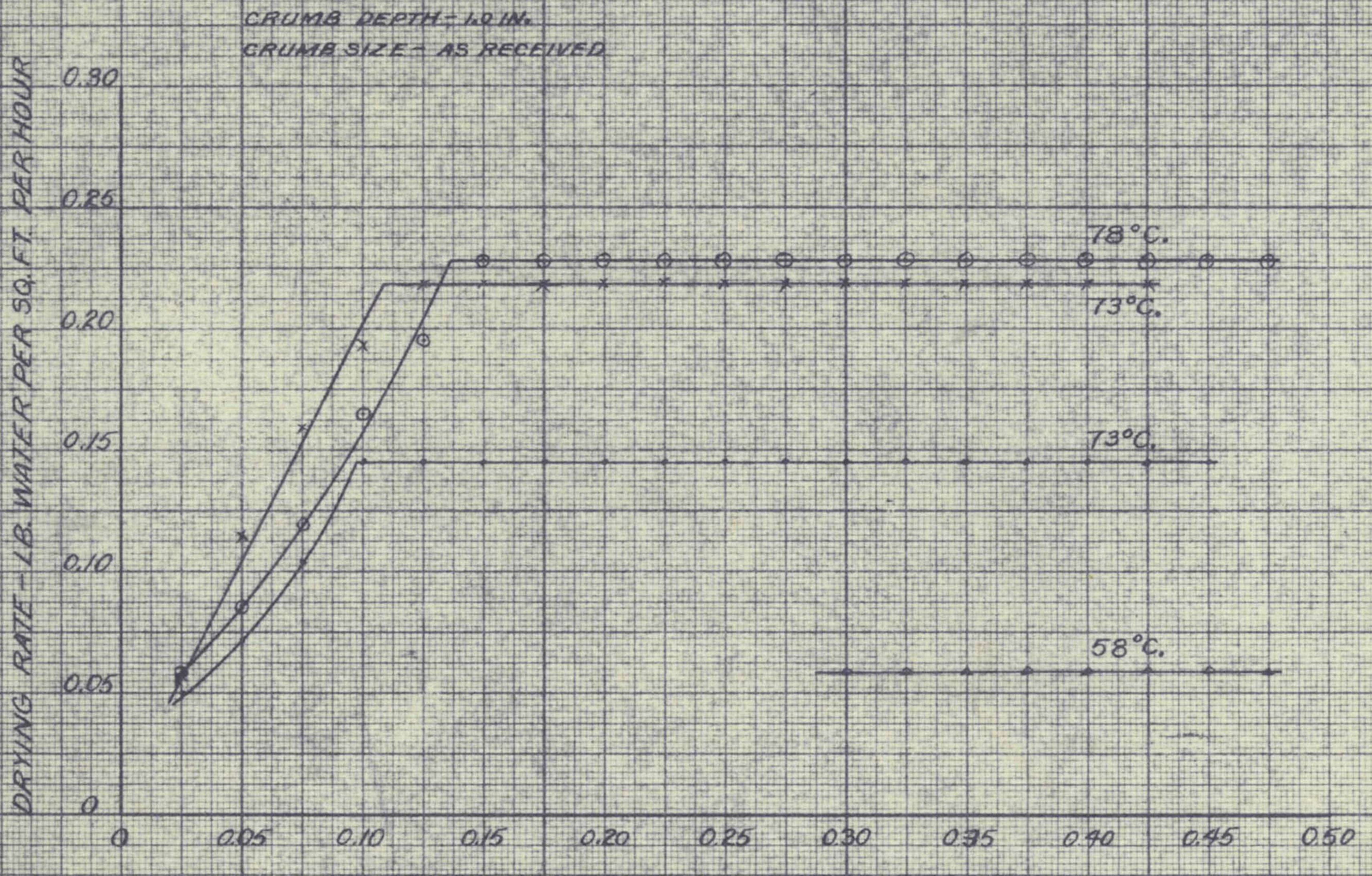


FIG. 10 DRYING RATE CURVES.
EFFECT OF TEMPERATURE AT 15 IN. HG VACUUM.

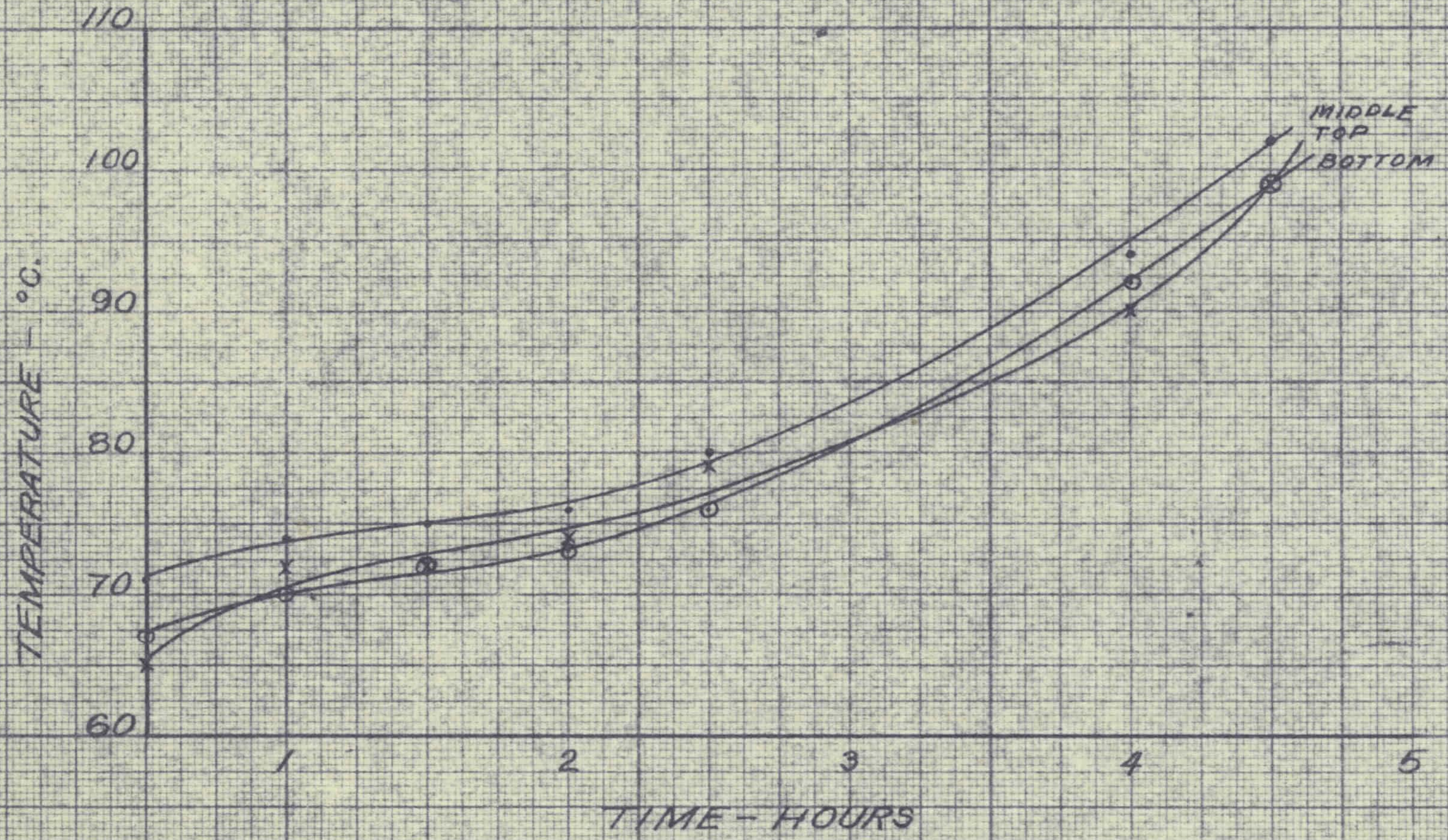


FIG. 11 TEMPERATURE-TIME CURVES FOR 15 IN. HG. VACUUM AT 73°C.

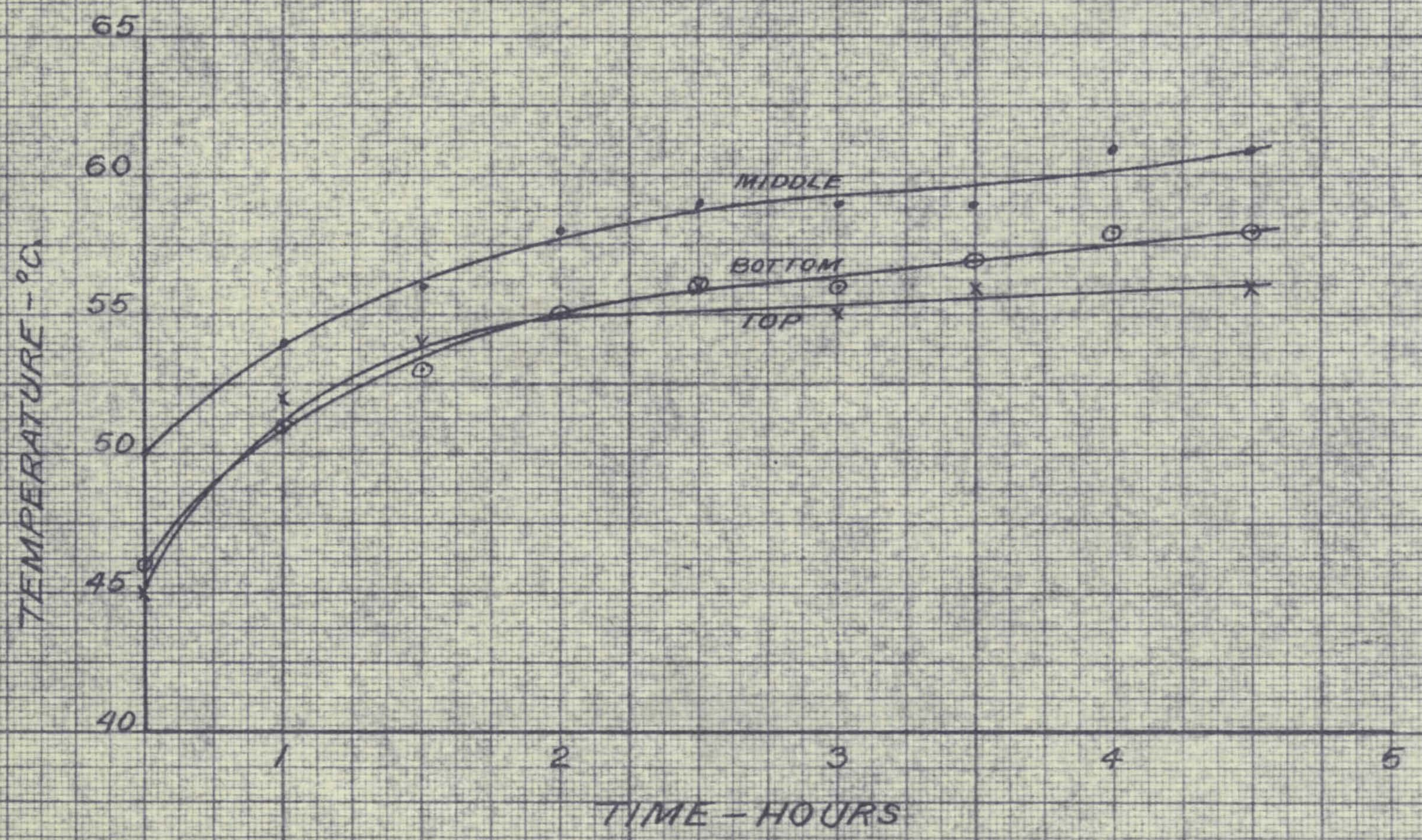


FIG. 12 TEMPERATURE-TIME CURVES FOR 16 IN. HG. VACUUM AT 58°C.

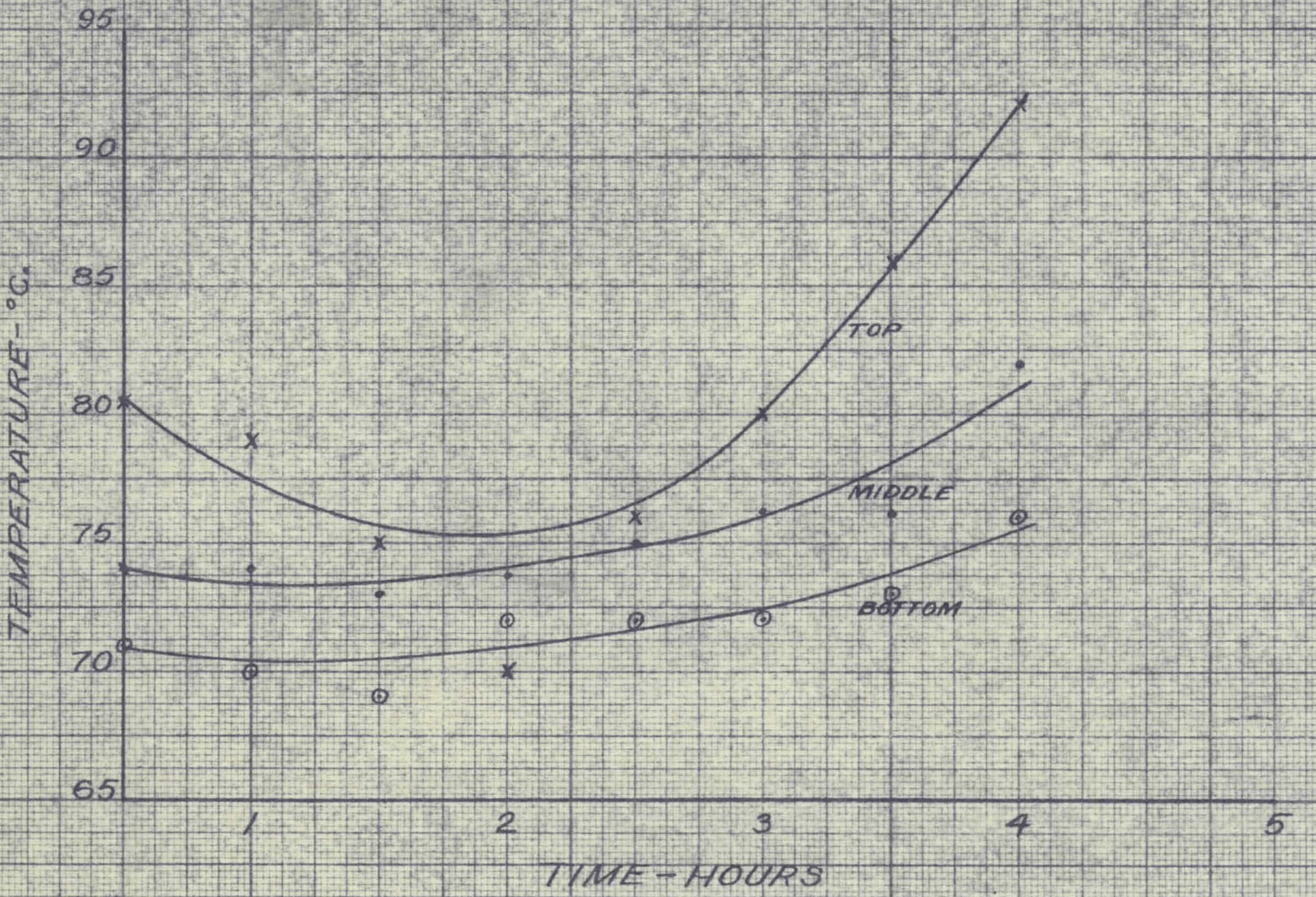


FIG. 13 TEMPERATURE-TIME CURVES FOR 15 IN. HG. VACUUM AT 73°C.

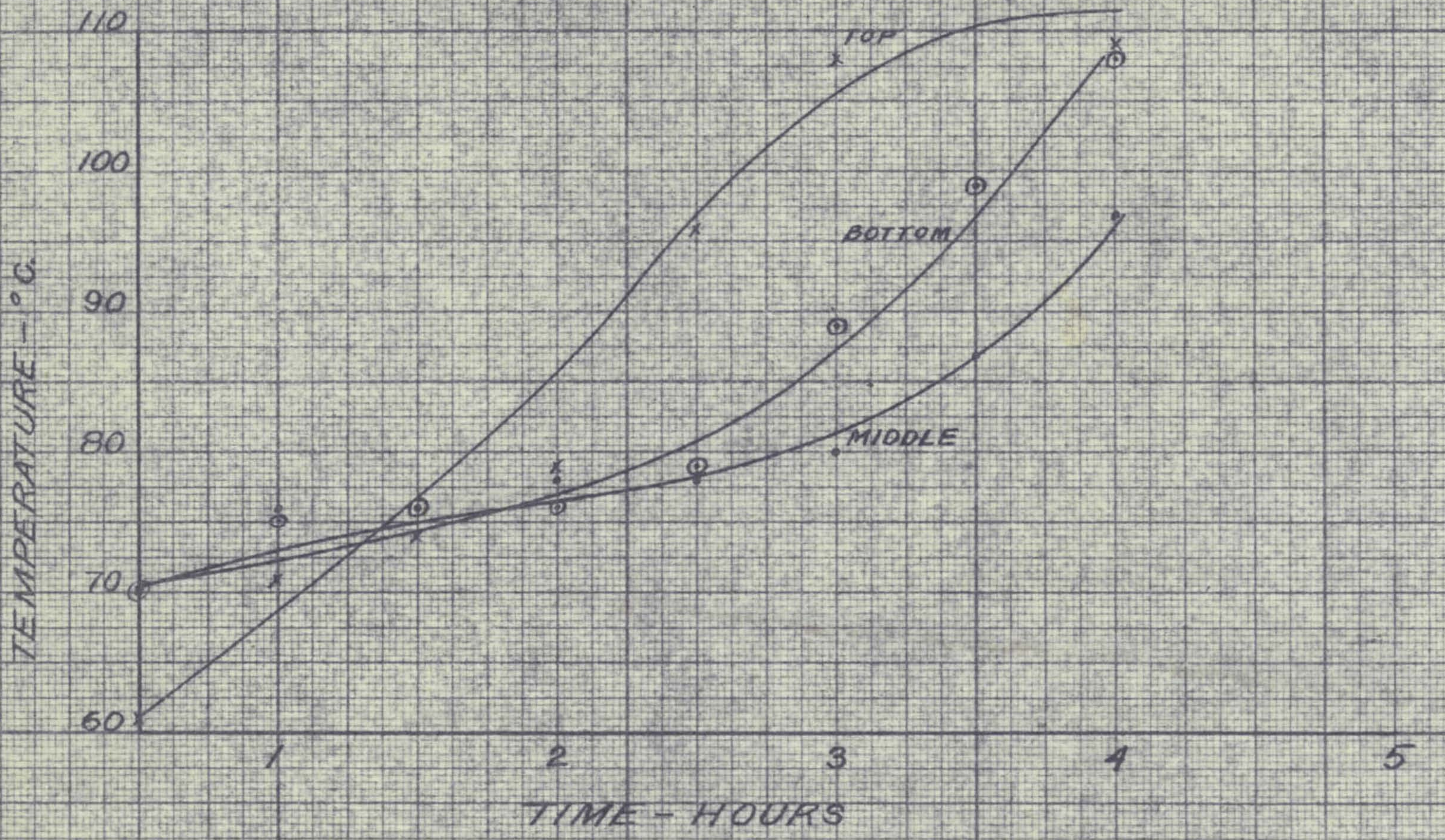


FIG. 14 TEMPERATURE-TIME CURVES FOR 15 IN. HG. VACUUM AT 78°C.

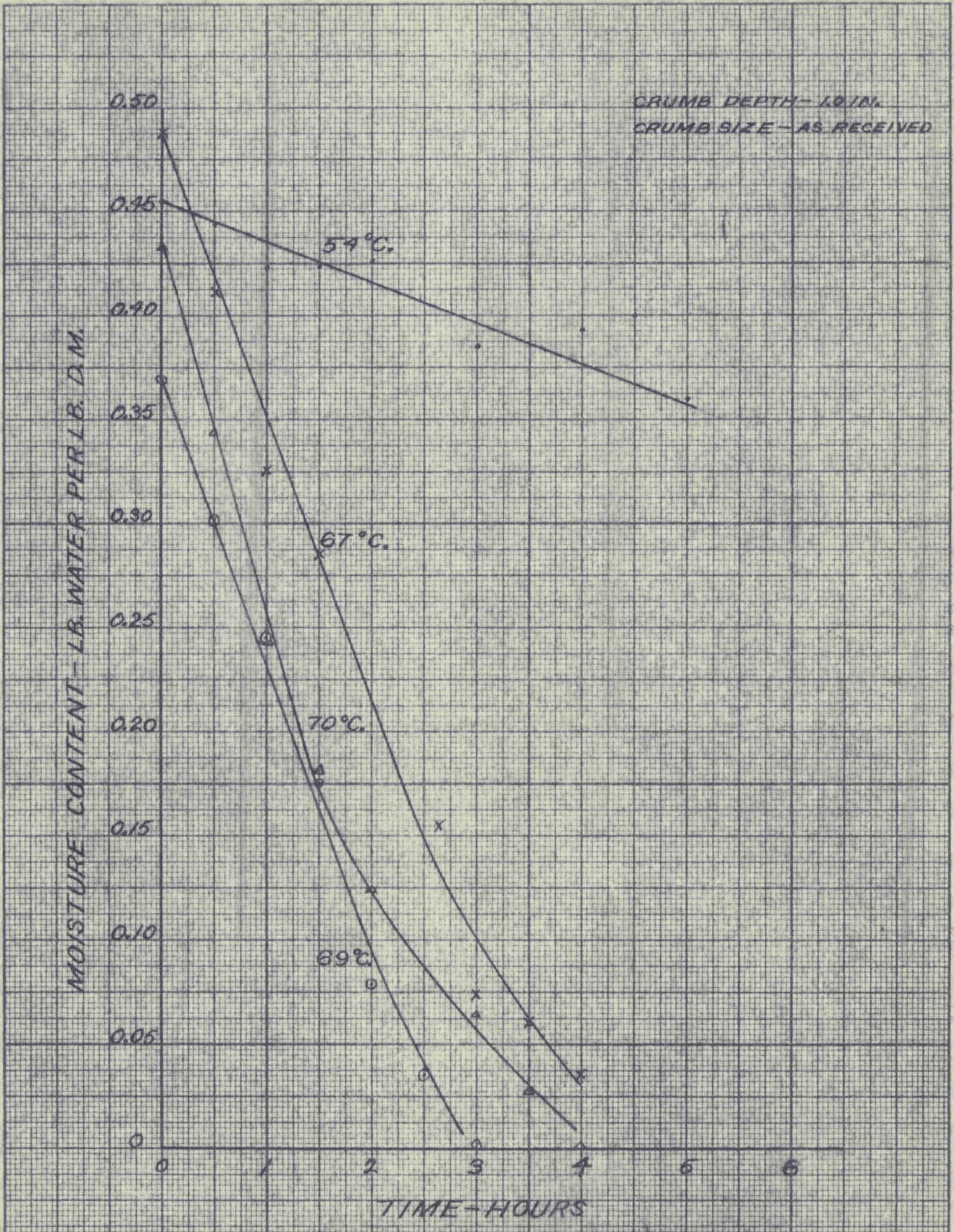


FIG. 15 MOISTURE CONTENT—TIME CURVES.
EFFECT OF TEMPERATURE AT 20 IN. HG. VACUUM.

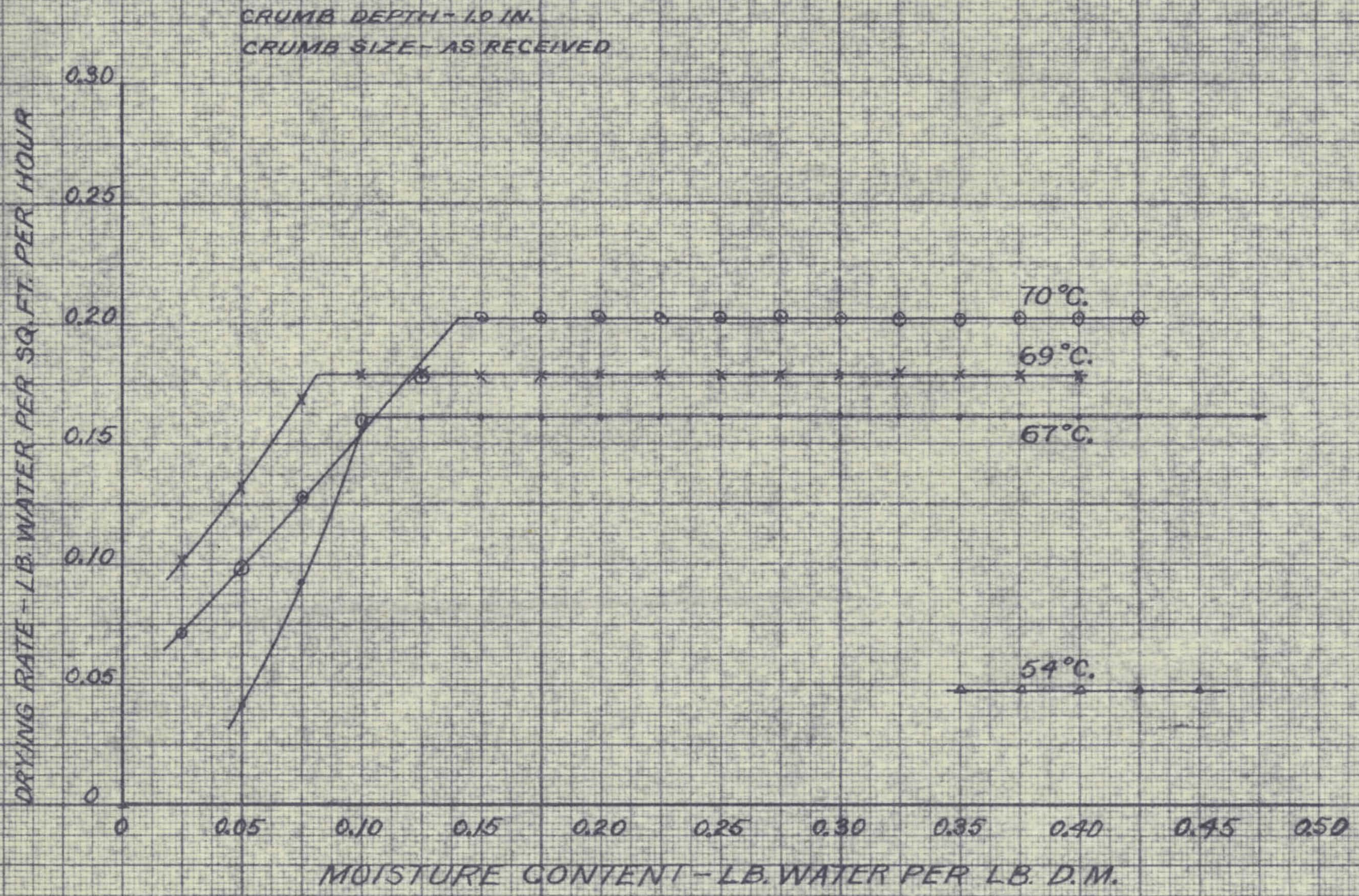


FIG. 16 DRYING RATE CURVES.
EFFECT OF TEMPERATURE AT 20 IN. HG. VACUUM.

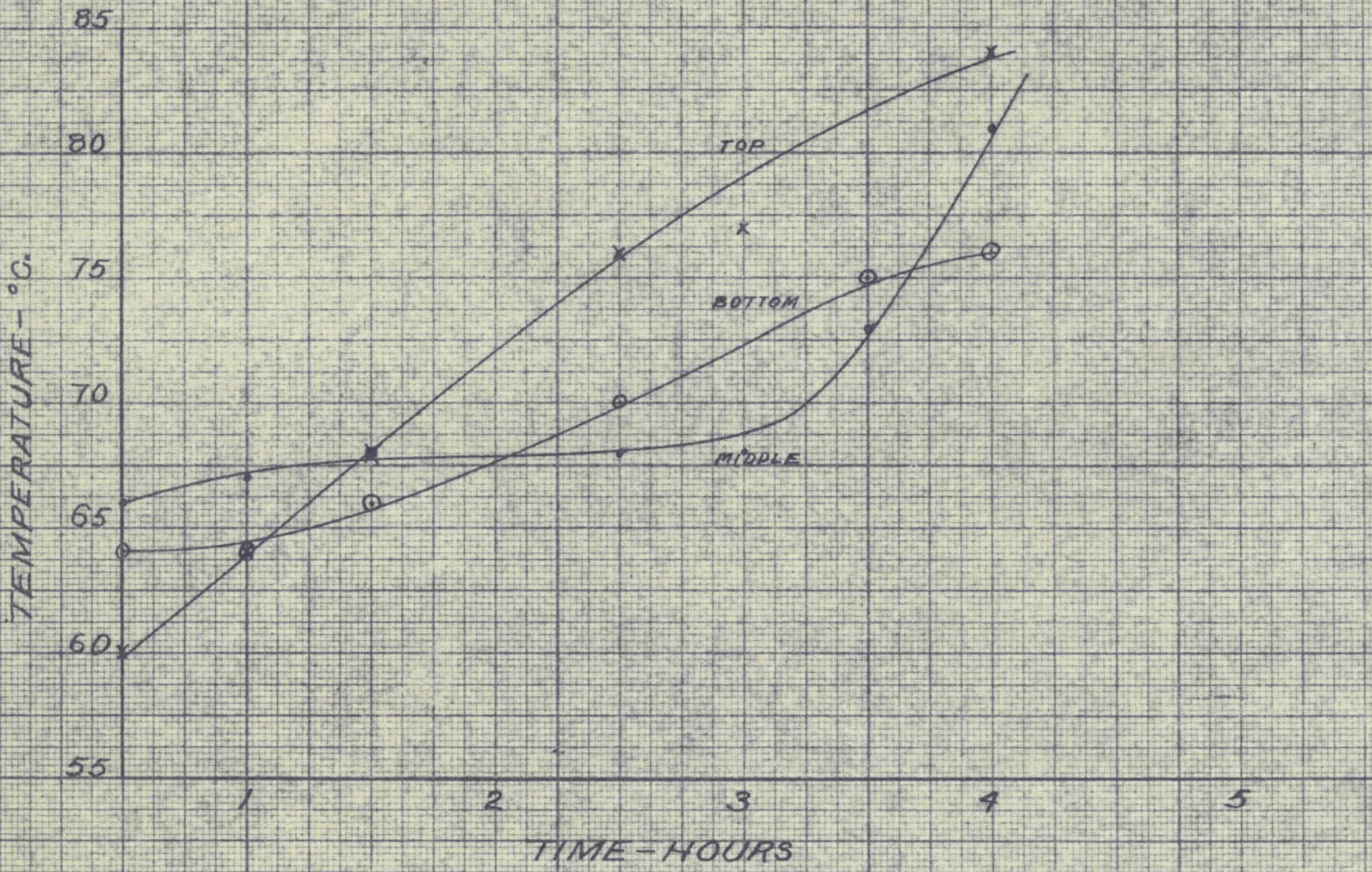


FIG. 17 TEMPERATURE-TIME CURVES FOR 20 IN. HG. VACUUM AT 67°C.

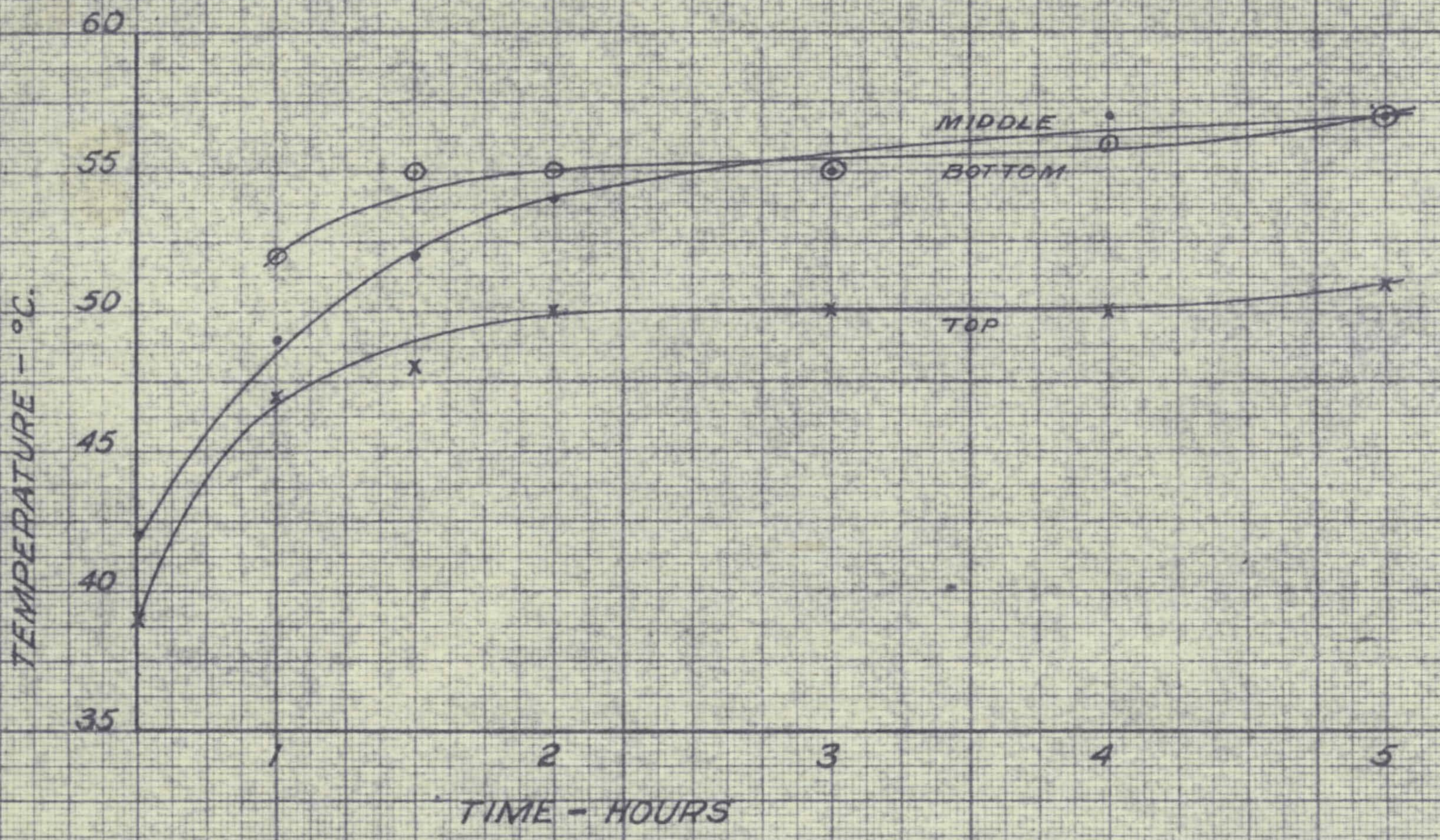


FIG. 18 TEMPERATURE-TIME CURVES FOR 20 IN. HG. VACUUM AT 57°C.

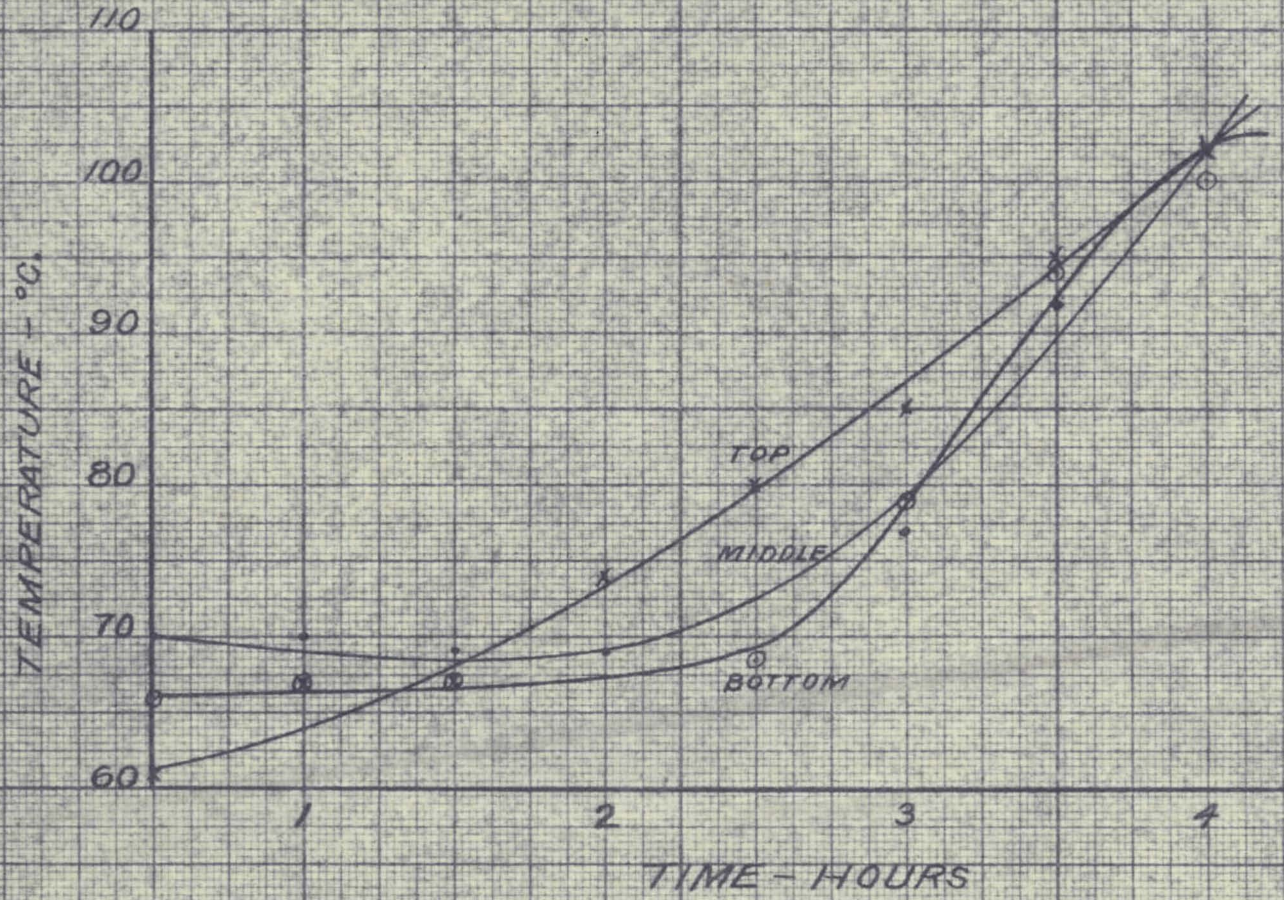


FIG. 19 TEMPERATURE-TIME CURVES FOR 20 IN. HG. VACUUM AT 70°C.

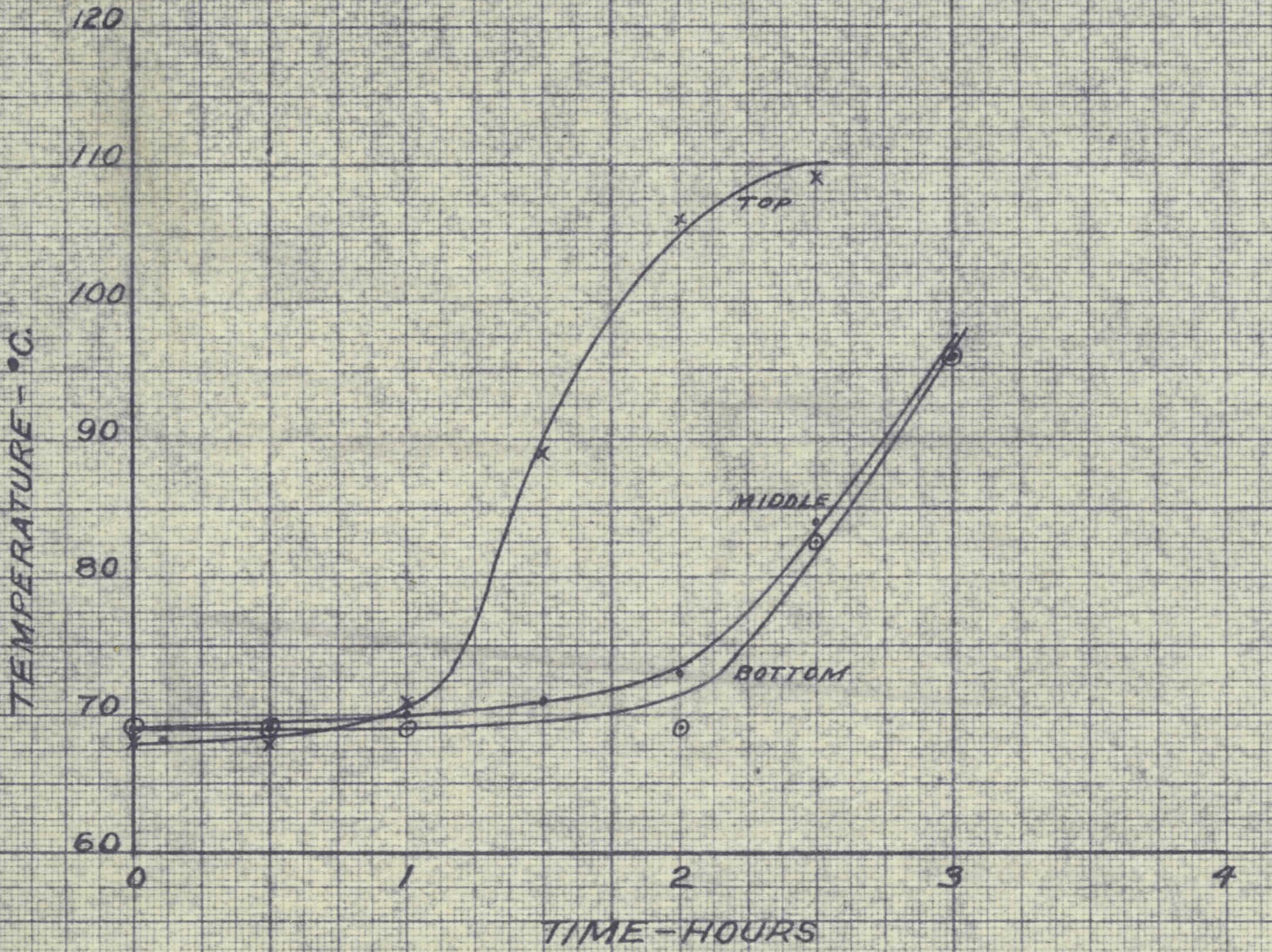


FIG. 20 TEMPERATURE—TIME CURVES FOR 20 IN. HG. VACUUM AT 69°C.

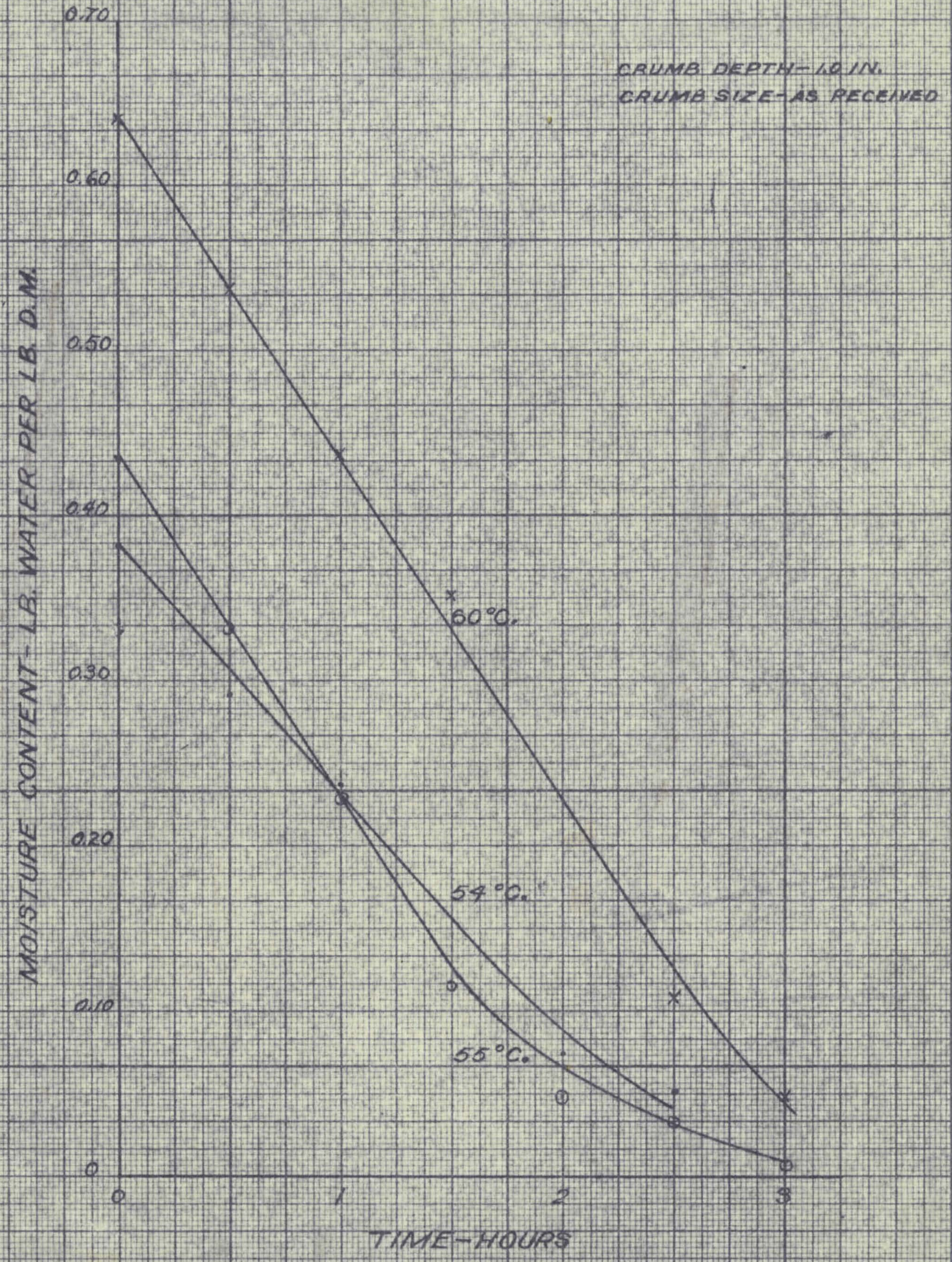


FIG. 21 MOISTURE CONTENT—TIME CURVES
EFFECT OF TEMPERATURE AT 25 IN. HG. VACUUM.

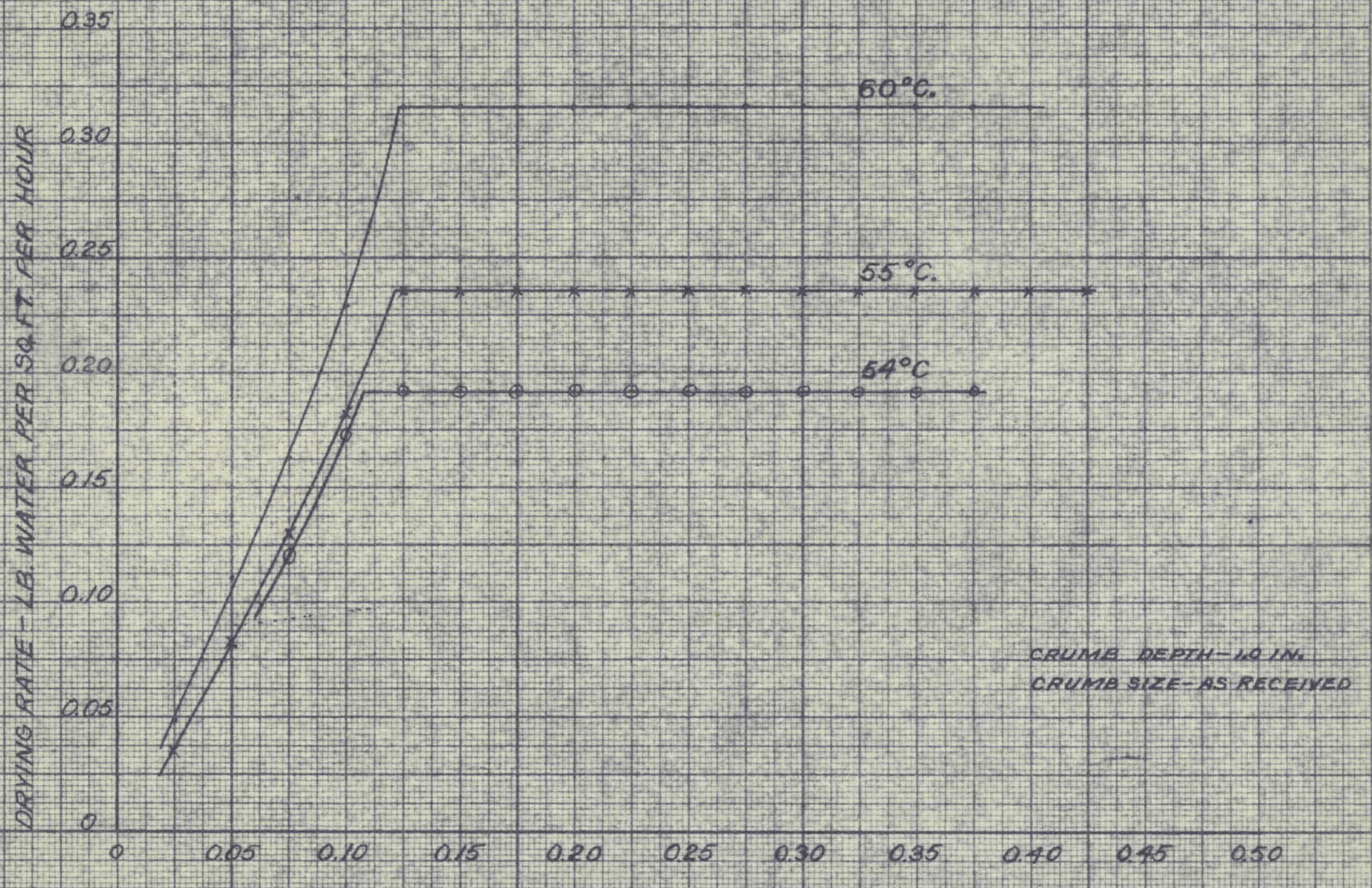


FIG. 22 DRYING RATE CURVES.
EFFECT OF TEMPERATURE AT 25 IN. HG. VACUUM.

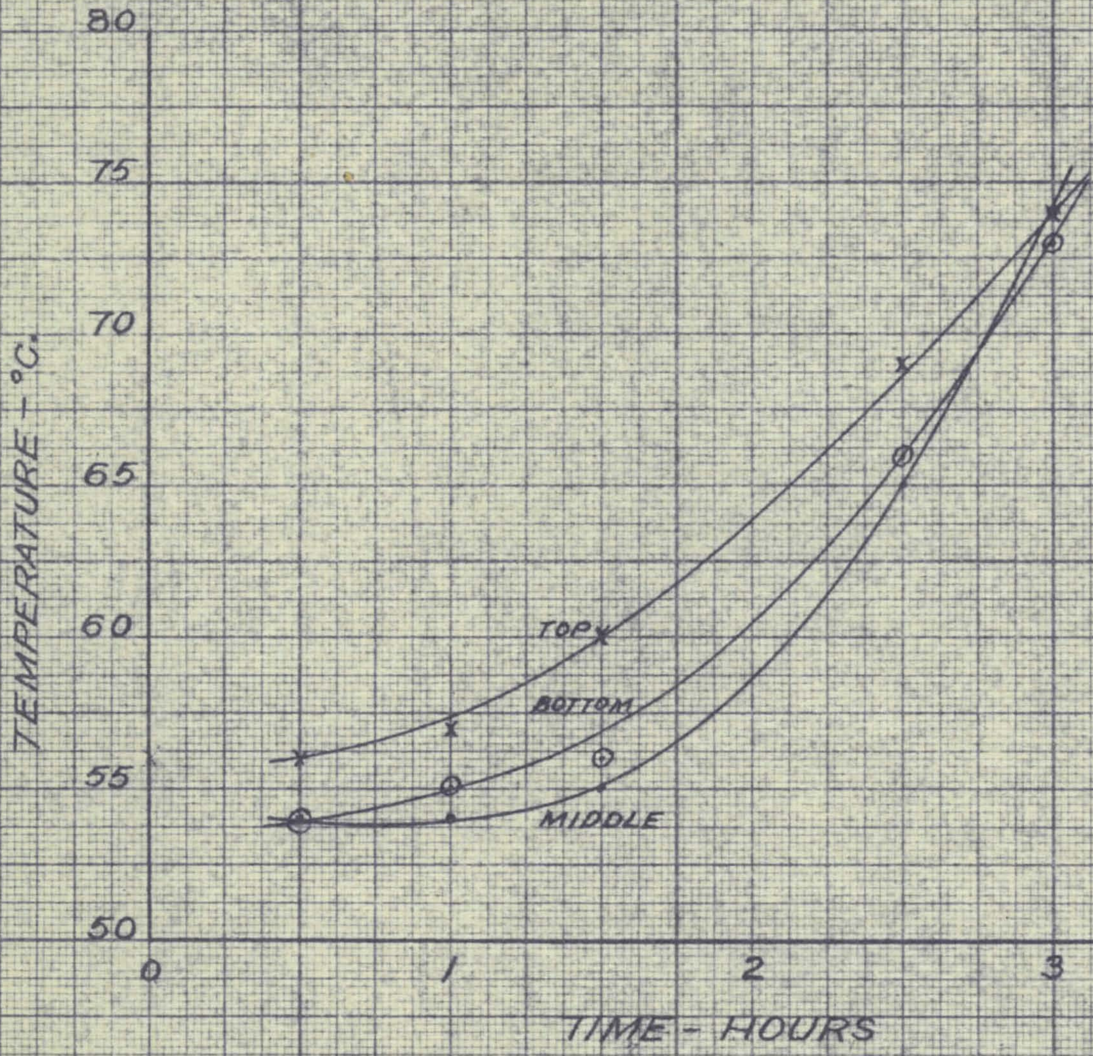


FIG. 23 TEMPERATURE-TIME CURVES FOR 25 IN. HG. VACUUM AT 54°C.

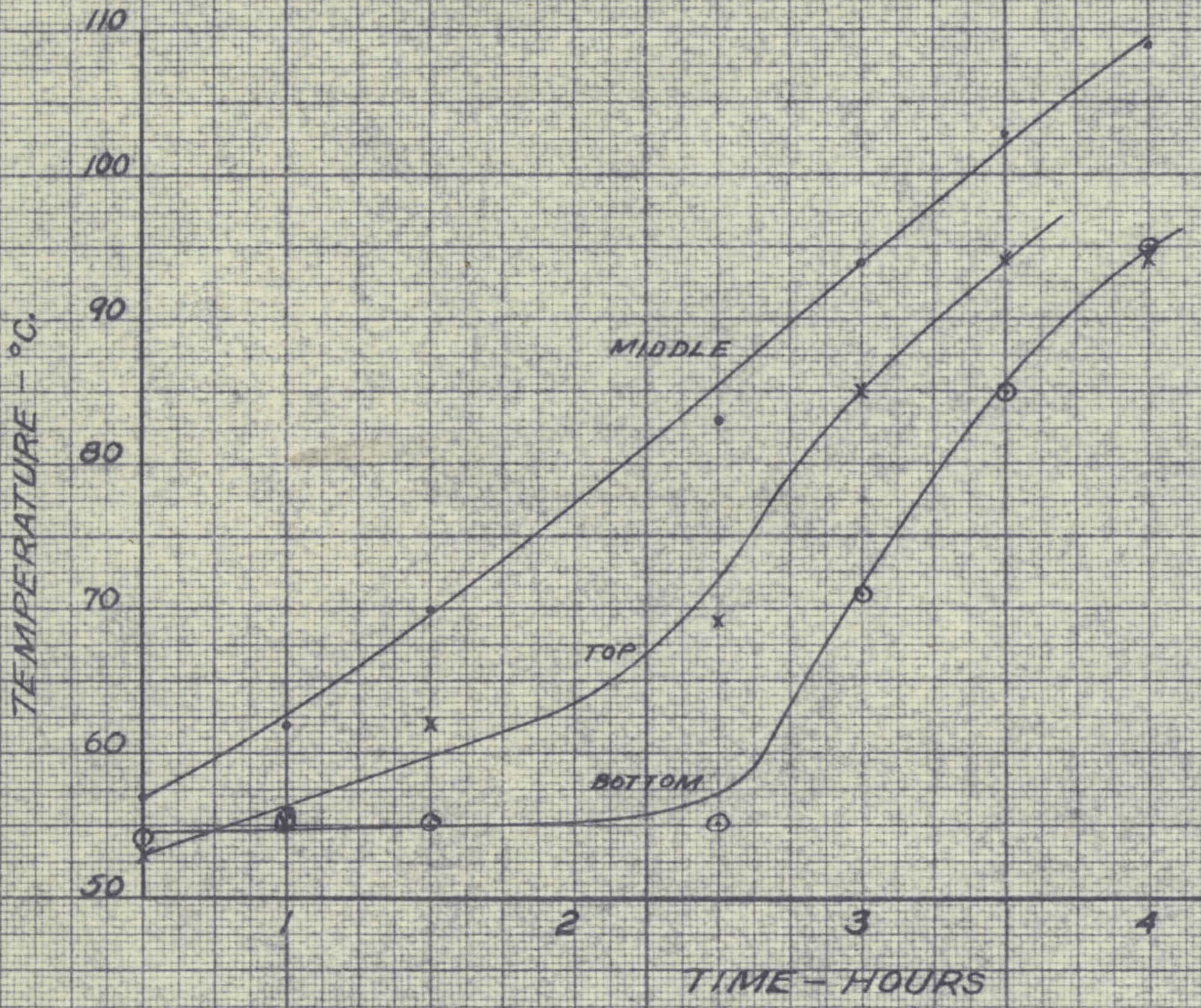


FIG. 24 TEMPERATURE-TIME CURVES FOR 26 IN. HG. VACUUM AT 55°C.

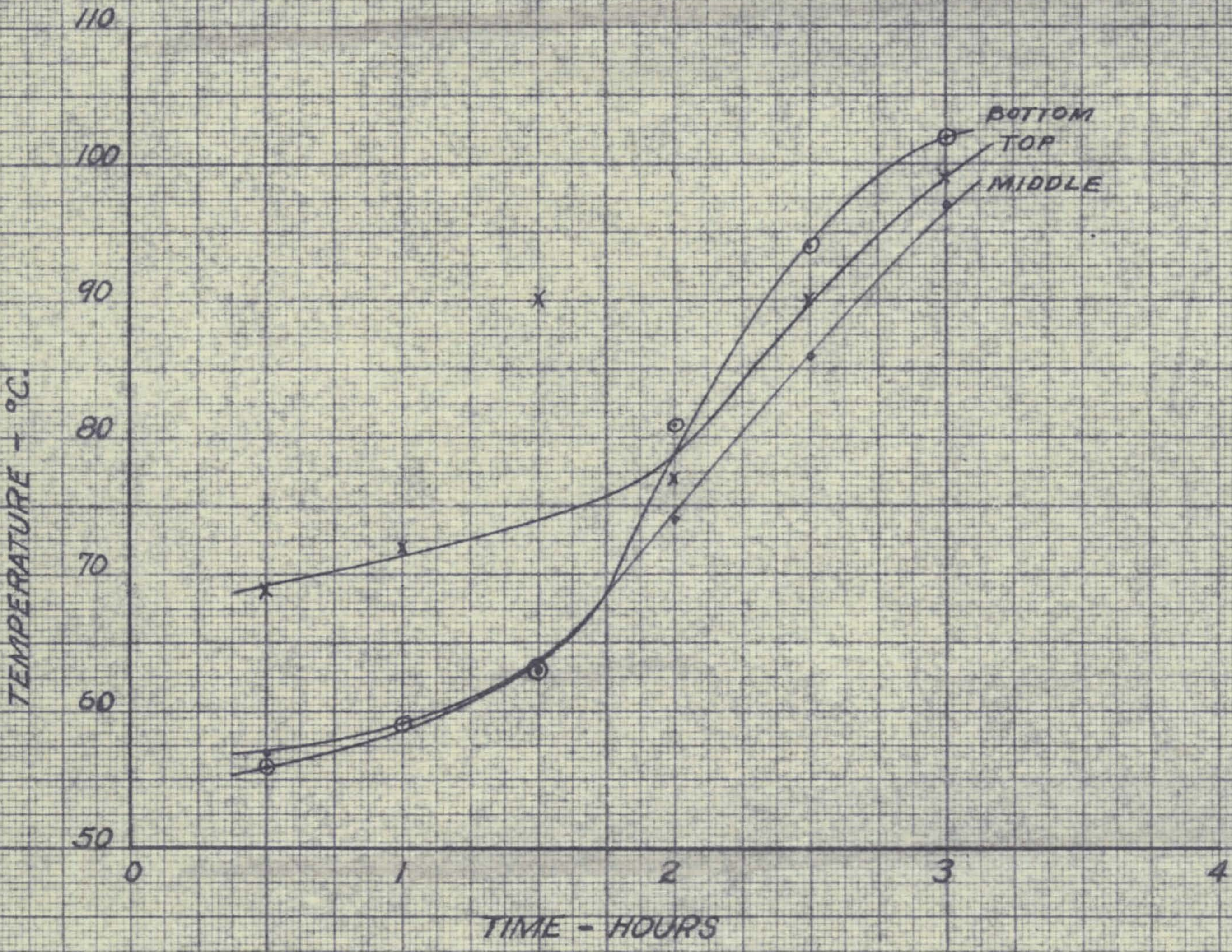


FIG. 25 TEMPERATURE–TIME CURVES FOR 26 IN. HG. VACUUM AT 60°C.

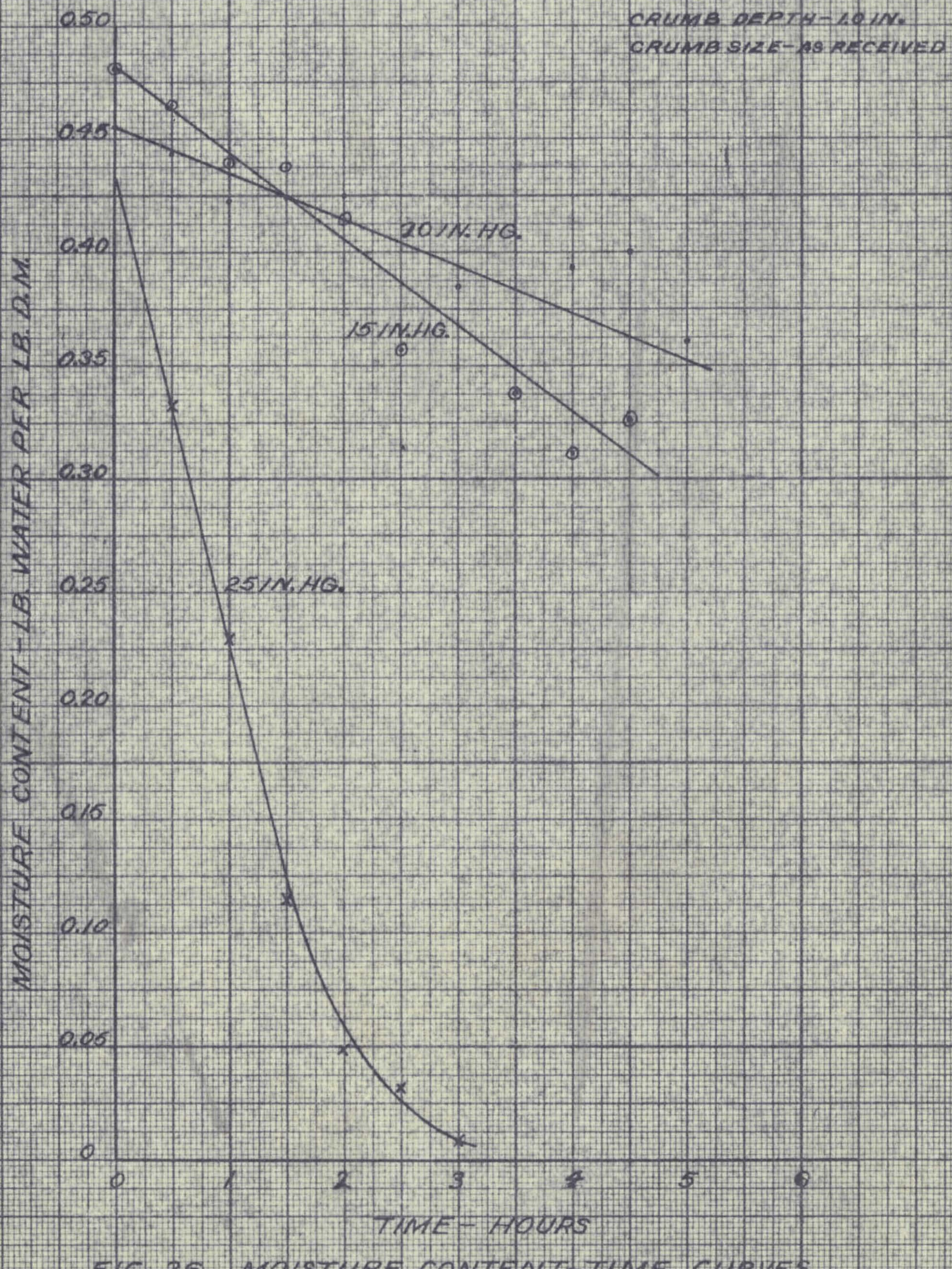


FIG. 26 MOISTURE CONTENT–TIME CURVES.
EFFECT OF VACUUM AT 54–58 °C.

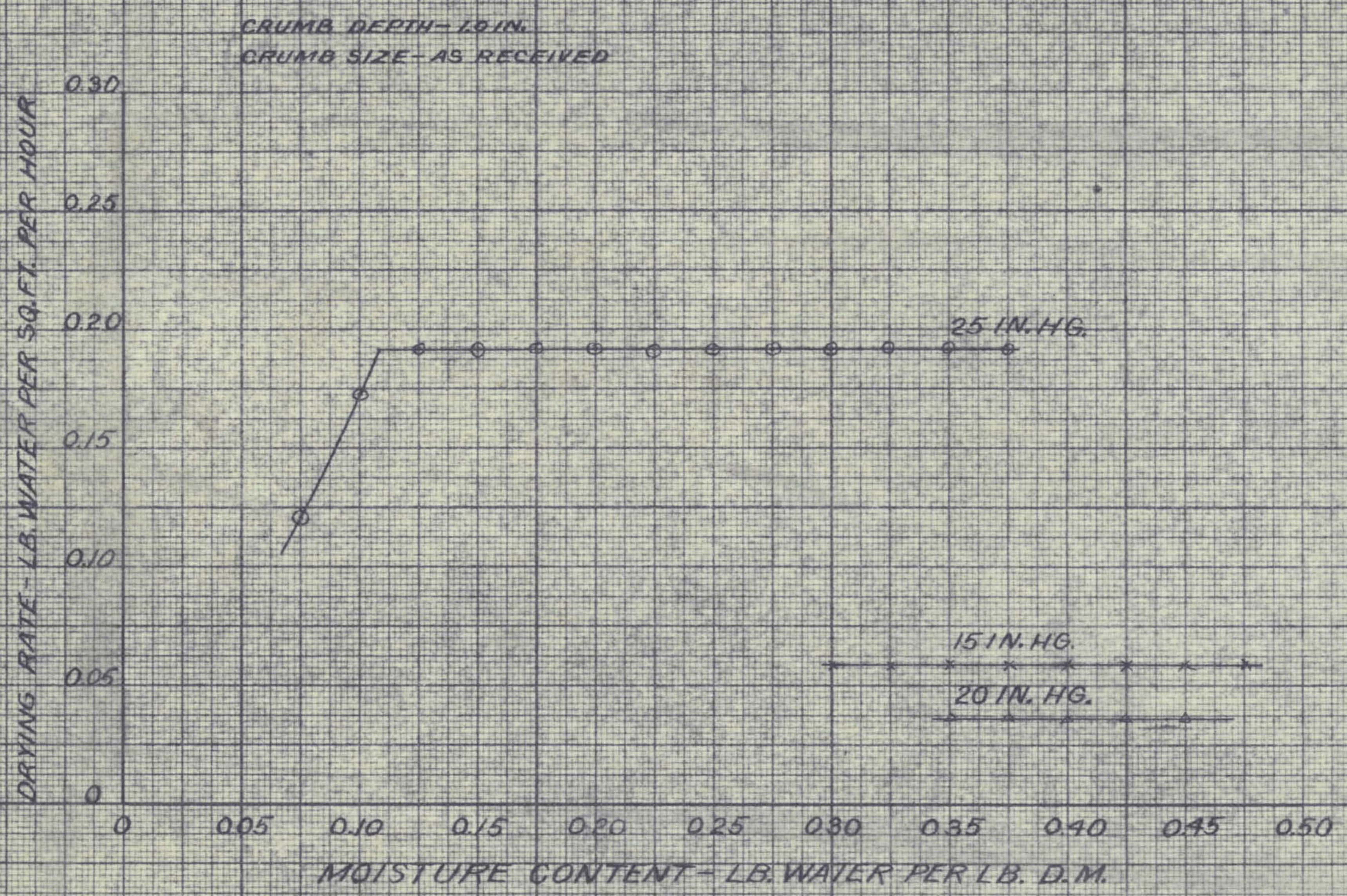


FIG. 27 DRYING RATE CURVES.
EFFECT OF VACUUM AT 54–58°C.

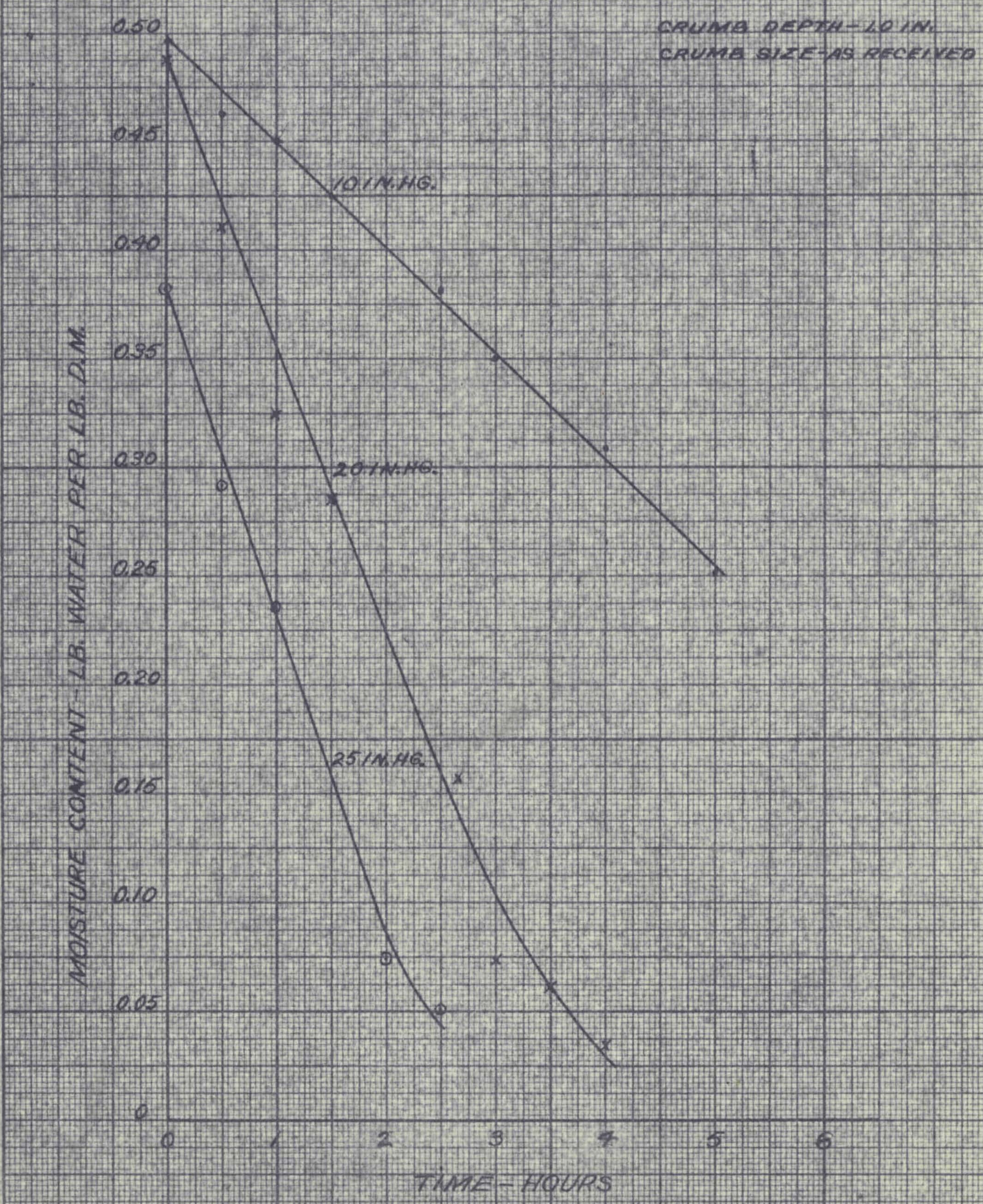


FIG. 28 MOISTURE CONTENT—TIME CURVES.
EFFECT OF VACUUM AT 60–67 °C.

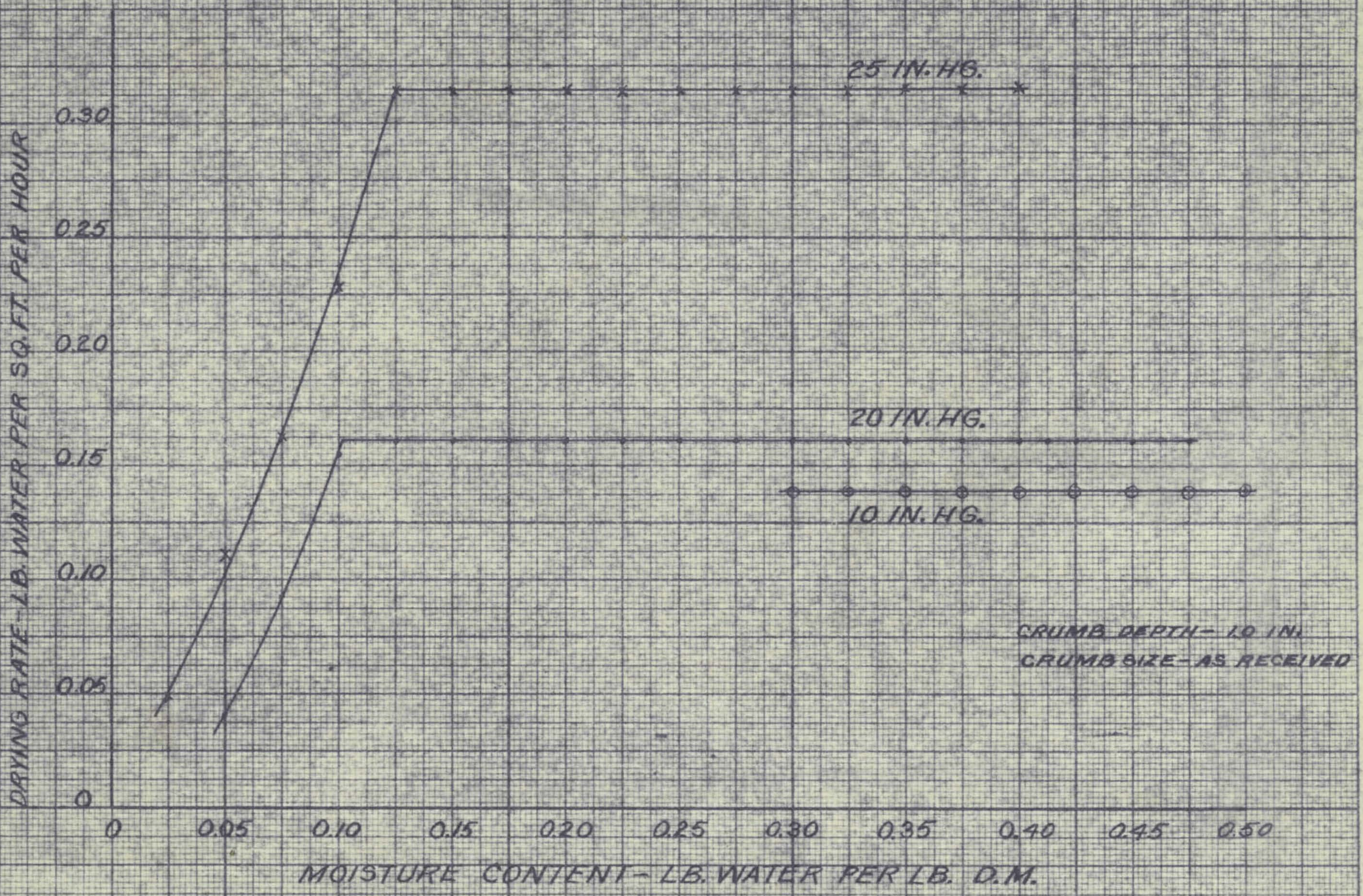


FIG. 29 DRYING RATE CURVES.
EFFECT OF VACUUM AT 60-67°C.

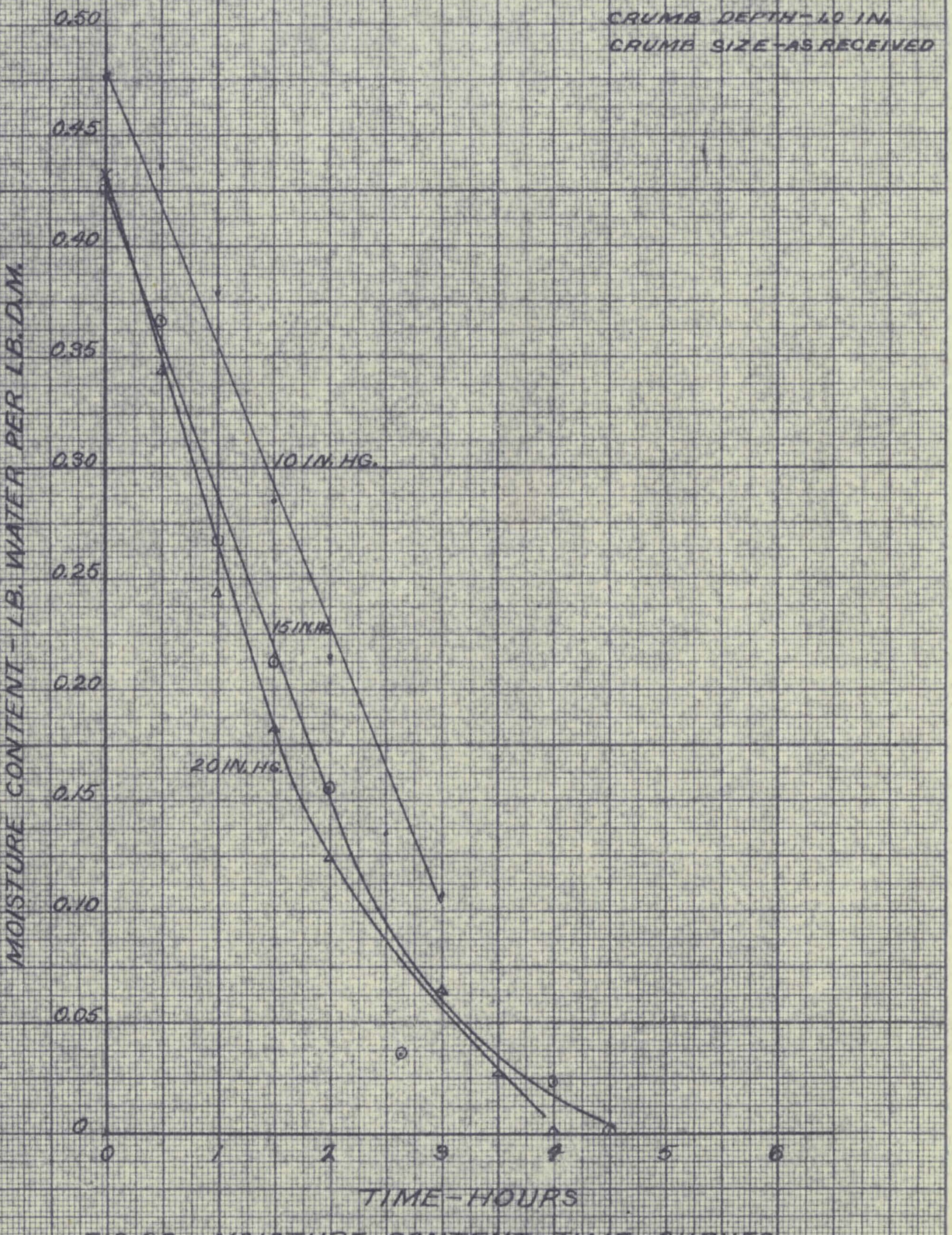


FIG. 30 MOISTURE CONTENT-TIME CURVES.
EFFECT OF VACUUM AT 70-83°C.

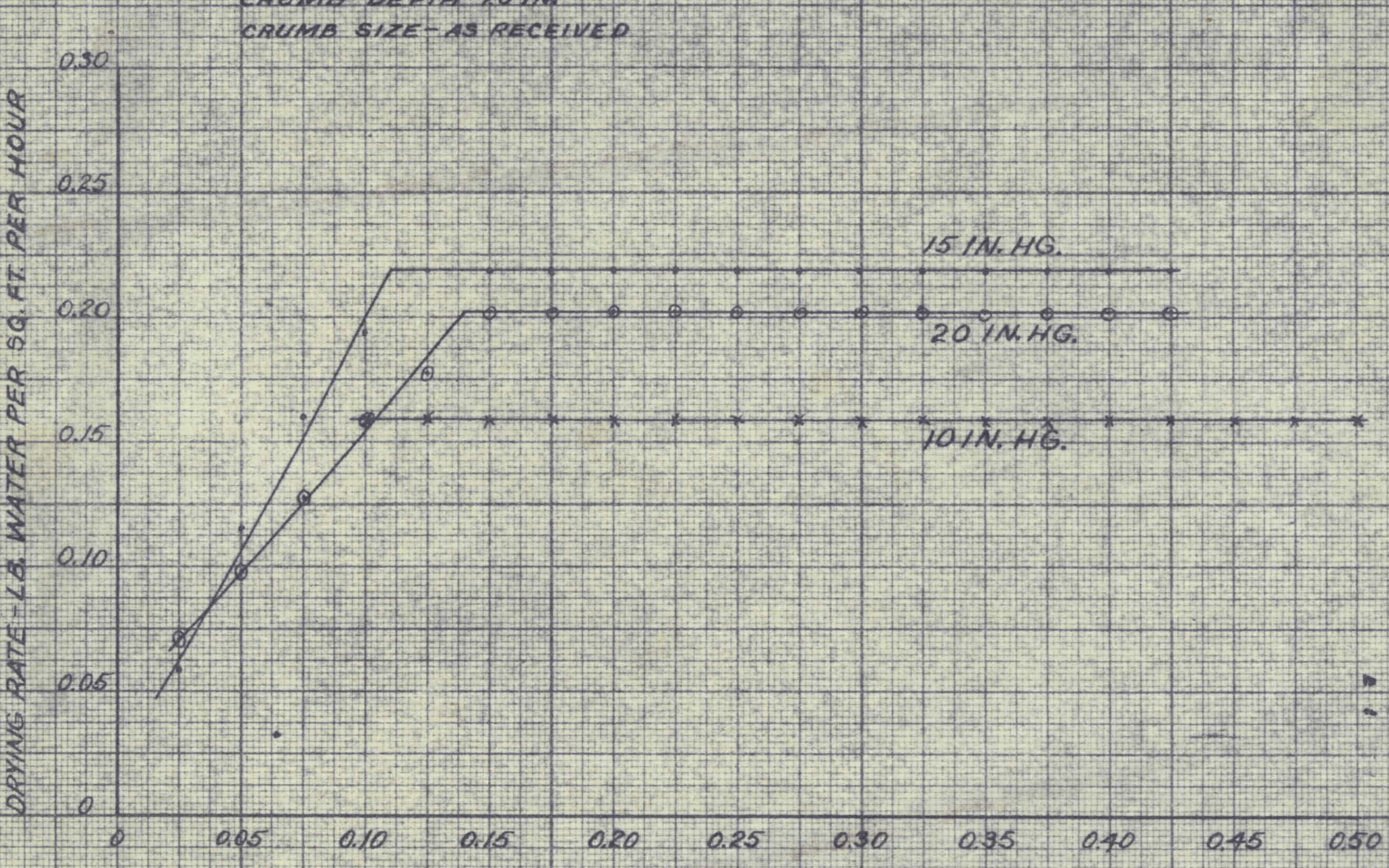


FIG. 31 DRYING RATE CURVES.
EFFECT OF VACUUM AT 70-83°C.

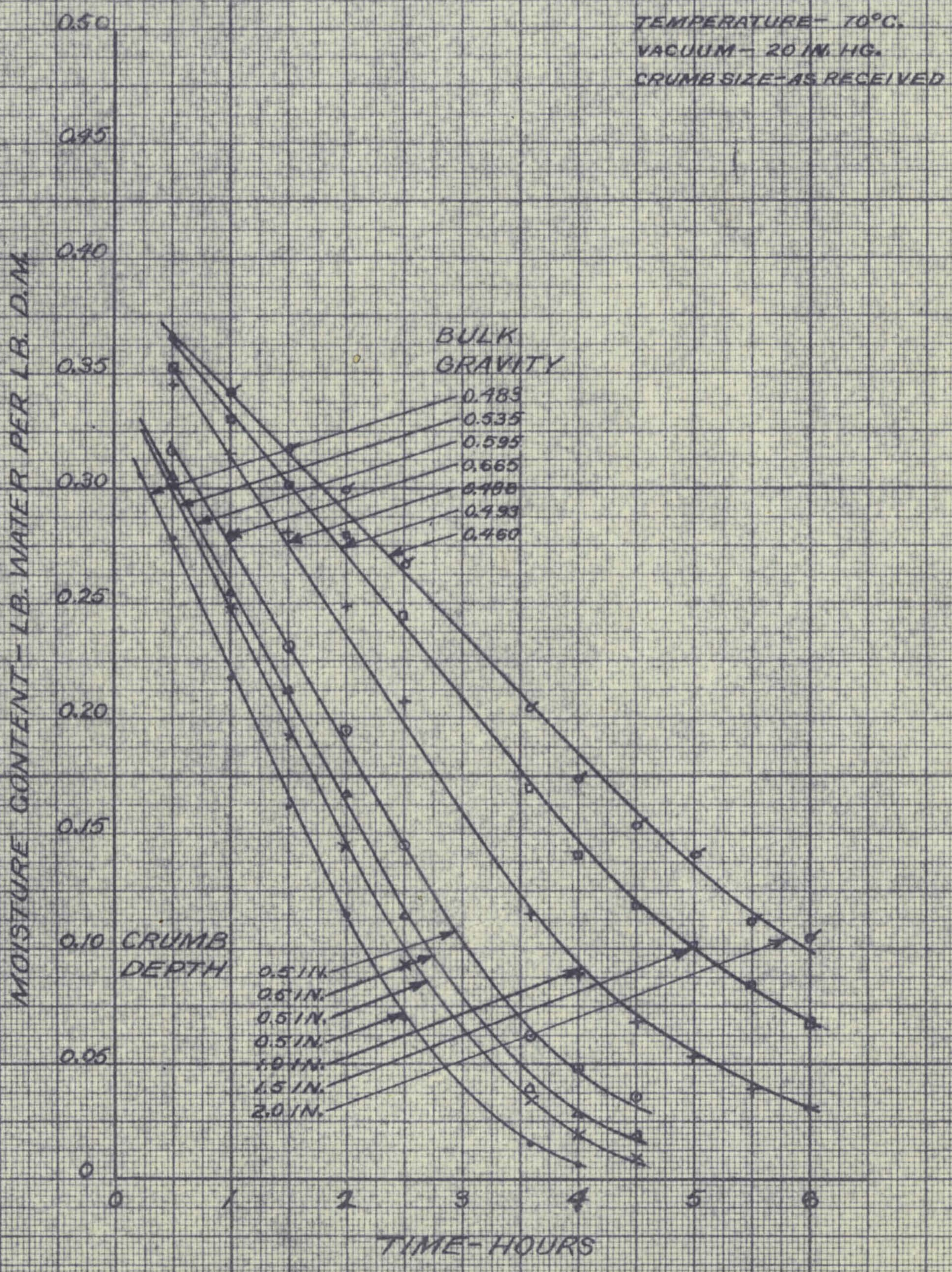


FIG. 32 MOISTURE CONTENT—TIME CURVES.
EFFECT OF BULK GRAVITIES AND CRUMB DEPTH.

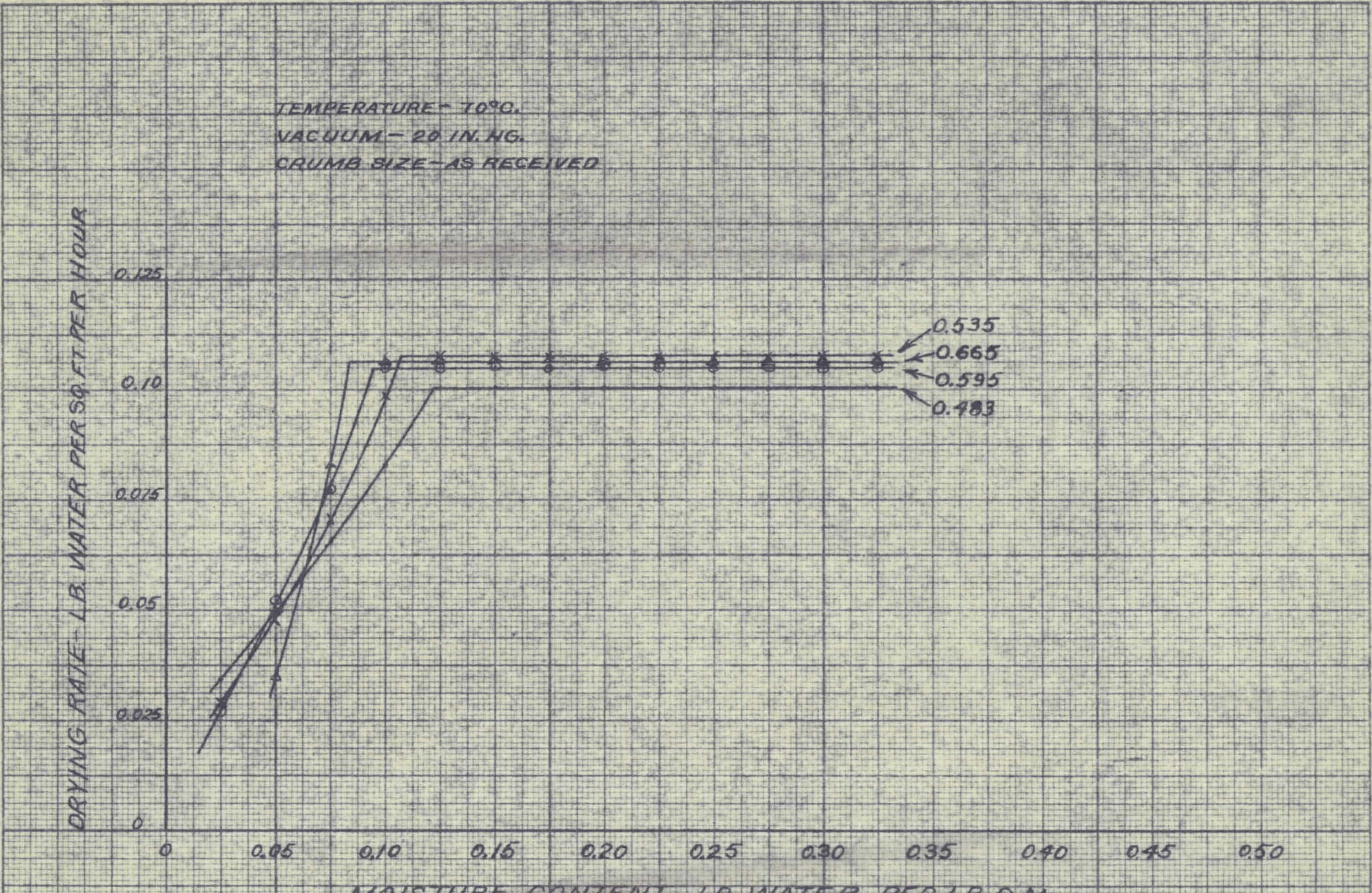


FIG. 33 DRYING RATE CURVES.
EFFECT OF BULK GRAVITIES.

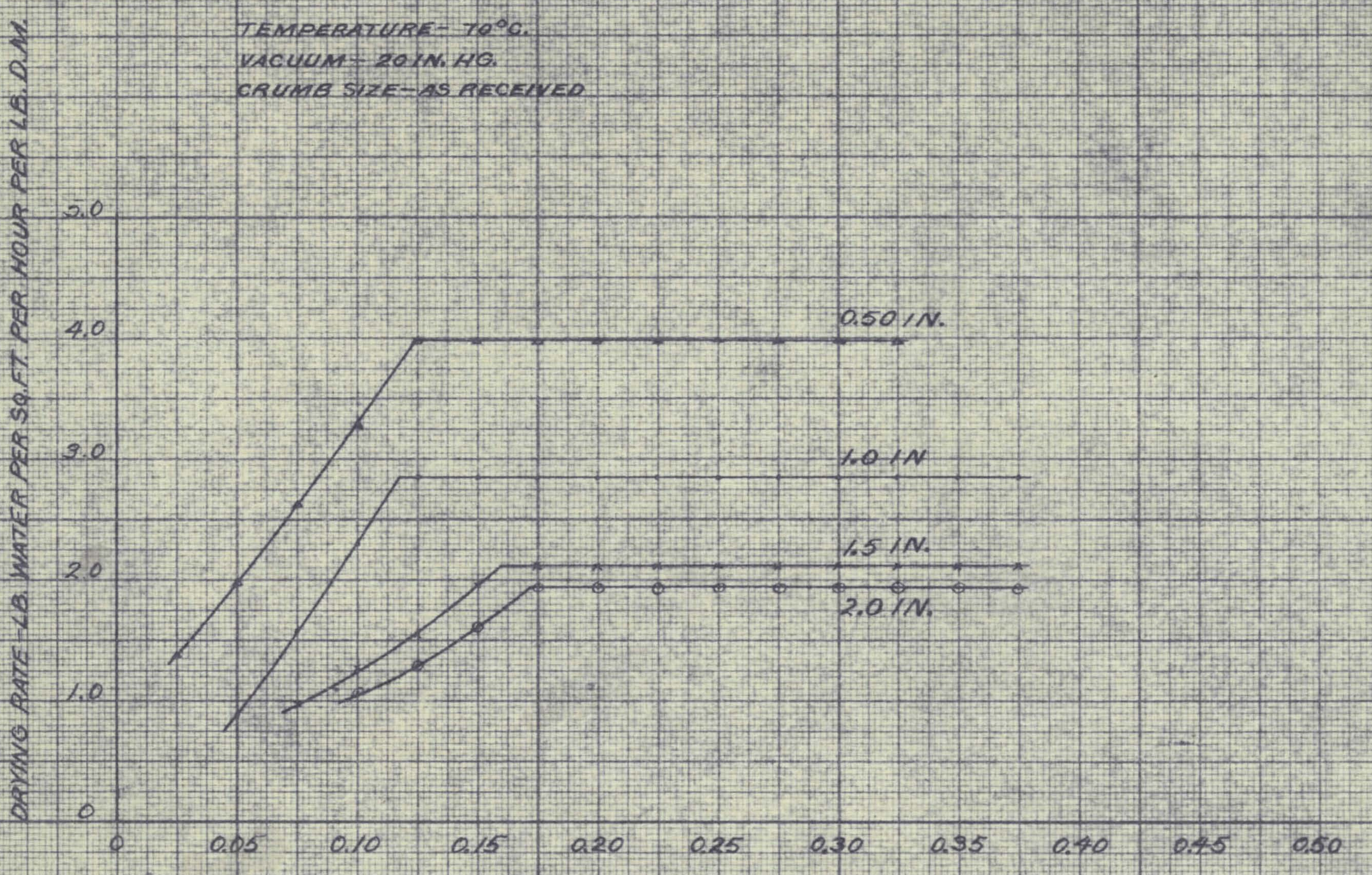


FIG. 34 DRYING RATE CURVES.
EFFECT OF CRUMB DEPTH.

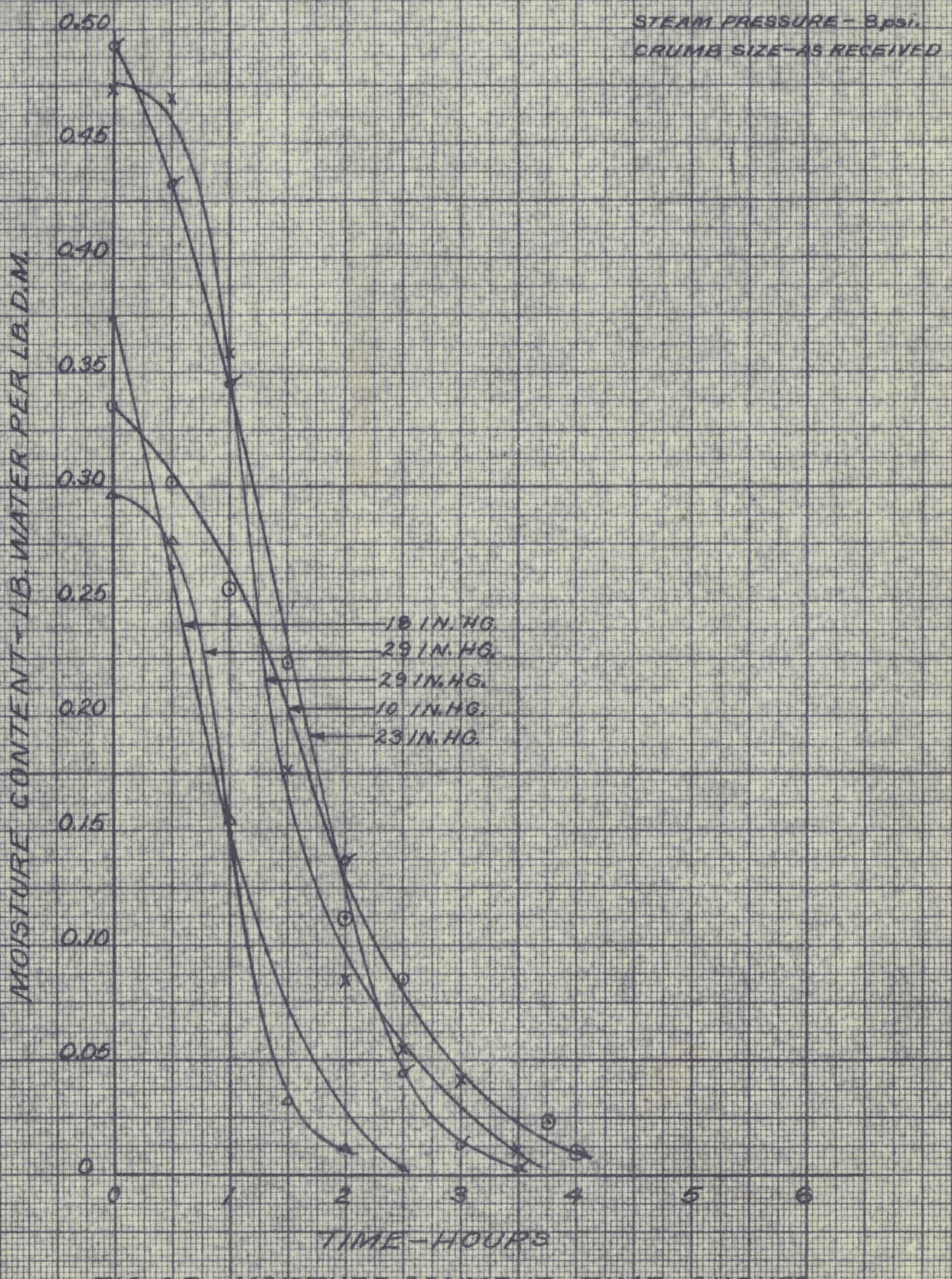


FIG. 36 MOISTURE CONTENT-TIME CURVES.
ROTARY VACUUM DRIER-EFFECT OF VACUUM.

DISCUSSION

The moisture content-time curves indicate that these methods, shelf vacuum drying and rotary vacuum drying, required a drying period too long for any practical value except a study of the drying characteristics. By sampling at not too frequent intervals sufficiently accurate data were obtained to show the effect of temperature of drying, of vacuum for drying, of bulk specific gravity, of thickness of cake, and of type of vacuum drying on the drying rate curves.

All the drying rate curves (see Figures 6, 10, 16, and 22) for a constant vacuum show that the value of the constant rate period increases as the nominal temperature increases. Comparison of Figures 6 and 22 show that at a higher vacuum, lower temperatures produced higher rates, indicating that the drying rate may be more sensitive to temperature than vacuum.

The time-temperature plots of the temperature measurements made prior to each sampling show an interesting phenomenon. The curves indicate that in nearly every case part of the drying occurred at some temperature which might be called the constant rate temperature--the level portion of the curve before the steep rise (see Figures 19 and 20). As soon as the critical moisture content was reached the trend was toward higher temperatures. For the runs shown by Figures 15, 16, 19, and 20, that point occurred after about two hour's time when the moisture content was about

0.075 to 0.125 pounds of water per pound of dry material. The time-temperature plots show a break about two hours after the beginning of the run, thereby coinciding with the break in the corresponding rate curve.

From these results it appears that the temperature of the crumb is going to remain at this constant rate temperature until the falling rate period of the drying is attained. When the falling rate is attained, the plane of evaporation (see THEORY--DRYING STUDIES) starts to move into the crumb layer. When this plane has passed through an amount of rubber leaving it dry, the temperature of that rubber starts to rise more rapidly. Thus the rubber at the top of the layer would reach the temperature of the heating medium sooner. This idea is upheld by the time-temperature curves, which show that the curve for the rubber nearest the top of the layer rises first, then that for the middle, and finally that for the bottom of the cake.

The drying rate curves of Figures 27, 29, and 31 give an index of the trend of the drying rates as the vacuum is varied and the temperature is held within rather narrow limits. These three figures might seem to indicate some discrepancies in trends; for in Figures 27 and 31 there is a displacement i.e., a lesser vacuum seems to have given a higher rate. However, referring to the drying rate curves at constant vacuum, it is readily apparent that a discrepancy occurs only at a higher vacuum.

The curve showing the variation of rate with a change in the bulk gravity (Figure 33) was constructed in an attempt to study the rate of drying as the particle size was changed. Provided that the true specific gravity or density of the material remain substantially constant, a good measure of the particle size should be the bulk gravity of the crumb that is being dried. This variation of particle size should affect the drying rate from a drying area point of view as well as from the standpoint of the time required to move the moisture from the interior of the discrete particles to a point where evaporation may occur. In order to make such an investigation, small samples were used and the bulk gravity was changed by pressing more or less crumb into the trays that were used to hold the crumb drying. Although a large variation in bulk gravity was not possible because of the nature of the crumb, a variation in the bulk gravity from 0.483 to 0.595 was possible. The gravity of 0.483 is approximately that of the un-compressed crumb. Thus a 23.2 per cent increase in the bulk gravity is indicated by a value of 0.595. However, the rate curves for the drying of the material at different bulk gravities show such a slight variation of the constant rate period that the deviations could easily be experimental errors.

The variation of the constant rate period, as the thickness of the sample was increased, and the variation of the rate with the change in bulk gravity were determined simultaneously. In the case of depth variation (Figure 34) as indicated on the plot, the rate is expressed as pounds of water per square foot per hour per lb. dry material. For the particular set of conditions of these data the increase in rate with increase in depth of bed was practically linear. However, it is noted that such a generalization applies only to the constant rate period and not to the falling rate period.

Not too much emphasis should be placed upon any one drying curve since the absolute value of any given point on the drying rate curve is quite sensitive to the location of the curve through the experimentally determined data.

AIR DRYING

AIR ACROSS CRUMB LAYER

APPARATUS

The apparatus used to vary the conditions in the study of air drying with the air moving across the cake was a laboratory shelf type unit (see Figure 36). The air was drawn in by a rotary blade type blower and forced by baffle arrangement across two sets of steam heating coils. A pair of slotted baffles then directs the air stream across the many trays, and then out the exit. A duct connecting the exit to the air entrance pipe was used to recirculate the air for higher temperatures with lower humidities. For higher temperatures coupled with higher humidities, the point of air entrance could be changed and the air drawn through a humidifying section, consisting of a set of steam coils arranged so that either a water spray or steam could be played upon them.

The use of the slotted baffle to direct the air stream across the sample gave point variations in the velocity because of the turbulence of the stream. Methods, such as removing all trays but one and blocking all slots but a few failed to correct this. Therefore the slotted baffles were removed and a set of cardboard baffles were set up, and the turbulence of the air stream was reduced.

Standard 100°C. thermometers were used for temperature measurements of the air. The inlet conditions were obtained by a dry bulb and a wet bulb thermometer inserted in a hole in the air duct. To take the exit conditions the thermometers were inserted in a hole in the exit pipe. The temperature gradient across the cake was obtained using a copper-constantan thermocouple in conjunction with a potentiometer.

The sample trays were of two different types. The first, a galvanized iron tray, 20 inches by 20 inches by 1 inch deep, was used for early runs. The second type was made of plastic and was 3 inches by 3 inches and different depths.

Other equipment used was as follows; 50 ml. weighing bottles, analytical balance, anemometer, small platform scale, and Tyler Standard screens.

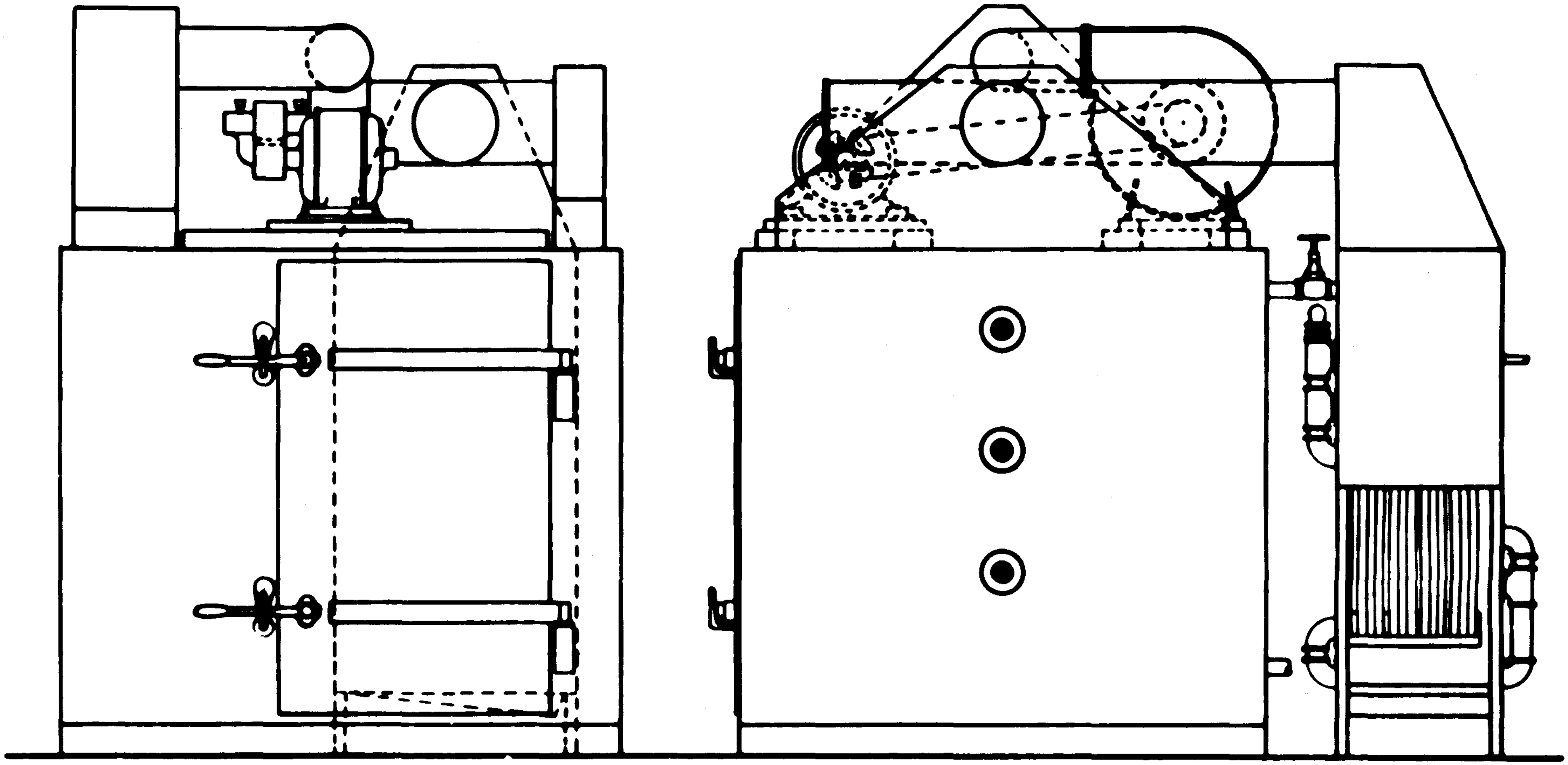


FIG. 36 LABORATORY AIR DRIER

PROCEDURE

The first procedure used did not give sufficiently accurate results. This method was that of using a large tray of crumb for the drying with periodic removal of samples for the moisture content determination. However, it was found that the results were dependent upon the sampling technique, the point of sampling, and other factors almost beyond control from a practical view point. Therefore a method of procedure was devised that would give satisfactory results, and this was used for obtaining the data in this section.

This method was that of using small trays made of plastic. The small boxes or trays were 3 in. by 3 in. and of varying depths. This size was used because it was the maximum size that could be used without overloading the balance and still maintain accuracy. The rubber was placed in these trays, weighed initially, and placed on a shelf of the cabinet type drier, which had previously been brought to operating conditions. The boxes were removed periodically and weighed, using a tared box cover to prevent loss of moisture during the weighings. From the initial weight of the tray of rubber, the periodic weights and the initial moisture content (see ANALYTICAL PROCEDURES--DRYING STUDIES) moisture content time curves were drawn. From each of these, drying rate curves were constructed.

In order to obtain other data for correlation purposes, the temperatures were taken periodically. These readings were taken just prior to the weighings so the effect of opening the door would be minimized. From the wet and dry bulb temperatures the humidities were obtained from a humidity chart both as per cent relative humidity and absolute humidity expressed as pounds of water per pound of dry air.

An anemometer, placed alongside the sample tray, was used to determine the air velocity. The measurements were made over a sufficiently long period of time to offset any discrepancies caused by opening and closing the door in starting and stopping the anemometer.

The crumb was sized by means of Tyler Standard screens for some runs and used as received for others. Because of the variation of the particle size of the crumb, it was necessary to size the crumb and to use the predominant sizes for consistent results.

RESULTS

The data for the study of the effect on the drying rate of temperature, humidity, particle size, air velocity, and thickness of cake are tabulated in the APPENDIX. For best visual presentation of the results the data were plotted first as moisture content-time curves and from these, the drying rate curves were derived.

The drying rate curves for the earlier runs, shown in Figures 37 and 40, are for samples of crumb as received. The non-uniformity of the rate curves is probably due to considerable variation in the crumb size. This difficulty was minimized in later runs by sizing.

The first effect studied was that of humidity, holding the temperature constant. Data were secured for different humidities at 165, 188, and 212^{o}F. The depth used was 2 inches, the velocity approximately 400 feet per minute, and the crumb size, that size that would pass through 0.371 inch sieve and be retained on 0.185 inch sieve.

Data for comparison of effects of temperatures were obtained from a cross-comparison of previous runs. For this comparison see Figures 57 and 58.

The data for the study of the effect of particle size are shown in Figures 59 and 60. Screening produced 10 different sizes, but in not large enough quantities to be run separately. Therefore, the ranges of sizes were selected as representing large enough size differences to show the effects. The tray depth used was 2 inches, the air velocity about 350 feet per minute, and the temperature 173°F., with a humidity of 5%.

Data are presented for the effect of velocity on the drying for velocities of 15, 120, and 230 feet per minute (see Figures 61 and 62). The crumb size used was between 0.371 and 0.185 inches.

Data for the effect of cake thickness were obtained for trays 1, 1½, and 2 inches deep. All three depths for any one temperature and humidity were run at the same time in the same drier. Two different sets of data are presented (see Figures 63 and 65) for the effect of cake thickness. The drying rate curves were computed and the rates expressed as pounds of water per square foot per hour per pound of dry material, in order to show comparison between rates for different types of drying studied (see Figures 64 and 66).

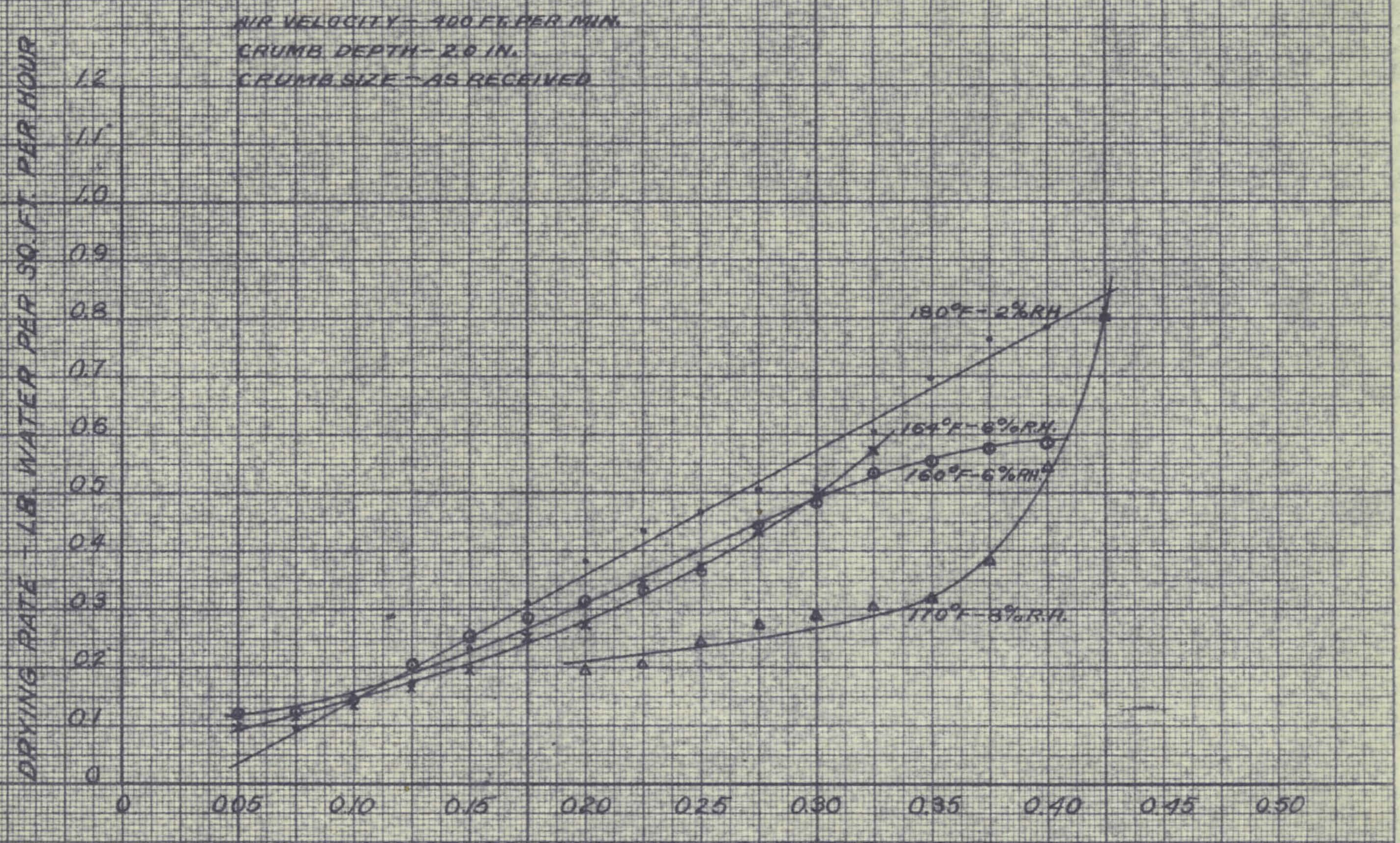


FIG. 37 DRYING RATE CURVES.
EFFECT OF TEMPERATURE AND HUMIDITY

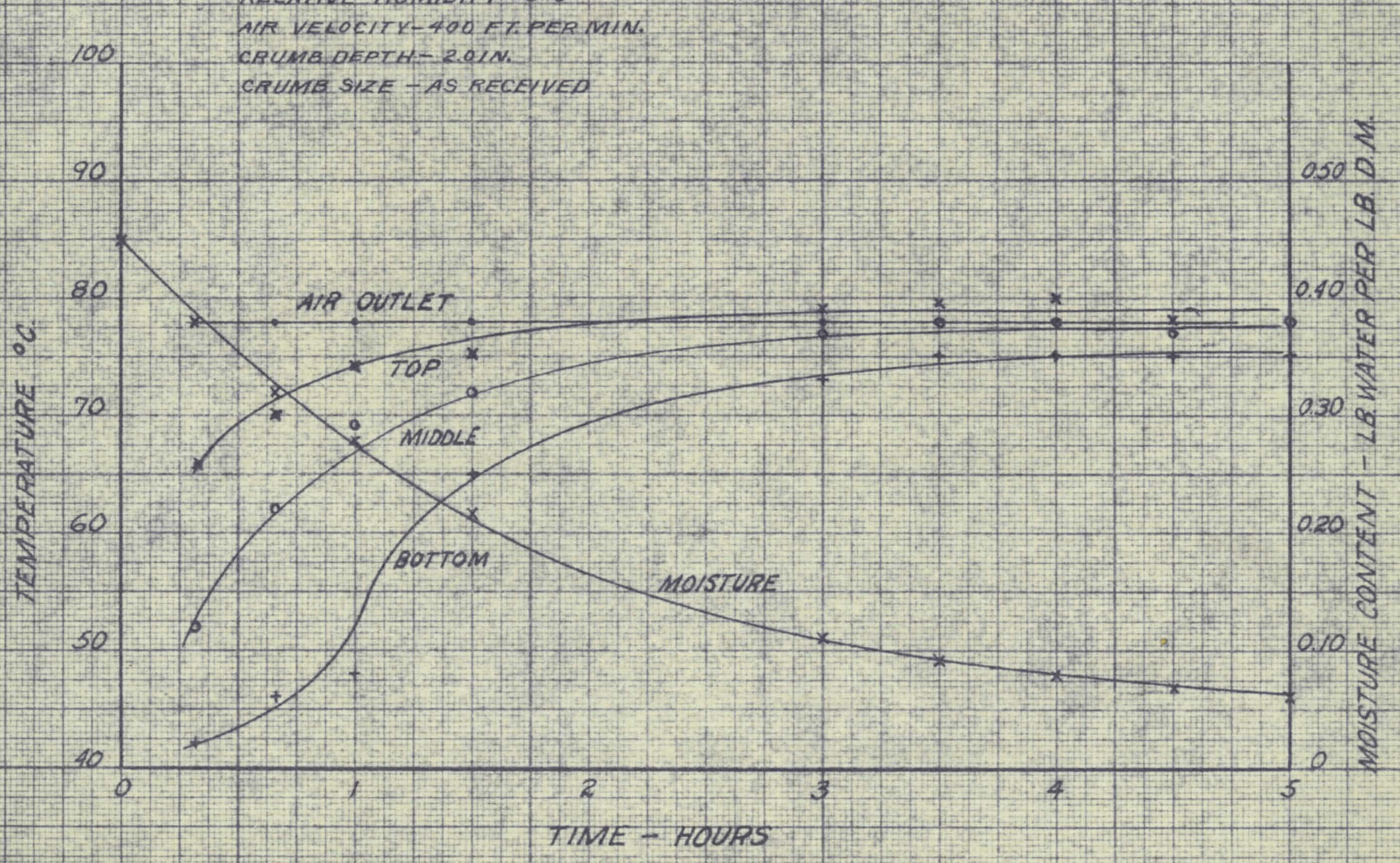


FIG. 38 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

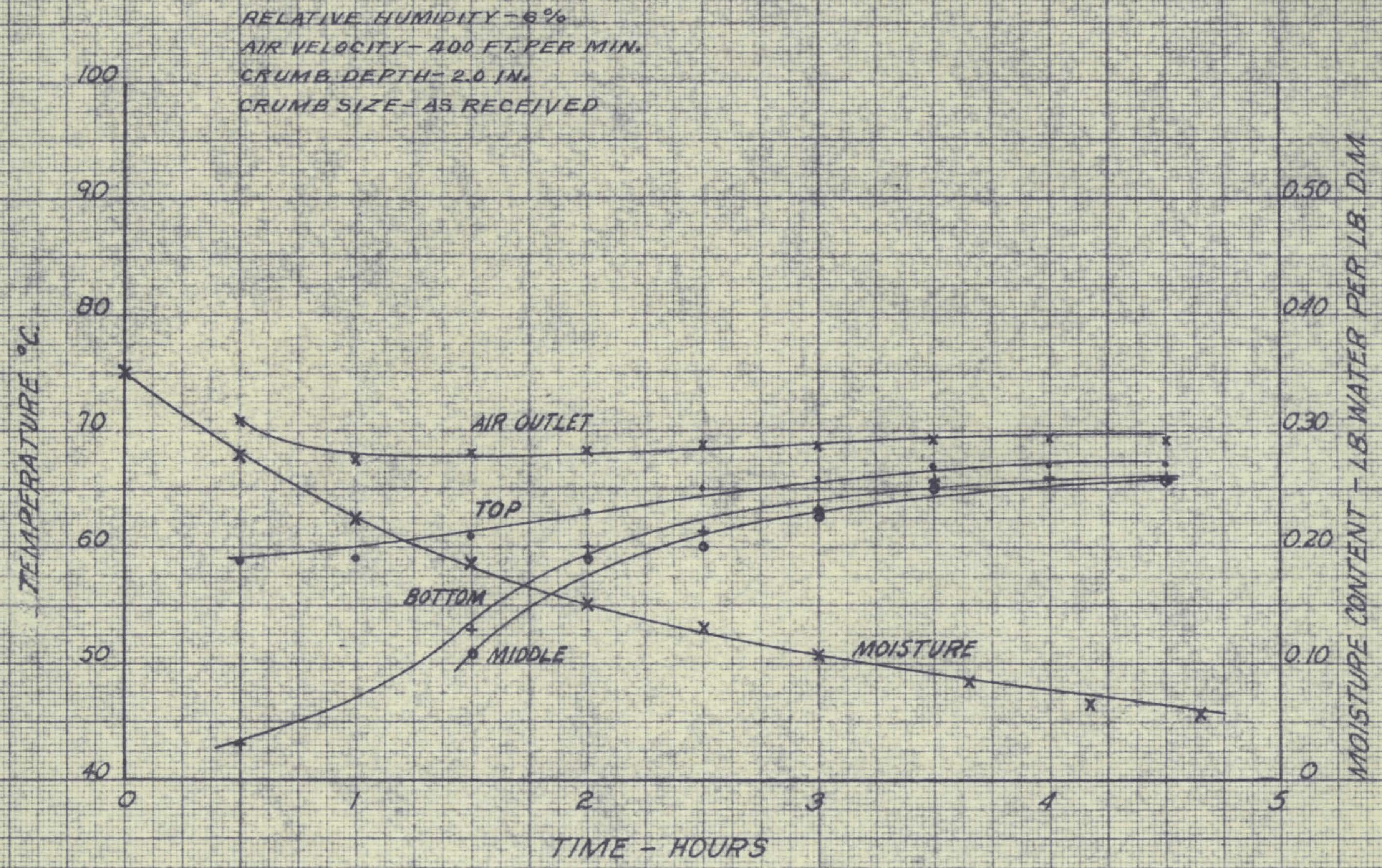


FIG. 39 MOISTURE CONTENT - TEMPERATURE - TIME CURVES.

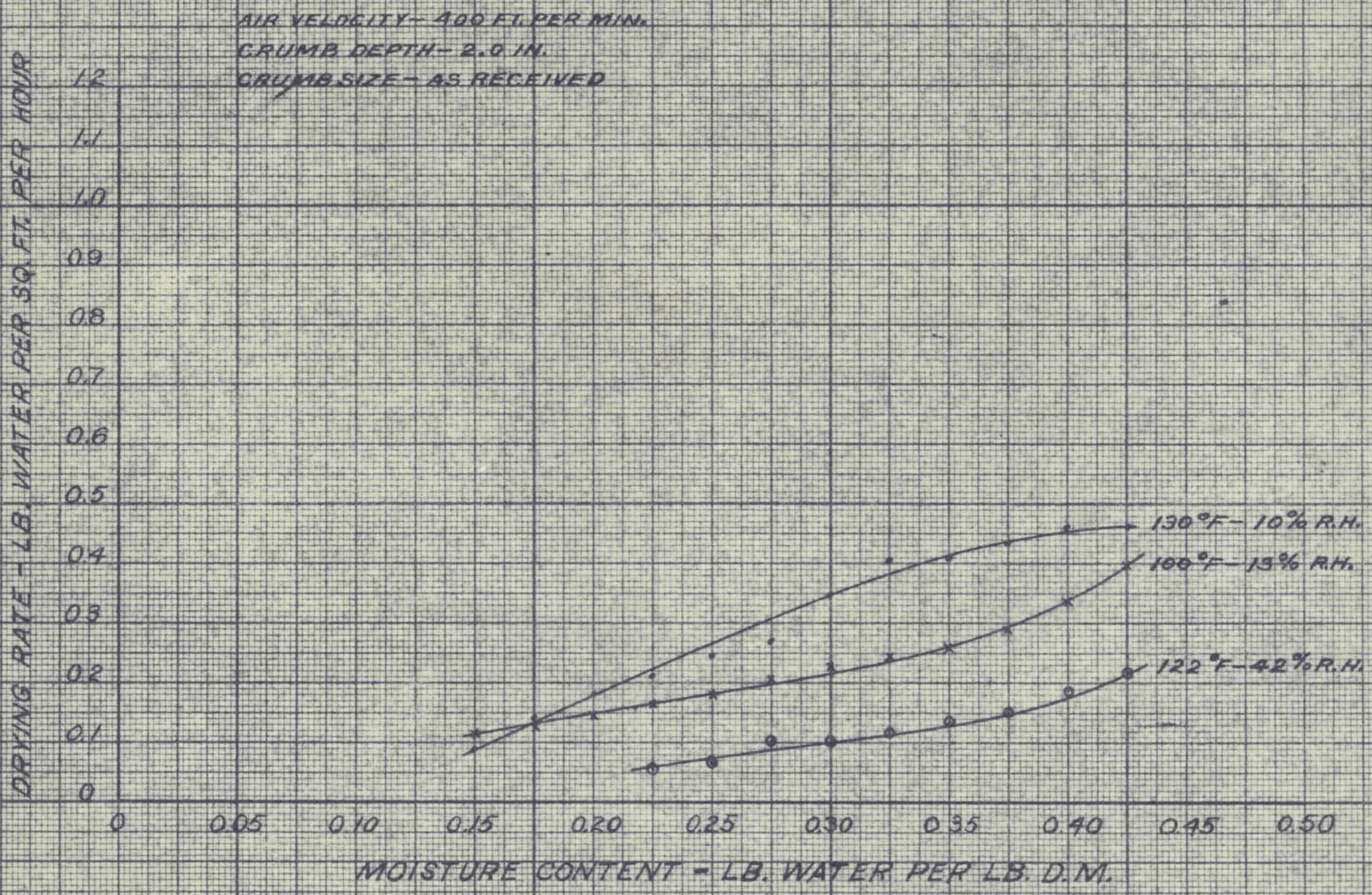


FIG. 40 DRYING RATE CURVES
EFFECT OF TEMPERATURE AND HUMIDITY

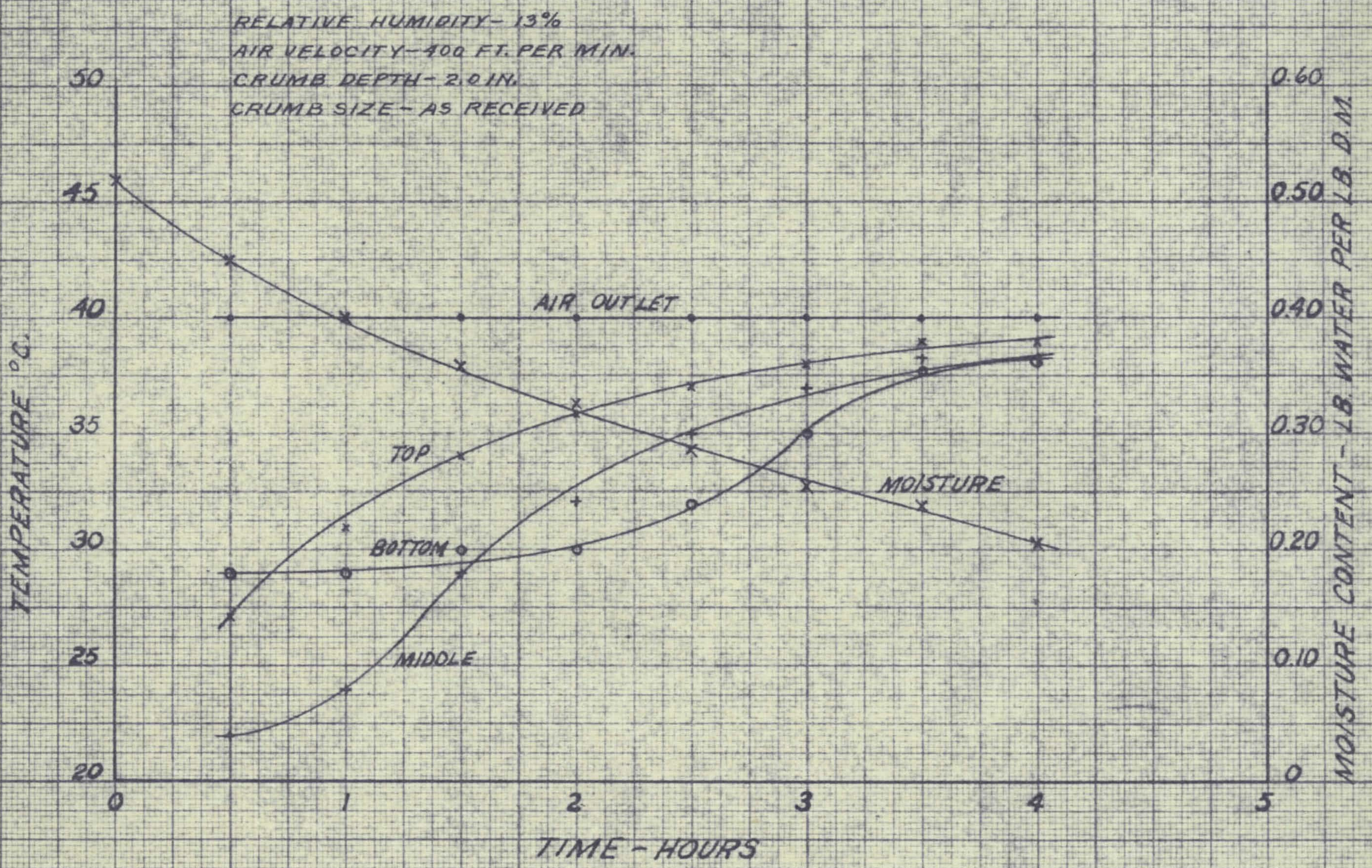


FIG. 41 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

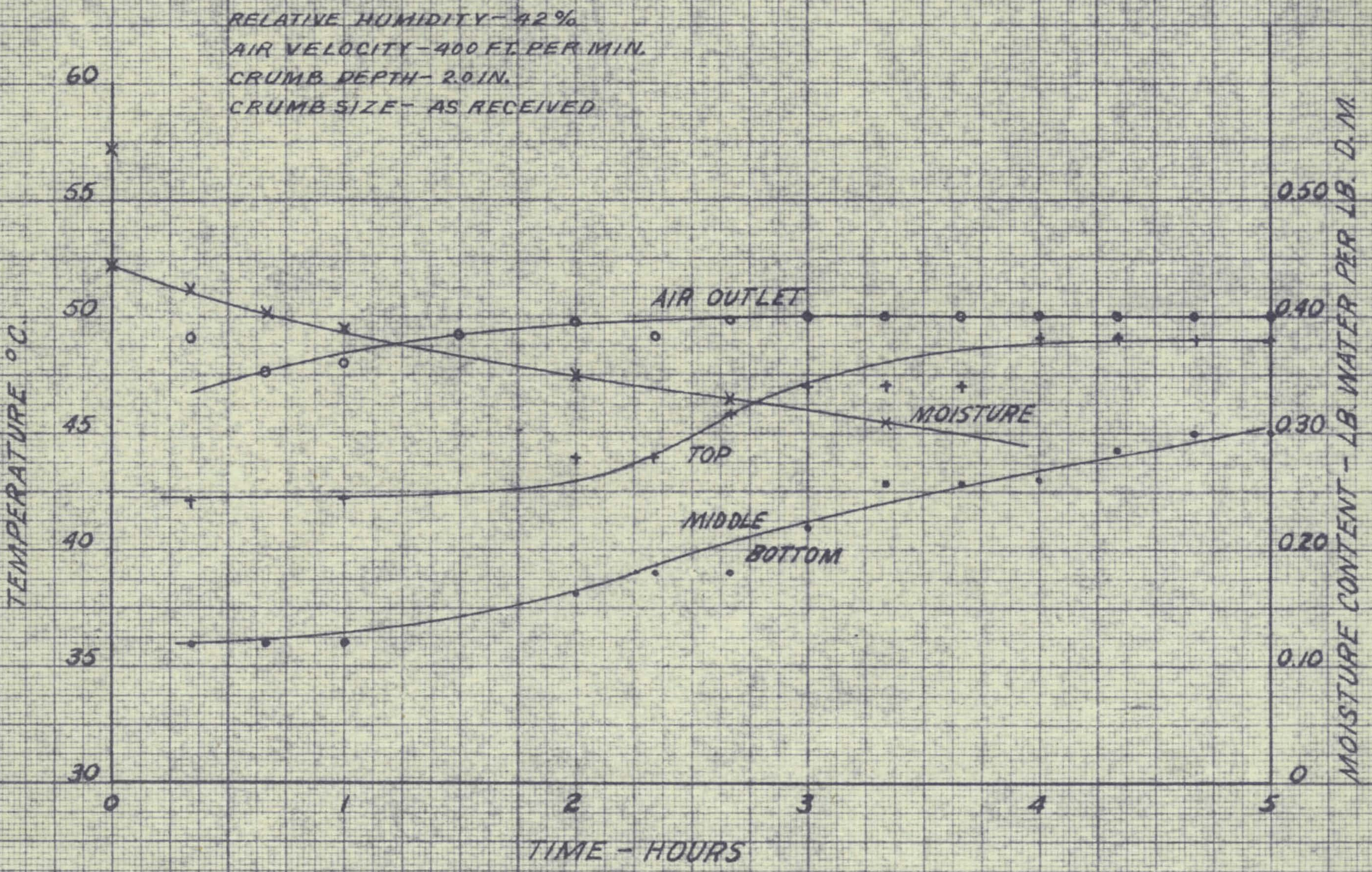


FIG. 42 MOISTURE CONTENT – TEMPERATURE – TIME CURVES

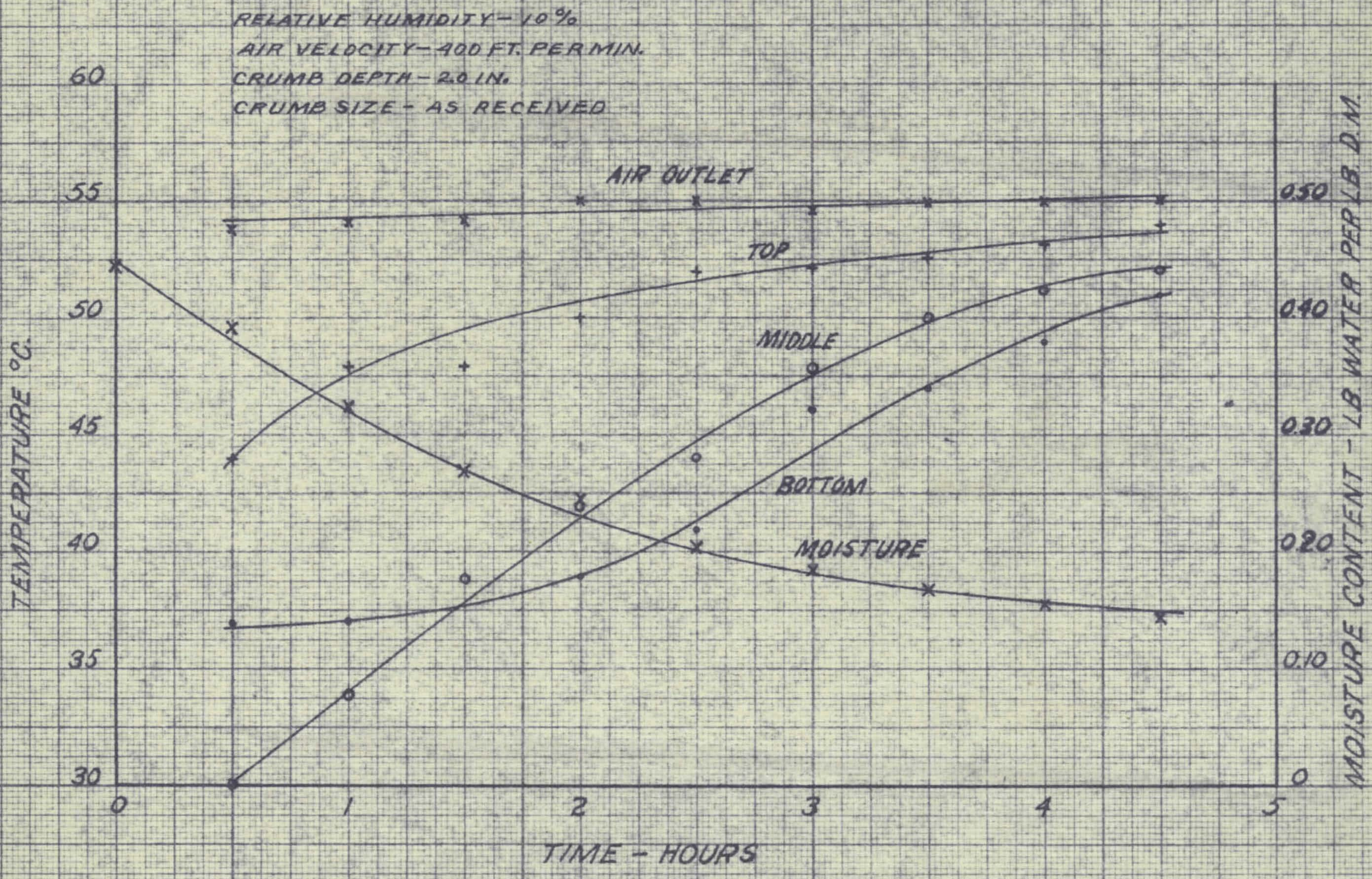


FIG. 43 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

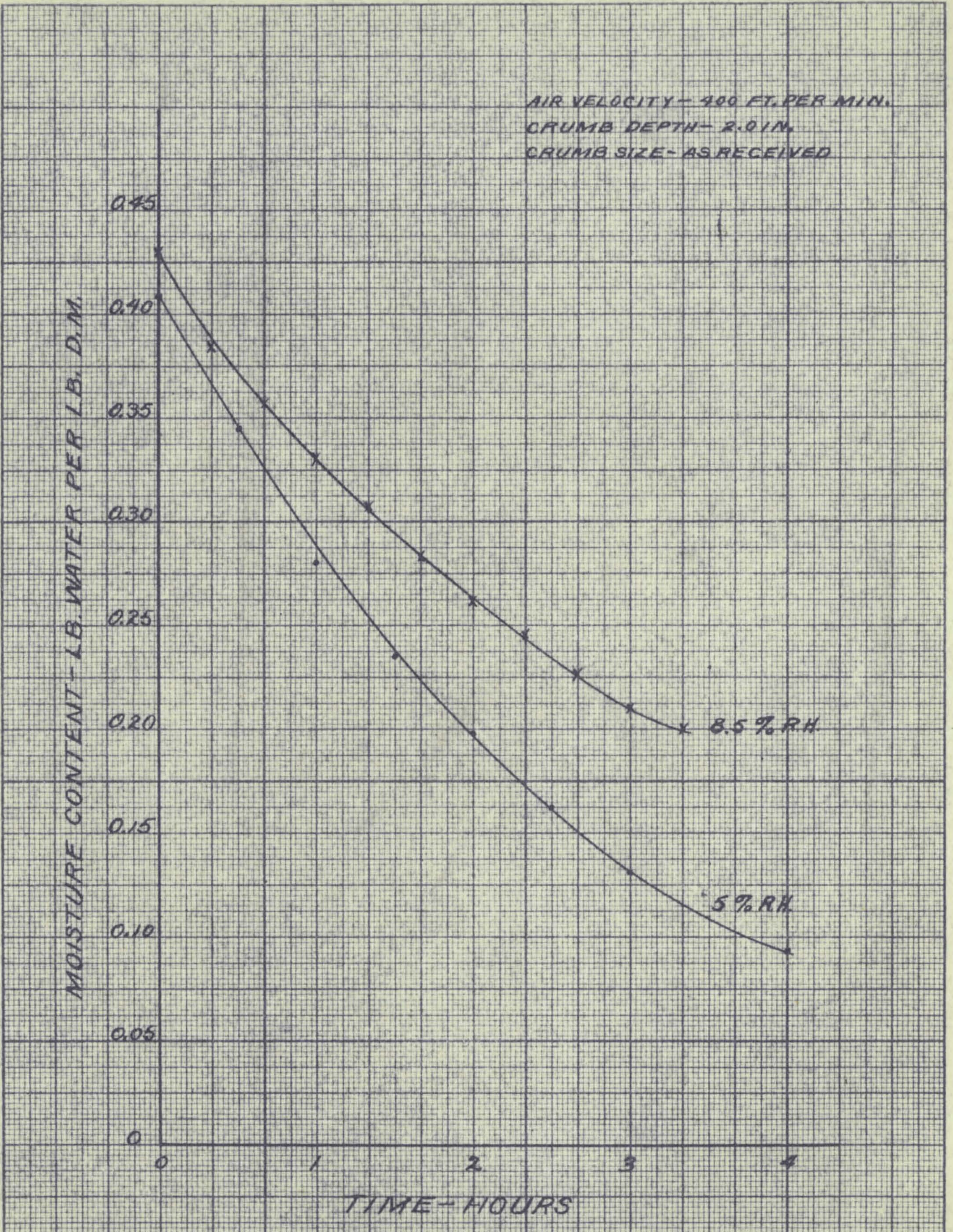


FIG. 44 MOISTURE CONTENT — TIME CURVES
EFFECT OF HUMIDITY AT 165 °F.

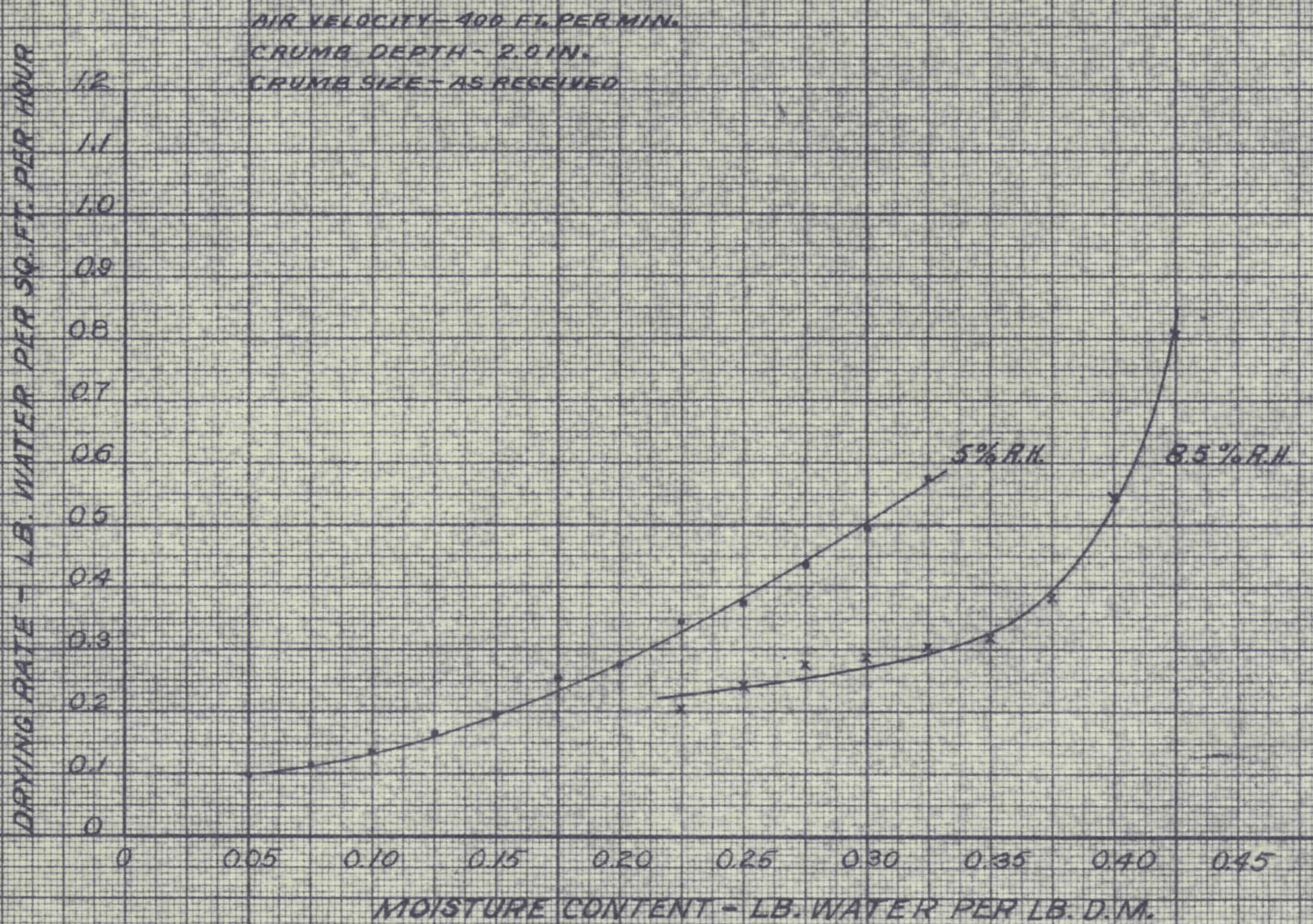


FIG. 45 DRYING RATE CURVES
EFFECT OF RELATIVE HUMIDITY AT 165 °F.

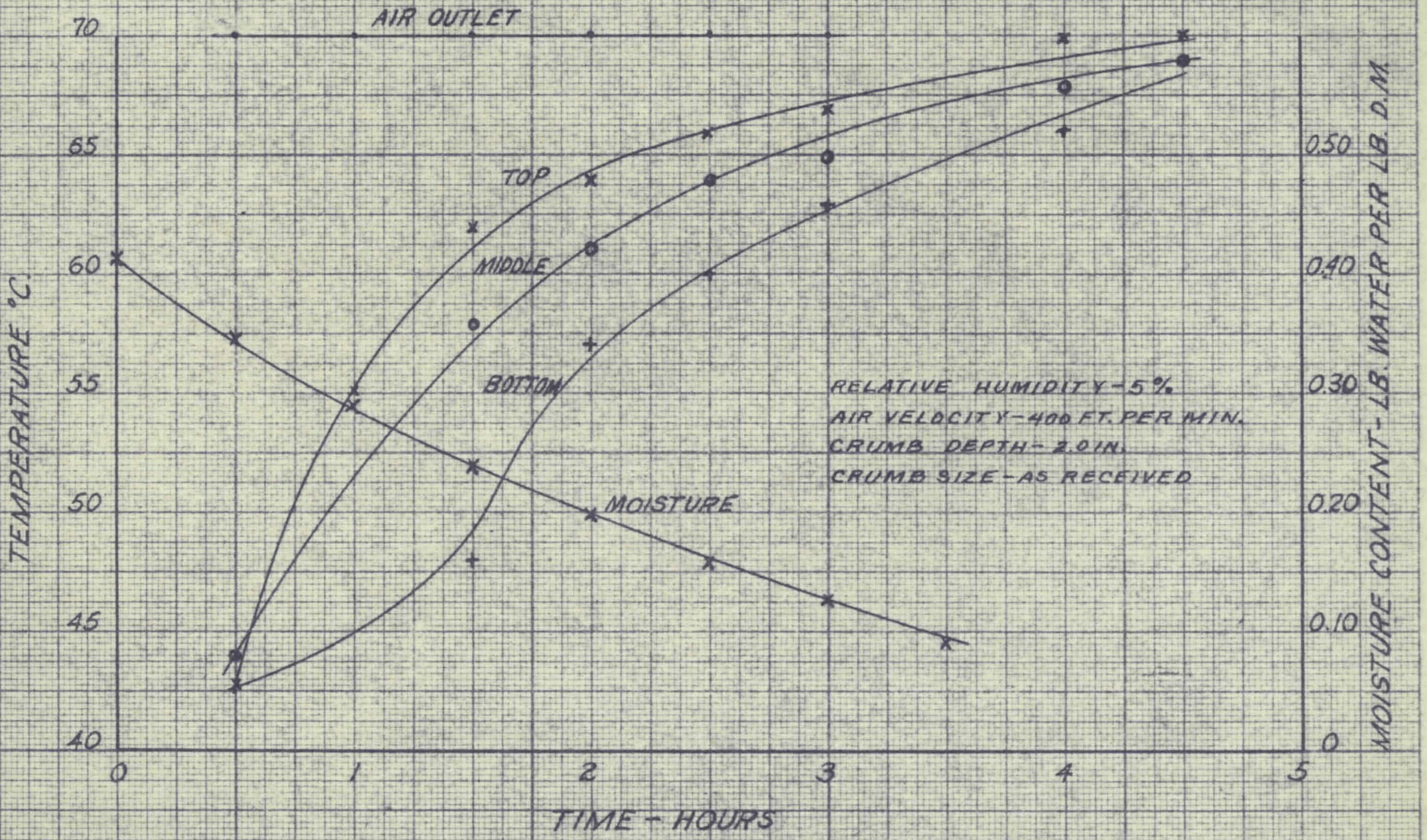


FIG. 46 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

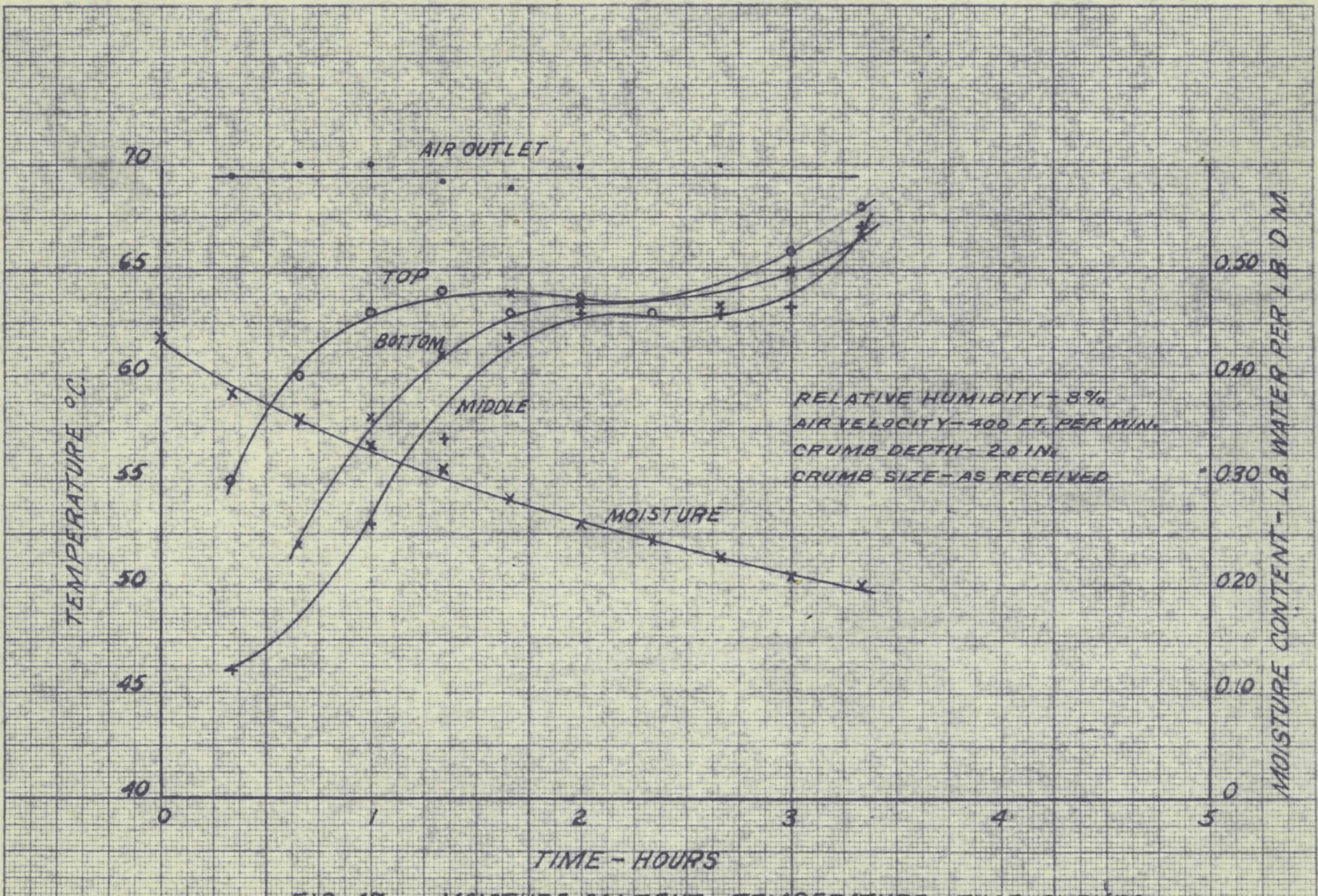


FIG. 47 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

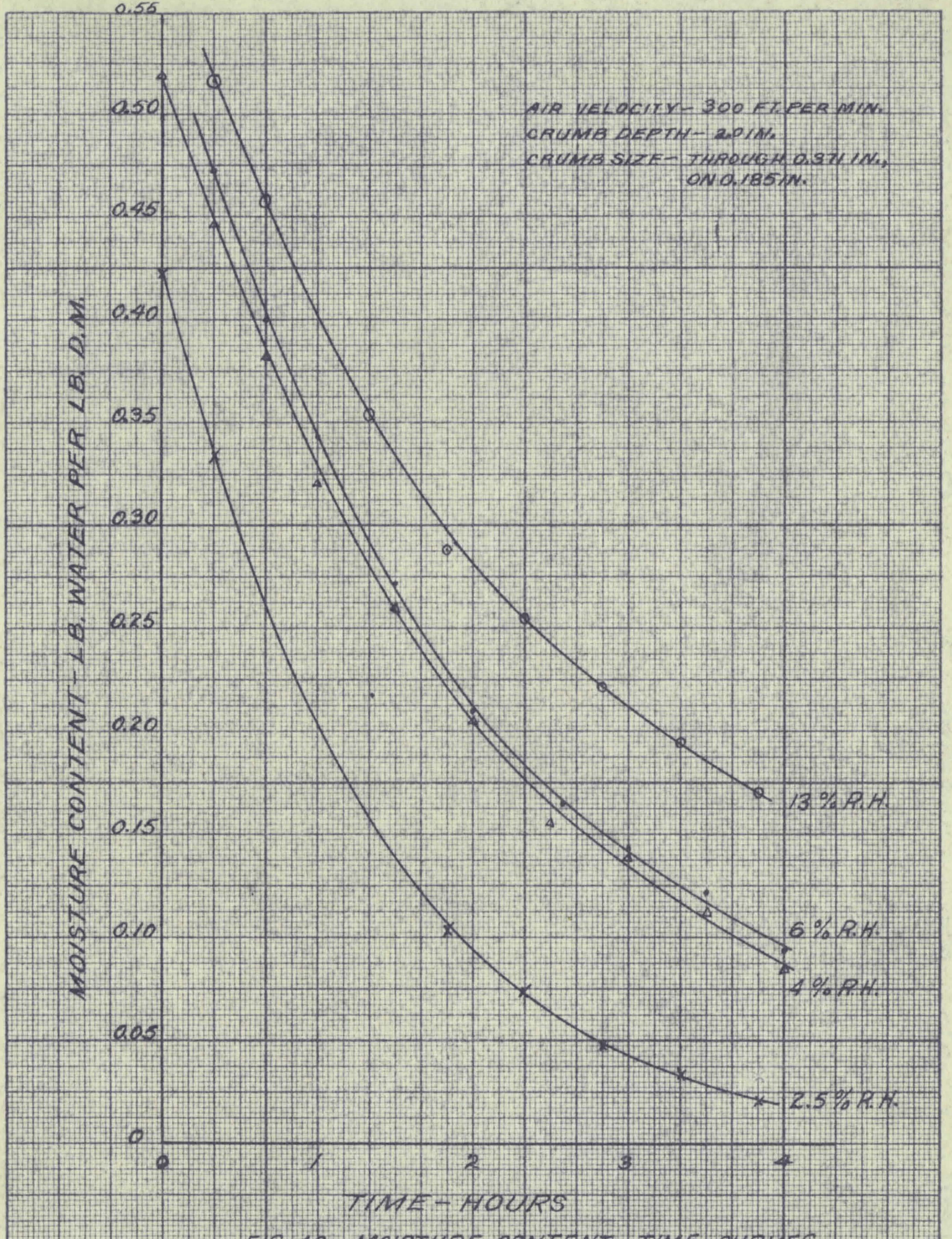


FIG. 48 MOISTURE CONTENT – TIME CURVES
EFFECT OF RELATIVE HUMIDITY AT 188 °F.

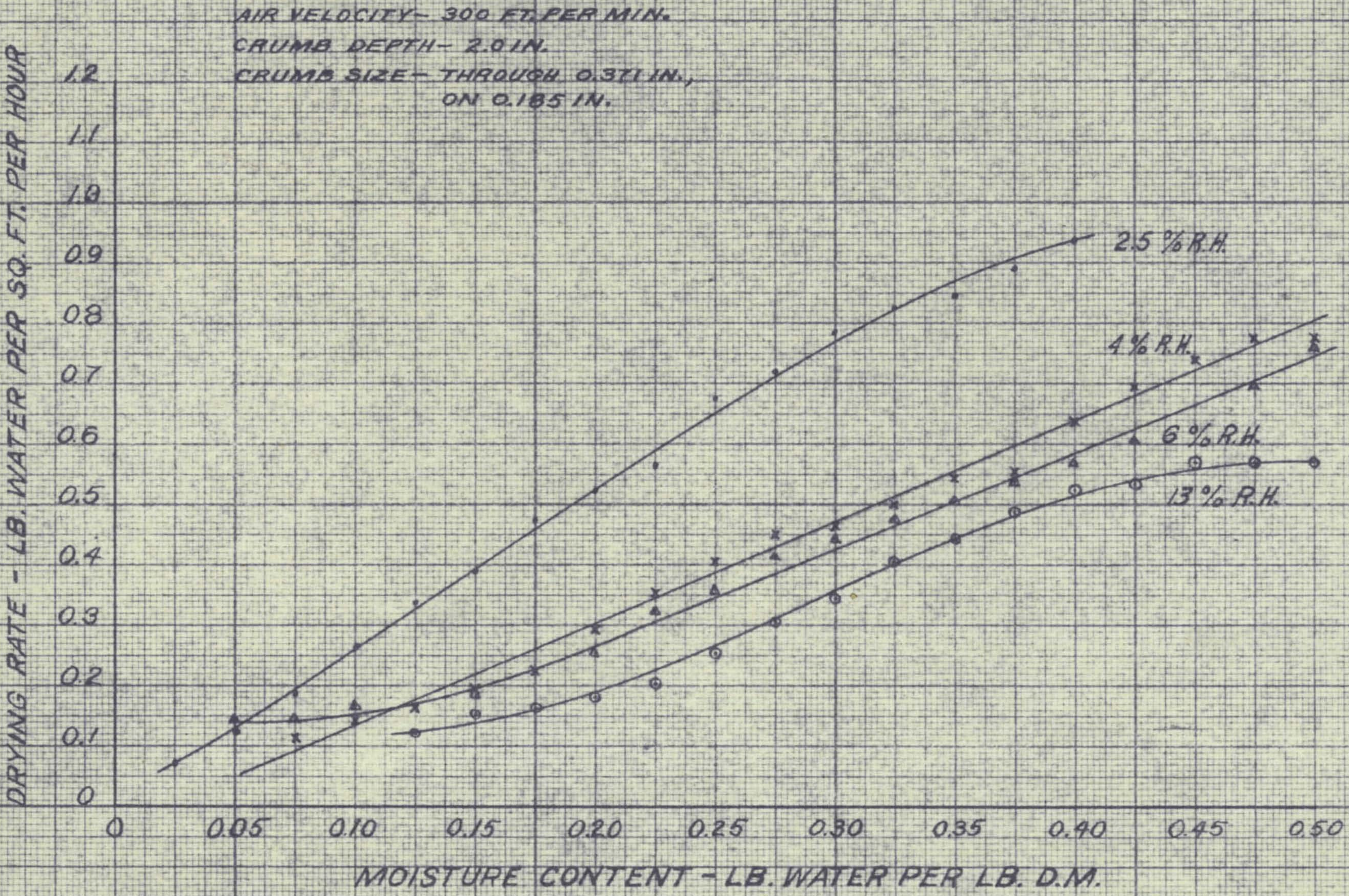


FIG. 49 DRYING RATE CURVES
EFFECT OF RELATIVE HUMIDITY AT 188°F.

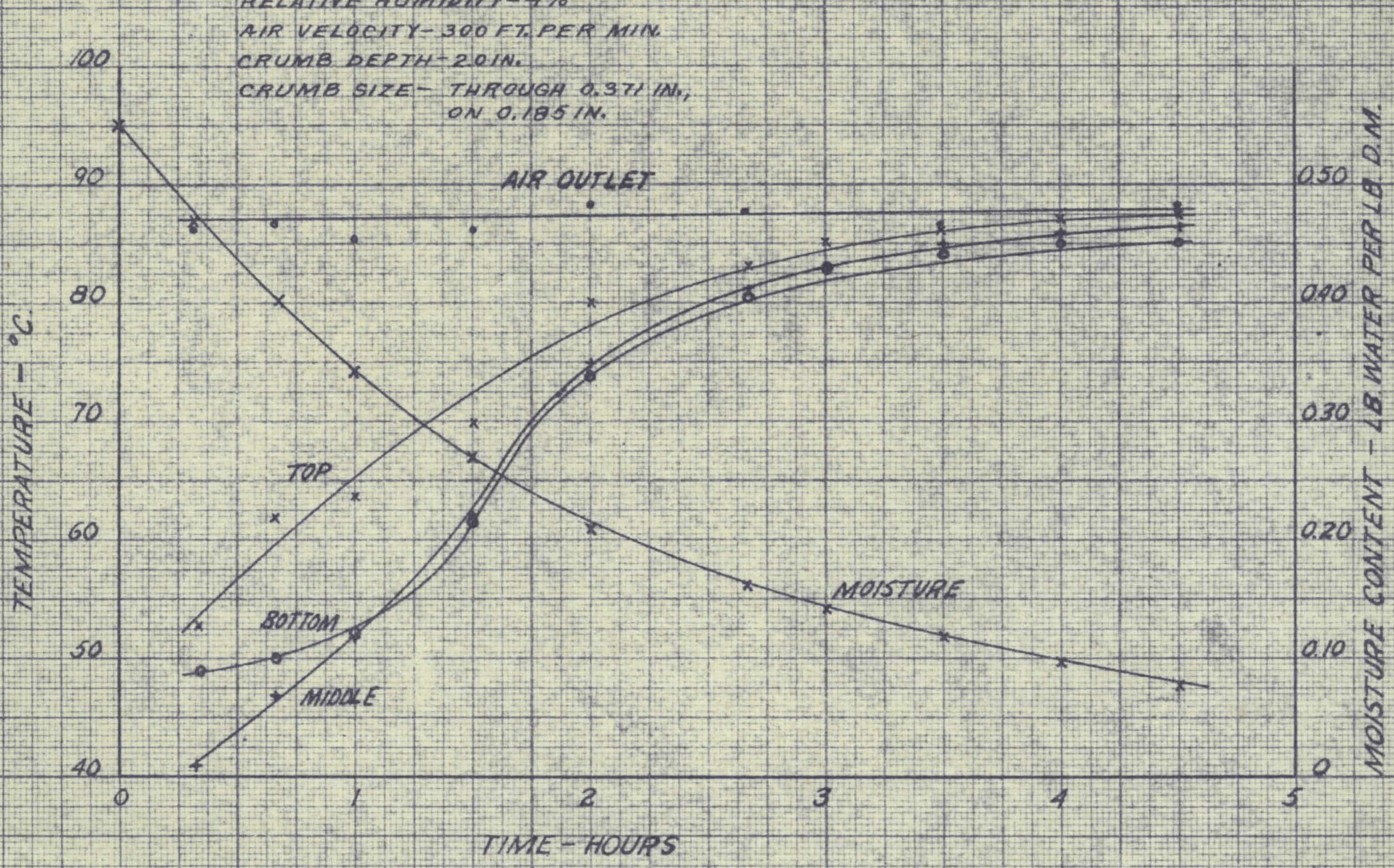


FIG. 50 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

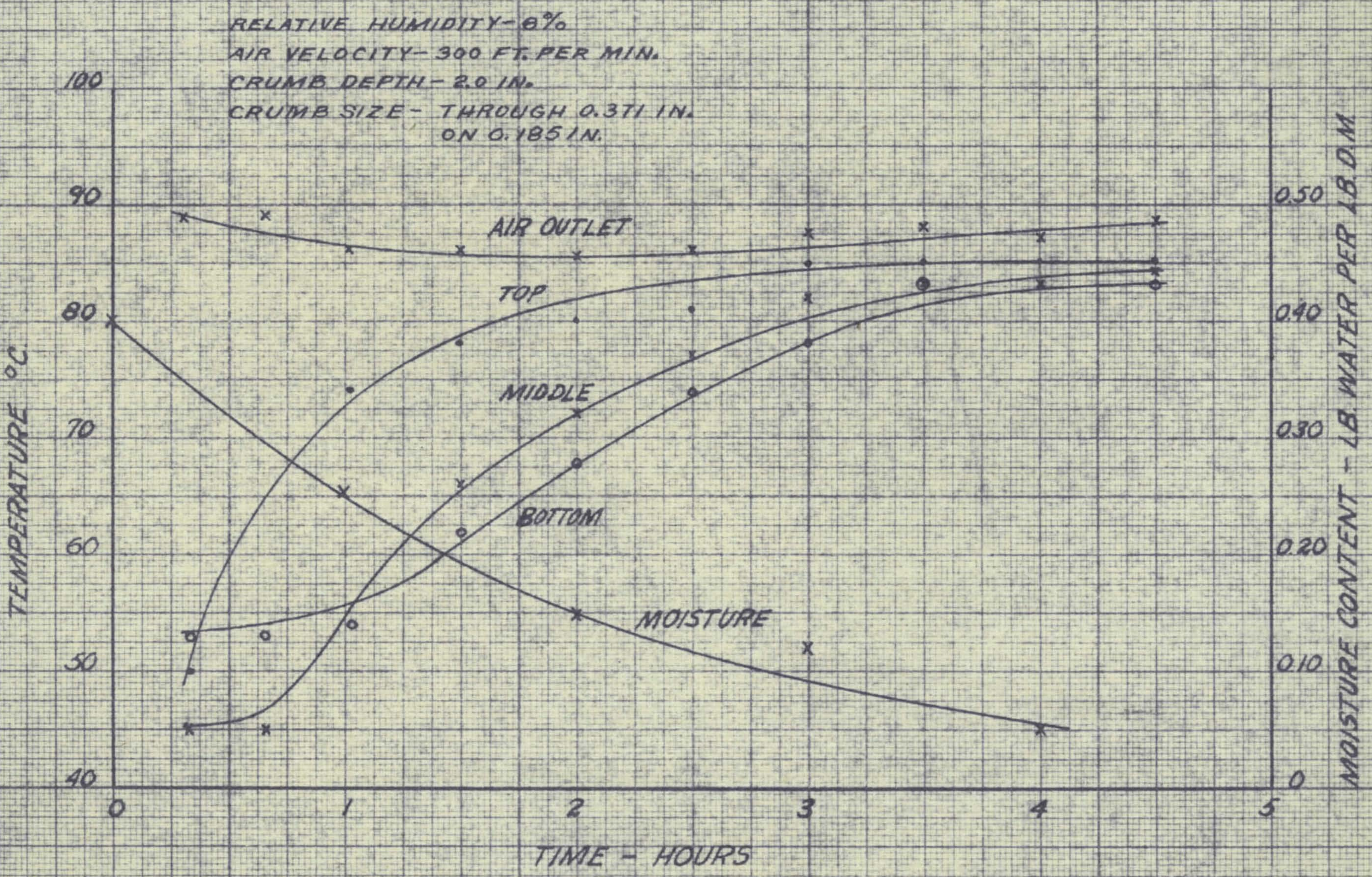


FIG. 51 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

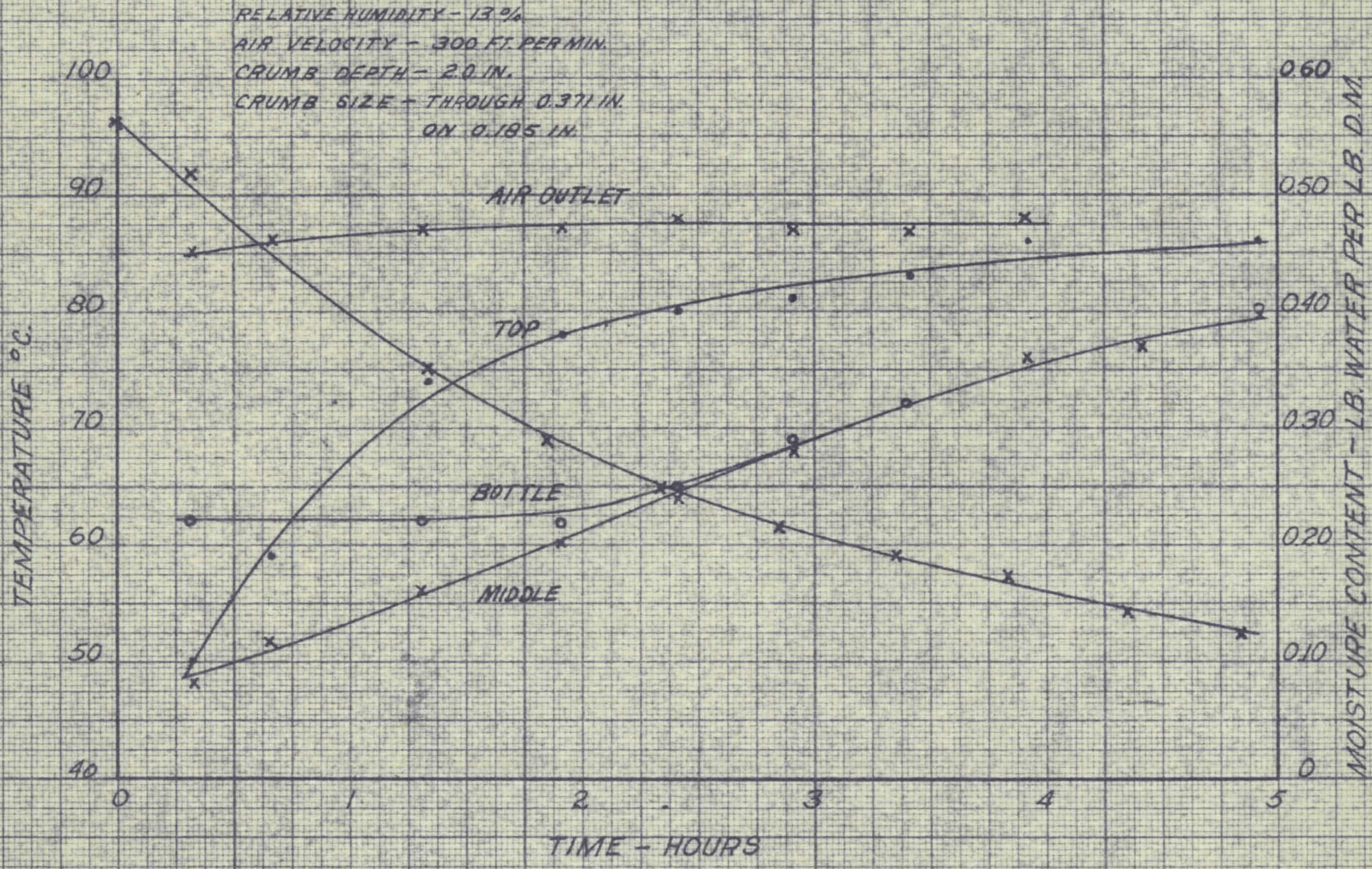


FIG. 52 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

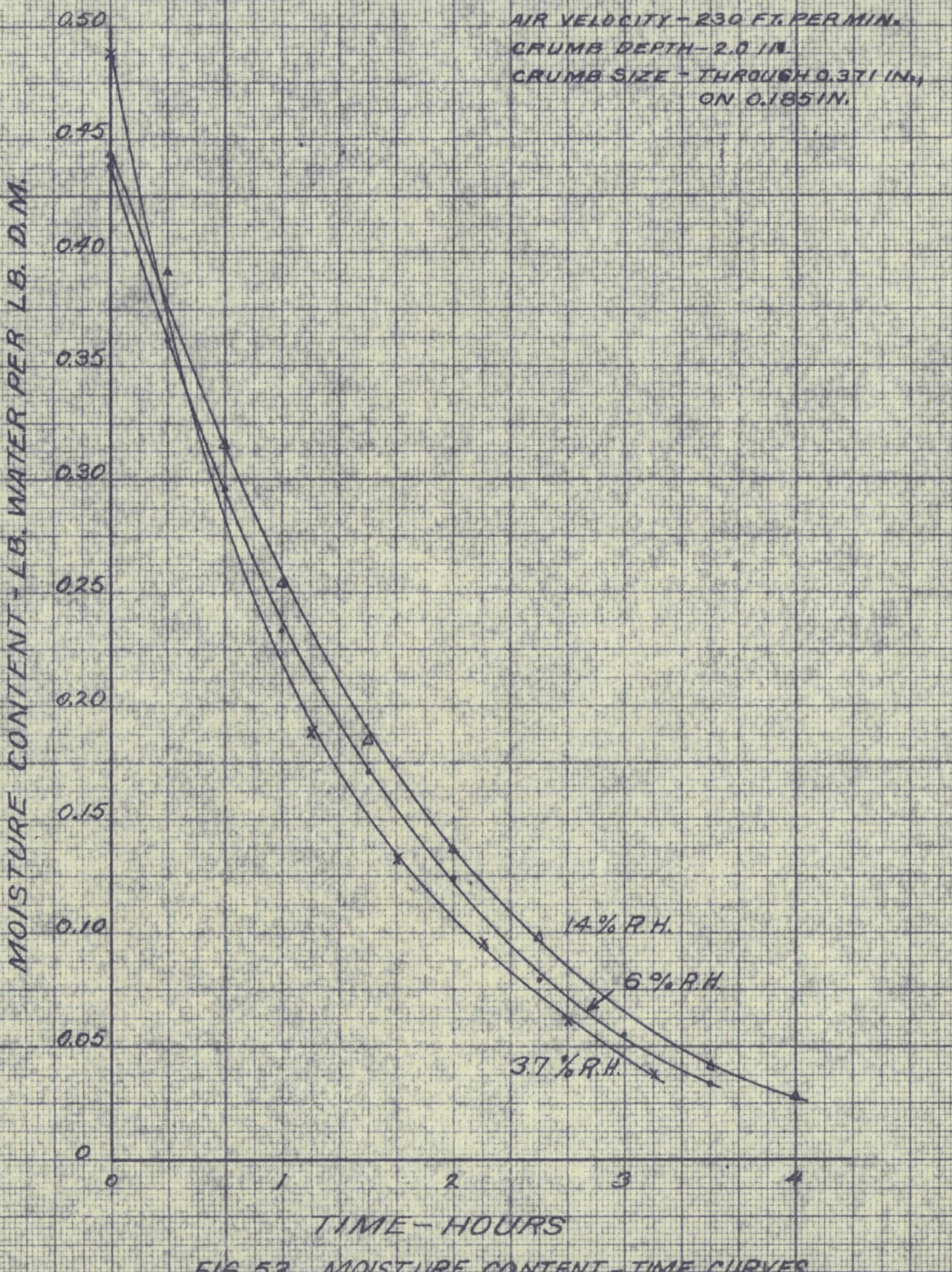


FIG. 53 MOISTURE CONTENT–TIME CURVES
EFFECT OF RELATIVE HUMIDITY AT 212°F.

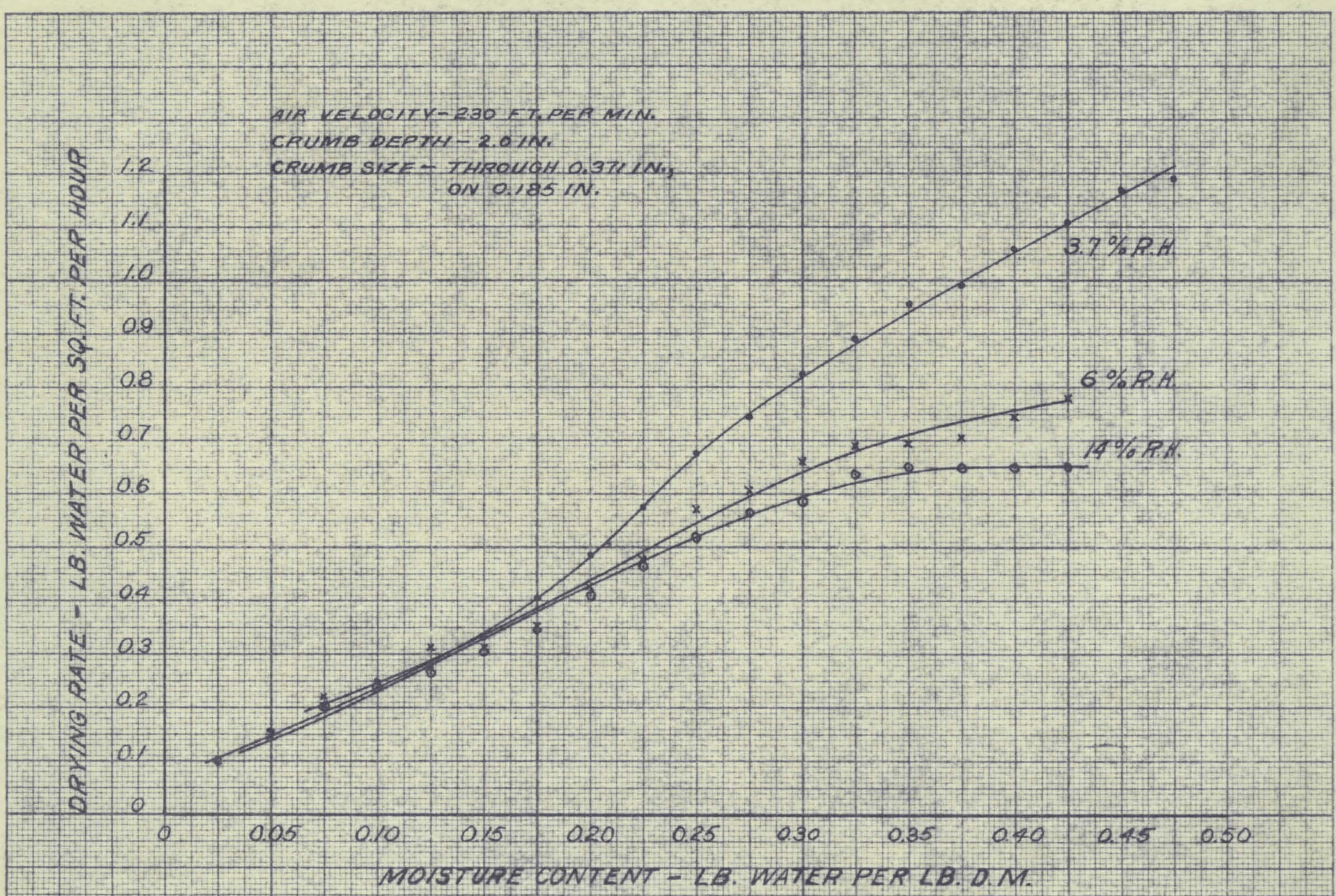


FIG. 54 DRYING RATE CURVES
EFFECT OF RELATIVE HUMIDITY AT 212°F.

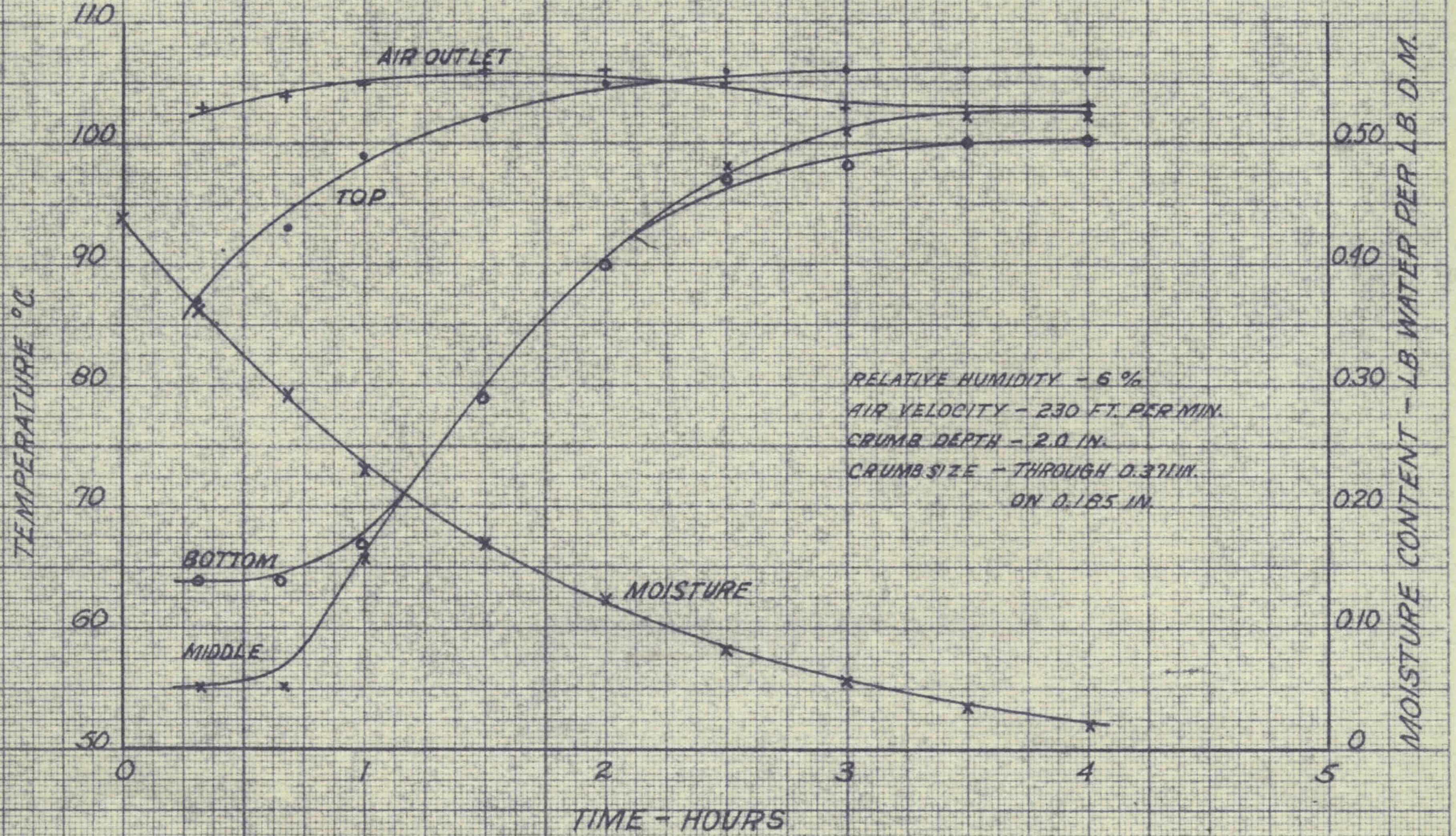


FIG. 55 MOISTURE CONTENT - TEMPERATURE - TIME CURVES

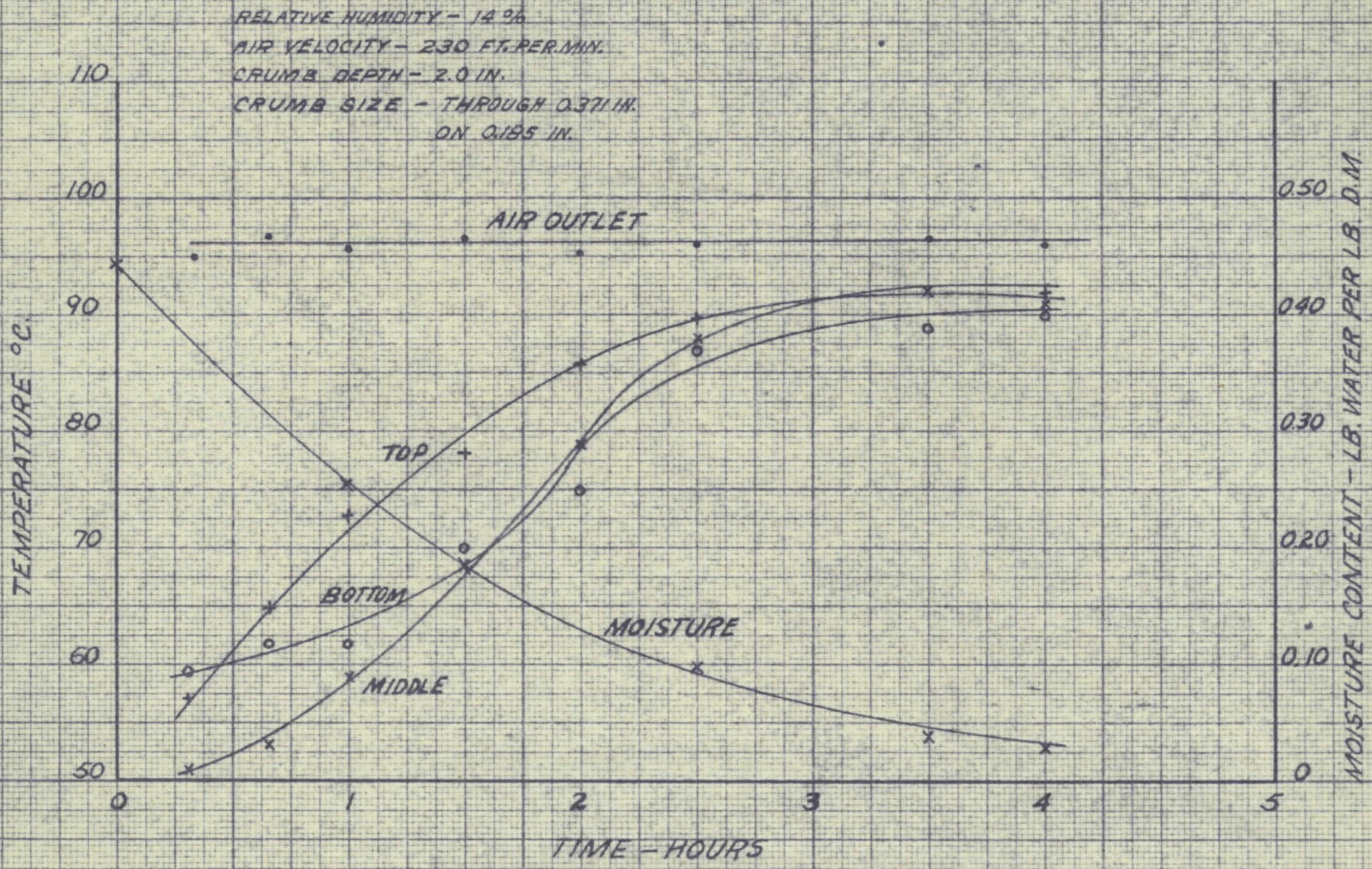


FIG. 56 MOISTURE CONTENT – TEMPERATURE – TIME CURVES

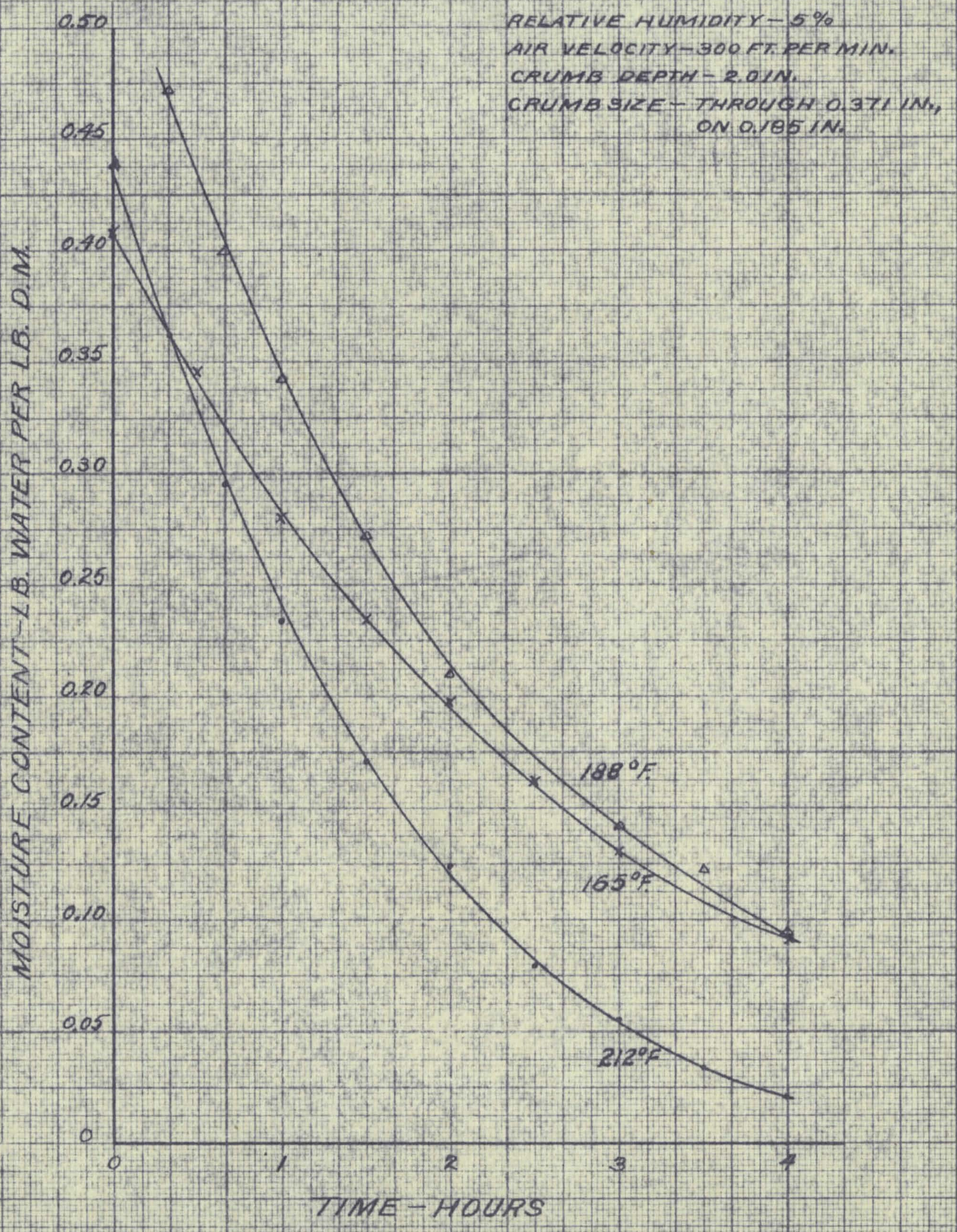


FIG. 57 MOISTURE CONTENT — TIME CURVES
EFFECT OF TEMPERATURE

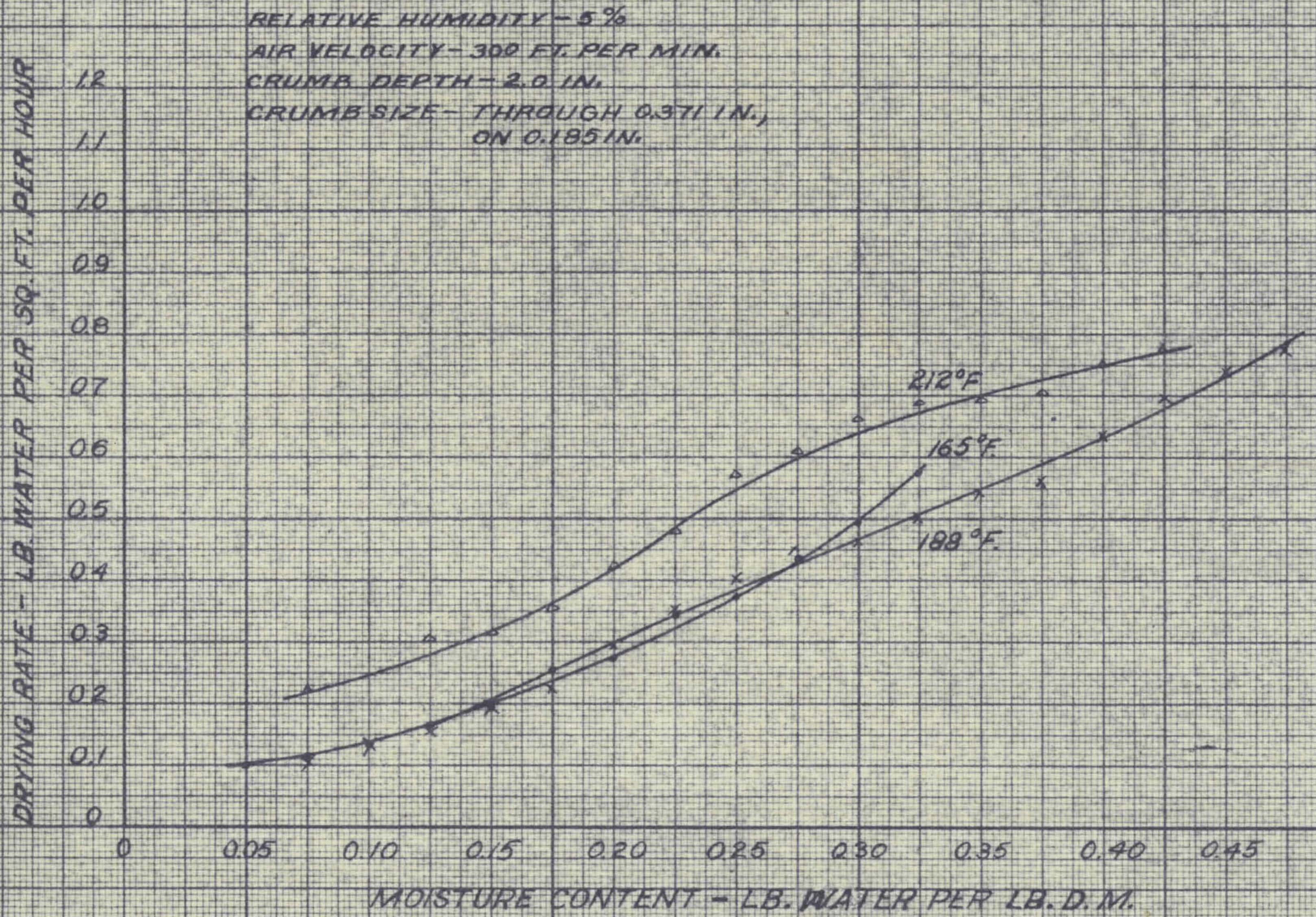


FIG. 58 DRYING RATE CURVES
EFFECT OF TEMPERATURE

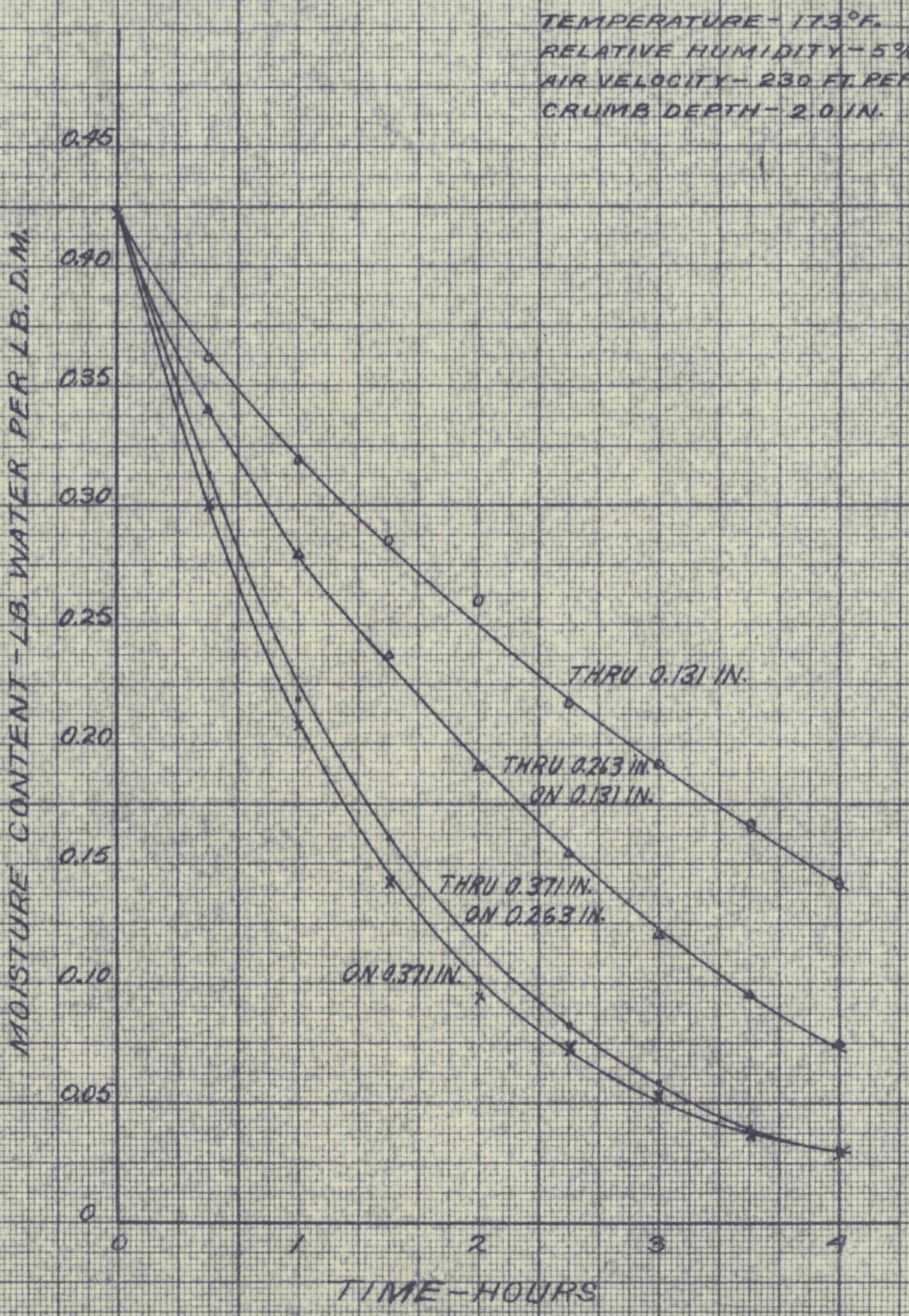


FIG. 59 MOISTURE CONTENT - TIME CURVES
EFFECT OF PARTICLE SIZE

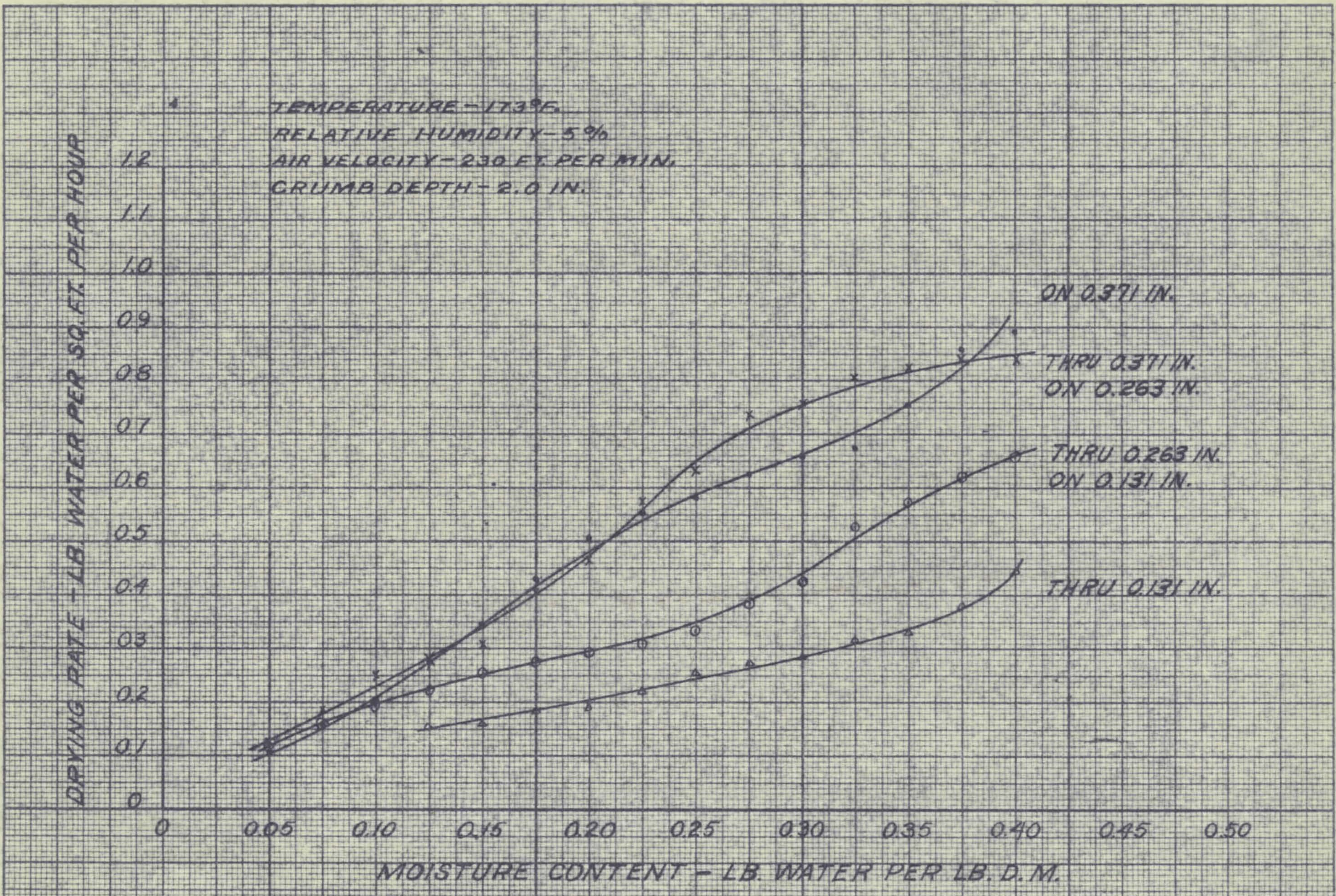


FIG. 60 DRYING RATE CURVES
EFFECT OF PARTICLE SIZE

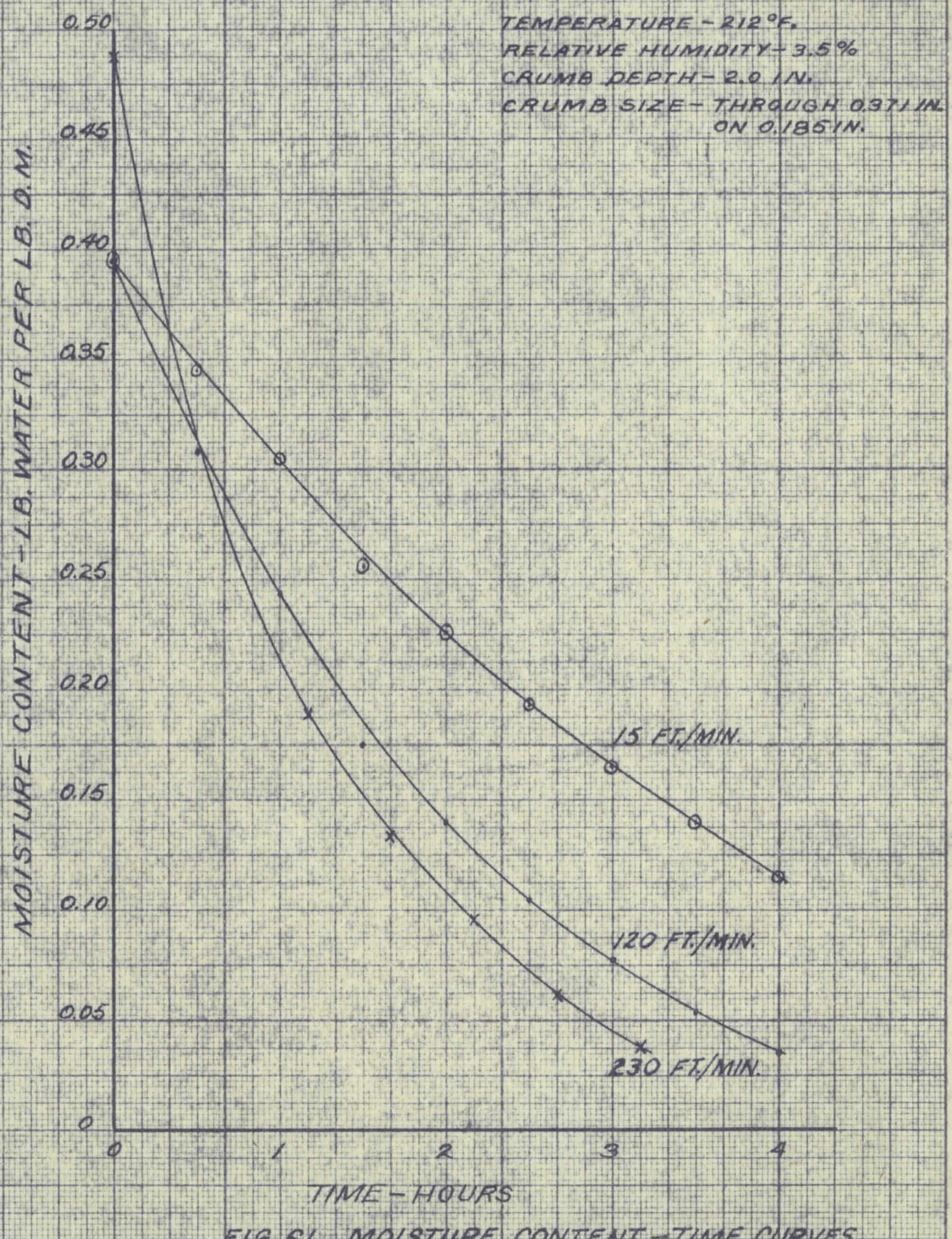


FIG. 61 MOISTURE CONTENT - TIME CURVES
EFFECT OF AIR VELOCITY

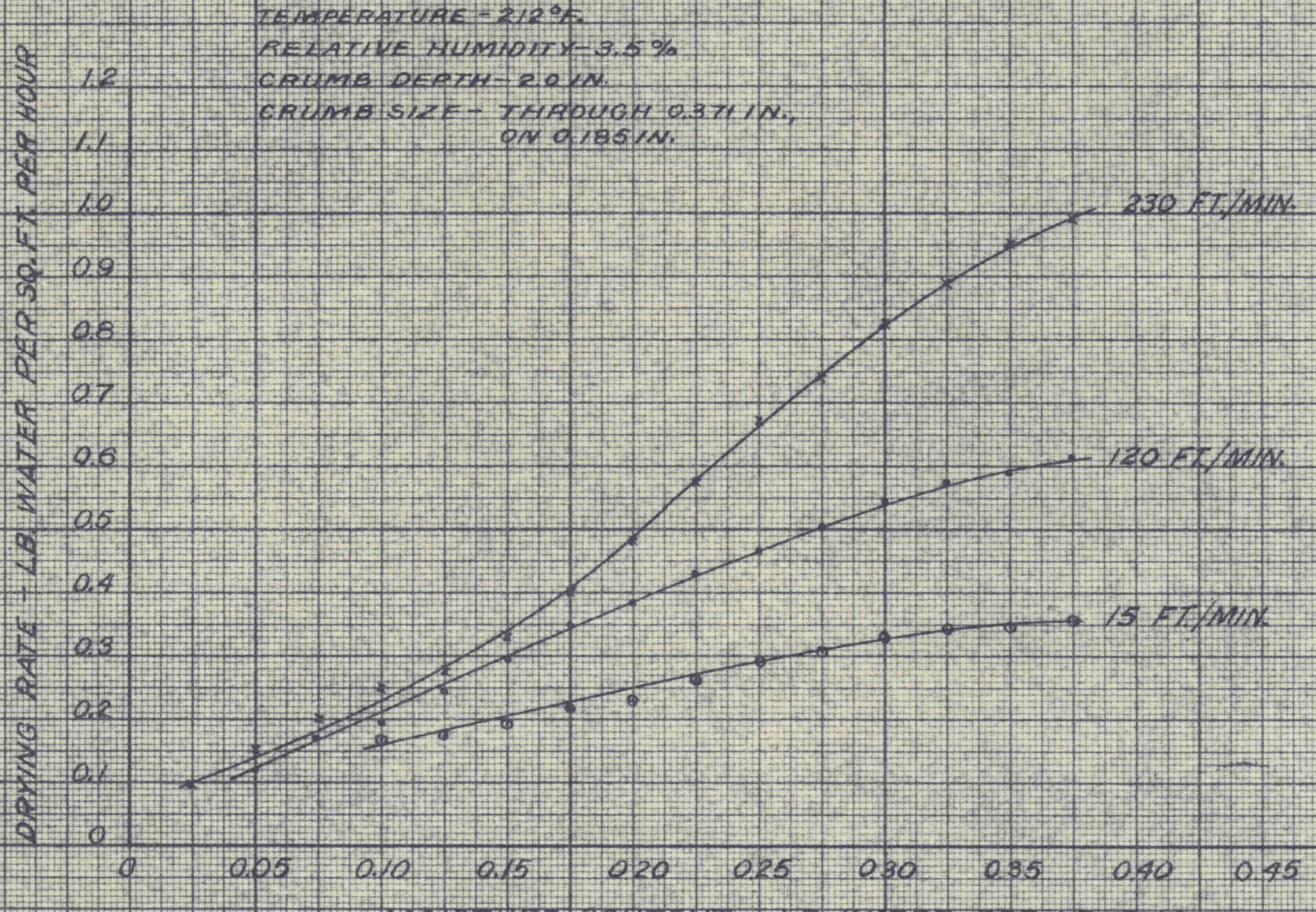


FIG. 62 DRYING RATE CURVES
EFFECT OF AIR VELOCITY

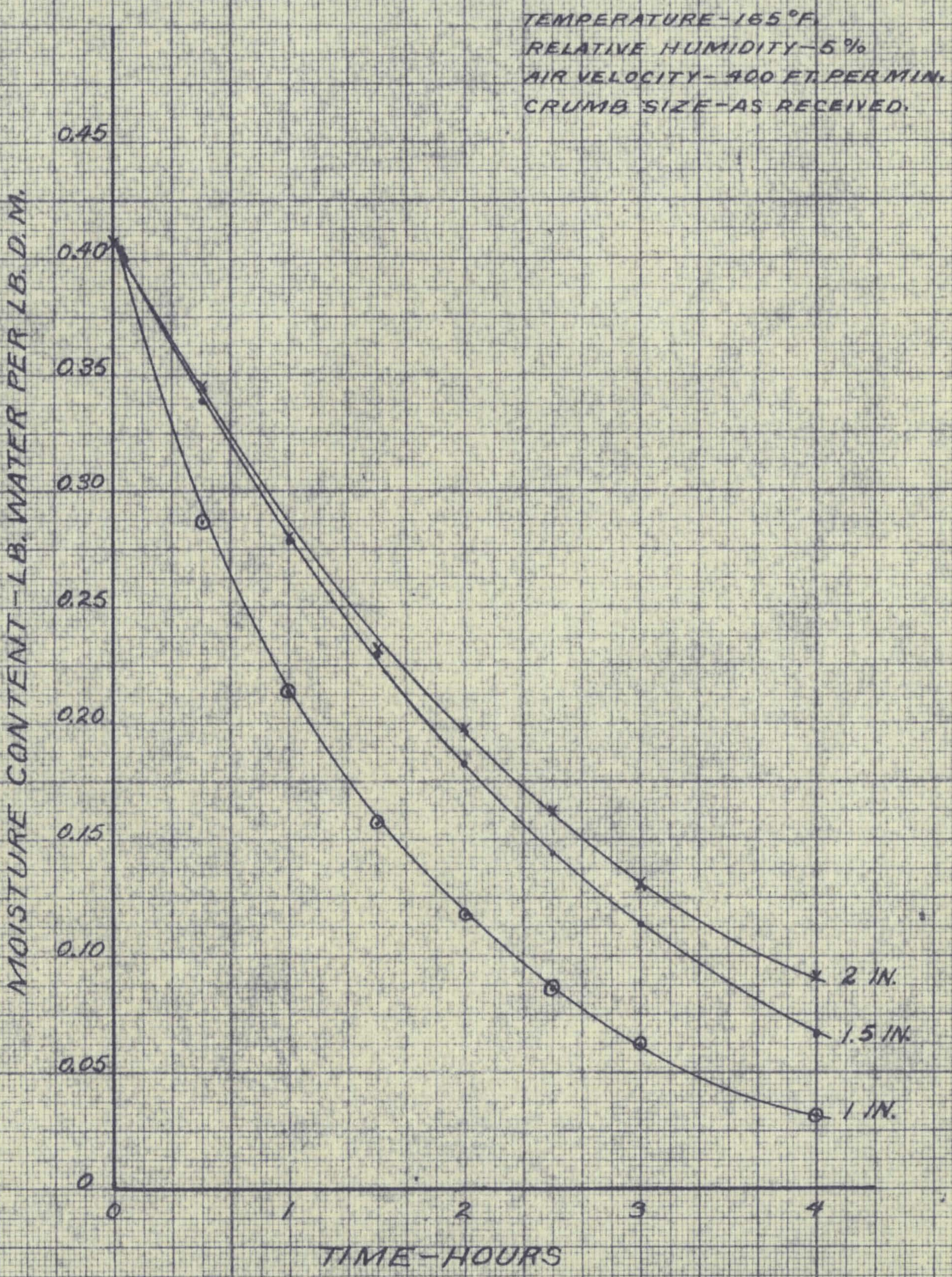


FIG. 63 MOISTURE CONTENT - TIME CURVES
EFFECT OF CRUMB DEPTH

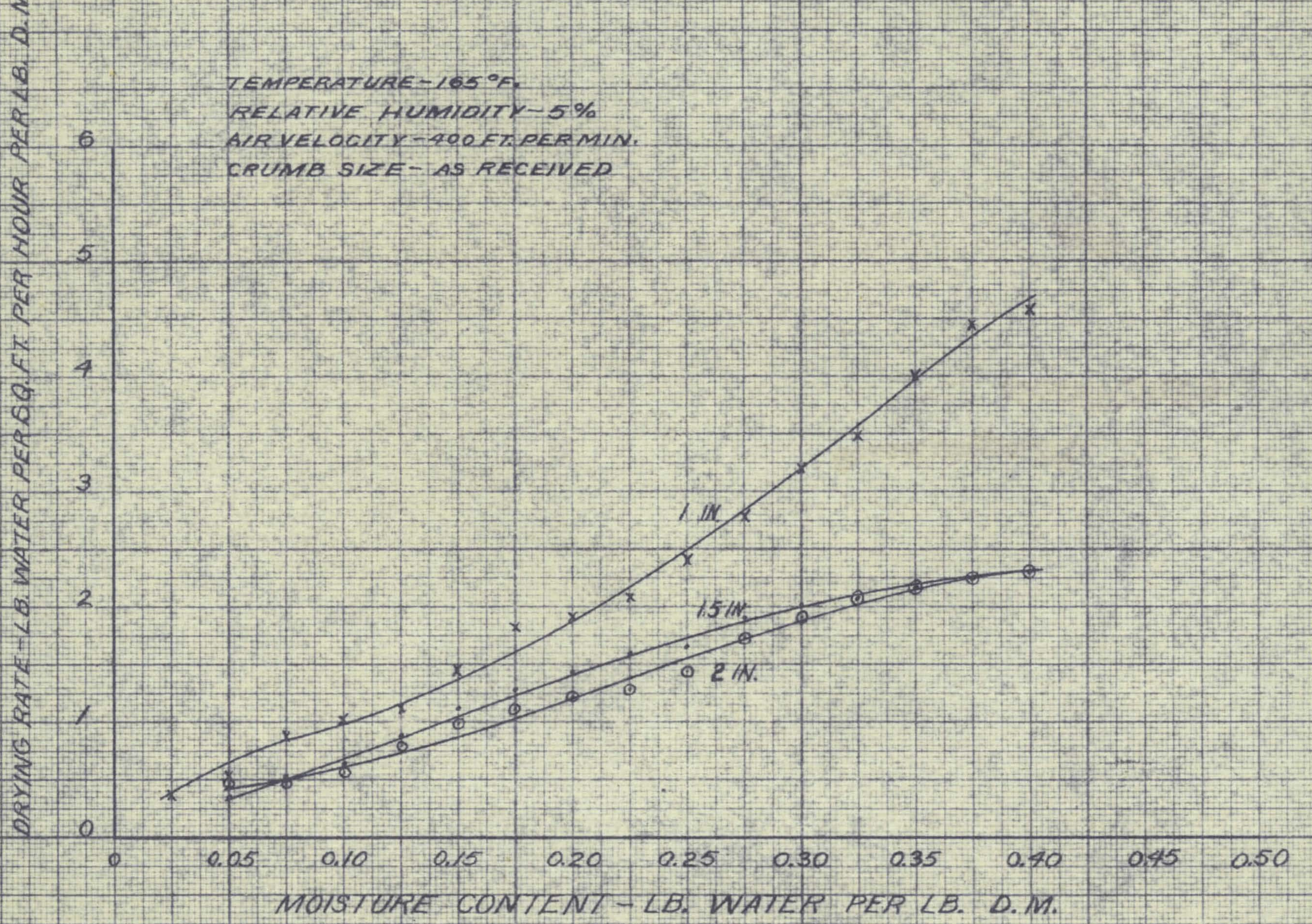


FIG. 64 DRYING RATE CURVES
EFFECT OF CRUMB DEPTH

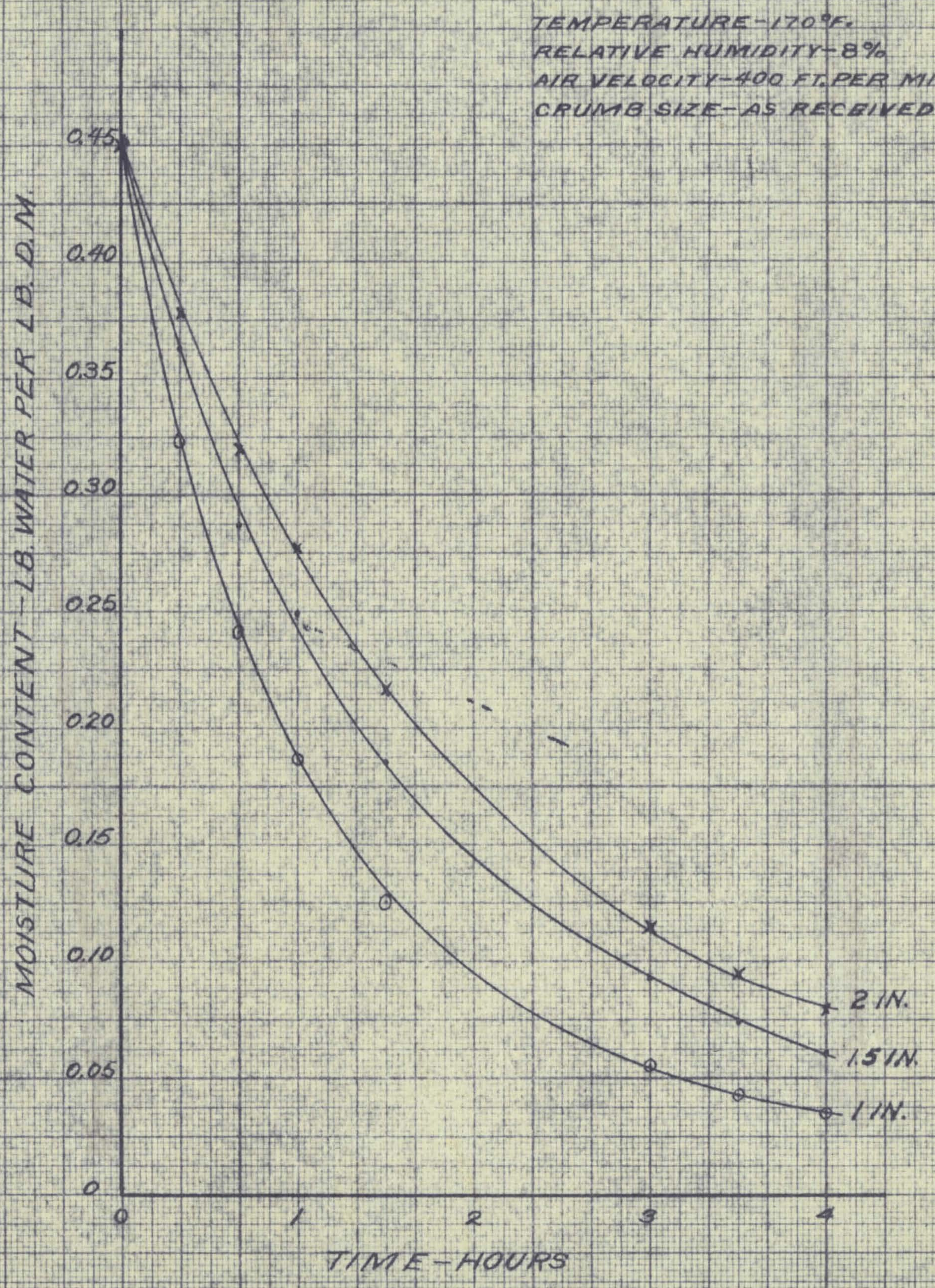


FIG. 65 MOISTURE CONTENT–TIME CURVES
EFFECT OF CRUMB DEPTH

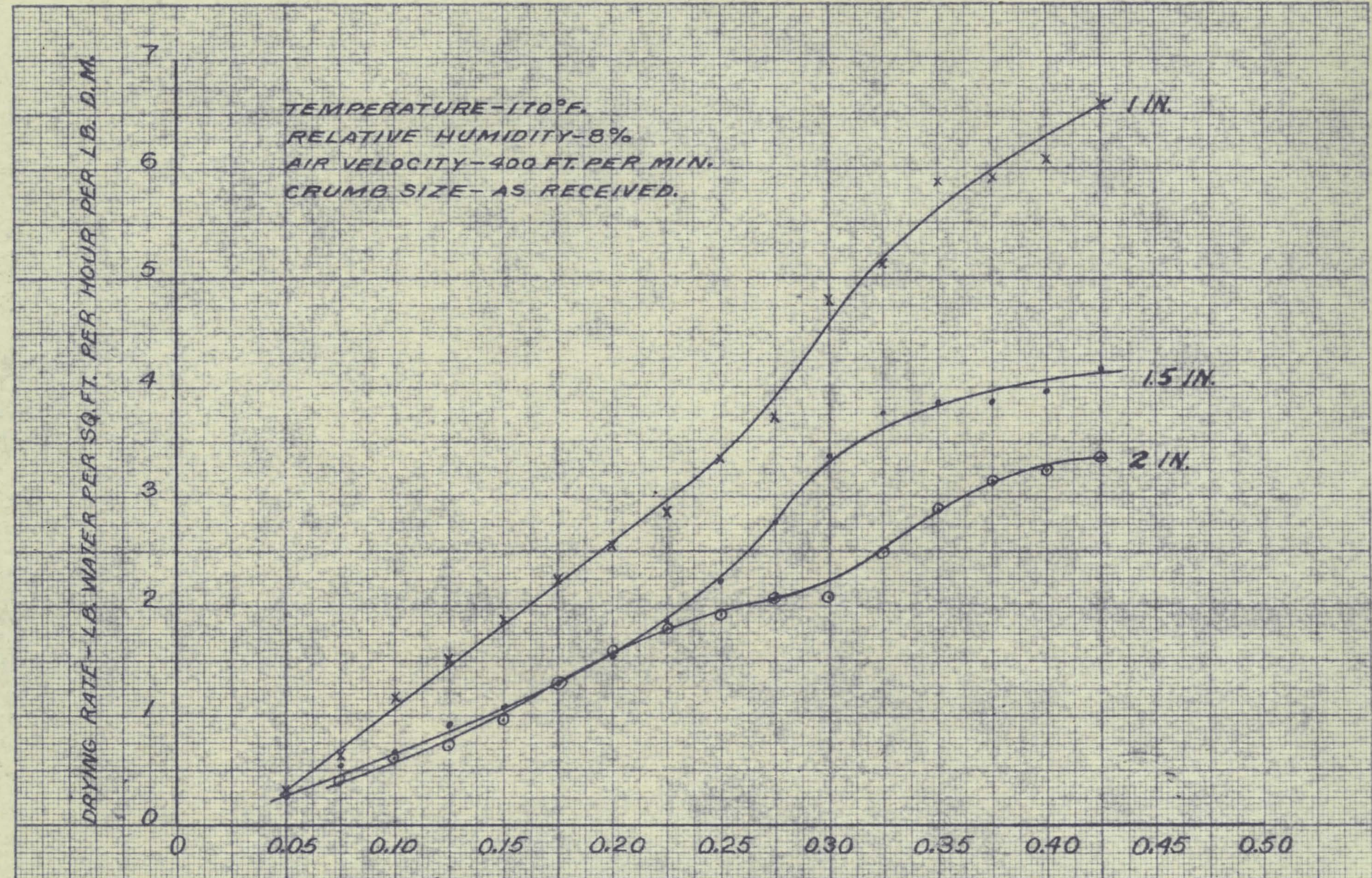


FIG. 66 DRYING RATE CURVES
EFFECT OF CRUMB DEPTH

DISCUSSION

In this particular study of air drying of GR-S crumb an attempt has been made to investigate the several variables of the process with air moving across the surface of the material. A study has been made of the effect of temperature, humidity, particle size, air velocity, and thickness of layer on the drying rate. Although the methods that were used in the work were merely a changing of several factors and studying the drying of the crumb, a number of difficulties were encountered in the development of methods that would yield consistent results, since they were dependent on the sampling technique, the point of sampling, and other factors beyond control.

Although the total time necessary for drying using vacuum drying and air drying with air moving across the cake is about the same, a comparison of the rate curves (see Figures 10 and 45) shows that there is a difference in the mechanism of drying between the two. The vacuum rate curves have a constant rate period, whereas none has been produced in the air drying. Also, the drying rates for this air drying are on the order of 2 to 3 times as great as the rates for vacuum drying.

The set of curves for the effect of humidity (Figures 45, 49, and 54) show that as the humidity is increased the drying rate is decreased. However, it is to be noted that the variation of the relative humidity at higher temperatures is of less significance than at lower temperatures, especially at lower moisture contents. Referring to the theory, it was expected that higher humidities would produce lower rates since the driving force across the evaporation plane is less.

The effect of temperature as shown by the curve of Figure 58 is that higher temperatures induce higher rates. The curves of Figure 40 indicate further that temperature is not the most significant factor affecting the drying rate. The 100°F. and 122°F. curves show that an increase in relative humidity may offset the effect of an increase in temperature.

All the time-temperature curves (for example Figures 55 and 56) show a condition not found with vacuum drying in that there is no constant rate temperature. As may be expected there is no constant rate drying period. Furthermore, the rapid increase in temperature at the beginning of the run, or where the moisture content is high, would indicate that the decrease in the drying rate would be greater at the beginning of the run than at the end. These time-temperature curves show further that portions of the cake reach the temperature of the drying medium only when that portion of the cake is dry. As was discussed in VACUUM DRYING the top would tend to become dry first and thereby reach that temperature first.

Another item is noted. Since the temperature in the various parts of the crumb differs from and does not become equal to the air temperature until the crumb is substantially dry regardless of the air temperature, the crumb is not subjected to this temperature during the entire process, but only when it has become dry. Also indicated is that the portions of the crumb coming in contact with the drying air are subjected to higher temperatures for longer periods of time than those portions of the crumb farther away from the drying air. Hence, absolute uniformity of drying with air moving across the cake is an impossibility.

The effect of the size of the particle on the drying rate is shown in Figure 60. The curves show that for certain sizes of the crumb the rate is quite critical with respect to size. The drying rate increases with increase in crumb size up to some value, above which the rate does not seem to increase. Further research on finer divisions of size would perhaps show the optimum size.

The highest attainable velocities for comparative purposes was only 230 feet per minute. Similar to the effect of other variables, that of velocity is not a linear function for there is an improportionate increase in rate with almost equal increases in velocity. For the increase in rate, at doubling the velocity from 120 to 230 feet per minute, is about 1.75, whereas a velocity factor of 10 is produced by only a doubled rate. It is possible that there is a maximum rate with respect to velocity but the data presented here indicate that it would be outside the range herein investigated.

Data for the effect of cake thickness were obtained for trays 1, 1½, and 2 inches deep. All three depths for any one temperature and humidity were run at the same time in the same drier. Two different sets of data are presented (see Figures 63 and 65) for the effect of cake thickness. The drying rates were computed with rates expressed as pounds of water per square foot per hour per pound of dry material, in order to show comparison with rates for other types of drying (see Figures 64 and 65).

In considering the correct or optimum depth of crumb to use it must be taken into account whether the increase in rate (decrease in drying time) would compensate for the loss of bulk due to using the thinner layer of crumb or which conditions would give greater amounts of dried rubber in the shorter time. Another consideration which must be correlated in figuring the optimum conditions is the amount of gel formed by the conditions under observation.

AIR DRYING

AIR THROUGH CRUMB LAYER

APPARATUS

The apparatus used in this study consisted of a laboratory air drier unit of special construction, Tyler Standard screens, thermometers, and an anemometer.

Figure 67 shows a sketch of the drier constructed for use in this investigation. The heating unit (not shown) consisted of steam coils and apparatus for humidifying the air with either water or steam. Humidities of 50% saturation at temperatures of 220°F. could be produced. The air was drawn from the room and forced over the heating and humidifying coils and into the drier by a blower capable of producing air velocities up to 500 feet per minute. Heated and conditioned air was introduced at the top, passed through baffles, and then through the tray of wet crumb. The tray was of plywood and screen construction with a wide heavy paper gasket attached to the bottom. The screen openings were 1/16 inch square. The tray rested on a partition in the drier with an opening just the size of the screen bottom of the tray. Thus, all the air was forced through the crumb. Rods attached to the sides of the tray and leading through the top of the unit allowed the tray to be weighed periodically without removal from the drier.

During the weighing, the flow of air was stopped for a brief period. Usually the entire time for securing the weight of the tray and crumb did not exceed one minute.

A single pan, tripple beam balance was used for the weighings. The balance pan was equipped with a saddle to hold the rods from the tray. The balance, accurate to 0.10 GM., allowed sufficient precision for all practical purposes.

The air ducts were fitted with butterfly valves to control air velocities, and an anemometer was used to determine the air velocity in the exit duct. Wet and dry bulb thermometers were placed about three inches above the crumb in the dryer.

The dryer was equipped with a device for measuring the thickness of the crumb bed during drying. A brass rod, with a small screen attached at right angles, extended out of the top of the dryer. The screen was parallel to the bed of crumb and could be lowered on to it. Attached to the rod on top of the dryer was a scale from which measurements of the thickness of the crumb could be made.

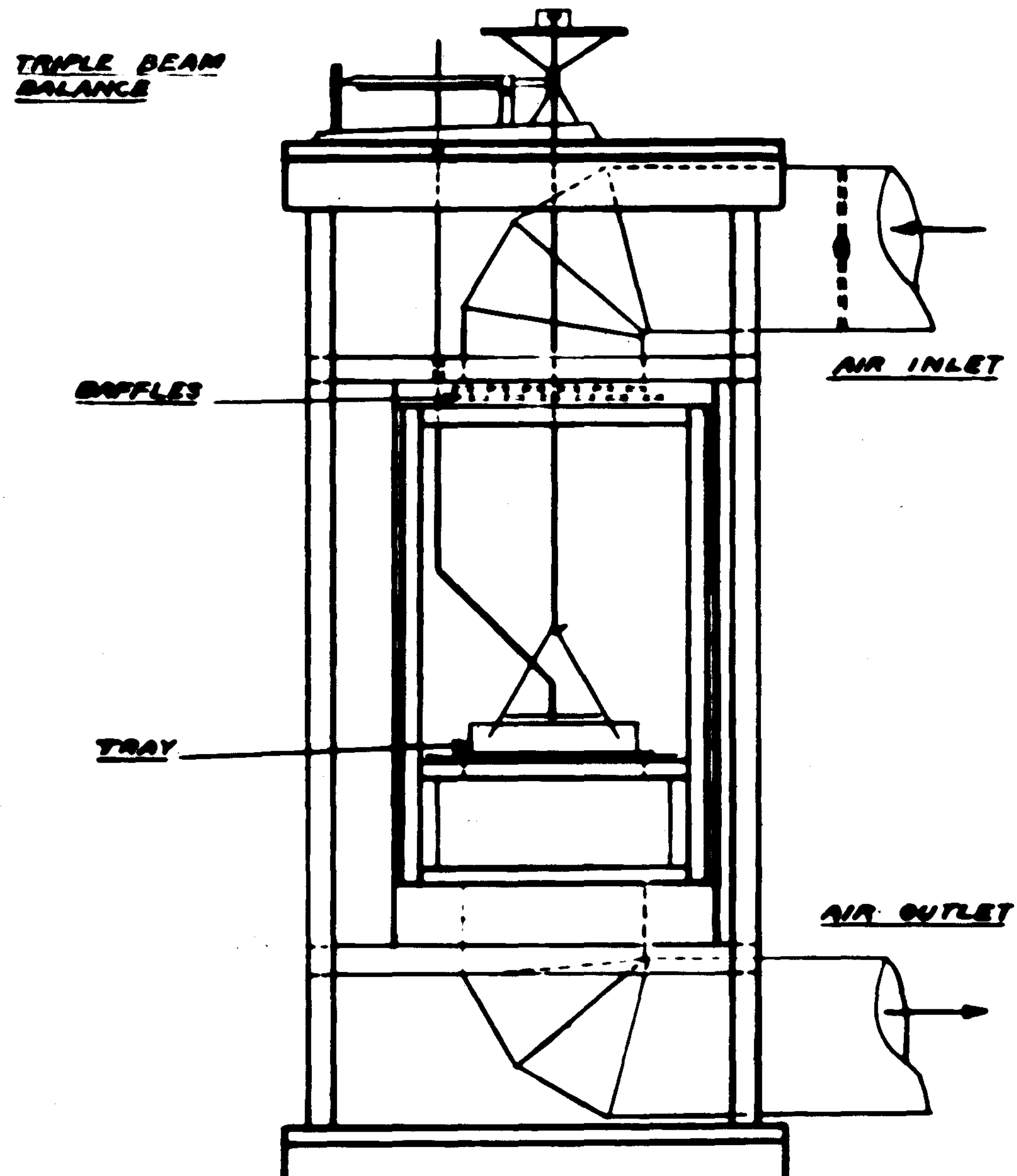


FIG. 67 LABORATORY AIR DRIER

G. W. WILLIAMS

PROCEDURE

Samples of wet crumb were obtained from the National Synthetic Rubber Company, Louisville, Kentucky, for the test of air drying by passing air through the crumb. These samples were taken daily from the Jeffrey mill insuring the same size crumb as that used in the plant driers.

The tray was placed in the drier and the balance rods connected. An initial weight was then secured after which the tray was placed in the drying position. During weighings the tray was elevated slightly to allow free movement of the balance and tray. The heated air was then started and allowed to run until the first weighing was to be made. Then the air was stopped and a weighing made. Weighings were made every few minutes in order to get enough points to plot the moisture content-time curves accurately. The drying was allowed to proceed until reasonably constant weight was obtained. The final weight was used as the dry weight and from this weight and the periodic weights, the moisture contents at the various times were calculated. From such data the moisture content-time curves were constructed. The slope of these curves at any time is $\frac{dW}{dT}$ where W is the moisture content at any time T. Therefore, $\frac{dW}{dT}$ is the rate of drying at moisture content W. Values of $\frac{dW}{dT}$ were tabulated for even increments of moisture content. The rate was calculated as pounds of water evaporated per hour per square foot of evaporating area. The evaporating area was assumed to be the area of the surface of the layer. The drying rate curves were constructed by plotting the values of moisture content versus drying rate. Variations in these calculations occur, but they will be noted when they are used.

All the samples were tested in the same unit in which the air velocity, temperature, and humidity could be varied within rather wide limits to give the desired comparative effects.

The effect of temperature of the air on the drying rate was first investigated, while other conditions such as air velocity, crumb size, humidity, and thickness were held constant within relatively narrow limits. The temperature was varied from 140°F. to 220°F. with the heating unit being operated and not the humidifier.

Water and steam were used in the humidifier to give wide variation in the humidity of the air. The effect of changing the driving force was studied in this way with all the other conditions held constant.

Air velocity was varied from 70 to 450 feet per minute through the bed of crumb. A dry bulb temperature of 180°F., and 6 per cent relative humidity were the conditions used in this study of the effect of air velocity.

In all these investigations the crumb as received was screened by Tyler Standard screens and the predominant size was used in the test. This size was that which would go through a 0.371 inch sieve and not through a 0.185 inch sieve.

The effect of varying the particle size was studied using three size ranges; on 0.263 inch sieve, through 0.263 inch - on 0.131 inch sieve, and through 0.131 inch sieve. The drying conditions were: 180°F. dry bulb, 4.5 per cent relative humidity, and an air velocity of 440 feet per minute.

The thickness of the layer dried was varied from one half to four inches. For this study average particle size and drying conditions were used.

The temperature of the layer of crumb was studied during the drying operation. Copper-constantan thermocouples were buried in the crumb at different depths and the temperatures recorded every five minutes during the time of drying. These measurements were made at the top, the middle, and the bottom of the layer.

Measurements were made on the thickness of the bed of crumb during drying. These measurements were made on a two inch bed of crumb and were taken periodically throughout the drying by lowering the screen to the crumb and recording the height. The procedure for drying the samples and obtaining data for plotting drying rate curves was the same in all cases.

RESULTS

The first effect investigated was that of temperature. This effect is shown in Figures 68 and 69. The moisture content-time curves are plotted in Figure 68 for several different temperatures and the corresponding drying rate curves in Figure 69. These rate curves show, in general, that as the temperature is increased the drying rate is increased. However, over the range investigated, the rate is not greatly influenced by changing temperatures.

Figures 70, 72, and 74 show moisture content-time curves portraying the effect of humidity on the drying. The corresponding rate curves are shown in Figures 71, 73, and 75. These curves like those for the effect of temperature show little change in the rate for a change in the variable. In general, although the effect is slight, air of low relative humidity produces a greater drying rate.

In the investigation of the effect of air velocity on the drying rate, an extremely wide range of conditions has not been covered. However, a sufficiently wide variation has been obtained to indicate the trend. The moisture content-time plot for 70, 180, and 360 feet per minute is shown in Figure 76. The corresponding rate curves appear in Figure 77. These results indicate that of the effects thus far mentioned, the drying rate is much more sensitive to air velocity than to any of the other variables. Also a definite constant rate period is noticed for some of these cases.

The next variation investigated was that of particle size of the crumb. This variable was studied by separating the crumb into three size ranges: on 0.263 inch sieve, through 0.263 inch--on 0.131 inch sieve, and through 0.131 inch sieve. Tyler Standard screens were used for such separations. The moisture content-time curves for this study are given in Figure 73 and the rate curves in Figure 79. The rate curves of Figure 79 readily show that over the range of sizes considered, the particle size of the crumb has little effect on the drying rate.

The curves of Figure 80 are moisture content-time plots for the drying of samples of crumb using several different layer thicknesses. The rate curves derived from Figure 80 are those of Figure 81. These rate curves are plotted using the rate units, lb. water lost per square foot per hour per pound dry material. These curves plainly show the advantages of the thin crumb layer in drying.

The time-temperature curves of Figure 82 show the variation in temperature of the crumb during drying with air passing through the crumb. Temperatures are given in degrees centigrade and time in minutes. This plot shows the rapidity with which the crumb changed temperature in the first few minutes of the drying operation. After the first five minutes, the top, the middle, and the bottom of the crumb are only a few degrees apart. This difference becomes steadily less and after a period of time a uniform temperature throughout the crumb is obtained presumably when the major portion of the water has been lost from the crumb.

Moisture content and shrinkage data are plotted versus time in Figure 83. From this plot the rate curves of Figure 84 were calculated. These shrinkage measurements are for one dimension only. It is certainly true that the shrinkage will occur in the other two dimensions. The method used, however, was considered a practical method of obtaining such information.

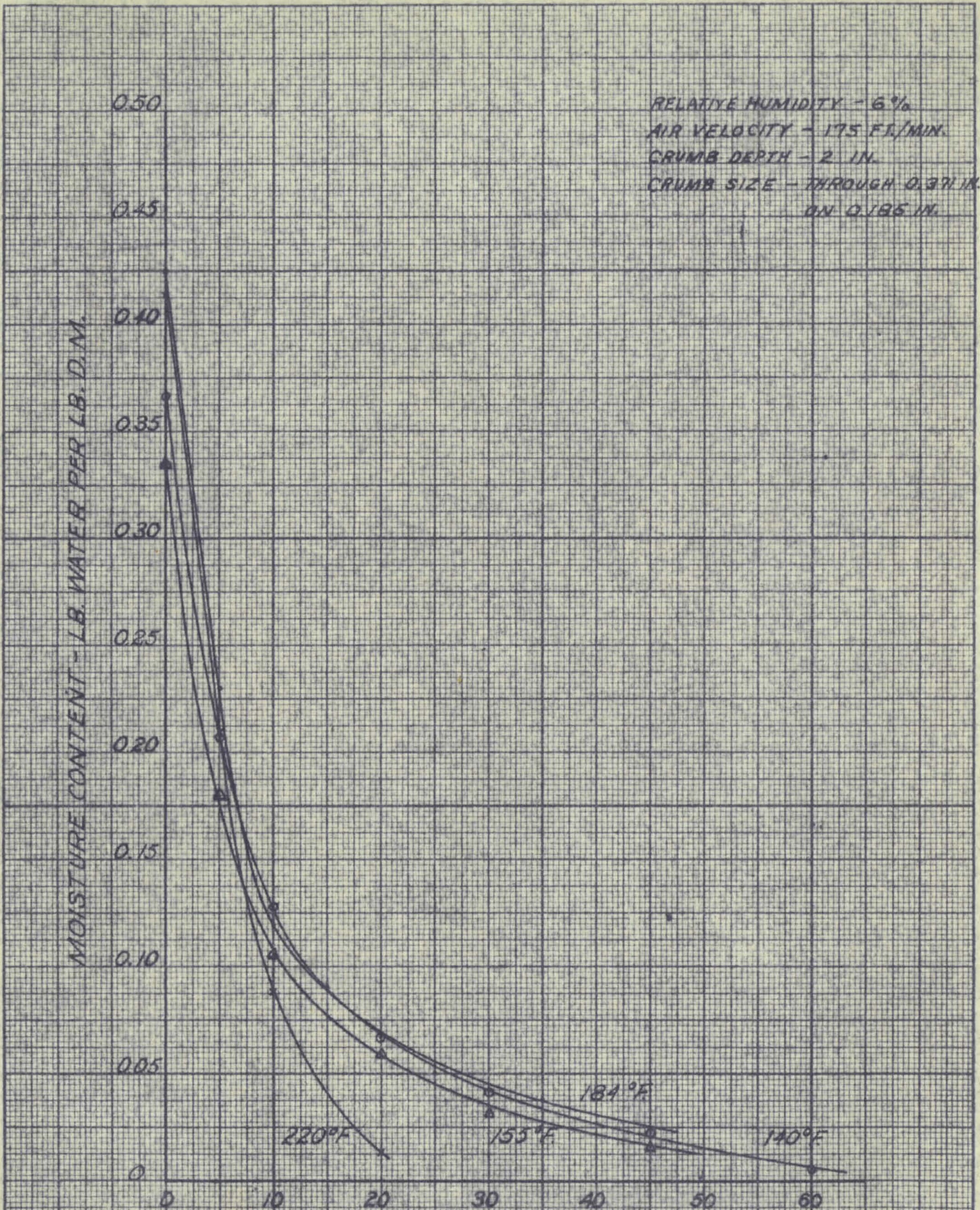


FIG. 68 MOISTURE CONTENT - TIME CURVES
EFFECT OF TEMPERATURE

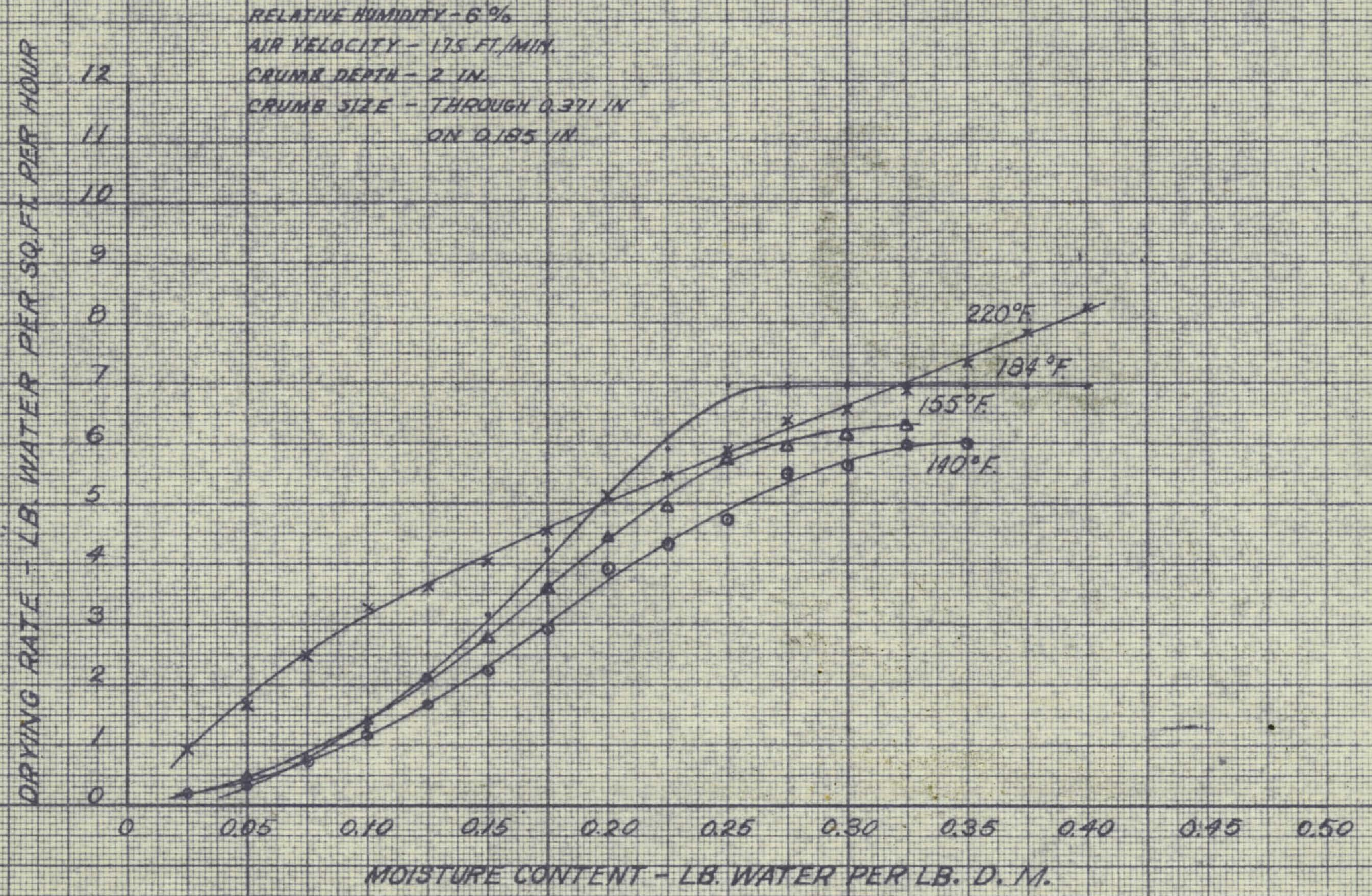


FIG. 69 DRYING RATE CURVES
EFFECT OF TEMERATURE

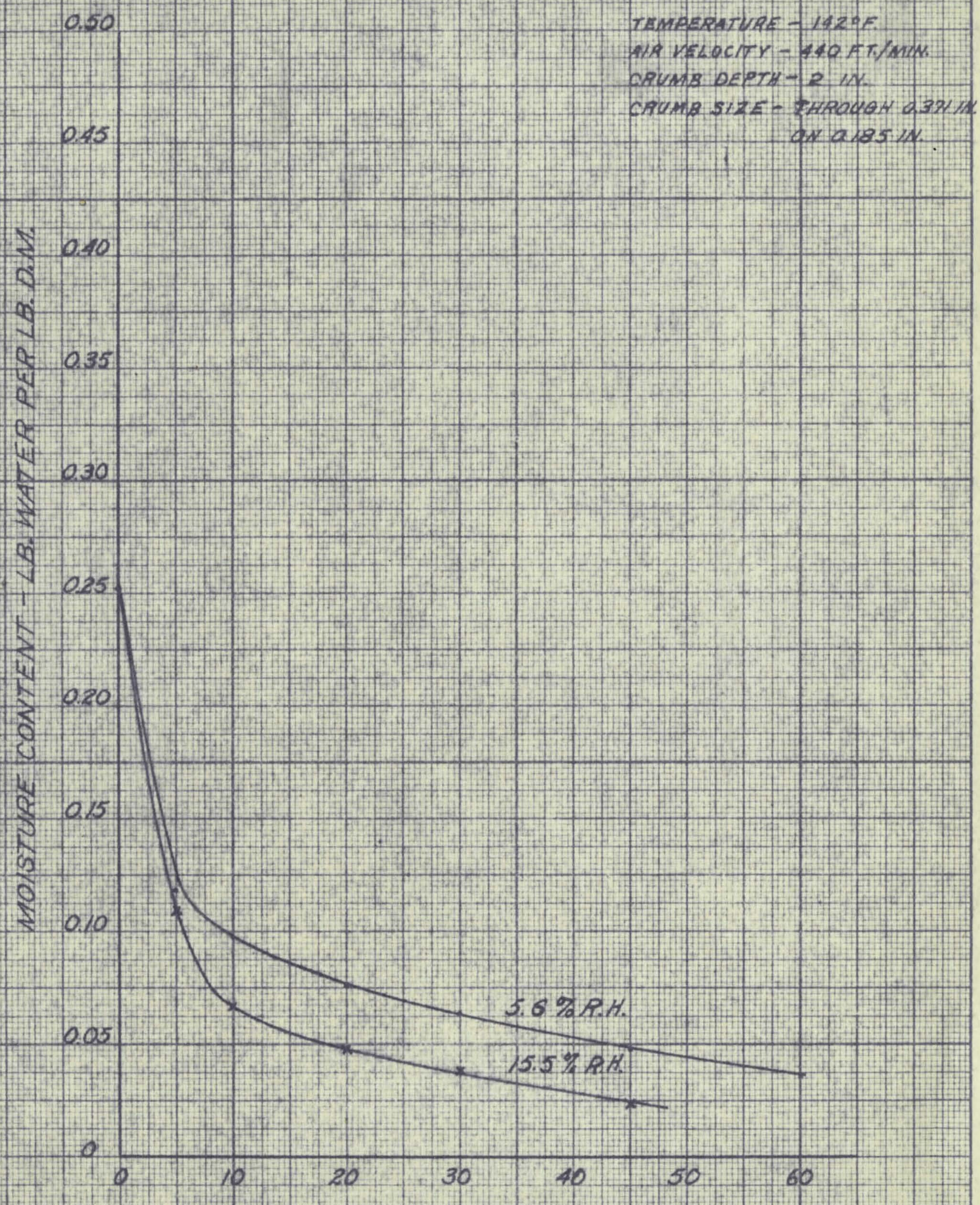


FIG. 70 MOISTURE CONTENT - TIME CURVES
EFFECT OF RELATIVE HUMIDITY

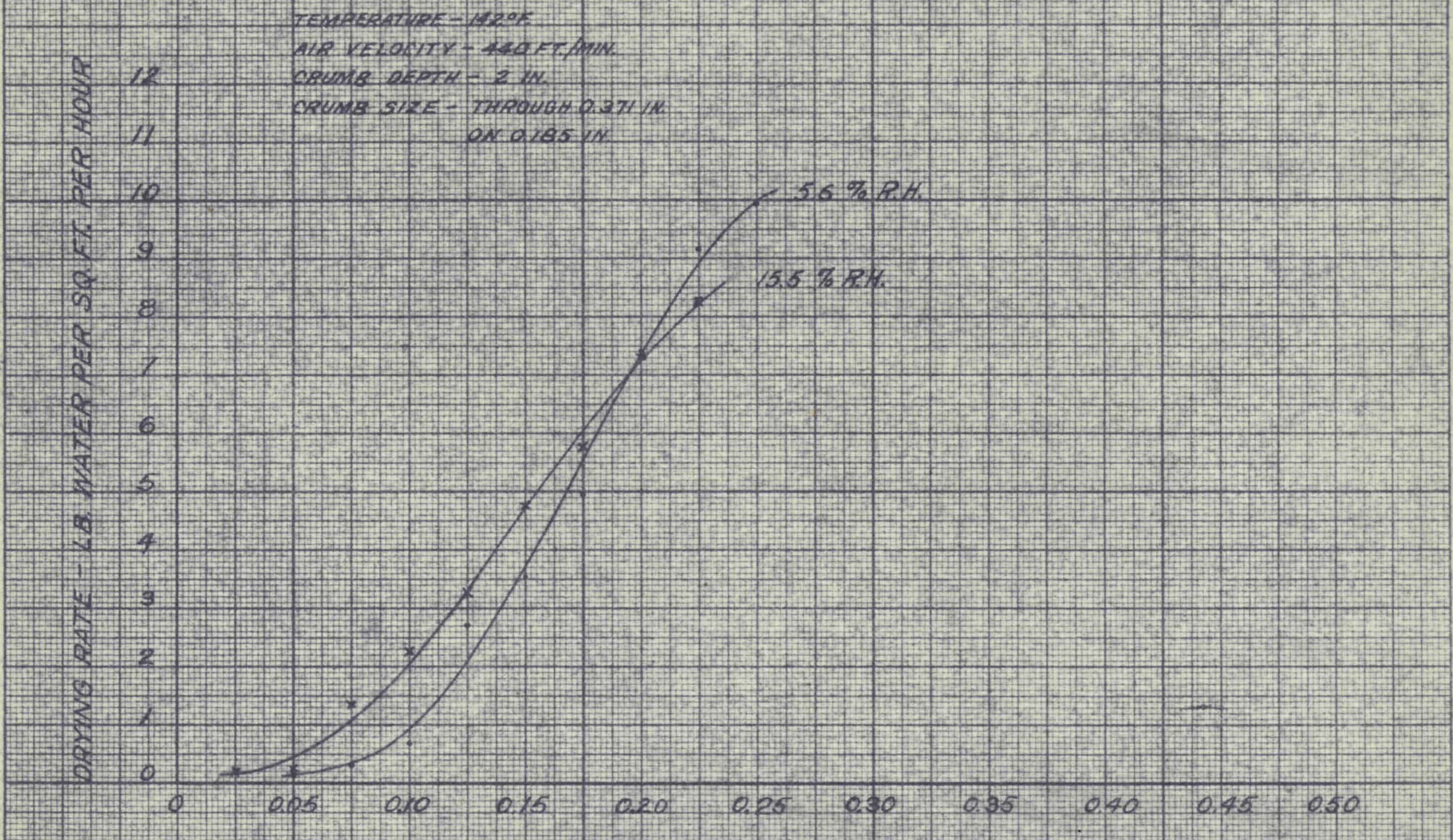


FIG. 71 DRYING RATE CURVES
EFFECT OF RELATIVE HUMIDITY

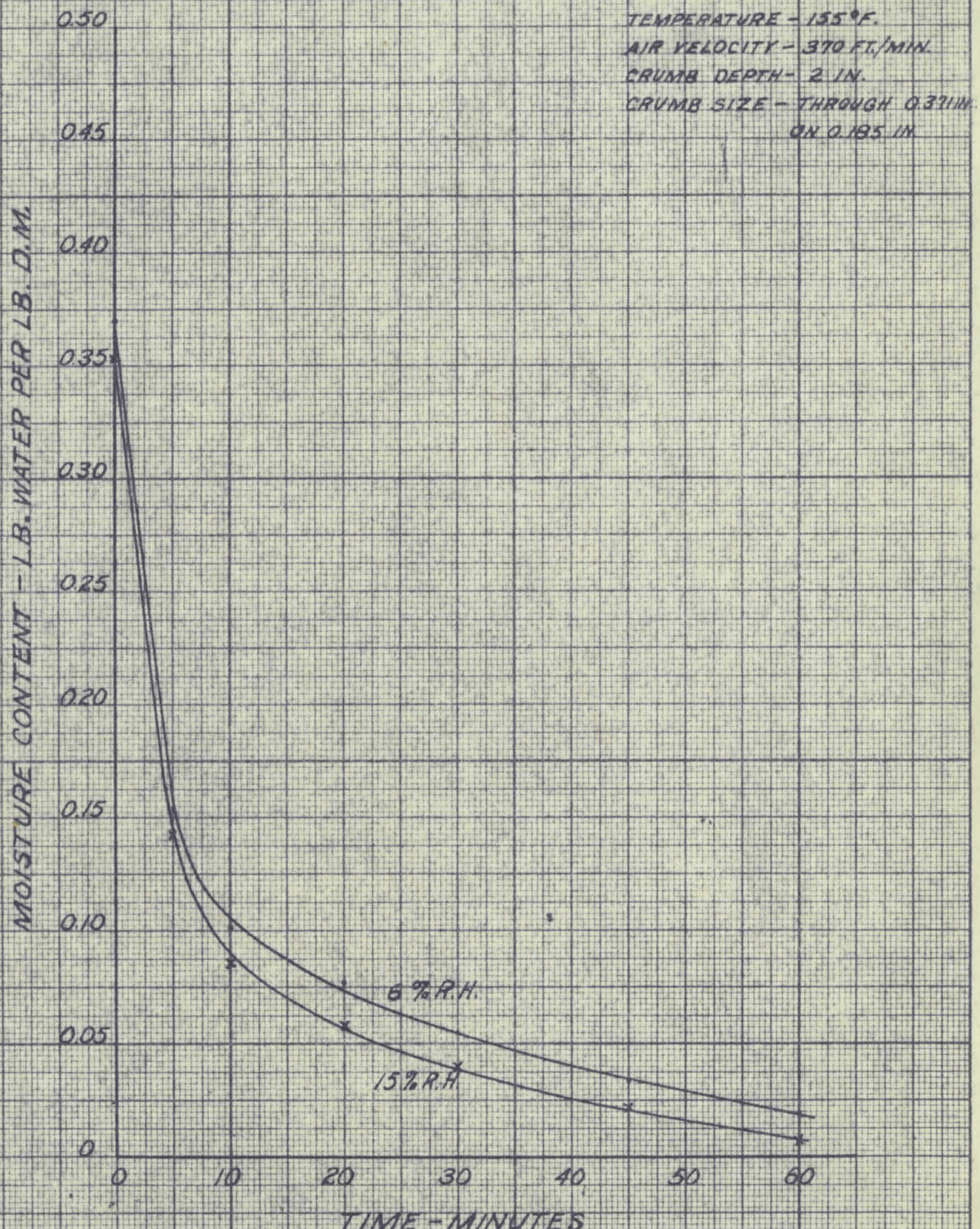


FIG. 72 MOISTURE CONTENT - TIME CURVES
EFFECT OF RELATIVE HUMIDITY

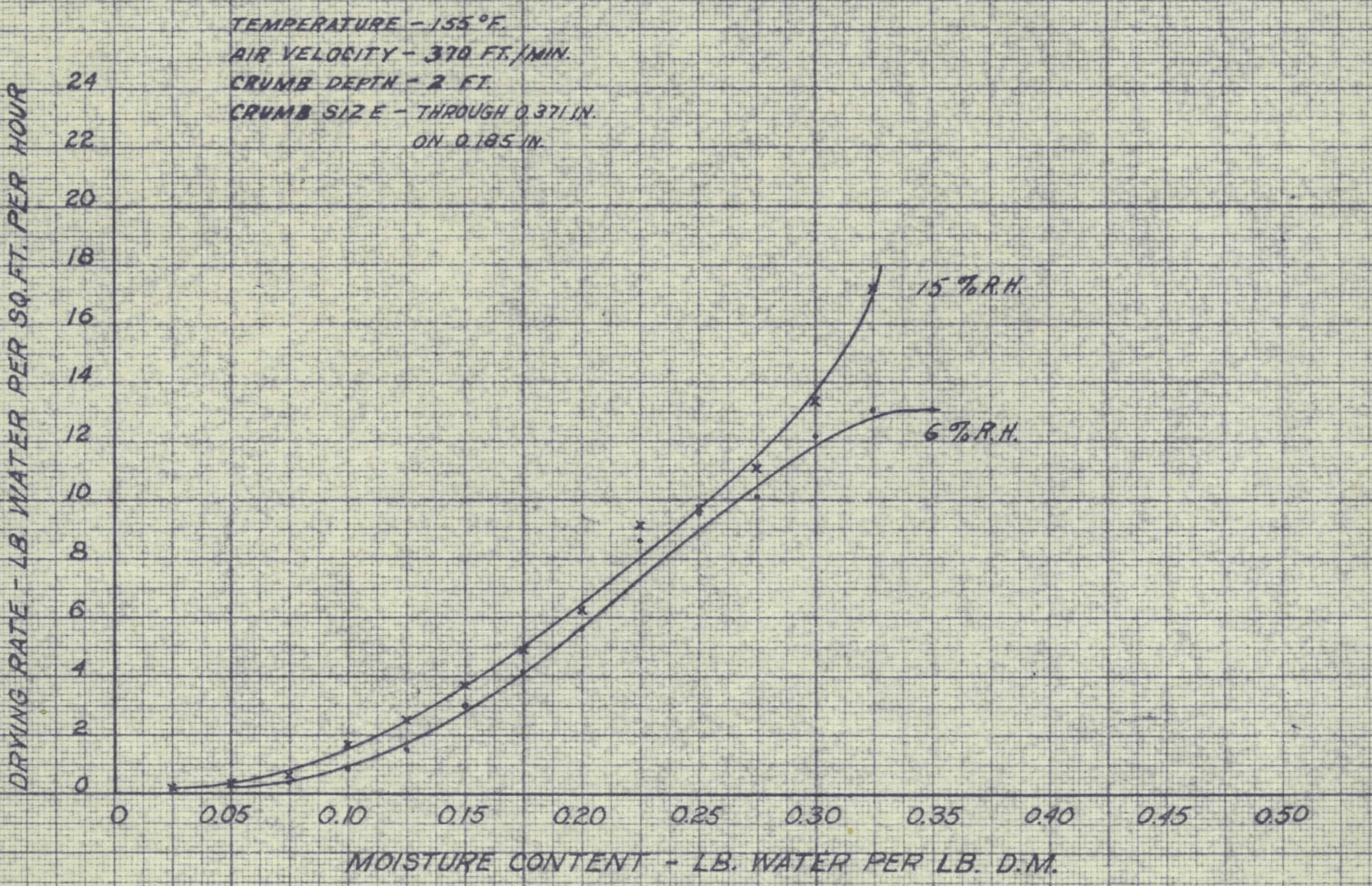


FIG. 73 DRYING RATE CURVES
EFFECT OF RELATIVE HUMIDITY

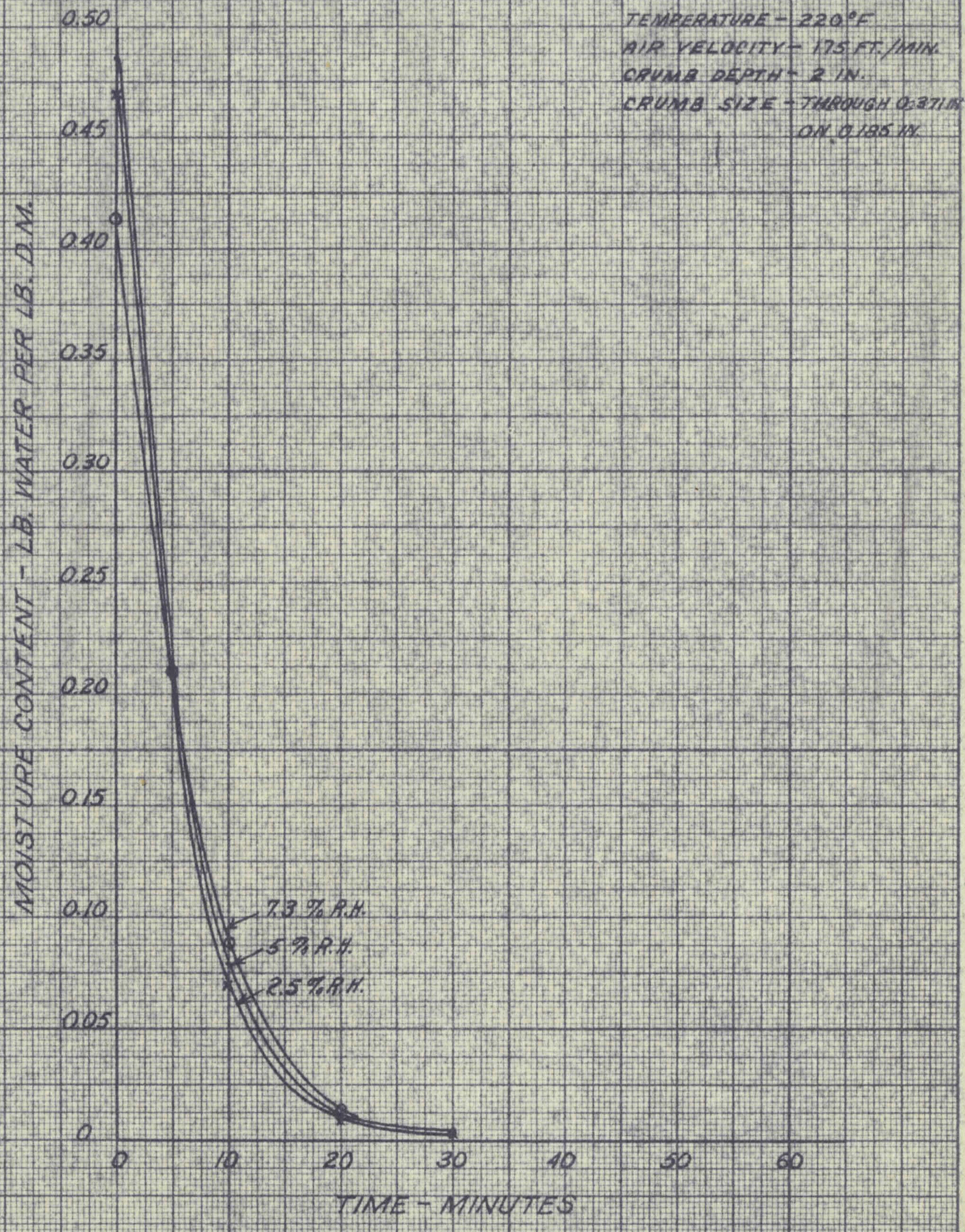


FIG. 74 MOISTURE CONTENT - TIME CURVES
EFFECT OF RELATIVE HUMIDITY

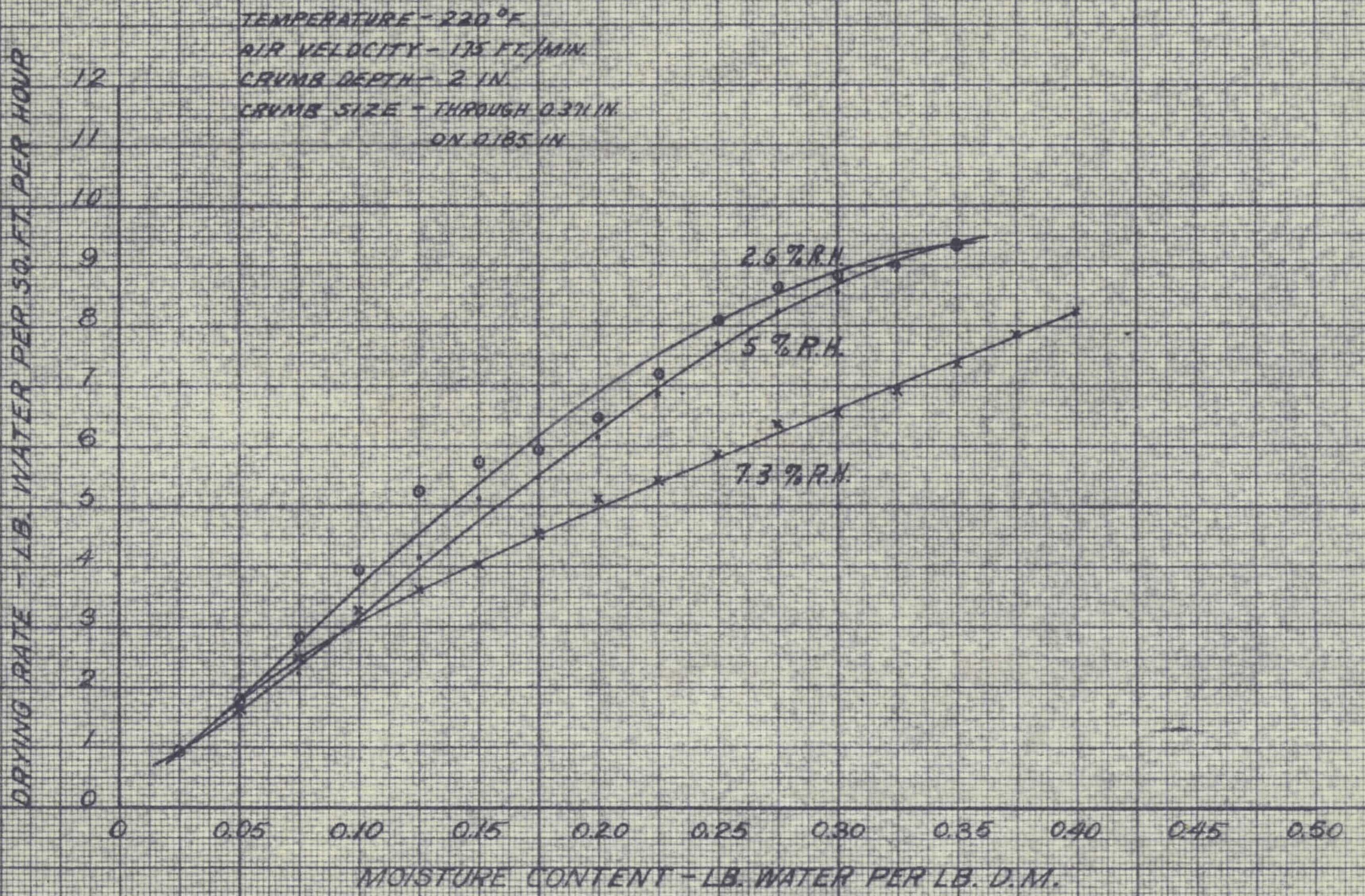


FIG. 75 DRYING RATE CURVES
EFFECT OF RELATIVE HUMIDITY

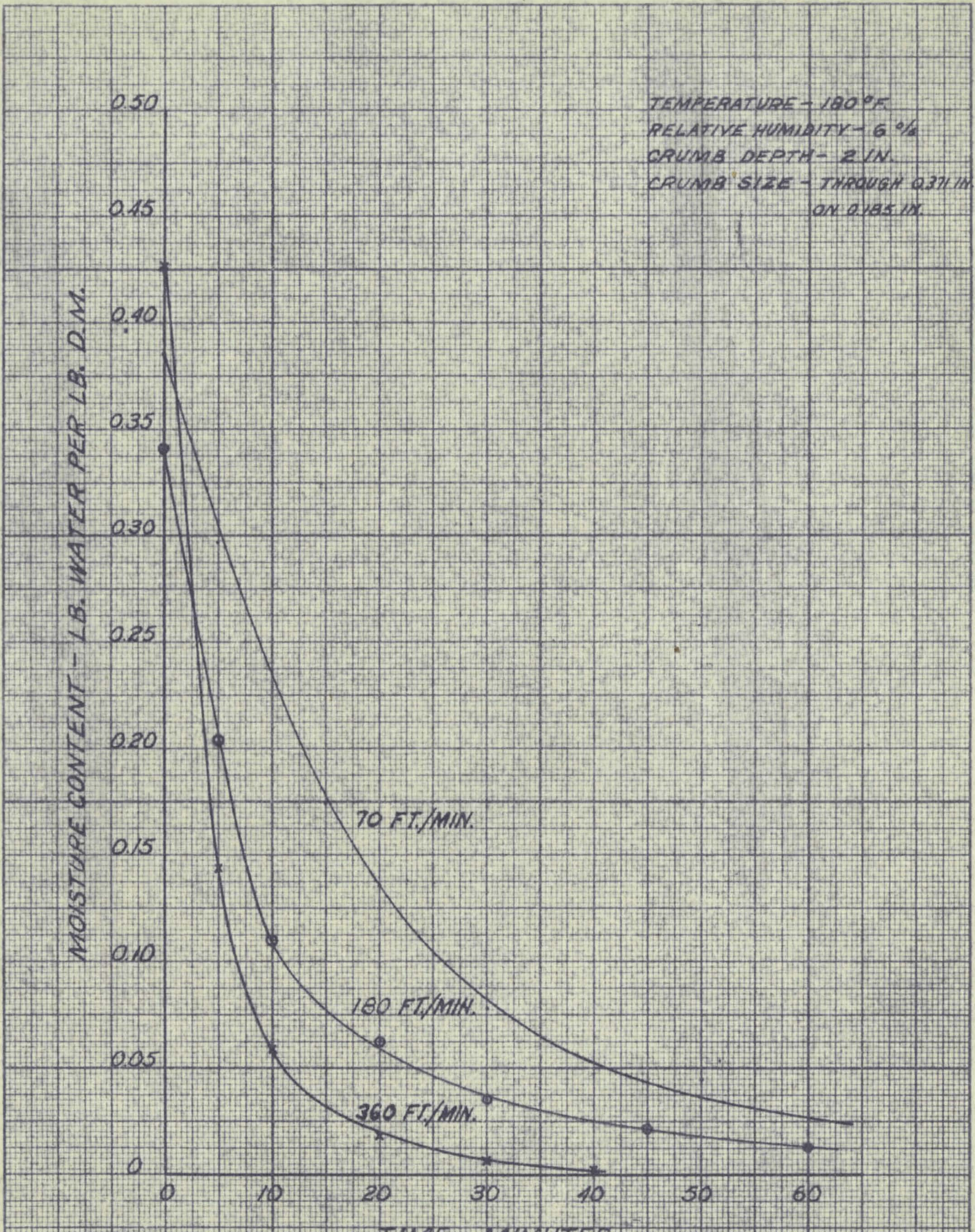


FIG. 76 MOISTURE CONTENT - TIME CURVES
EFFECT OF AIR VELOCITY

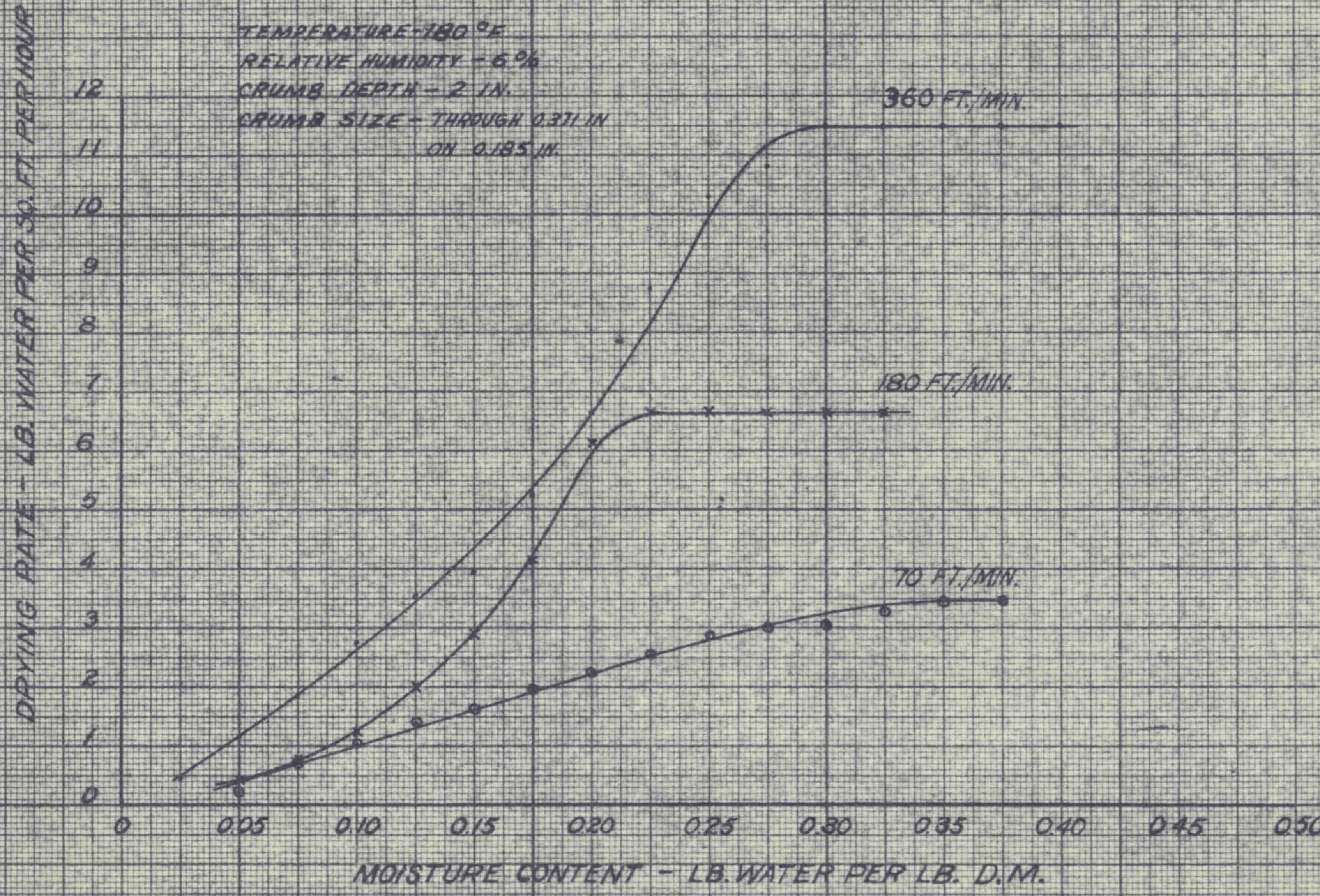


FIG. 77 DRYING RATE CURVES
EFFECT OF AIR VELOCITY

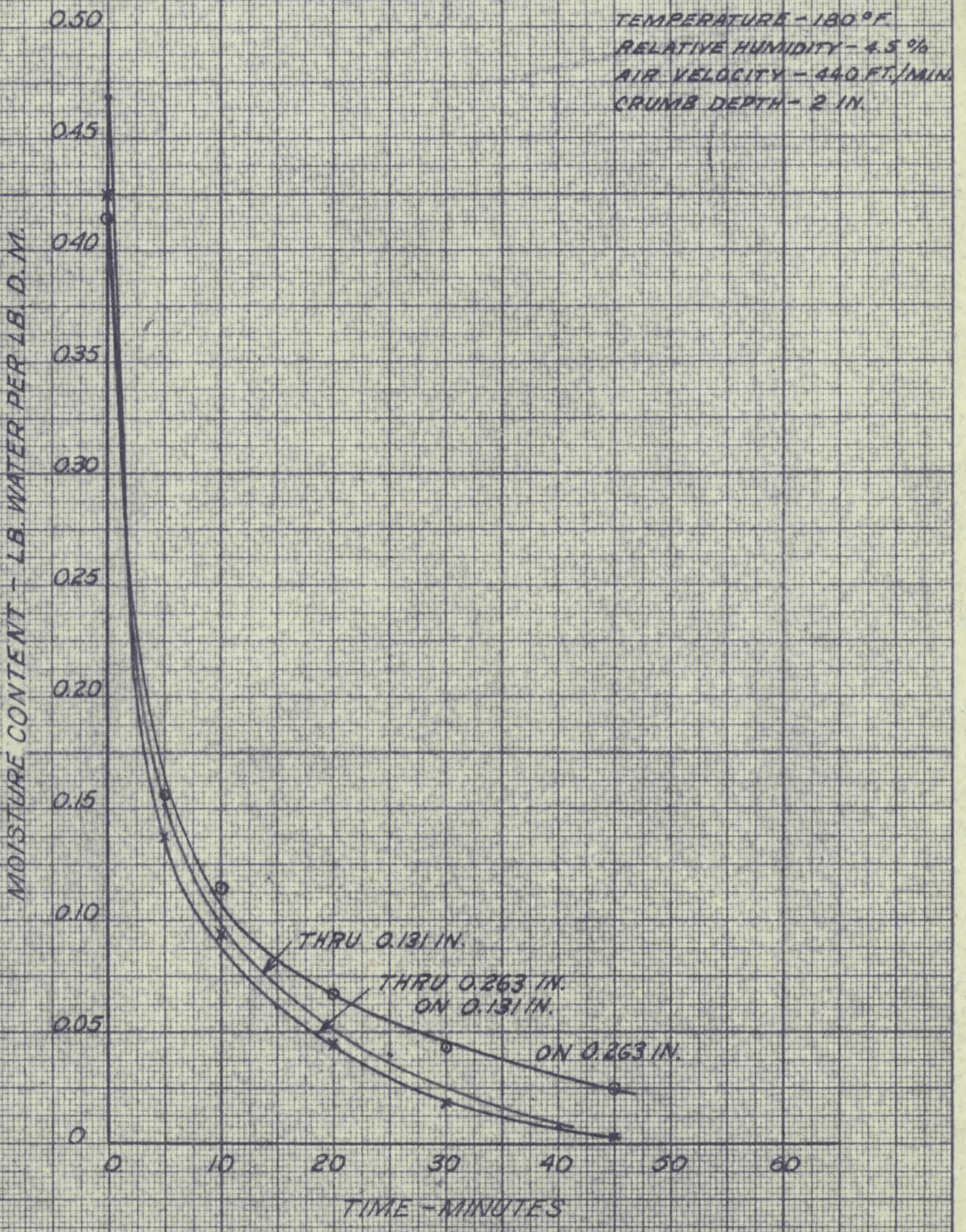


FIG. 78 MOISTURE CONTENT-TIME CURVES
EFFECT OF PARTICLE SIZE

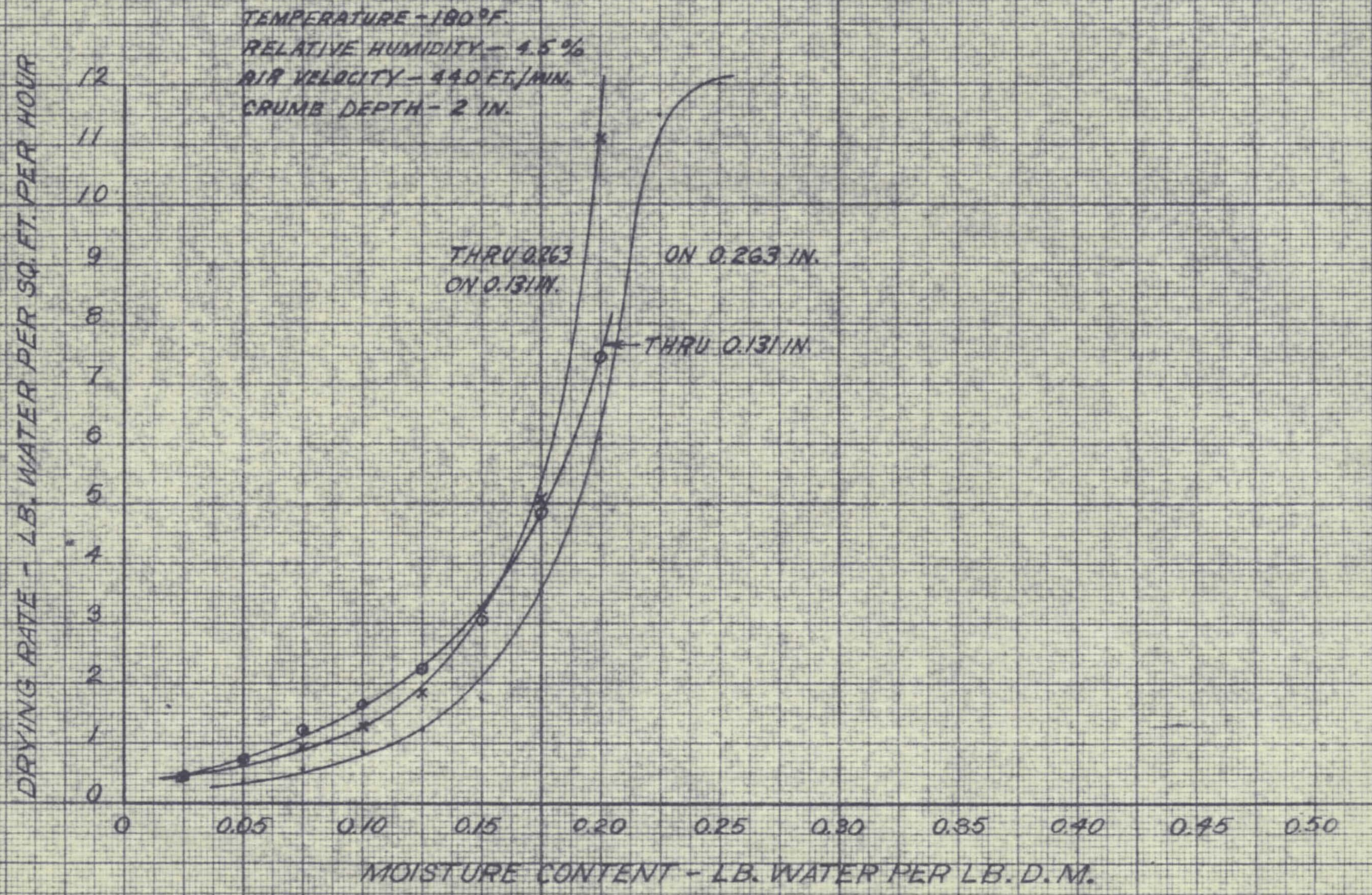


FIG. 79 DRYING RATE CURVES
EFFECT OF PARTICLE SIZE

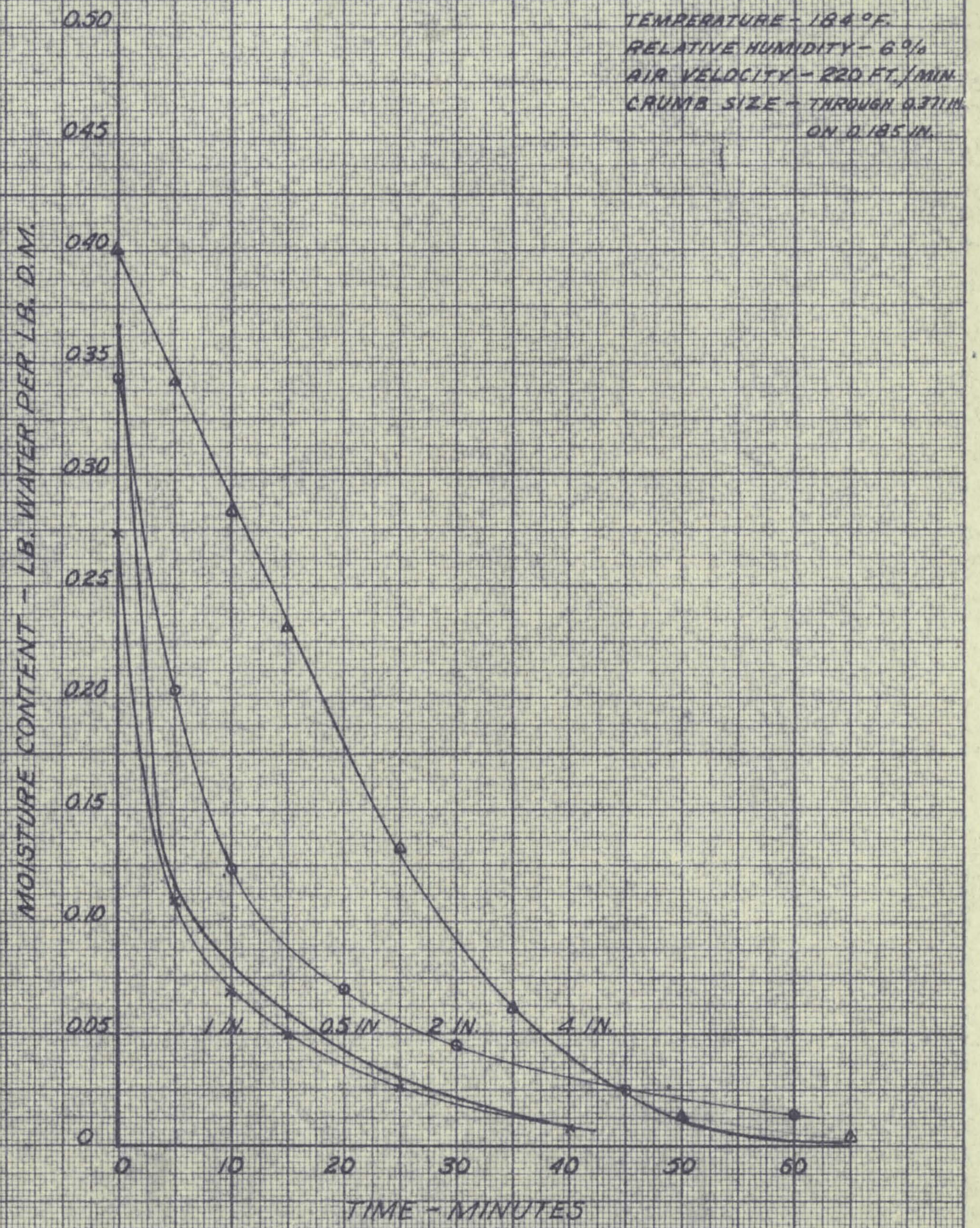


FIG. 80 MOISTURE CONTENT - TIME CURVES
EFFECT OF LAYER THICKNESS

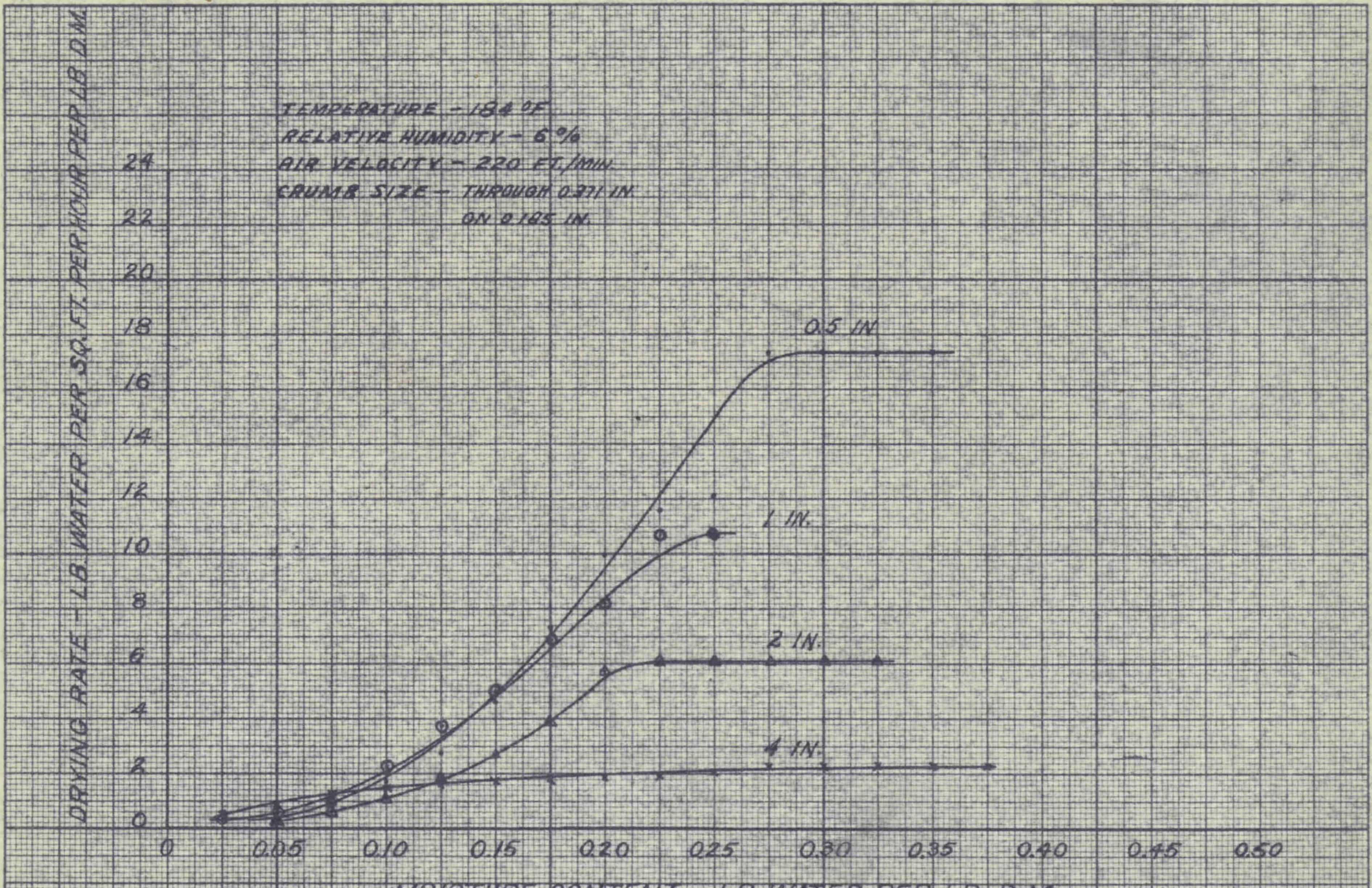


FIG. 81 DRYING RATE CURVES
EFFECT OF LAYER THICKNESS

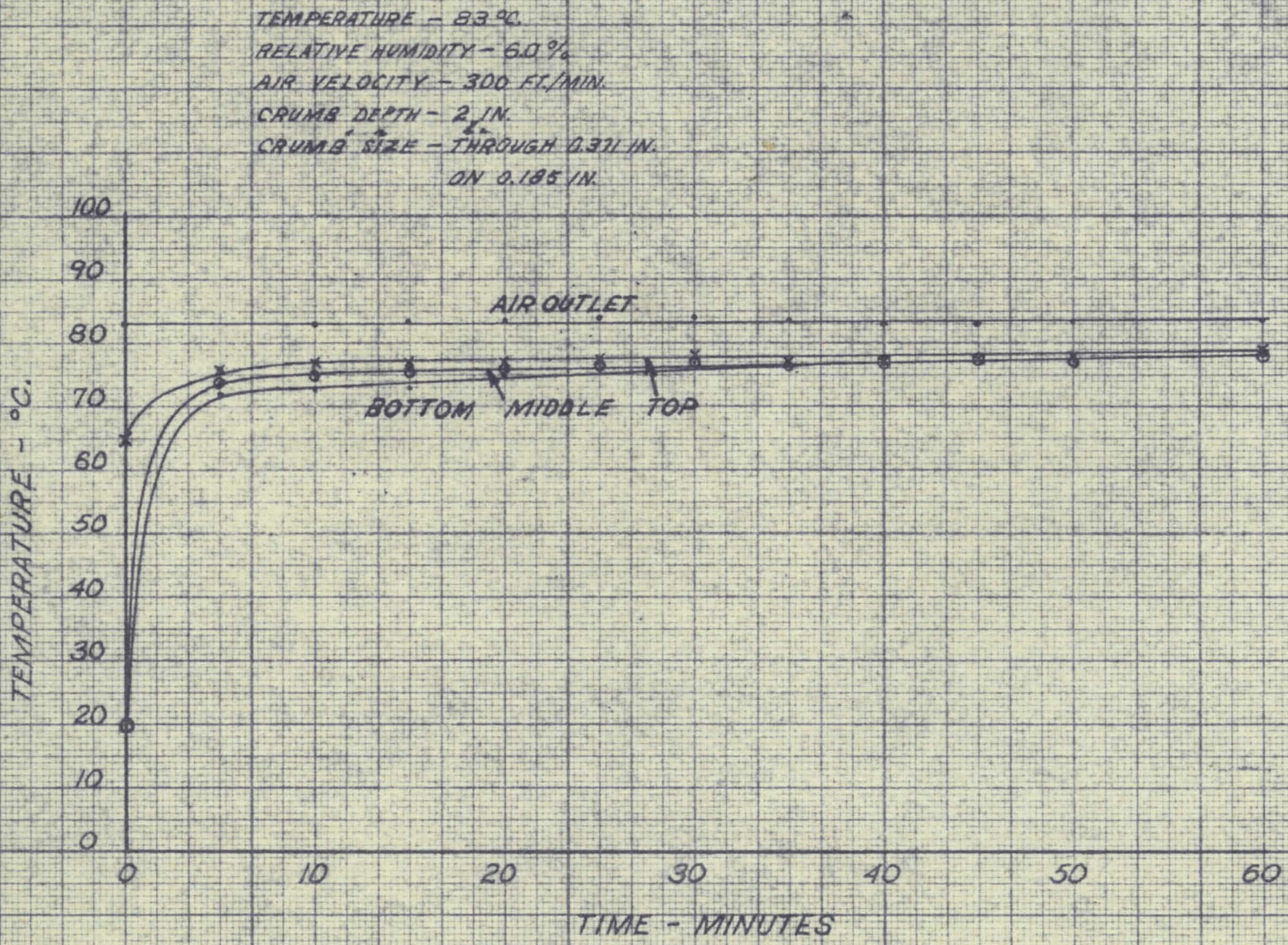


FIG. 82 TEMPERATURE - TIME CURVES

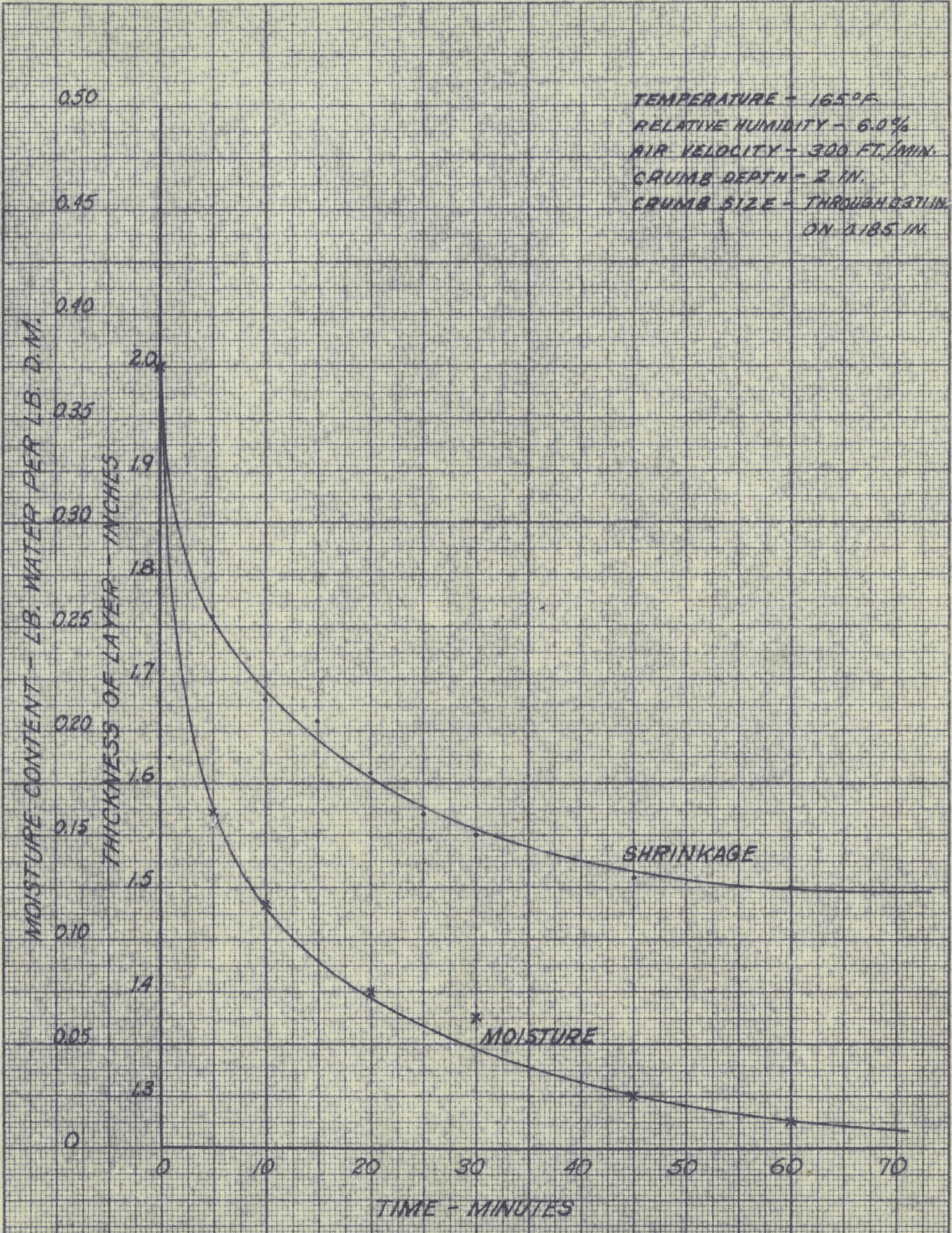


FIG. 83 MOISTURE CONTENT - THICKNESS - TIME CURVES

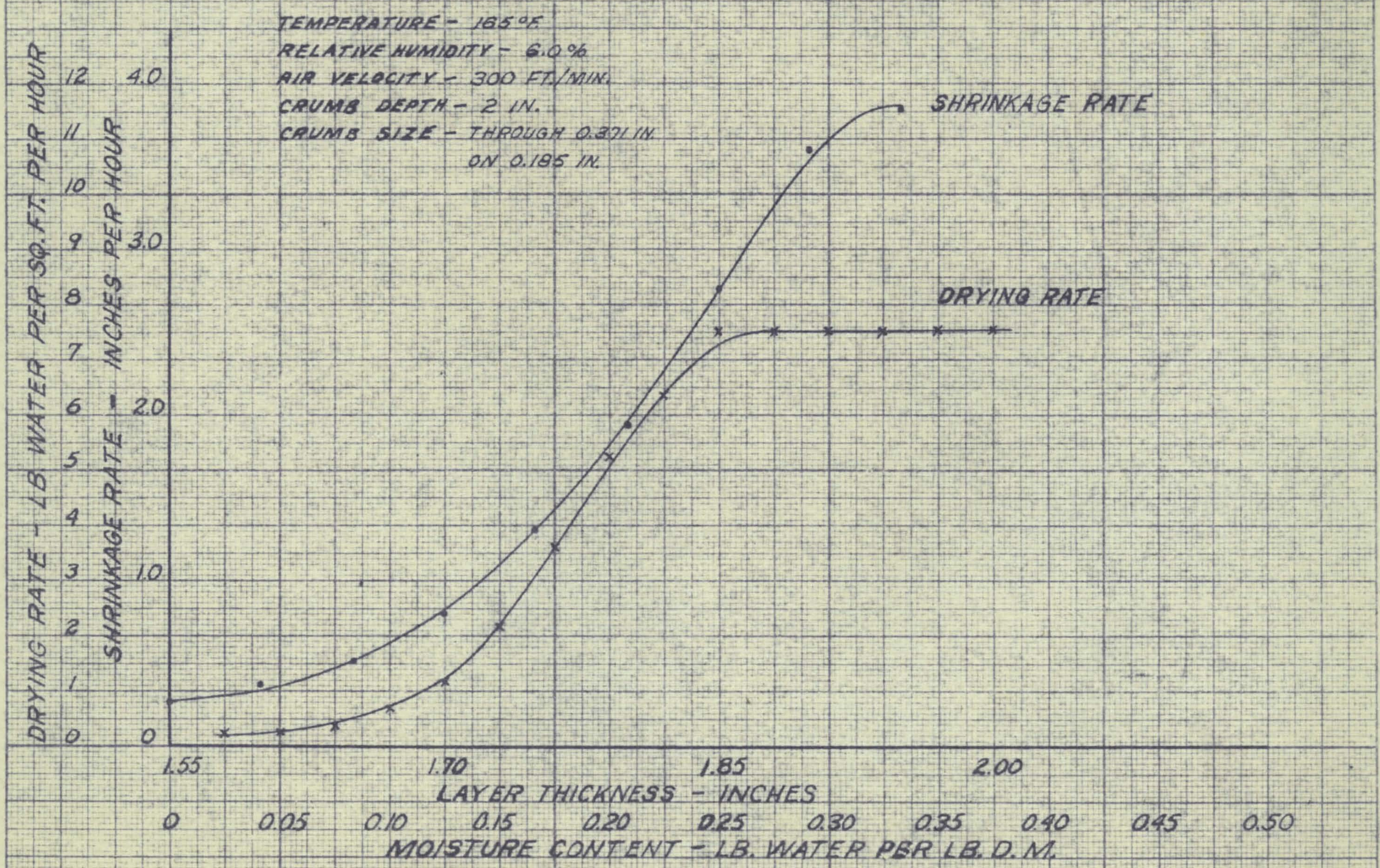


FIG. 84 SHRINKAGE AND DRYING RATE CURVES

DISCUSSION

Air drying with the air blown through the bed of crumb presents a method which, from the results of this investigation, appears superior to all other methods studied thus far. Regardless of the extent of variation of the variables, the resulting drying rates were approximately three times higher than the values obtained by using vacuum or air drying with air moving across the bed of crumb. In general, an increase in temperature increased the drying rate and decreased the time of drying. However, this effect is not great, i.e. the temperature can be increased considerably without increasing the drying rate greatly (see Figure 69). An increase of humidity resulted in a slight decrease of the drying rate and increase in the time of drying (see Figures 71, 73, and 75). As in the case of variation of temperature, this effect was relatively slight.

The variation of the air velocity produced a wide variation in the drying rate and time (see Figure 77). An increase of air velocity increased the drying rate as a direct proportion, i.e. doubling the air velocity approximately doubled the drying rate. It would be expected that at higher velocities the proportion of increase would be lessened and some limiting value would be approached.

A variation in particle size only slightly effected the drying rate (see Figure 79) and was considered an unimportant factor in drying except where the size interfered with the operation of the equipment as in the case of fines clogging flight openings.

Some variation in the drying rate was found by changing the thickness of the layer of crumb (see Figure 81). The variation was less, however, than that for air velocity. This effect could be due, in part, to a change in the driving force as the air passed through the crumb. As the air passed through the crumb the humidity was increased and consequently was greater where the thickness was greater. Another reason could be that more water evaporated in the thicker samples produced a lower average temperature. Therefore, in the thicker samples the average driving force would be reduced.

The typical time-temperature curve for this method of drying indicated a rapid attainment of a fairly constant temperature throughout the crumb (see Figure 82). Within five minutes the crumb temperature was constant and had risen to within a few degrees of the air temperature. It is significant that in the case of the other drying methods the temperature of the middle and the bottom of the layer did not become equal to the temperature of the top until the drying was nearly complete. The temperature at the surface rose sharply at first and held constant. As the surface dried, the temperature plane gradually went into the layer, so that, at the end of drying, the whole layer was at the same temperature.

In the vacuum drying, where low drying rates were found, there was no circulation of air around the particles of rubber dried. Likewise, in the drying with air moving across the surface of the crumb the amount of circulation of air between the individual particles was slight to zero. In these methods of drying it was necessary for the water vapor to diffuse through the whole layer and into the air, where as with air circulating between the particle it was only necessary for the water to diffuse from the particle into the air. During vacuum or drying with air across the layer, the temperature of the remaining wet portion was relatively low, and little of the water was vaporized. In the case of air drying with air passing through the layer, however, the temperature was uniform throughout, and water was vaporized from all portions simultaneously.

The essential difference in drying characteristics between these methods, causing the difference in drying rates, was that in one water was being evaporated from all the particles at once while in the other methods water was evaporating from a moving surface. Thus, effectively, the drying or diffusion surface is increased by passing air through the layer.

The curves of shrinkage and moisture content versus time suggest some very interesting conclusions.

Since these curves have the same general shape, it was expected that their corresponding rate curves would have the same general shape (see Figure 84). This situation indicated that the reduction in depth of the crumb occurs nearly at the same rate as the reduction in moisture content. The plot of Figure 85, moisture content versus shrinkage reading, verified these conclusions. It was noted, however, that the curve of Figure 85 was not straight over the entire range but deviated from a straight line in the lower part (shown as a broken line). The reduction in depth, therefore, must have been primarily caused by the loss of moisture and only slightly by a change in the dimensions of the rubber.

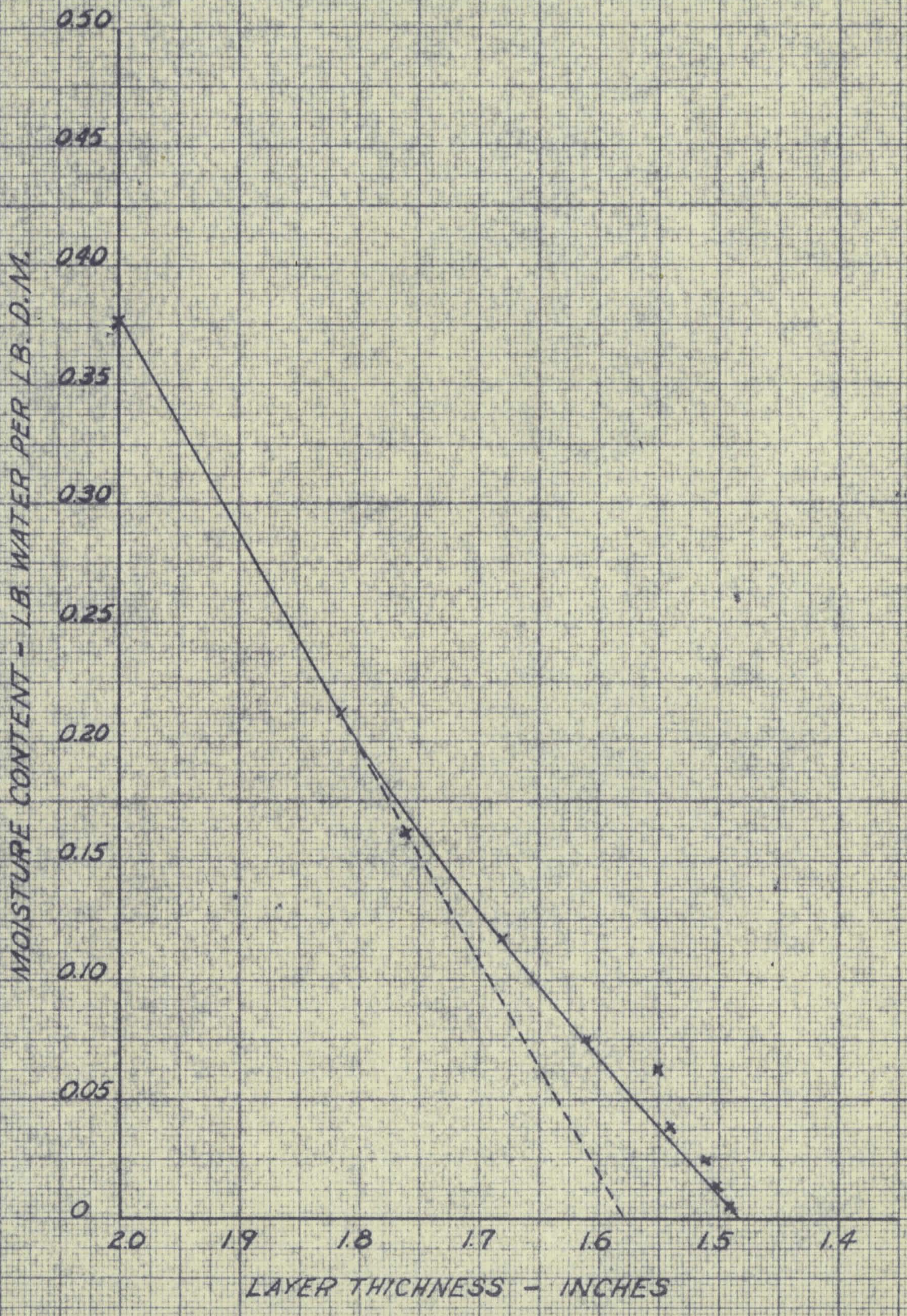


FIG. 85 MOISTURE CONTENT-THICKNESS CURVE.

PART II.

GEL STUDIES

THEORETICAL

In the study of drying by the method already described, it was noticed that changing various factors influencing drying produced a change in the appearance and tackiness of the GR-S rubber. This change was attributed to the extension of the polymerization reaction either through breakdown or disappearance of the inhibitor or by some reaction not affected by the inhibitors used in the rubber. This continuation of reaction, nevertheless, resulted in larger molecular units and produced a species which was insoluble in solvents in which it would otherwise be entirely soluble. This observation led to the use of analytical methods to ascertain the extent of gelation (formation of gel or large cross-linked molecular species) in rubber samples treated in the various ways already described. This property of GR-S rubber was recognized, and work was started before this present investigation was undertaken. Procedures and apparatus for analytical measurements of gel content were reported in the literature (10), and these methods were employed by the authors in their work.

It was the authors' purpose not only to determine the effect of drying on gel formation but also to study the gel formation process. This investigation involved the determination of the factors influencing gel formation, such as temperature-time relationships. With these factors established they were employed to give the data necessary on gel formation with respect to time. These data were plotted to give a curve of per cent gel versus time.

Inhibitors or modifiers are added to GR-S rubber to prevent polymerization beyond the desired point; however, further reaction apparently occurs. This situation suggests a possible breakdown or disappearance of the modifier. The modifier used is usually hydroquinone.

In the study of the modifier, the sublimation rate at various temperatures was found and the data correlated. To give further insight on the problem of inhibitors, the effect of allowing the crumb to stand in various concentrations of sulfuric acid before heating was studied.

Correlations of Mooney viscosity, processability, and other physical tests with gel content have been established by other investigators (9). Gel content has also been shown to be dependent not only upon drying but upon the whole process. Because of these direct correlations and the ease and relative quickness with which gel determinations may be carried out, this test has become a valuable factor in quality control. It was therefore considered an adequate test for following the quality of samples treated.

The theory involved in the justification of gel determinations as an index of the quality of GR-S necessitates defining the requirements of quality control in GR-S polymer. Quality control of a polymer requires:

(1) determination of the composition including proportions of isomers and (2) estimation of the size and shapes of the primary valence bonded particles. It thereby differs from the control of a heavy chemical, wherein composition alone is an adequate specification.

Much work on this subject has been carried out by Baker and Mullen (9), and the following discussion has been derived from their work.

The measurement of these properties has involved numerous and complex difficulties resulting in the general policy of relying on traditional chemical analyses for non-rubber constituents and a processing test such as plasticity, Mooney viscosity, and the like, for the raw polymer.

Plasticity or viscosity tests are accepted as widely useful, but they have been difficult to duplicate and standardize. They require closely controlled sample preparations, and are sharply varied by soaps, moisture, and other extraneous components.

It is significant that these processability tests, used to specify the raw polymer, yielded ambiguous evidence of the history of the rubber. Therefore, the connection with the polymerization process is remote. This ambiguity comes from the result that high viscosities (i.e., low plasticities or high Mooney values) come from either high molecular weights or from cross-linkage of any molecular species.

Recalling the original requirements for product control, and since the reaction process controls the polymer composition, within rather broad limits, molecular weight and gel content estimations are appropriate for particular attention. Examination of the possible particle types from the GR-S polymerization reaction shows that under suitable conditions a definite, characteristic, insoluble species of branched or netted particles could be separated or proved to be absent from the GR-S polymer. It was found that much GR-S rubber contained a class of particles which were linked together by primary valence bonds to form vastly larger units than the remaining benzene soluble molecules of the polymer. All polymer particles which are truly soluble are also fusible, and thus are truly thermoplastic and will blend together, stick to each other, resist tear, etc. Further, no example has yet been found of linear polymers which are insoluble because of size alone, even those of 10,000,000 molecular weight are completely soluble and are fusible. The implications of these facts for GR-S rubber, in which one insoluble, infusible species is often found comingled with a soluble, blendable species, are so basic that results could not fail to be found in practical properties. Apparatus and techniques have been developed with which all the truly insoluble fraction was separated consistently and accurately from a given polymer. The process was so designed as not to obtain erratic results which destroy or confuse correlations through the failure to isolate weak gel, dispersion of micro-gel, and insolubles.

Modifiers in diene polymerization limit propagation of chain branches and chain transfer. Thus their direct effect in GR-S rubber is to inhibit gel formation during the polymerization reaction. The exact correspondence of gel content with modifier efficiency seems plausable and is generally assumed true. The basic problem of variation of GR-S properties with polymerization temperature involves particularly gel content, judging from the poorer processability of high temperature polymers.

While the netted particles to which poor processability is attributed exist as microgel in the latex, opportunity for introduction of more extended gelation first occurs during stripping and coagulation. Continued cross-linkage in the stripping section could come from double bond activation and reaction in the interior of latex micells where no short stopper had penetrated.

Coagulation initiates wide spread opportunity for the formation of new primary valence bonds between GR-S polymer particles. For instance, new cross-links between units of microgel can convert these finally to an extensive microgel like the actual form of a valcanizate. However data are available which tend to prove that the reaction during salt-acid or alum coagulation is small and probably unimportant. The product of alum coagulation processes has generally lower plasticity than other types probably because of the small plasticizing effect of aluminum soaps as contrasted to alkali soaps. The difference in product necessitates more extreme drying conditions for the alum-coagulated rubber, and therefore tends to give higher gel contents because of promotion of both chain length and molecular cross linkage.

The drying of GR-S most certainly presents opportunity for gelation because the rubber is exposed to a relatively high temperature for periods of several hours. It must be noted, however, that oxygen and heat induced gelation by nature promote surface gel to a larger extent than internal gel. This condition results in a heterogeneous product and must be considered when sampling. An example of this may be seen in Table I. This sample gave evidence of being a gel free polymer. Many sections did give no gel, but some area evidently exposed to higher temperatures or more oxygen during drying yielded the scattered gel contents.

TABLE I.
SURFACE GEL

POLYMER SAMPLE	TREATMENT	GEL CONTENT
"Protected Sections"	Dried at Room Temperature	0, 0, 0
Other Sections	Dried at 104°C. in Plant Drier	9-7, 13-7, 7-2, 12-9, 2-8

In contrast to gelation which shows up as "thermal shortening" of the GR-S there is the concurrent reaction of chain splitting or heat softening. It is possible that this heat softening might be achieved during drying since it, too, is a function of temperature. Nevertheless such heat softening is regarded generally as a source of higher modulus in cured stock. In natural rubber this softening effect with time under aging conditions almost completely submerges the hardening effect of additional cross linkage. This stage in GR-S rubber is transient and brief, and the result of prolonged aging such as may occur in tires long operated at high temperature would be increased gel. Examination of the Table II. will tend to show the contrast between natural and GR-S rubber in this respect.

TABLE II.
EFFECT OF TIME OF HEATING

TREATMENT TIME HOURS	TREATMENT TEMPERATURE	GEL CONTENT	REMARKS
0	80°C.	1.2%	WEAK GEL
24	80°C.	44.5%	FIRM GEL
51	80°C.	60.8%	VERY FIRM GEL
73	80°C.	65.6%	STRONG GEL
190	80°C.	75.0%	RESINOUS
648	80°C.	84.2%	RESINOUS

The GR-S rubber under the treatment shown in Table II. gradually was hardened to the point that it appeared as a resin and no longer retained the usual rubber-like characteristics of elasticity, softness, etc. While natural rubber has a resinous state on aging it would have liquified from oxidation during the above treatment.

ANALYTICAL PROCEDURE

In the study of gel content in the GR-S polymer the procedure used was that of Baker and Mullen (Bell Telephone Laboratories) (10). It was found that in order to get comparative results, extreme accuracy was necessary and solvent of high purity was essential.

The procedure that follows is standard for the determination of gel content in GR-S rubber.

I. Sampling

A piece of rubber weighing about 10 grams is selected from a clear portion of the sample. In the case of samples of rubber that do not appear homogeneous a slice of rubber may be made across the cross section and several pieces of this used.

II. Apparatus

The apparatus used in the gel studies consisted of an extraction unit to separate the soluble gel from the insoluble gel, bottle for holding solution of soluble rubber in benzene, large (50 ml.) weighing bottles for evaporation of benzene from solution. Other laboratory apparatus such as balance, pipettes, etc., were used.

The extraction unit was of special type, (see Figures 86 and 87) designed especially for this procedure (10). It consisted of a glass tube with a stopcock for drainage at the bottom. Fitted into the tube was a set of twelve screens on a long threaded rod held in place by nuts.

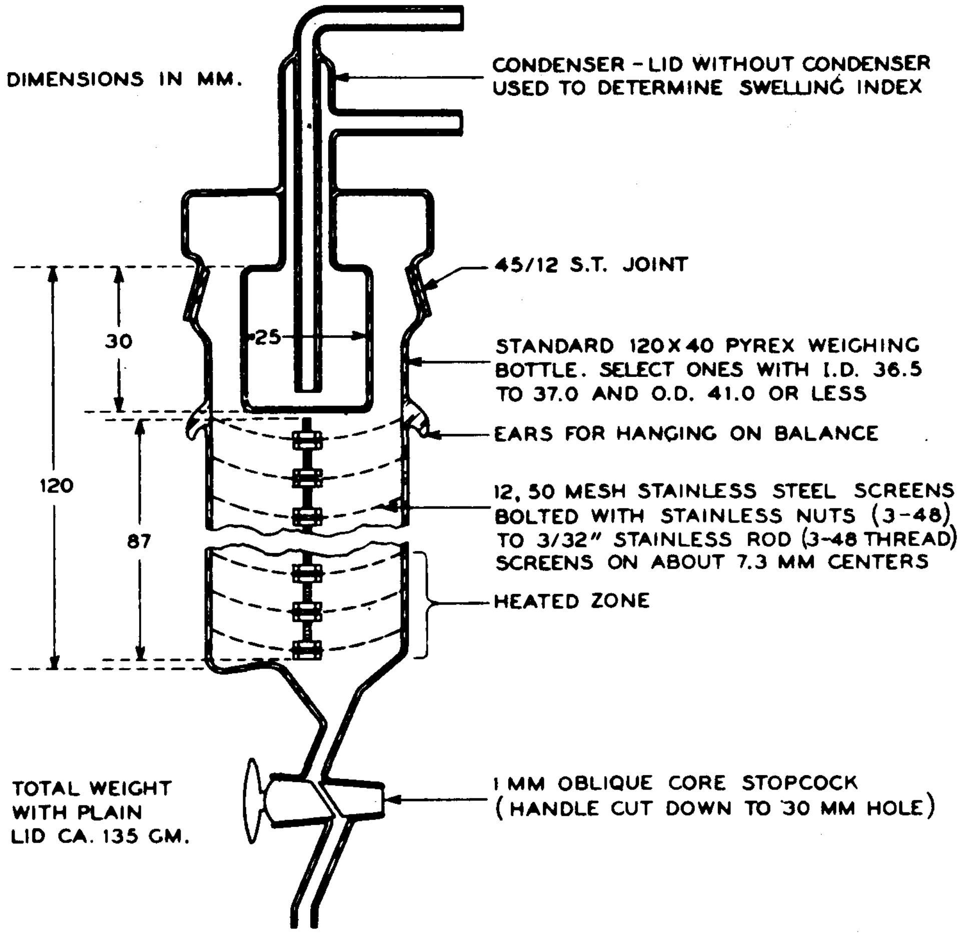


FIG. 86 RUBBER EXTRACTOR

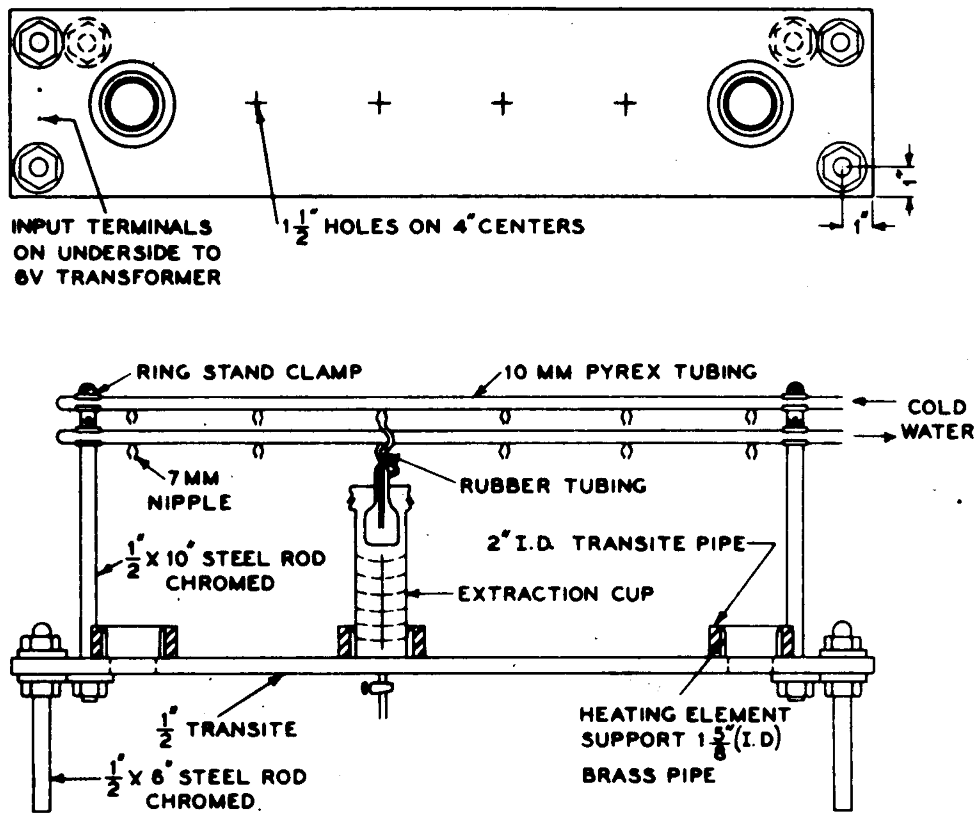


FIG. 87 RUBBER EXTRACTOR ASSEMBLY

The screens were made of stainless steel to withstand the acid used in cleaning. The top of the tube was fitted with a condenser or cooler which was connected by a ground glass joint. This tube assembly sat inside a hollow cylindrical heater which was controlled by a transformer giving very low voltage to maintain a very low temperature, about 30°C. The apparatus was designed to create convection movements thus keeping benzene solution homogeneous without moving weak gel particles from screen to screen.

III. Cleaning the Apparatus:

The stainless steel screens are removed from the cup (see Figure 86) with aid of pliers and the major portion of the benzene saturated gel is shaken into a waste jar. The screens and the cups are then put into a container provided with a cover. Concentrated nitric acid is then added and allowed to come to a boil. This should be done under a hood or some other suitable device to draw off the vapors. The nitric acid is allowed to cool and is drawn off by suction or syphon into a container. The apparatus is then washed off under water and dried in a laboratory oven. The stopcock is regreased and the screens inserted. This assembly is then weighed (A).

IV. Determination of the Gel Content:

Between 0.2000 and 0.3000 GM. of the dried sample are weighed (B) to 0.0002 GM. on a tared watch glass. The sample is then cut into about 20 small pieces and placed on the screens (none on the top screen). The screens with the rubber in place are then inserted into the cup. Reagent benzene (100 ml.) is run into the cup making sure that no air bubbles remain between the screens. The cup is placed in the holder rack (see Figure 87) and the cap put in position. This assembly is allowed to stand for 24 hours without disturbance.

At the end of the extraction period the cap is loosened and the benzene solution is slowly drained through the stopcock, collecting in a narrow-mouthed bottle only that portion of the solution which drains freely. Preferably the assembly should not be removed from the rack in this operation. After separation of the sol the cock is closed and the assembly is inclined about 45^{o} and rotated about a vertical axis several times to cause the free solution to separate more completely from the residual gel and drain to the bottom of the assembly. This is removed and discarded and the outlet tip dried with filter paper. The entire assembly is reweighed with a tared cap in place of the one used during extraction (C). The weight of the residual benzene film (D) left inside the apparatus is determined separately as described later. The weight of swollen gel (S.G.) may be calculated as follows:

$$\text{Weight of S.G.} = C - (A + D)$$

From the sol in the bottle is pipetted 50 ml.

of the polymer solution. This is transferred to a weighed 50 ml. weighing bottle (E) and evaporated at $80^{\circ}C$. for 12 hours. This time must be the same for all samples in order to have correlation. The sample dried is cooled in a desiccator and weighed (F).

$$2(F - E) = G, \text{ the weight of gel.}$$

$$\% \text{ Gel} = \frac{(B - G)100}{B}$$

Percentage gel should be reported to three significant figures or to the nearest 0.1%. Samples containing less than two percent of gel should be considered 100% soluble.

V. Determination of the Weight of the Benzene Film:

An assembly filled with 100 ml. of benzene is placed in the holder with an inverted cap resting over the mouth. The stopcock is adjusted to give a rate of flow that is just continuous (i.e., not dropwise) flow. When the cup has drained, it is rotated in the usual manner and the benzene thus collected is discarded. The unit is weighed and the difference in weight between this and the clean weight represents the weight of the benzene film.

EXPERIMENTAL PROCEDURE

At the outset of the study of gel formation, it was desired to determine the nature of the gel content--time curve at different temperatures and find the difference in gel forming tendencies in several types of GR-S. Samples of salt-acid coagulated rubber dried by a Proctor and Schwartz drier, B. F. Goodrich sheet rubber, and dry pellitized alum coagulated rubber were obtained. A sample of undried salt-acid coagulated rubber from the Jeffrey mill was also obtained.

The samples were all dried either by the plant driers or by a laboratory vacuum drier at 80°C. and 29 inches of Hg. Each of the samples was broken into small pieces, to minimize surface effects, and placed on small metal trays. The trays were then placed in a laboratory air drier pre-adjusted to the desired temperature. Thermocouples (copper-constantan) were placed inside the trays to make sure the temperature of the rubber was the same as the temperature indicated by the thermometer in the drier.

One sample of sheet dried crumb (plant dried) was held at 90°C. and another portion of the same sample was held at 80°C. The same technique was applied to the sample of plant dried alum coagulated rubber. A sample of salt-acid coagulated crumb from the Jeffrey mill was dried in the laboratory at 80°C. and held at 80°C. for the duration of the test.

Small portions of these several samples were withdrawn periodically and the gel content determined. The procedure for determining the gel content was given in the section on "Analytical Procedures".

Samples of GR-S crumb were prepared by heating and pressing in a hydraulic press and the gel formation characteristics studied. For this, 10 GM. samples of wet crumb were placed between two small metal plates which were in turn placed between the platens of a hydraulic press along with a thermocouple. The platens were quickly brought together and a constant gage pressure of 100 psi. maintained for the duration of the test. The temperature of the platens was from 187°F. to 300°C., and the time at each temperature was varied from 0 to 30 minutes. At the end of the desired time of heating and pressing the crumb was quickly removed from the press. The gel content was determined for each of the samples dried in this manner. The remainder of each of the samples was placed on metal trays and put in a laboratory oven at 90°C. At the end of 24 hours small portions of each were taken and the gel content determined. This sampling was repeated at 240 hours.

Samples of hydroquinone were heated in a laboratory oven in order to study the effect of heating. Technical hydroquinone (3 GM.) was placed on a weighed watch glass and put in the oven at the desired temperature.

At frequent time intervals this was removed and weighed.

The samples were heated until all the hydroquinone had sublimed. Temperatures of 80, 100, 115, 140, and 160 degrees centigrade were employed.

The effect of sulfuric acid on gel formation in GR-S crumb was studied. Equal weights of crumb from the Jeffrey mill were placed in 500 ml. erlenmeyer flasks. Sulfuric acid in five different concentrations was prepared (1, 5, 10, 20, 40% H_2SO_4 by weight). A 100 ml. sample of acid of each concentration was put in five flasks containing rubber and 100 ml. of water was added to another. The samples of crumb were allowed to remain in contact with the acid for 24 hours. At the end of this period the samples of crumb were removed and washed several times in water to remove all acid. All samples were dried in a laboratory oven at 70°C. for twelve hours. The samples were then prepared for heating by breaking them up and putting them on small trays. These were then placed in an oven at 100°C. Small portions of each sample were removed periodically and the gel content determined.

Samples of GR-S crumb which were dried by air passing through the layer of rubber in the laboratory drier were heat treated to study the formation of the gel. Samples were chosen which were dried at various temperatures, from 140-220°F. These samples were broken up into many small pieces and placed on watch glasses. These were put in a laboratory, forced-air oven regulated at 115°C. Small portions of these samples were removed at very frequent intervals, namely, every 30 minutes at first and then every hour as the test progressed. These were all examined for gel content.

Rubber which was dried by the laboratory vacuum drier was tested for gel content. Samples were chosen which were dried at various temperatures.

DATA, RESULTS, AND DISCUSSION

The results of this investigation gave insight into the formation of gel in GR-S rubber and bear out the extent and importance of this property as a control problem in production. The results also indicate that during the drying operation there is possibility for more extensive gel formation than in other parts of the production process. For instance, the samples of GR-S crumb from the Jeffrey mill, as noted in Table I., show no gel or at least an amount smaller than the accuracy of the determination (10). However, these samples when dried by plant driers showed varying amounts of gel. Some of the variance could, of course, come from the difference in operation of the drier.

The data in Table III. show the formation of gel as time progresses, at a temperature of 80°C. Tables IV. and V. show gel formation at other temperatures. Figure 88 shows the variation of gel content for these samples of rubber held at definite temperatures. The trends to be noted from these data are the same for all the samples regardless of the preliminary treatment. An increase in temperature above room temperature promotes gel, rapidly at first and very slowly after long periods of time. Also to be noted is that for a given type sample, a higher temperature causes more gel formation in a specific length of time. All the samples apparently approached some asymptotic value after a long period of time. This fact would tend to indicate that very mild temperatures and short drying periods would yield the best rubber. From a standpoint of gel content this situation would certainly be true; however, the necessity for thorough and complete drying provides a counterbalance since it was found that wet rubber gave poor tread processing (9).

These results were also substantiated by the data in Tables VI., VII., and VIII. These samples were prepared by heating and pressing at various temperatures and the same pressure. It is noted that generally higher temperature and longer times of drying resulted in more gel formation. Also, in general, the material dried at the milder conditions does not have so much gel after 24 hours at 90°C. as the material dried under the more strenuous conditions. Again it is apparent that after a long treatment, in this case 240 hours, the samples all approached substantially the same high gel content.

The data in Tables III., IV., and V. indicate gel formation trends in GR-S when treated for extremely long periods of time. This length of time is obviously greater than the time of production under any drying conditions or processing techniques. Table XVIII. gives data on gel formation over a short period of time at 115°C. Figure 89 is a plot of these data and therefore is an enlarged section of the first portion of the gel content-time curves in Figure 88. The rate of gel formation was rapid for a short time and the gel content at the first maximum point was very high relative to the final value. At this point the effect of heat softening became greater than the forward reaction and the gel content decreased to about one-half the first maximum value. From here the gel formation increased but at a rate much less than at first. Rapid gel formation was partially suppressed by continued heat softening reaction. The time required for the sample to attain a gel content equal to the first maximum was three times greater than originally. Furthermore it was noted that the sample became very sticky after heat softening began; however, as the gel content became high the sample lost its stickiness and elasticity and became brittle and resinous.

In the drying of GR-S in the standard plant driers, many special techniques have been applied in order to eliminate the problems caused by the crumb sticking to the flights. The stickiness of the crumb is probably only a surface condition which possibly results after the surface has dried and is still subjected to the heat in the drier. It is recognized that in the drying operation the surface would dry first because of the small resistance of the air film compared to the resistance offered to diffusion of water through the crumb particle. It follows also, from results of work by the authors, that the crumb temperature rises rapidly after the moisture has been removed. Therefore, by the time the whole crumb has dried, the surface has been at a relative high temperature for most of the drying time. This would then give rise to both gel formation and stickiness on the surface of the crumb particle. It is the opinion of the authors that shorter drying times and removal of the crumb when it is dry would be a step in the right direction toward eliminating the stickiness problem. This improvement requires greater flight speeds and higher apparent air velocity through the layer of crumb. Data are available which show that the crumb is usually dry at the end of the second pass in the plant driers. The third pass subjects the dried rubber to needless heating and thus gives rise to gel formation and stickiness.

It is evident from the data already presented that gel formation in GR-S depends largely on the temperature and time of drying. If the normal operating conditions of the driers are sufficient to have any material effect on the hydroquinone present, then it might be for this reason that the gel is formed. An attempt was made to determine the hydroquinone stability to heat at various lengths of time. These data are presented in Tables IX., X., and XI. and are plotted in Figure 90. It is significant that at temperatures above 100°C. the sublimation of hydroquinone sharply increased and at a relatively low temperature of

115^{o}C. the quantity has decreased by 1/6 in two hours. The loss of an appreciable amount of this anti-oxidant at this surface of the crumb particle is conceivable under the usual drying conditions.

The effect of acidity of the coagulating bath was investigated. Tables XII., XIII., XIV., and XV. show the results of treating the crumb with various concentrations of sulfuric acid and the subsequent heat treatment. However, these results are not intended to be conclusive but merely to give an indication of a trend. These data are plotted on Figure 91. Regardless of the preliminary treatment, none of the samples formed gel when dried at 70^{o}C. for twelve hours. Also, the crumb that was subjected to the sulfuric acid treatment, on heating, had consistently less gel than the untreated sample. Except for slight discrepancies it appears that the samples treated with the lower concentrations of acid gave less gel than those treated with higher concentrations of acid. The effect of heat softening is again exhibited in all the samples. However, the higher concentrations of acid gave samples in which the initial gelation was suppressed.

No attempt is made in this thesis to explain the mechanism of this action, rather it is left for more extensive work to be done in the study of anti-oxidents and their effects.

Samples dried by vacuum drying procedures used in this investigation were examined for gel content and the data presented in Table XVI. It is significant that the sample which formed the greatest amount of gel was not dried at the highest temperature but was dried for the longest period of time. This is important in consideration of the discussion on formation of surface gel when drying times become too long, regardless of temperature.

Data are also presented on gel formation in samples dried by air passing through the layer of crumb. Table XVII. shows the gel contents of these samples at the end of the drying. The apparent discrepancies in the samples comes from the effects of both temperature and time of drying on the gel and heat softening reactions as well as possible differences in the wet crumb. However, Tables XVIII., XIX., and XX. show data on the gel forming characteristics of these samples at 115°C. Figure 92 shows that all these samples followed the usual trends. It is important, however, that at this temperature (115°C.) the effect of heat softening was greatly accentuated, and the maximum point came both at a higher gel content and much sooner than the samples studied at 100°C.

The important generalizations to be derived from this study are:

1. GR-S crumb when heated forms larger molecules through chain growth and/or cross linkage.

2. When the time of heating is sufficient, a noticeable amount of molecular increase is effected.

3. Ordinary drying conditions are sufficient in most cases to produce detectable gel.

4. Gel formation during drying places limits on the drying conditions to be used for best results.

TABLE III.
GEL CONTENT DATA
GR-S CRUMB

SAMPLE NO.	TEMPERATURE (°C.)	TIME OF DRYING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
1	80	3.0	0.2446	38.9441	50	39.0645	0.2408	0.0038	1.50
2	80	11.5	0.3368	51.8714	50	52.0376	0.3324	0.0044	1.30
3	80	22.5	0.2804	38.2193	50	38.3500	0.2614	0.0190	6.78
4	80	30.0	0.2709	37.4469	50	37.5518	0.2098	0.0611	22.6
5	80	46.5	0.3021	37.4448	50	37.5820	0.2744	0.0277	9.16
6	80	72.0	0.2780	51.8688	50	51.9721	0.2066	0.0714	25.7
7	80	100.0	0.3012	34.4887	50	34.4887	0.1784	0.1228	39.4
8	80	120.0	0.2261	38.2170	50	38.2170	0.1238	0.1023	45.2
9	80	168.0	0.3064	38.9425	50	39.0200	0.1550	0.1514	49.5
10	80	385.0	0.2308	12.0530	20	12.0667	0.0685	0.1623	70.4
11	80	624.0	0.3013	12.2054	20	12.2220	0.0830	0.2183	72.5
12	80	826.0	0.2625	12.8483	20	12.8616	0.0665	0.1960	74.8

TABLE IV.
GEL CONTENT DATA
ALUM COAG. GR-S

SAMPLE NO.	TEMPERATURE OF DRYING (°C.)	TIME OF DRYING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
13	80	0	0.2367	12.8733	20	12.9096	0.1815	0.0552	23.3
14	80	23.5	0.2919	12.8730	20	12.8996	0.1330	0.1589	54.5
15	80	51.0	0.2480	13.3487	20	13.3724	0.1185	0.1295	52.2
16	80	73.0	0.2264	12.0520	20	12.0745	0.1125	0.1139	50.3
17	80	190.0	0.2554	12.2052	20	12.2279	0.1135	0.1419	55.5
18	80	648.0	0.2480	7.0461	20	7.0586	0.0625	0.1855	74.9
19	90	24.0	0.2381	12.1601	20	12.1830	0.1145	0.1236	51.9
20	90	50.5	0.2420	12.6300	20	12.6500	0.1000	0.1420	58.7
21	90	73.5	0.2257	12.8485	20	12.8657	0.0860	0.1397	62.0
22	90	190.0	0.2434	11.9562	20	11.9658	0.0480	0.1954	80.4
23	90	648.0	0.2649	13.3480	20	13.3535	0.0275	0.2374	89.7

TABLE V.
GEL CONTENT DATA
SHEET DRIED GR-S

SAMPLE NO.	TEMPERATURE OF DRYING (°C.)	TIME OF DRYING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
24	80	0	0.2849	13.3491	20	13.4054	0.2815	0.0034	1.2
25	80	24.0	0.2905	12.8732	20	12.9054	0.1610	0.1295	44.5
26	80	51.0	0.2421	13.3492	20	13.3681	0.0945	0.1476	60.8
27	80	73.5	0.2626	12.0520	20	12.0701	0.0905	0.1721	65.6
28	80	190.0	0.2516	12.2052	20	12.2178	0.0630	0.1886	75.0
29	80	648.0	0.2349	12.2048	20	12.2123	0.0375	0.1974	84.2
30	90	24.0	0.2319	12.1602	20	12.1805	0.1015	0.1304	56.3
31	90	50.5	0.2316	12.6300	20	12.6428	0.0640	0.1676	72.4
32	90	73.5	0.2945	12.8485	20	12.8630	0.0725	0.2220	75.4
33	90	190.0	0.2462	11.9563	20	11.9633	0.0350	0.2112	85.8
34	90	648.0	0.2574	12.1597	20	12.1660	0.0315	0.2259	88.0

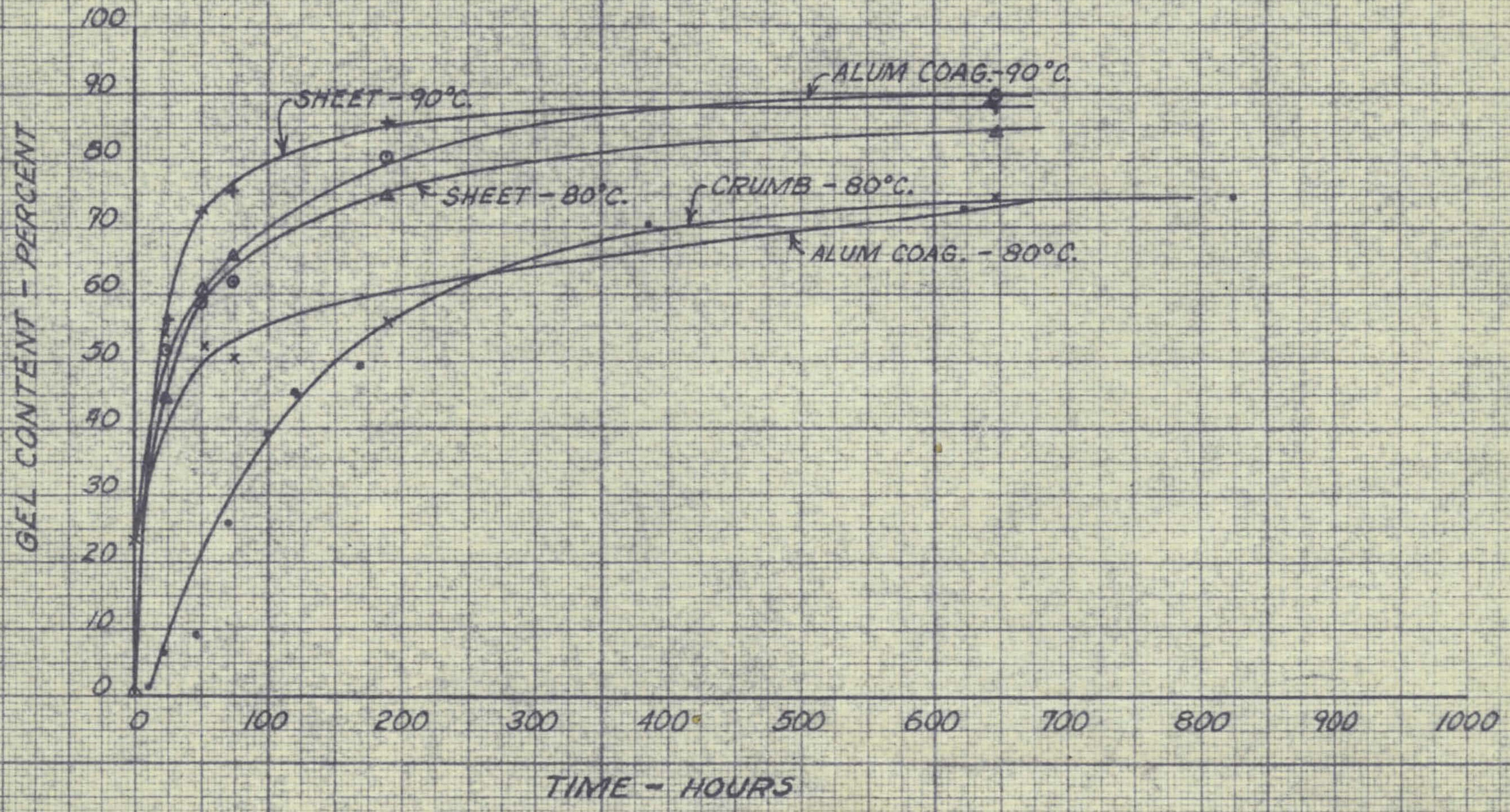


FIG. 88 GEL CONTENT - TIME CURVES

TABLE VI.
GEL CONTENT DATA
GR-S DRIED BY HEATING AND PRESSING

SAMPLE NO.	TEMPERATURE OF PLATENS (°F.)	TIME OF PRESSING AT 100 PSI. (MIN.)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
35	187	15	0.2327	11.8423	20	11.8870	0.2235	0.0092	4.0
36	187	30	0.2125	12.0558	20	12.0960	0.2010	0.0115	5.4
37	200	15	0.2489	7.0466	20	7.0928	0.2310	0.0179	7.2
38	205	30	0.2045	13.3494	20	13.3868	0.1870	0.0175	8.6
39	203	5	0.2290	12.1596	20	12.2024	0.2140	0.0150	6.6
40	200	10	0.2245	12.1600	20	12.2034	0.2170	0.0075	3.3
41	266	5	0.2577	12.1593	20	12.2073	0.2396	0.0182	7.1
42	255	10	0.2352	12.8484	20	12.8907	0.2116	0.0237	10.1
43	255	15	0.2520	11.8426	20	11.8893	0.2335	0.0185	7.3
44	300	2	0.2224	12.0557	20	12.0996	0.2195	0.0029	1.3
45	300	5	0.2702	13.3486	20	13.3934	0.2240	0.0462	17.1
46	300	8	0.2395	12.2041	20	12.2420	0.1895	0.0500	20.9

TABLE VII.
GEL CONTENT DATA
SUPPLEMENTARY TREATMENT OF GR-S DRIED BY HEATING AND PRESSING

SAMPLE NO.	TEMPERATURE OF TREATMENT (°C.)	TIME OF HEATING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
35	90	24	0.2107	13.3490	20	13.3809	0.1595	0.0512	24.3
36	90	24	0.1820	12.2054	20	12.2365	0.1555	0.0255	14.0
37	90	24	0.2456	12.5518	20	12.5893	0.1875	0.0581	23.7
38	90	24	0.2305	12.8486	20	12.8820	0.1670	0.0635	27.6
39	90	24	0.3193	11.8422	20	11.8834	0.2060	0.1133	35.5
40	90	24	0.1966	12.0558	20	12.0840	0.1410	0.0556	28.3
41	90	24	0.1985	12.2033	20	12.2276	0.1115	0.0870	43.8
42	90	24	0.1902	12.4338	20	12.4566	0.1140	0.0762	40.0
43	90	24	0.2695	12.6457	20	12.6757	0.1500	0.1195	44.4
44	90	24	0.2422	12.6467	20	12.6777	0.1550	0.0872	36.0
45	90	24	0.2919	12.8063	20	12.8410	0.1735	0.1184	40.7
46	90	24	0.2826	13.0704	20	13.1007	0.1515	0.1311	46.4

TABLE VIII.
GEL CONTENT DATA
SUPPLEMENTARY TREATMENT OF GR-S DRIED BY HEATING AND PRESSING

SAMPLE NO.	TEMPERATURE OF TREATMENT (°C.)	TIME OF HEATING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
35	90	240	0.2408	12.1598	20	12.1725	0.0635	0.1773	73.7
36	90	240	0.2397	13.3487	20	13.3609	0.0610	0.1787	74.6
37	90	240	0.2420	12.8483	20	12.8599	0.0580	0.1840	76.1
38	90	240	0.2636	12.2053	20	12.2177	0.0620	0.2016	76.5
39	90	240	0.2328	12.4341	20	12.4474	0.0665	0.1663	71.5
40	90	240	0.2640	12.6463	20	12.6594	0.0655	0.1985	75.2
41	90	240	0.2367	12.6470	20	12.6575	0.0525	0.1842	77.9
42	90	240	0.2313	12.8072	20	12.8190	0.0590	0.1723	74.5
43	90	240	0.2378	13.0708	20	13.0833	0.0625	0.1753	73.8
44	90	240	0.2378	12.5517	20	12.5633	0.0580	0.1798	75.6
45	90	240	0.2596	12.7790	20	12.7917	0.0635	0.1961	75.6
46	90	240	0.2550	17.3966	20	17.4157	0.1055	0.1495	58.6

TABLE IX.
HYDROQUINONE STABILITY DATA AT 80°C. AND AT 100°C.

TIME OF HEATING (HOURS)	TEMPERATURE OF HEATING (°C.)	TARE WEIGHT (GM.)	TARE AND SAMPLE WEIGHT (GM.)	SAMPLE WEIGHT (GM.)	WEIGHT LOST (GM.)	PER CENT LOST
0	80	24.1650	27.1652	3.0002	0	0
0.75	80	24.1650	27.1458	2.9808	0.0194	0.65
1.33	80	24.1650	27.1356	2.9706	0.0296	0.99
2.0	80	24.1650	27.1265	2.9615	0.0387	1.29
4.2	80	24.1650	27.1000	2.9350	0.0652	2.17
7.33	80	24.1650	27.0544	2.8894	0.1108	3.69
20.0	80	24.1650	26.7724	2.6074	0.3928	13.10
0	100	24.1650	26.7724	2.6074	0	0
0.66	100	24.1650	26.7350	2.5700	0.0374	1.43
1.59	100	24.1650	26.7250	2.5600	0.0474	1.82
5.0	100	24.1650	26.6870	2.5220	0.0854	3.28
6.3	100	24.1650	26.6800	2.5150	0.0924	3.54
25.5	100	24.1650	26.4750	2.3100	0.2974	11.40
52.5	100	24.1650	26.2285	2.0635	0.5439	20.85

TABLE X.
HYDROQUINONE STABILITY DATA AT 105°C. AND 115°C.

TIME OF HEATING (HOURS)	TEMPERATURE OF HEATING (°C.)	TARE WEIGHT (GM.)	TARE AND SAMPLE WEIGHT (GM.)	SAMPLE WEIGHT (GM.)	WEIGHT LOST (GM.)	PER CENT LOST
0	105	31.0680	34.0680	3.0000	0	0
1.0	105	31.0680	33.9775	2.9095	0.0905	3.02
2.25	105	31.0680	33.7657	2.6977	0.3023	10.08
4.5	105	31.0680	33.6670	2.5990	0.4010	13.37
5.75	105	31.0680	33.5790	2.5110	0.4890	16.30
9.75	105	31.0680	33.3179	2.2499	0.7501	25.00
23.0	105	31.0680	31.9392	0.8712	2.1288	70.96
0	115	23.4302	26.4302	3.0000	0	0
3.5	115	23.4302	25.7157	2.2855	0.7145	23.80
4.75	115	23.4302	25.4820	2.0518	0.9482	31.55
24.0	115	23.4302	23.5432	0.1130	2.8870	96.20
25.5	115	23.4302	23.5150	0.0848	2.9152	97.20
27.5	115	23.4302	23.4470	0.0168	2.9832	99.40

TABLE XI.
HYDROQUINONE STABILITY DATA AT 130°C., 150°C., and 160°C.

TIME OF HEATING (HOURS)	TEMPERATURE OF HEATING (°C.)	TARE WEIGHT (GM.)	TARE AND SAMPLE WEIGHT (GM.)	SAMPLE WEIGHT (GM.)	WEIGHT LOST (GM.)	PER CENT LOST
0	130	31.0690	34.0690	3.0000	0	0
2.75	130	31.0690	32.6300	1.5610	1.4390	47.90
6	130	31.0690	31.5078	0.4388	2.5612	85.50
7	130	31.0690	31.3390	0.2700	2.7300	91.10
0	150	32.7750	35.7750	3.0000	0	0
0.09	150	32.7750	35.5980	2.8230	0.1770	5.90
0.16	150	32.7750	35.4510	2.6760	0.3240	10.80
0.25	150	32.7750	35.4130	2.6380	0.3620	12.07
0.33	150	32.7750	35.3530	2.5780	0.4220	14.07
0	160	23.4275	26.4275	3.0000	0	0
0.25	160	23.4275	25.3258	1.8983	1.1017	36.72
0.50	160	23.4275	25.1010	1.6735	1.3265	44.22
0.75	160	23.4275	24.6823	1.2548	1.7452	58.17

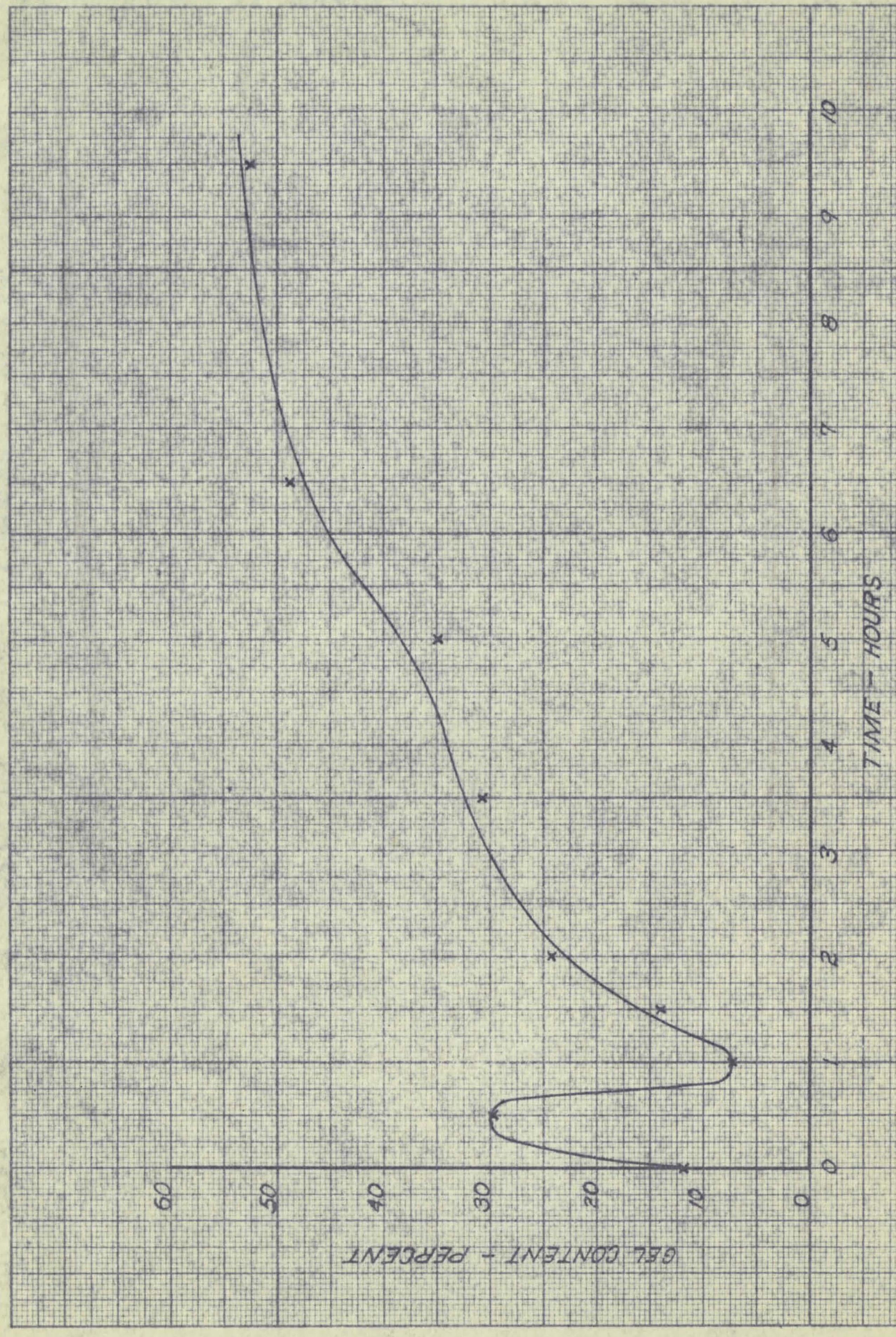


FIG. 89 GEL CONTENT-TIME CURVE
EFFECT OF HEATING AT 115°C.

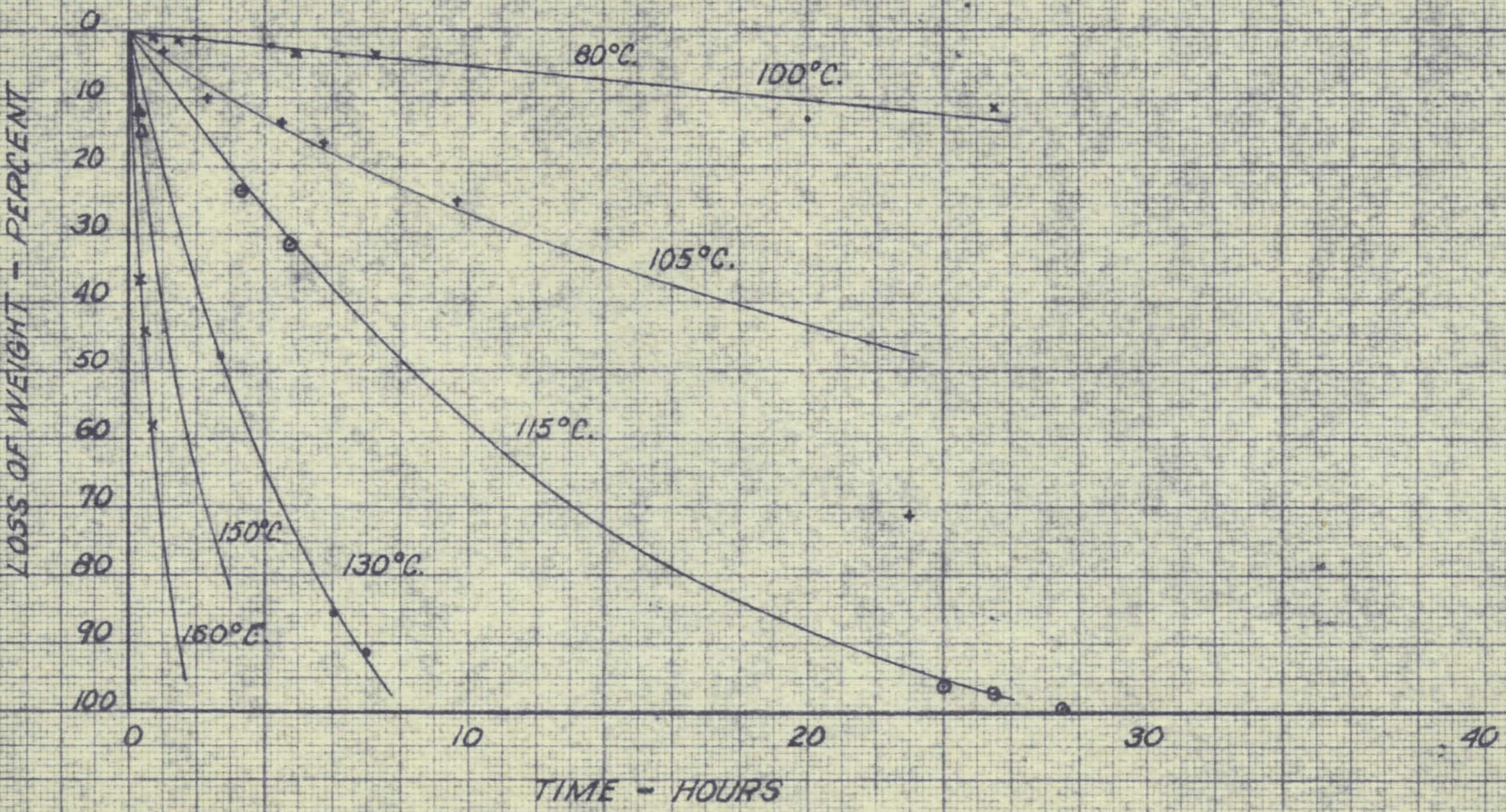


FIG. 90 HYDROQUINONE STABILITY
EFFECT OF HEATING

TABLE XII.
GEL CONTENT DATA
SULFURIC ACID TREATMENT OF GR-S RUBBER

SAMPLE NO.	CONCENTRATION OF ACID (%)	TIME OF DRYING (HOURS) AT 70°C.	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
47	0	12	0.2810	28.9061	50	29.0638	0.3154	--	0
48	1	12	0.2694	28.5330	50	28.6880	0.3100	--	0
49	5	12	0.2720	26.9210	50	27.0818	0.3216	--	0
50	10	12	0.2719	29.2393	50	29.3961	0.3136	--	0
51	20	12	0.2597	29.0334	50	29.1851	0.3034	--	0
52	40	12	0.2700	28.9330	50	29.0894	0.3128	--	0

TABLE XIII.
GEL CONTENT DATA
SUPPLEMENTARY TREATMENT OF ACID TREATED GR-S RUBBER

SAMPLE NO.	TEMPERATURE OF HEATING (°C.)	TIME OF HEATING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
47	100	1	0.2563	28.9057	50	29.0055	0.1996	0.0567	22.1
48	100	1	0.2512	29.1957	50	29.3114	0.2378	0.0134	5.3
49	100	1	0.1844	28.8557	50	28.9417	0.1720	0.0124	6.7
50	100	1	0.2487	28.5338	50	28.6636	0.2596		0
51	100	1	0.2493	29.2557	50	29.3764	0.2414	0.0079	3.2
52	100	1	0.2698	29.7018	50	29.8278	0.2520	0.0179	6.6
47	100	2	0.2127	29.1953	50	29.2597	0.1288	0.0839	39.4
48	100	2	0.2764	26.9210	50	27.0315	0.2210	0.0554	20.1
49	100	2	0.2150	29.1910	50	29.2410	0.2000	0.0150	7.0
50	100	2	0.2550	26.9195	50	26.9803	0.2432	0.0118	4.6
51	100	2	0.2430	29.2368	50	29.2957	0.2356	0.0074	3.0
52	100	2	0.2563	29.0316	50	29.0917	0.2404	0.0159	6.2

TABLE XIV.
GEL CONTENT DATA
SUPPLEMENTARY TREATMENT OF ACID TREATED GR-S RUBBER

SAMPLE NO.	TEMPERATURE OF HEATING (°C.)	TIME OF HEATING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
47	100	3	0.2650	28.9044	50	29.0104	0.2120	0.0530	20.0
48	100	3	0.2792	29.1919	50	29.3126	0.2414	0.0378	13.5
49	100	3	0.3691	28.8542	50	28.9832	0.2562	0.0129	4.8
50	100	3	0.2680	28.5323	50	28.6576	0.2506	0.0174	6.5
51	100	3	0.2683	29.2530	50	29.3836	0.2612	0.0071	2.6
52	100	3	0.2592	29.6988	50	29.8246	0.2516	0.0076	2.9
47	100	4	0.2486	29.1905	50	29.2870	0.1930	0.0556	22.4
48	100	4	0.2512	26.9206	50	27.0310	0.2208	0.0304	12.1
49	100	4	0.2641	29.2364	50	29.3665	0.2602	0.0039	1.5
50	100	4	0.2369	29.0315	50	29.1463	0.2296	0.0073	3.1
51	100	4	0.2360	28.9310	50	29.0480	0.2340	0.0020	0.85
52	100	4	0.2436	27.4034	50	27.5246	0.2424	0.0012	0.5

TABLE XV.
GEL CONTENT DATA
SUPPLEMENTARY TREATMENT OF ACID TREATED GR-S RUBBER

SAMPLE NO.	TEMPERATURE OF HEATING (°C.)	TIME OF HEATING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
47	100	22	0.2848	28.9043	50	28.9947	0.1808	0.1040	36.5
48	100	22	0.2700	29.1906	50	29.2811	0.1810	0.0890	33.0
49	100	22	0.2689	28.8543	50	28.9766	0.2446	0.0243	8.4
50	100	22	0.2700	28.5315	50	28.6346	0.2062	0.0638	23.6
51	100	22							
52	100	22	0.2684	29.6974	50	29.8104	0.2260	0.0424	15.8
47	100	72	0.2870	29.1904	50	29.2840	0.1872	0.0998	34.8
48	100	72	0.2780	26.9202	50	27.0250	0.2096	0.0684	24.6
49	100	72	0.2633	29.2357	50	29.3554	0.2394	0.0239	9.1
50	100	72	0.2561	29.0326	50	29.1466	0.2280	0.0281	11.0
51	100	72	0.2616	28.9320	50	29.0540	0.2440	0.0172	6.6
52	100	72	0.2726	27.5262	50	27.5262	0.2450	0.0276	10.1

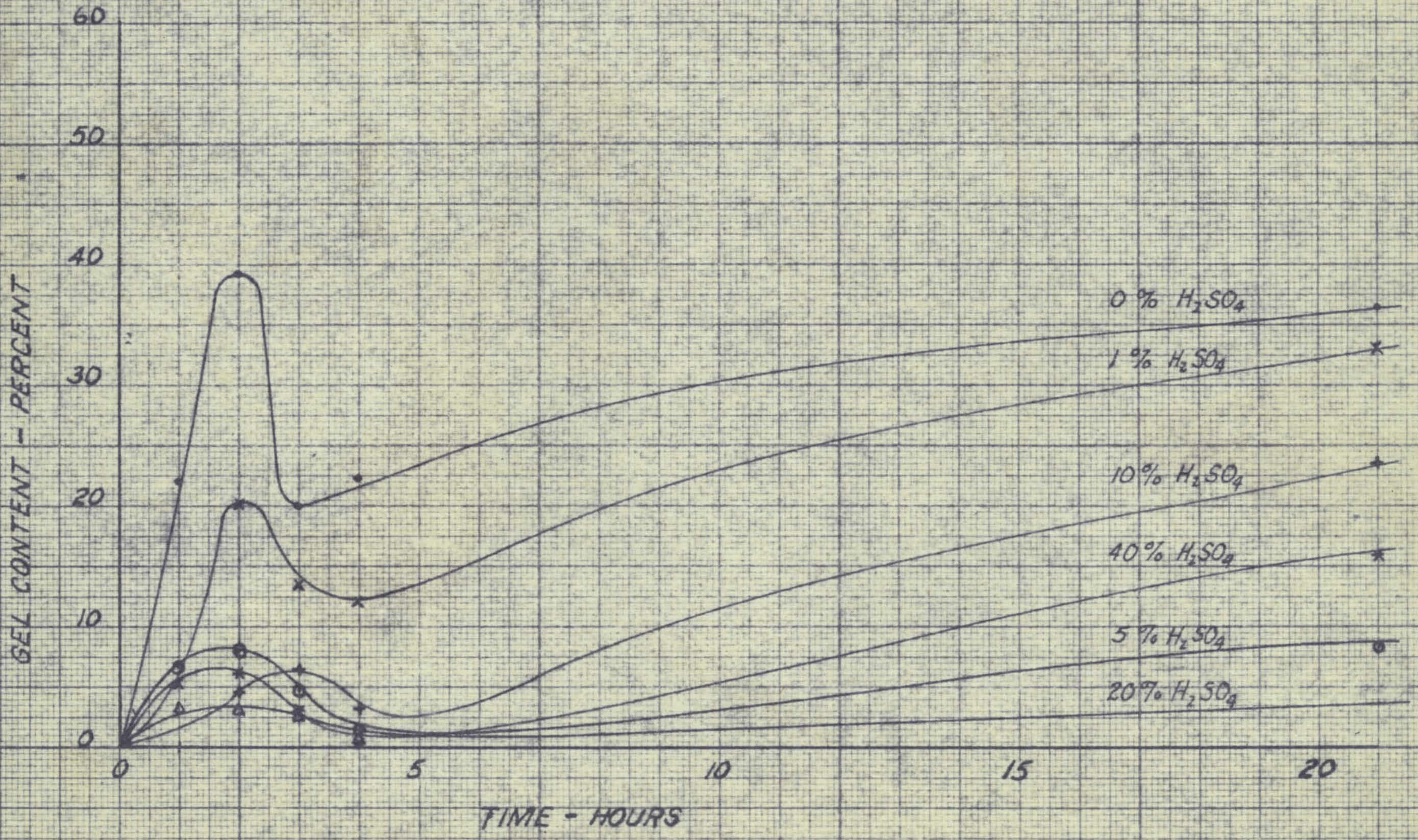


FIG. 91 GEL CONTENT – TIME CURVES
EFFECT OF SULFURIC ACID ON GEL FORMATION

TABLE XVI.
GEL CONTENT DATA
VACUUM DRIED GR-S RUBBER

SAMPLE NO.	VACUUM IN. OF HG.	TEMPERATURE OF DRYING (°C.)	TIME OF DRYING (HOURS)	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X 100/ALIQUOT	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
53	25	70	2.5	0.2605	7.0472	20	7.0985	0.2565	0.0040	1.54
54	15	85	4.0	0.2452	13.3490	20	13.3978	0.2440	0.0012	0.49
55	25	85	4.0	0.2361	12.0525	20	12.0995	0.2350	0.0011	0.47
56	21	60	5.5	0.2641	12.2056	20	12.2555	0.2495	0.0146	5.53
57	26	70	2.5	0.2351	12.1600	20	12.2070	0.2350	0.0001	0
58	15	70	4.5	0.2647	12.8484	20	12.9034	0.2750		0
59										
60	20	66	3.5	0.2104	11.8427	20	11.8850	0.2115		0
61	20	75	3.0	0.2480	11.9556	20	12.0066	0.2550		0

TABLE XVII.
GEL CONTENT DATA
GR-S RUBBER DRIED BY AIR THROUGH CRUMB LAYER

SAMPLE NO.	TEMPERATURE OF DRYING (°F.)	TIME OF DRYING (HOURS)	RELATIVE HUMIDITY (%)	AIR VELOCITY FT. PER MIN.	GEL CONTENT (%)
62	141	1.00	15.5	420	11.9
63	155	1.84	6.0	290	33.2
64	178	1.75	8.0	80	2.4
65	184	2.00	6.0	170	8.7
66	220	1.75	5.0	175	34.8

TABLE XVIII.
GEL CONTENT DATA
SUPPLEMENTARY TREATMENT OF SAMPLES DRIED WITH AIR THROUGH CRUMB LAYER

SAMPLE NO.	DETERMINATION NO.	TEMPERATURE OF HEATING (°C.)	TIME OF HEATING HOURS	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
62	1	115	0	0.2355	28.9319	50	29.0346	0.2074	0.0281	11.9
	2	115	0.5	0.2559	28.9045	50	28.9942	0.1794	0.0765	29.9
	3	115	1	0.2280	29.6978	50	29.8036	0.2116	0.0164	7.2
	4	115	1.5	0.1680	29.1903	50	29.2625	0.1444	0.0236	14.05
	5	115	2	0.2106	28.5320	50	28.6119	0.1598	0.0508	24.2
	6	115	3.5	0.2393	29.0315	50	29.1143	0.1656	0.0737	30.8
	7	115	5	0.2732	28.8530	50	28.9420	0.1780	0.0952	34.9
	8	115	6.5	0.2604	28.8528	50	28.9194	0.1332	0.1272	48.8
	9	115	9.5	0.2410	26.9194	50	26.9767	0.1146	0.1264	52.5
63	1	115	0	0.2281	27.4034	50	27.4796	0.1524	0.0757	33.2
	2	115	0.5	0.2594	29.1898	50	29.2611	0.1426	0.1168	45.0
	3	115	1	0.2407	29.6972	50	29.7930	0.1916	0.0491	20.4
	4	115	1.5	0.1779	29.9043	50	28.9824	0.1562	0.0217	12.2
	5	115	2	0.2286	29.2523	50	29.3480	0.1914	0.0372	16.3
	6	115	3.5	0.2587	28.9314	50	29.0250	0.1872	0.0715	27.6
	7	115	5	0.2487	28.5317	50	28.6171	0.1708	0.0779	31.3
	8	115	6.5	0.2434	28.5315	50	28.5958	0.1286	0.1148	47.1
	9	115	9.5	0.2191	29.0318	50	29.0865	0.1094	0.1097	50.0

TABLE XIX.
GEL CONTENT DATA
SUPPLEMENTARY TREATMENT OF SAMPLES DRIED WITH AIR THROUGH CRUMB LAYER

SAMPLE NO.	DETERMINATION NO.	TEMPERATURE OF HEATING (°C.)	TIME OF HEATING HOURS	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
64	1	115	0	0.2340	28.9025	50	29.0167	0.2284	0.0056	2.39
	2	115	0.5	0.2529	28.8530	50	28.9430	0.1800	0.0729	28.8
	3	115	1	0.2135	29.2519	50	29.3429	0.1820	0.0315	14.75
	4	115	1.5	0.1828	28.9034	50	28.9732	0.1396	0.0432	23.6
	5	115	2	0.2141	29.6979	50	29.7742	0.1526	0.0615	28.7
	6	115	3.5	0.2380	27.4034	50	27.4866	0.1664	0.0716	30.1
	7	115	5	0.2693	29.2520	50	29.3491	0.1942	0.0751	27.9
	8	115	6.5	0.2530	29.2518	50	29.3136	0.1236	0.1294	51.2
	9	115	9.5	0.2230	28.9315	50	28.9895	0.1160	0.1070	48.0
65	1	115	0	0.2536	29.1890	50	29.3048	0.2316	0.0220	8.7
	2	115	0.5	0.2567	28.5314	50	28.6080	0.1532	0.1035	40.4
	3	115	1	0.2200	28.5315	50	28.6200	0.1774	0.0426	19.4
	4	115	1.5	0.1749	29.1903	50	29.2624	0.1442	0.0307	17.6
	5	115	2	0.2226	29.1896	50	29.2763	0.1734	0.0492	22.1
	6	115	3.5	0.2808	28.9035	50	29.0022	0.1974	0.0834	29.7
	7	115	5	0.2415	28.9048	50	28.9676	0.1256	0.1159	48.0
	8	115	6.5	0.2312	29.6972	50	29.7583	0.1222	0.1090	47.2
	9	115	9.5	0.2741	28.9040	50	28.9797	0.1514	0.1227	44.8

TABLE XX.
GEL CONTENT DATA
SUPPLEMENTARY TREATMENT OF SAMPLES DRIED WITH AIR THROUGH CRUMB LAYER

SAMPLE NO.	DETERMINATION NO.	TEMPERATURE OF HEATING (°C.)	TIME OF HEATING HOURS	SAMPLE WEIGHT (GM.)	WEIGHT OF EVAPORATING BOTTLE (GM.)	ALIQUOT (ML.)	WEIGHT OF BOTTLE AND DEPOSIT (GM.)	DEPOSIT X (100/ALIQUOT)	WEIGHT OF GEL (GM.)	GEL CONTENT (%)
66	1	115	0	0.1902	28.8520	50	28.9140	0.1240	0.0662	34.8
	2	115	0.5	0.2801	29.2520	50	29.3280	0.1520	0.1281	45.7
	3	115	1	0.2180	28.8526	50	28.9370	0.1688	0.0492	22.6
	4	115	1.5	0.2430	28.8534	50	28.9369	0.1670	0.0760	31.3
	5	115	2	0.2235	26.9205	50	27.0020	0.1630	0.0605	27.2
	6	115	3.5	0.2186	29.1896	50	29.2702	0.1612	0.0574	25.5
	7	115	5	0.2402	29.1894	50	29.2522	0.1256	0.1146	48.1
	8	115	6.5	0.2573	29.1892	50	29.2581	0.1378	0.1195	46.5
	9	115	9.5	0.2631	29.1903	50	29.2573	0.1340	0.1291	49.1

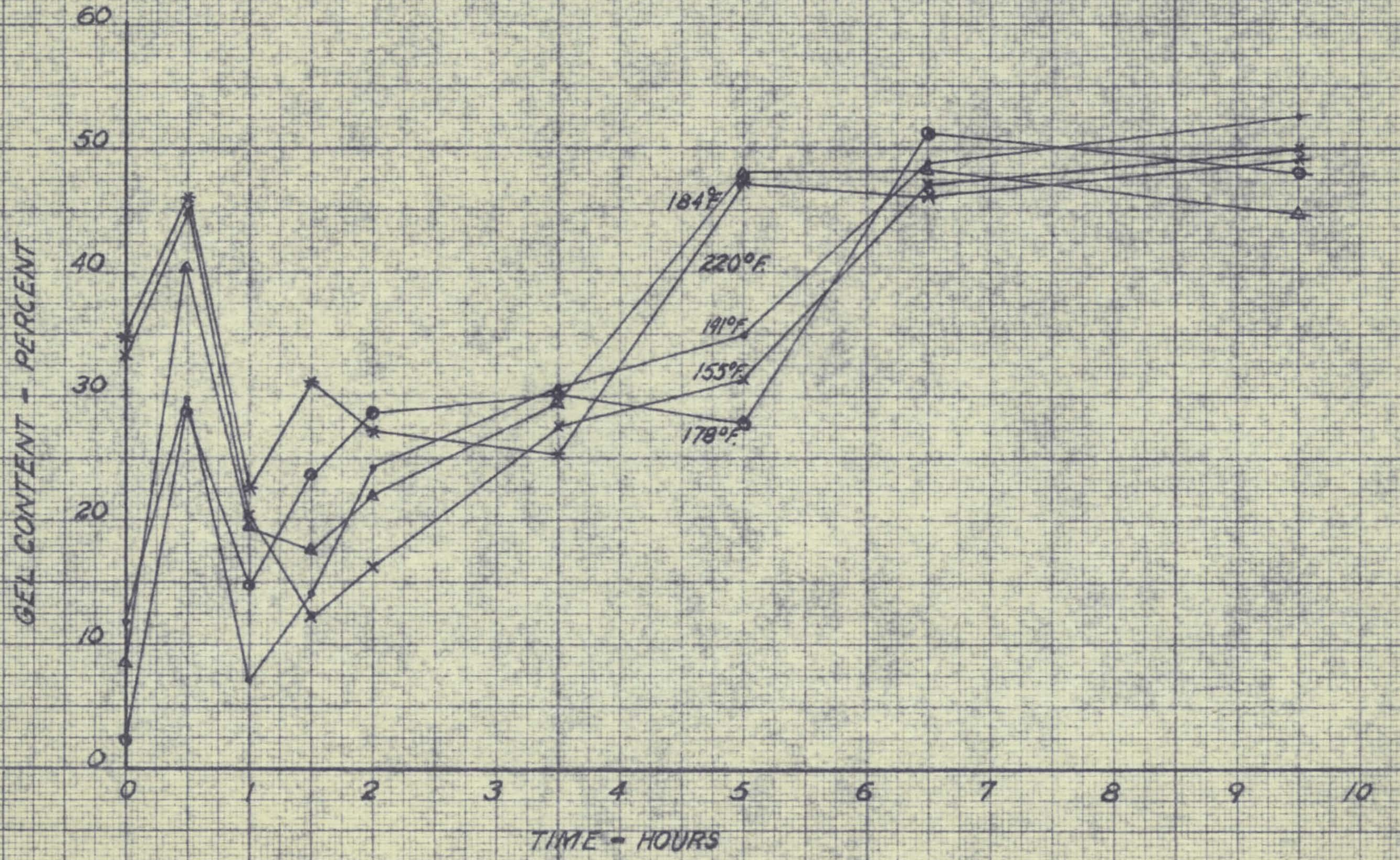


FIG. 92 GEL CONTENT—TIME CURVES
EFFECT OF DRYING TEMPERATURE ON GEL FORMATION AT 115°C.

CONCLUSIONS

From the studies contained in this thesis the general conclusions are as follows:

1. In general, air drying with air through the layer of crumb gives the greatest drying rates and the shortest drying times. Figure 93 is a plot comparing the drying rates of the three methods of drying investigated. It is apparent that the rate of drying with the air through the layer is on the order of ten times greater than that for the others.

2. The factors which influence air drying are temperature, humidity, and velocity of the air, size, bulk gravity, thickness of drying layer, and condition of the crumb before drying. Of these factors the most important, in drying with air through the layer, are velocity and temperature of the air. However, high rates are possible with a comparatively mild temperature and a high air velocity.

3. Limitations are placed on drying conditions by the necessity for quality control. The factors in quality control, which are inherent with drying, are gel and moisture content of the dried rubber, both of which must be low. The necessity for dry rubber requires sufficient drying conditions, and the possibility of gel formation demands modified conditions.

4. The drying rate of GR-S crumb, although a very porous material, is considerably lower than that of other materials of like porosity such as wood chips and natural sponge

(Figure 94). This lower rate for the rubber indicates that the nature of the coagulum retards the liquid diffusion and/ or the surface evaporation.

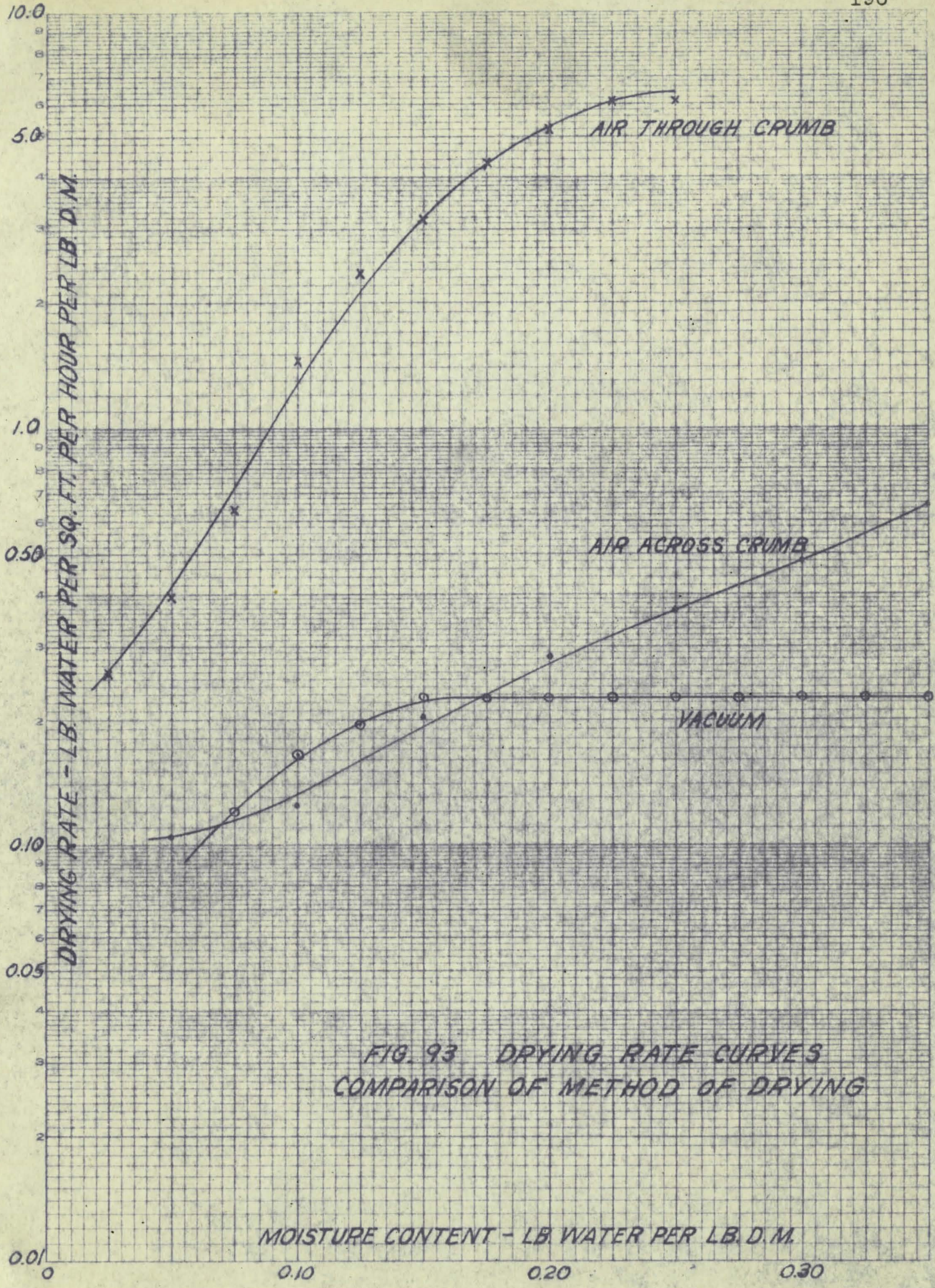


FIG. 93 DRYING RATE CURVES
COMPARISON OF METHOD OF DRYING

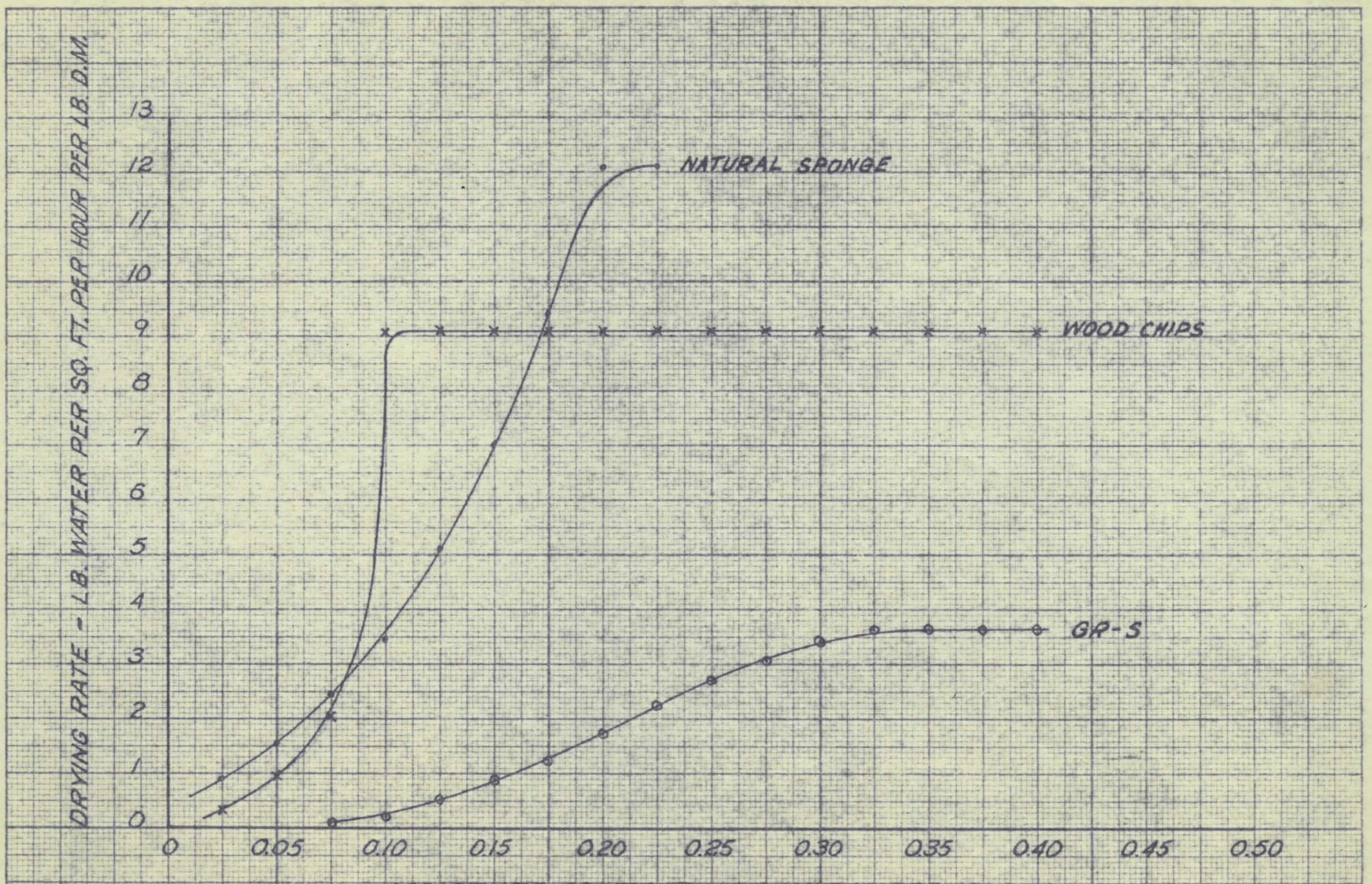


FIG. 94 DRYING RATE CURVES
COMPARISON OF DRYING RATES OF VARIOUS MATERIALS

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APPENDIX

LIST OF SYMBOLS

A	Air drying with air across the crumb layer
$^{o}C.$	Centigrade, degrees
coag.	Coagulated
D.M.	Dry material
$^{o}F.$	Fahrenheit, degrees
FT.	Feet
GM.	Grams
GR-S	Government rubber - Buna S
Hg.	Mercury
H_2O	Water
In.	Inches
LB.	Pounds
MIN.	Minutes
ml.	Milliliters
N	Normality
psi.	Pounds per square inch
rpm.	Revolutions per minute
R.H.	Relative humidity
S.G.	Swollen gel
SQ.	Square
T	Air drying with air through the crumb layer
V	Vacuum drying

SAMPLE CALCULATIONS

I. Moisture Content

(a) Vacuum Drying: Run No. V8

The sample wet weight was found by subtracting the tare weight from the total wet weight.

Total Wet Weight	=	18.5193 GM.
Tare Weight	=	14.6605 GM.
Sample Wet Weight	=	3.8588 GM.

The sample was then dried and the dry weight was found by subtracting the tare weight from the total dry weight.

Total Dry Weight	=	17.0136 GM.
Tare Weight	=	14.6605 GM.
Sample Dry Weight	=	2.3531 GM.

By subtracting the sample dry weight from the sample wet weight the amount of water in the sample was found.

Sample Wet Weight	=	3.8588 GM.
Sample Dry Weight	=	2.3531 GM.
Water Lost	=	1.5057 GM.

From the values of water lost and the dry sample weight the moisture content as pounds of water per pound of dry material was calculated.

Moisture Content = 1.5057/2.3531 =

0.640 Lb. Water per Lb. Dry Material

(b) Air Drying - Air Across the Crumb Layer: Run No. A1

The initial moisture content was found by determining the moisture content of small sample of the material dried. By subtracting the total dry weight from the total wet weight the weight of the water lost by the sample was determined.

Total Wet Weight = 24.7319 GM.

Total Dry Weight = 22.4926 GM.

Water Lost = 2.2393 GM.

The dry material weight was found by subtracting the tare weight from the total dry weight.

Total Dry Weight = 22.4926 GM.

Tare Weight = 17.4400 GM.

Sample Dry Weight = 5.0526 GM.

By dividing the water lost by the weight of dry material the moisture content was found.

Moisture Content = 2.2393/5.0526 =

0.442 Lb. Water per Lb. Dry Material.

From the initial moisture content and the weight of wet material, the weight of dry material in the larger sample being studied was determined.

(Weight of Wet Material)/(1 + Initial

Moisture Content) = Weight of Dry Material.

The weight of wet material was found by subtracting the tare weight from the total wet weight of the sample tested.

Total Wet Weight = 163.5284 GM.

Tare Weight = 13.5694 GM.

Sample Wet Weight = 149.9590 GM.

Dry Material = 149.9590/(1 + 0.442) = 103.800 GM.

The water present at any time was found by subtracting the dry material and tare weights from the total wet weight.

Dry Material = 103.800 GM.

Tare Weight = 13.569 GM.

Total Dry Weight = 117.369 GM.

Total Wet Weight = 163.528 GM.

Total Dry Weight = 117.369 GM.

Water Lost = 46.159 GM.

From the water lost and the dry sample weight the moisture content was calculated.

Moisture Content = 46.159/103.800 = 0.442 Lb. Water per Lb. Dry Material.

(c) Air Drying - Air Through the Crumb Layer: Run No. T1

The weight of dry material present was the final weight of the tray of rubber minus the tare weight.

Final Total Weight = 842.0 GM.

Tare Weight = 404.0 GM.

Dry Material = 438.0 GM.

By subtracting the final total weight from the total weight at any time the water present was found.

Total Weight = 1047.0 GM.

Final Total Weight = 842.0 GM.

Water Present = 205.0 GM.

The weight of water present at any time divided by the dry weight of the sample gave the moisture content.

Moisture Content = 205.0/438.0 = 0.469 Lb. Water per Lb. Dry Material.

2. Drying Rates:

The normal to the moisture content-time curve at any moisture content is drawn. The slope of the normal is found by counting the number of units along the lines AC and BC in Figure 95.

Slope of Normal = 20/37

The slope of the tangent to the curve at this point is the negative reciprocal of the slope of the normal.

Slope of Tangent = 37/20

However, 400 units on the ordinate represent one pound of water per pound of dry material and 240 units on the abscissa represents one hour. The values measured along the ordinate must be multiplied by 240/400 to be on an equivalent scale basis.

Corrected Slope of Tangent = (37) (240)/(20)(400)

The units of the above expression are Lb. Water per Lb. Dry Material per Hour. In order to express the drying rate as Lb. Water per Sq. Ft. per Hour it is necessary to multiply the corrected slope of the tangent by the weight of dry material and divide it by the area of the drying surface, all in the appropriate units. The weight of dry material in this example is 400 GM. or 400/454 Lb. The drying area is 48.1/144 Sq. Ft.

Drying Rate = (37)(240)(400)(144)/(20)(400)(452)(48.1)

= 2.95 Lb. Water per Sq. Ft. per Hour

When samples were dried using varying thicknesses of rubber the drying rate was calculated as Lb. Water per Sq. Ft. per Hour per Lb. Dry Material. This value was obtained from the drying rate in the usual units by dividing by the Lb. Dry Material.

3. Gel Content: Sample 35, Table No. 7

The amount of soluble fraction in a sample of rubber was determined by drying an aliquot of the benzene solution drained from the gel unit. The weight of soluble fraction in the aliquot was found by subtracting the bottle tare weight from the deposit and tare weight.

Tare and Deposit Weight	=	13.3809 GM.
Tare Weight	=	13.3490 GM.
Deposit Weight	=	0.0819 GM.

The deposit weight was then multiplied by the aliquot fraction giving the total soluble fraction.

Total Soluble Weight = (0.0319)(100/20) = 0.1595 GM.

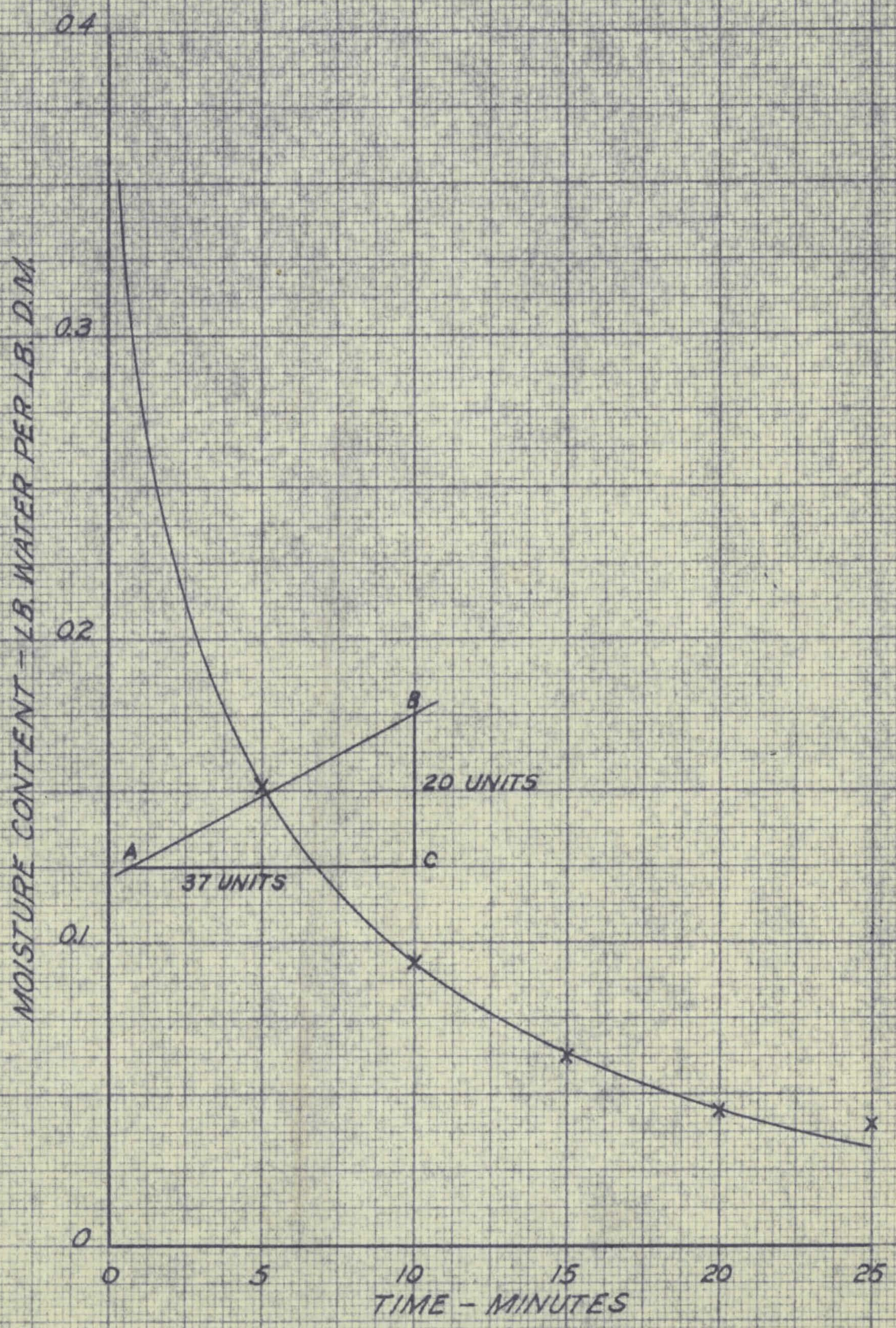

FIG. 95 DETERMINATION OF DRYING RATE

The difference in the original sample weight and the total soluble weight was the weight of insoluble gel.

Sample Weight = 0.2107 GM.

Total Soluble Weight = 0.1595 GM.

Insoluble Gel Weight = 0.0512 GM.

Gel content was calculated as weight of insoluble gel per unit weight of sample. By dividing the weight of soluble gel by the weight of the sample the gel content was found.

Gel Content = 0.0512/0.2107 = 24.3%

COMPLETE DATA

TABLE OF RUNS

RUN NO.	VACUUM IN. OF HG.	TEMPERATURE DESIGNATION DEG. F.	HUMIDITY DESIGNATION % R.H.	VELOCITY DESIGNATION FT. PER MIN.	CRUMB DEPTH IN.	CRUMB SIZE	BULK GRAVITY
V 1	20.0	158			0.5	A.R.	0.483
V 2	20.0	158			0.5	A.R.	0.535
V 3	20.0	158			0.5	A.R.	0.656
V 4	20.0	158			0.5	A.R.	0.595
V 5	20.0	158			1.0	A.R.	0.488
V 6	20.0	158			1.5	A.R.	0.493
V 7	20.0	158			2.0	A.R.	0.460
V 8	25.0	131			1.0	A.R.	
V 9	25.0	129			1.0	A.R.	
V 10	25.0	140			1.0	A.R.	
V 11	15.0	199			1.0	A.R.	
V 12	15.0	163			1.0	A.R.	
V 13	15.0	172			1.0	A.R.	
V 14	15.0	136			1.0	A.R.	
V 15	10.0	147			1.0	A.R.	
V 16	10.0	176			1.0	A.R.	
V 17	20.0	158			1.0	A.R.	
V 18	20.0	152			1.0	A.R.	
V 19	20.0	158			1.0	A.R.	
V 20	20.0	129			1.0	A.R.	
R 1	29.0					A.R.	
R 2	18.0					A.R.	
R 3	10.0					A.R.	
R 4	29.0					A.R.	
R 5	23.0					A.R.	

TABLE OF RUNS (CONTINUED)

RUN NO.	VACUUM IN. OF HG.	TEMPERATURE DESIGNATION DEG. F.	HUMIDITY DESIGNATION % R.H.	VELOCITY DESIGNATION FT. PER MIN.	CRUMB DEPTH IN.	CRUMB SIZE
A 1		122	42.0	400	2.0	A.R.
A 2		100	13.0	400	2.0	A.R.
A 3		160	6.0	400	2.0	A.R.
A 4		212	3.5	120	2.0	NOM.
A 5		188	2.5	400	2.0	NOM.
A 6		188	4.0	400	2.0	NOM.
A 7		188	13.0	400	2.0	NOM.
A 8		188	6.0	400	2.0	NOM.
A 9		130	10.0	400	2.0	A.R.
A 10		170	8.0	400	1.0	A.R.
"		"	"	"	1.5	A.R.
"		"	"	"	2.0	"
A 11		165	5.0	400	1.0	A.R.
"		"	"	"	1.5	"
"		"	"	"	2.0	"
A 12		165	8.5	400	2.0	A.R.
A 13		212	3.5	15	2.0	2
A 14		212	14.0	240	2.0	2
A 15		212	3.7	240	2.0	2
A 16		173	5.0	230	2.0	1
"		"	"	"	"	2
"		"	"	"	"	3
"		"	"	"	"	4
A 17		212	6.0	330	2.0	NOM.

TABLE OF RUNS (CONTINUED)

RUN NO.	VACUUM IN. OF HG.	TEMPERATURE DESIGNATION DEG. F.	HUMIDITY DESIGNATION % R.H.	VELOCITY DESIGNATION FT. PER MIN.	CRUMB DEPTH IN.	CRUMB SIZE
T 1		180	4.5	400	2.0	4
T 2		180	4.5	400	2.0	3
T 3		180	4.5	440	2.0	5
T 4		184	6.0	220	2.0	NOM.
T 5		143	5.6	450	2.0	NOM.
T 6		141	15.5	440	2.0	NOM.
T 7		155	6.0	370	2.0	NOM.
T 8		158	15.0	370	2.0	NOM.
T 9		184	6.0	175	2.0	NOM.
T 10		180	6.0	70	2.0	NOM.
T 11		184	6.0	220	0.5	NOM.
T 12		184	6.0	220	1.0	NOM.
T 13		221	5.0	175	2.0	NOM.
T 14		221	2.6	175	2.0	NOM.
T 15		221	7.3	175	2.0	NOM.
T 16		140	6.0	175	2.0	NOM.
T 17		155	6.0	175	2.0	NOM.
T 18		177	6.0	360	2.0	NOM.
T 19		184	6.0	220	4.0	NOM.
T 20		165	6.0	330	2.0	NOM.
T 21		183	6.0	300	2.0	NOM.

V VACUUM DRYING
A AIR DRYING - AIR ACROSS CRUMB
T AIR DRYING - AIR THROUGH CRUMB
R ROTARY VACUUM DRYING
A.R. AS RECEIVED
NOM. THROUGH 0.371 IN., ON 0.185 IN.

1 ON 0.371 IN.
2 THROUGH 0.371 IN., ON 0.263 IN.
3 THROUGH 0.263 IN., ON 0.131 IN.
4 THROUGH 0.131 IN.
5 ON 0.263 IN.

VACUUM DRYING DATA

RUN NO. V 1

TIME	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	WATER PRESENT GM.	LBS. WATER PER LB. DRY MATERIAL
2:25	27.8265	15.8265	4.38	0.383
2:55	26.6167	14.6167	3.18	0.278
3:25	25.9400	13.9000	2.50	0.218
3:55	25.3000	13.3000	1.86	0.162
4:25	24.7676	12.7670	1.32	0.115
4:55	24.2350	12 .2350	0.80	0.070
6:00	23.6300	11.6300	0.19	0.0166
6:25	23.5280	11.5280	0.08	0.007
6:55	23.4910	11.4910	0.00	0.00

CONTAINER TARE 12.000 GMS. CRUMB DEPTH 0.50 IN.
TEMPERATURE 70°C BULK GRAVITY 0.483
VACUUM 20 IN. OF HG.

RUN NO. V 2

TIME	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	WATER PRESENT GM.	LBS. WATER PER LB. DRY MATERIAL
2:25	29.5610	17.6544	4.87	0.384
2:55	26.5130	16.5164	3.82	0.301
3:25	27.8410	15.8450	3.15	0.248
3:55	27.1200	15.1240	2.43	0.192
4:25	26.5310	14.5350	1.84	0.145
4:55	25.9720	13.8760	1.19	0.093
6:00	25.1300	13.1340	0.44	0.035
6:25	24.9610	12.9650	0.21	0.0213
6:55	24.8000	12.8090	0.11	0.0087

CONTAINER TARE 11.9966 GMS. CRUMB DEPTH 0.50 IN.
TEMPERATURE 70°C Bulk GRAVITY 0.535
VACUUM 20 IN. OF HG.

VACUUM DRYING DATA

RUN NO. V 3

TIME	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	WATER PRESENT GM.	LBS. WATER PER LB. DRY MATERIAL
2:25	33.4238	21.7998	6.05	0.384
2:55	32.3880	20.7350	5.00	0.317
3:25	31.7610	20.1380	4.39	0.279
3:55	31.0460	19.4130	3.66	0.323
4:25	30.4400	18.8070	3.05	0.194
4:55	29.6520	18.0190	2.27	0.144
6:00	28.3550	16.7220	0.97	0.062
6:25	28.1330	16.5000	0.75	0.0476
6:55	27.9710	16.3380	0.58	0.0368

CONTAINER TARE 11.6300 GMS. CRUMB DEPTH 0.50 IN.
TEMPERATURE 70° C BULK GRAVITY 0.656
VACUUM 20 IN. OF HG.

RUN NO. V 4

2:25	31.7687	19.5001	5.40	0.383
2:55	30.8761	18.4075	4.30	0.305
3:25	30.0100	17.7410	3.60	0.255
3:55	29.3600	17.0910	2.99	0.212
4:25	28.7430	16.4740	2.37	0.168
4:55	28.0040	15.7350	1.63	0.116
6:00	26.9470	16.4860	0.57	0.040
6:25	26.7910	14.5220	0.42	0.0298
6:55	26.6350	14.3860	0.28	0.0199

CONTAINER TARE 12.2686 CRUMB DEPTH 0.50 IN.
TEMPERATURE 70°C Bulk GRAVITY 0.595 GM/c.c.
VACUUM 20IN. OF HG

DRYING RATE DATA

MOISTURE CONTENT LB.WATER PER LB. DRY MATERIAL	RUN NO. V 1 (Cont'd) SLOPE OF CURVE	RUN NO. V 1 (Cont'd) DRYING RATE LB.WATER PER SQ. FT PER HOUR	RUN NO. V 2 (Cont'd) SLOPE OF CURVE	RUN NO. V 2 (Cont'd) DRYING RATE LB.WATER PER SQ.FT. PER HOUR
0.325	0.905	0.1005	0.939	0.1075
0.300	0.905	0.1005	0.939	0..075
0.275	0.905	0.1005	0.939	0.1075
0.250	0.905	0.1005	0.939	0.1075
0.225	0.905	0.1005	0.939	0.1075
0.200	0.905	0.1005	0.939	0.1075
0.175	0.905	0.1005	0.939	0.1075
0.150	0.905	0.1005	0.939	0.1075
0.125	01905	0.1005	0.939	0.1075
0.100	1.095	0.0830	1.015	0.0985
0.075	1.370	0.0660	1.430	0,0704
0.050	1.820	0.050	2.11	0.0482
0.025	2.630	0.0345	5.50	0.0292

D RY MATERIAL 1.54 GM.
TRAY AREA 4.0 SQ.IN.
CONVERSION FACTOR 0.908

DRY MATERIAL 12.69 GM.
TRAY AREA 4.05 SQ.IN.
CONVERSION FACTOR 1.005

	RUN NO. V 3 (Cont'd)		RUN NO. V 4 (ContId)	
0.325	1.070	1.05	1.175	0.106
0.300	1.070	1.05	1.175	0.106
0.275	1.070	1.05	1.175	0.106
0.250	1.070	1.05	1.175	0.106
0.225	1.070	1.05	1.175	0.106
0.200	1.070	1.05	1.175	0.106
0.175	1.070	1.05	1.175	0.106
0.150	1.070	1.05	1.175	0.106
0.125	1.070	1.05	1.175	0.106
0.100	1.070	1.05	1.175	0.106
0.075	1.41	0.077	1.515	0.083
0.050	2.17	0.052	3.63	0.034
0.025	4.08	0.0275		

DRY MATERIAL 14.10 GM.
TRAY AREA 4.0 SQ.IN.
CONVERSION FACTOR 1.12

DRY MATERIAL 15.75 GM.
TRAY AREA 4.0 SQ.IN.
CONVERSION FACTOR 1.25

VACUUM DRYING DATA

RUN NO. V 5

TIME	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	WATER PRESENT GM.	LBS. WATER PER LB. DRY MATERIAL
2:25	49.5175	32.0580	8.88	0.383
2:55	48.6200	31.1605	7.88	0.345
3:25	47.9300	30.4700	7.29	0.315
3:55	47.1450	29.6850	6.50	0.281
4:25	46.4210	28.9610	5.78	0.249
4:55	45.4200	27.9620	4.78	0.209
6:00	43.3220	26.8820	2.68	0.116
6:25	42.7110	25.2510	2.07	0.089
6:55	42.2100	24.7500	1.57	0.068
7:25	41.8130	24.4130	1.23	0.053
7:55	41.5550	24.0950	0.91	0.0393
8:25	41.3420	23.8820	0.70	0.0302

CONTAINER TARE 17.4595 GMS. CRUMB DEPTH 1.0 IN.
TEMPERATURE 70° C BULK GRAVITY 0.488
VACUUM 20IN.OF HG. DRY WEIGHT 23.18 GM.

RUN NO. V 6

2:25	71.4324	47.5383	13.16	0.383
2:55	70.4295	46.5555	121.5	0.353
3:25	69.6700	45.7960	11.39	0.331
3:55	68.7650	44.8010	10.40	0.302
4:25	67.9310	44.0390	9.64	0.280
4:55	66.7000	42.8260	8.42	0.245
6:00	64.1140	40.2400	5.84	0.170
6:25	53.0820	39.2080	4.80	0.140
6:55	62.3560	38.4820	4.08	0.119
7:25	61.8320	37.9580	3.55	0.103
7:55	61.2270	37.3530	2.95	0.086
8.28	60.6400	36.6770	2.36	0.0686

CONTAINER TARE 23.4741 GMS. CRUMB DEPTH 1.5 IN.
TEMPERATURE 70 C BULK GRAVITY 0.943 GMS/cc.
VACUUM 20 IN. OF HG. DRY WEIGHT 34.40

VACUUM DRYING DATA

RUN NO. V 7

TIME	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB. DRY MATERIAL
2:25	91.9000	60.1569	16.65	0.383
2:55	90.9150	59.1720	15.67	0.360
3:25	90.1460	58.4030	14.90	0.343
3:55	89.0500	57.3070	13.80	0.318
4:25	88.2800	56.5370	13.03	0.300
4:55	86.8680	55.1250	11.62	0.267
6:00	84.1880	52.4450	8.94	0.205
6:25	82.8100	51.0670	7.56	0.174
6:55	81.9550	50.2120	6.71	0.154
7:25	81.3700	49.6270	6.12	0.141
7L55	80.0664	48.3230	4 .88	0.111
8:25	79.8300	48.0870	4.58	0.105

CONTAINER TARE 31.7431 CRUMB DEPTH 2.0 IN.
TEMPERATURE 70°C BULK GRAVITY 0.460 GM/CC.
VACUUM 20 IN. OF HG. DRY WEIGHT 43.50 G MS.

VACUUM DRYING DATA

RUN NO. V 8

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS. WATER PER LB. DRY MATERIAL
11:00	14.6605	18.5193	3.8588	17.0136	2.3531	1.5057	0.640
11:30	13.7630	17.9956	4.2326	16.5180	2.7550	1.4776	0.537
12:00	13.3200	16.9251	3.6051	15.8287	2.5087	1.0964	0.437
12:30	14.2698	18.6546	4.3848	17.5126	3.2428	1.1420	0.352
1:30	13.2736	15.8322	2.5586	15.5817	2.3081	0.1570	0.1085
2:00	13.8686	17.2278	3.3592	17.0708	3.2022	0.1570	0.049
2:30	14.6947	17.5685	2.8738	17.5055	2.8108	0.0630	0.0224
3:00	13.5720	16.9280	3.3560	16.8848	3.3126	0.0432	0.01305

TEMPERATURE-DEGREES CENTIGRADE

TIME	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	VACUUM IN. OF HG.
11:00							25.0
11:30	121	68	53	56	54	56.5	25.0
12:00	122	72	55	59	55	58	25.0
12:30	121	74	62	64	55	58	25.0
1:30	120	78	69	79	55	66	25.0
2:00	122	81	85	92	71	67	25.2
2:30	121	82	94	103	85	68.5	25.2
3:00	121	83	93	109	95	68	25.0

STEAM PRESSURE 18 LB. psi.
TRAY WEIGHT 9.125 LB.
TOTAL WET WEIGHT 14.250 LB.
SAMPLE WET WEIGHT 5.125 LB.

TOTAL DRY WEIGHT 12.1875 LB.
SAMPLE DRY WEIGHT 3.0625 LB.
WATER LOST 2.0675 LB.
MOISTURE CONTENT 40.2%

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. V 5 (Cont'd) SLOPE OF CURVE	RUN NO. V 5 (Cont'd) DRYING RATE LB. WATER PER SQ. FT PER HOUR	RUN NO. V 6 (Cont'd) SLOPE OF CURVE	RUN NO. V 6 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.375	1.268	0.145	1.695	0.161
0.350	1.268	0.145	1.695	0.161
0.325	1.268	0.145	1.695	0.161
0.300	1.268	0.145	1.695	0.161
0.275	1.268	0.145	1.695	0.161
0.250	1.268	0.145	1.695	0.161
0.225	1.268	0.145	1.695	0.161
0.200	1.268	0.145	1.695	0.161
0.175	1.268	0.145	1.695	0.161
0.150	1.268	0.145	1.852	0.147
0.125	1.268	0.145	2.32	0.117
0.100	1.575	0.117	2.86	0.096
0.075	2.27	0.081	3.64	0.075
0.050	4.08	0.045		

DRY MATERIAL 23.18 GM.
TRAY AREA 4.0 SQ.IN
CONVERSION FACTOR 1.84

DRY MATERIAL 34.40 GM.
TRAY AREA 4.0 SQ.IN.
CONVERSION FACTOR 2.73

	RUN NO. V 7 (Cont'd)		RUN NO. V 8 (Cont'd)	
0.375	1.85	0.186	0.158	0.192
0.350	1.85	0.186	0.158	0.192
0.325	1.85	0.186	0.158	0.192
0.300	1.85	0.186	0.158	0.192
0.275	1.85	0.186	0.158	0.192
0.250	1.85	0.186	0.158	0.192
0.225	1.85	0.186	0.158	0.192
0.200	1.85	0.186	0.158	0.192
0.175	1.85	0.186	0.158	0.192
0.150	2.22	0.155	0.158	0.192
0.125	2.78	0.124	0.158	0.192
0.100	3.33	0.103	0.149	0.181
0.075			0.100	0.121
0.050				

DRY MATERIAL 43.50 GM.
TRAY AREA 4.0 SQ.IN.
CONVERSION FACTOR 3.45

DRY MATERIAL 4.45 LB.
TRAY AREA 400 SQ.IN.
CONVERSION FACTOR 1.216
CRUMB DEPTH 1. IN.

VACUUM DRYING DATA

RUN NO.V 9

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM	LBS.WATER PER LB.DRY MATERIAL
11:25	13.6371	16.8711	3.2340	15.9762	2.3391	0.8949	0.382
11:55	14.6205	18.3921	3.7716	17.5404	2.9199	0.8517	0.292
12:25	14.2444	18.2210	3.9766	17.4593	3.2149	0.7617	0.237
1:25	13.6208	16.6790	3.0582	16.4779	2.8471	0.2111	0.074
1:55	13.6813	17.4971	3.8158	17.3149	3.6336	0.1822	0.0502

TIME	TEMPERATURE-DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.OF GH.
11:25	102	68	56	54	54	47	25.0
11:55	102	67	57	54	55	50.5	25.0
12:25	103	69	60	55	56	51	25.0
1:25	102	68	69	67	66	57	25.0
1:55	103	69	74	75	73	53	25.0

STEAM PRESSURE 2 LB. psi.
TRAY WEIGHT 9.125 LB.
TOTAL WET WEIGHT 14.1875 LB.
SAMPLE WET WEIGHT 5.0625 LB.

TOTAL DRY WEIGHT 12.506 LB.
SAMPLE DRY WEIGHT 3.381 LB.
WATER LOST 1.68 LB.
MOISTURE CONTENT 33.2%

VACUUM DRYING DATA

RUN NO. V 10

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
3:00							0.447
3:30	13.4995	16.8627	3.3632	16.0249	2.5254	0.8378	0.332
4:00	13.3408	16.9962	3.6554	16.3140	2.9732	0.6822	0.229
4:30	13.4604	16.7058	3.2454	16.3707	2.9103	0.3351	0.115
5:00	13.2114	17.6698	4.4584	17.4613	4.2490	0.2085	0.049
5:30	13.5425	16.7677	3.2253	16.6651	3.1227	0.1026	0.033
6:00	14.1409	17.7702	3.6311	17.7423	3.6014	0.0297	0.0082

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.OF HG.
3:00							25.0
3:30	127	80	69	57	56	53	25.0
4:00	129	82	62	73	54	67	25.2
4:30	129	84	90	59	63	63.5	25.0
5:00	131	88	77	73	81	69	25.0
5:30	132	91	90	88	94	71	25.4
6:00	130	92	99	100	102	70	25.4

STEAM PRESSURE	28 LB. psi.	TOTAL DRY WEIGHT	12.70 LB.
TRAY WEIGHT	8.81 LB.	SAMPLE DRY WEIGHT	3.89 LB.
TOTAL WET WEIGHT	14.44 LB.	WATER LOST	1.74 LB.
SAMPLE WET WEIGHT	5.63 LB.	MOISTURE CONTENT	30.9%

DRYING RATE DATA

MOISTURE CONTENT LB.WATER PER LB. DRY MATERIAL	RUN NO. V 9 (Cont'd) SLOPE OF CURVE	RUN NO. V 9 (Cont'd) DRYING RATE LB.WATER PER SQ. FT. PER HOUR	RUN NO. V 10 (Cont'd) SLOPE OF CURVE	RUN NO. V 10 (Cont'd) DRYING RATE LB.WATER PER SQ. FT. PER HOUR
0.500			0.214	0.236
0.475			0.214	0.236
0.450			0.214	0.236
0.425			0.214	0.236
0.400	0.214	0.316	0.214	0.236
0.375	0.214	0.316	0.214	0.236
0.350	0.214	0.316	0.214	0.236
0.325	0.214	0.316	0.214	0.236
0.300	0.214	0.316	0.214	0.236
0.275	0.214	0.316	0.214	0.236
0.250	0.214	0.316	0.214	0.236
0.225	0.214	0.316	0.214	0.236
0.200	0.214	0.316	0.214	0.236
0.175	0.214	0.316	0.214	0.236
0.150	0.214	0.316	0.214	0.236
0.125	0.214	0.316	0.214	0.236
0.100	0.155	0.229	0.165	0.182
0.075	0.110	0.163	0.118	0.130
0.050	0.0705	0.1112	0.0755	0.0831
0.025	0.0400	0.0492	0.0330	0.0367

RUN NO. V 9	RUN NO. V 10
DRY MATERIAL 4.11 LB.	DRY MATERIAL 3.06 LB.
TRAY AREA 400 SQ.IN.	TRAY AREA 400 SQ. IN.
CRUMB DEPTH 1.0 IN.	CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 1.48	CONVERION FACTOR 1.102

VACUUM DRYING DATA

RUN NO. V 11.

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
2:20	13.6208	17.3194	3.6986	16.1265	2.5057	1.1929	0.476
2:50	13.4995	17.6534	4.0539	16.3688	2.8693	1.1846	0.413
3:20	13.6813	17.7166	4.0353	16.6518	2.9705	1.0648	0.3 59
3:50	13.3408	17.7205	4.3797	16.7321	3.3913	0.9884	0.291
4:20	13.4604	17.5917	4.1313	16.7864	3.3260	0.8053	0.242
4:50	13.2114	17.3294	4.1180	16.7112	3.4998	0.6182	0.177
5:20	13.5424	17.1657	3.6233	16.8421	3.2997	0.3236	0.0982
5:50	14.1409	17.1780	3.5771	17.4893	3.3484	0.2287	0.0683
6:20	14.0981	17.2840	3.1859	17.1621	3.0640	0.1219	0.0398

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP of CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.of HG
2:50	114	80	81	71.5	71	67	14.6
3:20	111	81	78	72	70	66	15.0
3:50	112	80	75	70	69	67	15.0
4:20	112	81	70	72	72	66	15.0
4:50	112	83	76	71	72	66	15.4
5:20	110	82	80	70	72	65	15.2
5:50	110	82	86	72	73	66	15.0
6:20	113	83	92	77	76	68	15.0

STEAM PRESSURE	8 LB PER SQ.IN.	TOTAL DRY WEIGHT	12.312 LB.
TRAY WEIGHT	8.875 LB.	SAMPLE DRY WEIGHT	3.437 LB.
TOTAL WET WEIGHT	13.938 LB.	WATER LOST	1.626 LB.
SAMPLE WET WEIGHT	5.063 LB.	MOISTURE CONTENT	32.1%

VACUUM DRYING DATA

RUN NO. V 12.

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
3:05	13.6371	17.6408	4.0037	16.4424	2.8043	1.1494	0.427
3:35	13.4995	16.8349	3.3354	15.9384	2.4389	0.8965	0.367
4:05	13.6708	17.5962	3.9654	16.7456	3.1248	0.8400	0.268
4:35	13.6813	17.1316	3.4503	16.5248	2.8435	0.6088	0.213
5:05	13.3408	17.0607	3.7199	16.5610	3.2202	0.4997	0.155
5:45	13.4604	15.8948	2.4344	15.8024	2.3420	0.0924	0.391
7:05	13.2114	16.9383	3.7269	16.8532	3.6418	0.0851	0.0234
7:35	13.5424	16.9984	3.4560	16.9960	3.4536	0.0024	0.00069

TIME	TEMPERATURE- DEGREES CENTIGRADE: UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	VACUUM IN.OF HG.
3:05							15.0
3:35	121	73	65	71	67	66	15.2
4:05	121	75	72	74	70	69	14.9
4:35	121	79	72	75	72	72	15.0
5:05	122	80	74	76	73	71	16.0
5:45	122	82	79	80	76	74	15.0
7:05	121	85	90	94	92	74	13.8
7:35	121	87	99	102	99	74	14.4

STEAM PRESSURE 8 LB PER SQ.IN. TOTAL DRY WEIGHT 13.31 LB.
TRAY WEIGHT 9.12 LB. SAMPLE DRY WEIGHT 4.19 LB.
TOTALWET WEIGHT 15.09 LB. WATER LOST 1.78 LB.
SAMPLE WET WEIGHT 5.97 LB. MOISTURE CONTENT 29.9%.

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. V 11 (Cont'd) SLOPE OF CURVE	RUN NO. V 11 (Cont'd) DRYING RATE LB.WATER PER SQ. FT. PER HOUR	RUN NO. V 12 (Cont'd) SLOPE OF CURVE	RUN NO. V 12 (Cont'd) DRYING RATE LB.WATER PER SQ.FT. PER HOUR
0.450	0.117	0.145		
0.425	0.117	0.145	0.145	0.219
0.400	0.117	0.145	0.145	0.219
0.375	0.117	0.145	0.145	0.219
0.3 50	0.117	0.145	0.145	0.219
0.325	0.117	0.145	0.145	0.219
0.300	0.117	0.145	0.145	0.219
0.275	0.117	0.145	0.145	0.219
0.250	0.117	0.145	0.145	0.219
0.225	0.117	0.145	0.145	0.219
0.200	0.117	0.145	0.145	0.219
0.175	0.117	0.145	0.145	0.219
0.150	0.117	0.145	0.145	0.219
0.125	0.117	0.145	0.145	0.219
0.100	0.117	0.145	0.128	0.193
0.075	0.083	0.103	0.106	0.159
0.050	0.058	0.072	0.076	0.114
0.025	0.040	0.050	0.0376	0.057

RUN NO. V 11:
DRY MATERIAL 3.43 LB.
TRAY AREA 400 SQ· IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 1.235

RUN NO. V 12:
DRY MATERIAL 4.19 LB.
TRAY AREA 400 SQ. IN.
CRUMB DEPTH 1.0 IN.
CONVERION FACTOR 1.51

VACUUM DRYING DATA

RUN NO. V 13

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT G .	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
9:35	14.1409	18.2346	4.0937	16.8838	2.7420	1.3508	0.493
10:05	14.0981	1813656	4.2675	17.1285	3.0304	1.2371	0.408
10;35	17.6592	22.1055	4.4483	21.0178	3.3606	1.0877	0.302
11:05	18.5496	22.8204	4.2708	21.9509	3.4013	0.8695	0.255
11:35	18.6917	23.3200	4.6283	22.5867	3.8950	0.7333	0.188
12:05	17.8622	23.4681	5.6059	23.0844	5.2222	0.3837	0.0734
1:05	17.8057	23.3066	5.5009	23.0507	5.2450	0.2559	0.0478
1:35	13.7933	17.4410	3.6477	17.3816	3.5883	0.0594	0.0166

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.OF HG.
9:35							15.0
10:05	131	76	61	70	70	62	15.2
10:35	132	84	71	76	75	65	15.0
11:05	132	85	74	76	76	67	15.0
11:35	131	81	75	78	76		15.2
12:05	130	86	96	78	79	72	15.2
12:35	131	89	108	85	89	73	15.0
1:05	130	91	106	92	99	73	15.0
1:35	130	91	109	97	108	75	16.0

STEAM PRESSURE 8 LB. psi.
TRAY WEIGHT 9.125 LB.
TOTAL WET WEIGHT 15.125 LB
SAMPLE WET WEIGHT 6.00 LB.

TOTAL DRY WEIGHT 13.45 LB.
SAMPLE DRY WEIGHT 4.325 LB.
WATER LOST 1.675 LB.
MOISTURECONTENT 27.9%

VACUUM DRYING DATA

RUN NO. V 14

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
10:10	14.6605	11.8208	3.1603	16.7943	2.1338	1.0265	0.482
10:40	13.7630	11.4126	3.6496	16.2536	2.4906	1.1590	0.464
11:10	13.3200	16.8072	3.4872	15.7431	2.4231	1.0641	0.440
11:40	14.2698	17.3227	3.0529	16.3925	2.1227	0.9302	0.438
12:10	13.2736	16.2446	2.9710	15.3762	2.1028	0.8682	0.413
12:40	13.8686	17.5481	3.6785	16.5812	2.7126	0.9659	0.356
1:10	14.6947	17.3151	2.6201	16.4690	1.7693	0.8511	0.481
1:45	13.5720	16.0372	2.4652	15.4161	1.8441	0.6211	0.337
2:10	14.6205	18.4218	3.8013	17.5207	2.9002	0.9011	0.310
2:40	14.2444	18.3859	4.1415	17.3655	3.1211	1.0204	0.327

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	OF TOP CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.OF HG.
10:10							15.0
10:40	43	49	45	50	46	52	15.0
11:10	46	58	52	54	51	54	15.0
11:40	48	59	54	56	53	55	15.0
12:10	49	60	51	58	55	56	15.0
12:40	51	62	56	59	56	58	14.9
1:10	51	61	55	59	56	59	14.9
1:45	53	64	56	59	57	60	15.0
2:10	54	60	59	60	58	58	15.1
2:40	55	65	55	61	58	61	15.0

STEAM PRESSURE 5 LB. psi.
TRAY WEIGHT 9.875 LB.
TOTAL WET WEIGHT 14.875 LB.
SAMPLE WET WEIGHT 5.00 LB.

TOTAL DRY WEIGHT 13.250 LB.
SAMPLE DRY WEIGHT 3.375 LB.
WATER LOST 1.625 LB.
MOISTURE CONTENT 32.5%

DRYING RATE DATA

	RUN NO. V 13 (Cont'd)		RUN NO. V 14 (Cont'd)	
MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB. WATER PER SQ. FT PER HOUR	SLOPE OF CURVE	DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.475	0.147	0.228	0.0435	0.058
0.450	0.147	0.228	0.0435	0.058
0.425	0.147	0.228	0.0435	0.058
0.400	0.147	0.228	0.0435	0.058
0.375	0.147	0.228	0.0435	0.058
0.350	0.147	0.228	0.0435	0.058
0.325	0.147	0.228	0.0435	0.058
0.300	0.147	0.228	0.0435	0.058
0.275	0.147	0.228	0.0435	0.058
0.250	0.147	0.228	0.0435	0.058
0.225	0.147	0.228	0.0435	0.058
0.200	0.147	0.228	0.0435	0.058
0.175	0.147	0.228		
0.150	0.147	0.228		
0.125	0.125	0.195		
0.100	0.106	0.164		
0.075	0.007	0.119		
0.050	0.055	0.088		
0.025	0.0375	0.058		

DRY MATERIAL 4.32 LB.
TRAY AREA 400 SQ. IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 1.555

DRY MATERIAL 3.70 LB.
TRAY AREA 400 SQ. IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 1.33

VACUUM DRYING DATA

RUN NO. V 15.

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
10:50	14.6605	18.6582	3.9977	17.3332	2.6727	1.3250	0.497
11:20	13.7630	17.4709	3.7079	16.3007	2.5377	1.1702	0.462
11:50	13.3200	17.3084	3.9884	16.0698	2.7498	1.2386	0.450
12:20	14.2698	18.2829	4.0131	11.0843	2.8145	1.1986	0.425
1:20	13.2736	17.6885	4.4149	16.4724	3.1988	1.2161	0.381
1:50	13.8686	17.4492	3.5606	11.5064	2.6378	0.9228	0.350
2:20	14.6947	18.9681	4.2734	17.7897	3.0950	1.1784	0.381
2:50	13.5720	17.3115	37395	16.4298	2.8578	0.8817	0.309
3:20	13.3989	17.1376	3.7387	16.2964	2.8975	0.8412	0.291
3:50	13.7933	17.1008	3.3075	16.4363	2.6430	0.6625	0.251

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.OF HG.
10:50							10.0
11:20	49	65	47	52	51	53.5	10.0
11:50	52	68	52	59	57	56	10.0
12:20	53	70	57	61	60	57.5	10.0
1:20	55	72	60	65	63	60	10.0
1:50	56	73	58	63	61	60	15.0
2:20	57	73	65	65	63	59	10.0
2:50	58	74	63	65	64	61	10.2
3:20	58	75	65	65	63	62	10.0
3:50	58	74	62	65	65	62	10.0

STEAM PRESSURE 17 LB.PER SQ.IN.
TRAY WEIGHT 8.875 LB.
TOTAL WET WEIGHT 14.00 LB.
SAMPLE WET WEIGHT 5.125 LB.

TOTAL DRY WEIGHT 13.562 LB.
SAMPLE DRY WEIGHT 4.687 LB.
WATER LOST 0.438 LB.
MOISTURE CONTENT 8.55%

VACUUM DRYING DATA

RUN NO. V 16

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
6:20	14.0981	19.3262	5.2281	17.6346	3.3365	1.6916	0.478
6:50	17.6558	23.1836	5.5278	21.5118	3.8560	1.6718	0.433
7:20	18.5496	24.0046	5.5440	22.5131	3.9635	1.4915	0.377
7:50	18.5998	24.2445	5.6449	22.9893	4.3895	1.2552	0.286
8:20	17.7992	23.0710	5.2718	22.1357	4.3365	0.9352	0.216
8:50	17.4400	22.7504	5.3104	27.1179	4.6779	0.6325	0.135
9:20	18.0770	22.6309	4.5539	22.1865	4.1095	0.4444	0.108

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.OF HG
6:20							10.0
6:50	127	83	80	76	78	72	10.2
7:20	127	85	87	78	78	72	10.0
7:50	131	88	91	79	80	75	10.0
8:20	130	90	93	80	81	77	9.8
8:50	128	92	116	80	80	78	10.0
9:20	128	93	83	83	83	78	9.9

STEAM PRESSURE 30 LB. psi. MOISTURE CONTENT 32.4%

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. V 15 (Cont'd) SLOPE OF CURVE	RUN NO. V 15 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR	RUN NO. V 16 (Cont'd) SLOPE OF CURVE	RUN NO. V 16 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.500	0.1124	0.139	0.1302	0.159
0.475	0.1124	0.139	0.1302	0.159
0.450	0.1124	0.139	0.1302	0.159
0.425	0.1124	0.139	0.1302	0.159
0.400	0.1124	0.139	0.1302	0.159
0.375	0.1124	0.139	0.1302	0.159
0.300	0.1124	0.139	0.1302	0.159
0.275			0.1302	0.159
0.250			0.1302	0.159
0.225			0.1302	0.159
0.200			0.1302	0.159
0.175			0.1302	0.159
0.150			0.1302	0.159
0.125			0.1302	0.159
0.100			0.1302	0.159

RUN NO. V 15:
DRY MATERIAL 3.42 LB.
TRAY AREA 400 SQ. IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 1.22

RUN NO. V 16:
DRY MATERIAL 3.43 LB.
TRAY AREA 400 SQ. IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 1.22

VACUUM DRYING DATA

RUN NO. V 17.

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
4:00	18.6917	22.9718	4.2801	21.8199	3.1282	1.1519	0.369
4:30	17.5521	22.0714	4.5202	21.0271	3.4759	1.0443	0.301
5:00	17.8622	22.4598	4 .5876	21.5873	3.6851	0.9024	0.245
5:30	17.8057	21.6546	3.8489	21.0798	3.2741	0.5748	0.1755
6:00	13.7630	17.1722	3.4092	16.9243	3.1613	0.2479	0.0784
6:30	13.3200	16.3651	3.0451	16.2587	2.9387	0.1064	0.0363
7:00	14.2698	16.6555	2.3857	16.6501	2.3803	0.0054	0.0023

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN. OF HG.
4:00							20.0
4:30	128	85	68	69	69	69	20.0
5:00	128	86	71	70	69	69	20.1
5:30	128	87	90	71	68	73.5	20.0
6:00	128	88	88	73	69	73	20.0
6:30	128	92	106	85	85	75	20.0
7:00	129	93	109	98	96	74	20.0

TRAY WEIGHT 8.87 LB.
TOTAL WET WEIGHT 13.94 LB.
SAMPLE WET WEIGHT 5.07 LB.

TOTAL DRY WEIGHT 12.50 LB.
SAMPLE DRY WEIGHT 6.51 LB.
WATER LOST 1.44 LB.
MOISTURE CONTENT 28.5%

VACUUM DRYING DATA

RUN NO. V 18

TIME	BOTTLE TARE WEIGHT	TOTAL WET WEIGHT	SAMPLE WET WEIGHT	TOTAL DRY WEIGHT	SAMPLE DRY WEIGHT	WATER PRESENT	LBS WATER PER LB. DRY MATERIAL
11:00	17.6558	22.2767	4.6209	20.7600	3.1012	1.5167	0.488
11:30	18.5496	23.1414	4.5921	21.8050	3.2554	1.3367	0.411
12:00	18.5998	23.5840	4.9842	22.3634	3.7636	1.2206	0.325
12:30	17.7992	22.3812	4.5820	21.3634	3.5642	1.0178	0.286
1:40	18.0400	21.5542	4.1142	21.0030	3.5630	0.5512	0.156
2:00	18.0770	21.9688	3.8918	21.6990	3.6220	0.2698	0.0744
2:30	14.6605	17.9684	3.3079	17.7783	3.1178	0.1901	0.0612
3:00	13.7630	17.1862	3.4232	17.0657	3.3027	0.1205	0.0365

TIME	TEMPERATURE-DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.OF GH.
11:00							20.0
11:30	109	74	60	65	64	58	20.0
12:00	109	75	64	66	64	60	20.0
12:30	112	78	68	67	66	62	20.0
1:40	110	78	76	68	70	65	20.0
2:00	109	78	77	69	68	59	20.0
2:30	110	80	85	73	75	60	20.0
3:00	111	82	84	81	76	65	20.0

STEAM PRESSURE 8 LB. PER SQ.IN.
TRAY WEIGHT 9.13 LB
TOTAL WET WEIGHT 14.19 LB.
SAMPLE WET WEIGHT 5.06 LB.

TOTAL DRY WEIGHT 12.50 LB.
SAMPLE DRY WEIGHT 3.37 LB.
WATER LOST 1.69 LB.
MOISTURE CONTENT 33.4%

DRYING RATE DATA

RUN NO. V 17 (Cont'd) RUN NO. V 18 (Cont'd)

MOISTURE CONTENT LB.WATER PER LB. DRY MATERIAL	SLOPE OF CURVE (V 17)	DRYING RATE LB.WATER PER SQ.FT. PER HOUR (V 17)	SLOPE OF CURVE (V 18)	DRYING RATE LB.WATER PER SQ. FT. PER HOUR (V 18)
0.425			0.155	0.202
0.400	0.142	0.177	0.155	0.202
0.375	0.142	0.177	0.155	0.202
0.350	0.142	0.177	0.155	0.202
0.325	0.142	0.177	0.155	0.202
0.300	0.142	0.177	0.155	0.202
0.275	0.142	0.177	0.155	0.202
0.250	0.142	0.177	0.155	0.202
0.225	0.142	0.177	0.155	0.202
0.200	0.142	0.177	0.155	0.202
0.175	0.142	0.177	0.155	0.202
0.150	0.142	0.177	0.155	0.202
0.125	0.142	0.177	0.135	0.176
0.100	0.142	0.177	0.122	0.159
0.075	0.136	0.170	0.098	0.1283
0.050	0.106	0.132	0.075	0.098
0.025	0.081	0.1013	0.0545	0.0712

DRY MATERIAL 3.56 LB.
TRAY AREA 400 SQ. IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 1.247

DRY MATERIAL 3.625 LB.
TRAY AREA 400 SQ.IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 1.308

VACUUM DRYING DATA

RUN NO. V 19

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS.WATER PER LB.DRY MATERIAL
11:03	13.6813	17.0742	3.3929	16.0518	2.3705	1.0224	0.432
11:33	13.3408	15.8133	2.4725	15.1807	1.8399	0.6326	0.344
12:03	13.4604	16.7756	3.3152	16.2218	2.6614	0.6538	0.246
12:33	13.2114	16.0889	2.8775	15.6508	2.4394	0.4381	0.180
1:03	13.5424	16.1676	2.6252	15.8778	2.3354	0.2898	0.124
1:33	14.1409	16.3528	2.2119	16.2187	2.0778	0.1341	0.0647
2:03	14.0981	16.8805	2.7824	16.8060	2.7079	0.0745	0.0275
2:33	17.6572	20.5556	2.8984	20.5440	2.8864	0.0116	0.0040
3:03	18.5496	21.5107	2.9611	21.5023	2.9589	0.0022	0.0007

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN.OF HG.
11:03							20.0
11:33	121	80	61	69	66	62.5	20.0
12:03	122	81	67	69	67	59	20.1
12:33	120	78	67	69	67	61	20.1
1:03	120	80	74	69	66	66.5	20.1
1:33	120	82	80	70	68	63.5	20.6
2:03	120	83	85	80	79	66.5	20.0
2:33	123	88	95	97	94	71.5	19.9
3:03	123	79	102	105	100	71	20.0

TRAY WEIGHT 9.125 LB
TOTAL WET WEIGHT 14.125 LB.
SAMPEL WET WEIGHT 5.00 LB.

TOTAL DRY WEIGHT 12.75 LB.
SAMPLE DRY WEIGHT 3.625 LB.
MOISTURE CONTENT 27.5%
WATER LOST 1.375 LB.

VACUUM DRYING DATA

RUN NO. V 20.

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	TOTAL DRY WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER PRESENT GM.	LBS. WATER PER LB. DRY MATERIAL
10:30	14.6605	18.9246	4.2641	17.5904	2.9297	1.3342	0.455
11:00	13.7630	16.9474	3.2814	15.9984	2.2354	1.0460	0.444
11:30	13.3200	15.9184	2.5984	15.1445	1.8245	0.7739	0.423
12:00	11.2698	17.6430	3.3732	16.6382	2.7684	1.0048	0.424
12:30	13.2736	17.5525	4.2789	16.2896	3.1160	1.2829	0.426
1:30	13.8686	18.1657	4.2971	16.9712	3.1026	1.1948	0.385
2:00	14.6947	17.9378	3.2431	16.8782	2.1835	1.0596	0.485
2:30	13.5720	17.2126	3.6406	16.1850	2.6130	1.0276	0.293
3:00	14.6205	18.4927	3.8712	17.3841	2.7636	1.1076	0.400
3:30	14.2448	17.6703	3.3259	16.6903	2.4459	0.8800	0.360
4:00	13.4995	12.5957	4.0967	16.2815	2.7185	1.3777	0.506
4:30	13.6208	16.7795	3.1587	15.7180	2.0972	1.0615	0.506

TIME	TEMPERATURE- DEGREES CENTIGRADE						VACUUM
	UPPER SHELF	MIDDLE SHELF	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	AIR	IN. OF HG.
10:30							20.0
11:00	45	56	39	41	58	51	20.2
11:30	46	57	47	50	52	52	19.6
12:00	46	60	48	50	55	52	20.2
12:30	47	61	50	52	55	52	20.3
1:30	47	61	50	52	55	53	20.3
2:00	49	62	52	52	56	52	20.4
2:30	49	62	50	52	56	52	20.4
3:00	50	63	50	53	56	54	20.2
3:30	51	63	51	54	57	53	20.3
4:00	51	64	52	55	57	52	20.1
4:30	51	64	51	55	56		20.3

STEAM PRESSURE 16 LB. PER SQ. IN.
TRAY WEIGHT 9.08 LB.
TOTAL WET WEIGHT 17.16 LB
SAMPLE WET WEIGHT 8.08 LB.

DRYING RATE DATA

	RUN NO. V 19 (Cont'd)		RUN NO. V 20 (Cont'd)	
MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB. WATER PER SQ. FT. PER HOUR	SLOPE OF CURVE	DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.475			0.1314	0.161
0.450	0.0175	0.0372	0.1314	0.161
0.425	0.0175	0.0372	0.1314	0.161
0.400	0.0175	0.0372	0.1314	0.161
0.375	0.0175	0.0372	0.1314	0.161
0.350	0.0175	0.0372	0.1314	0.161
0.325	0.0175	0.0372	0.1314	0.161
0.300	0.0175	0.0372	0.1314	0.161
0.275	0.0175	0.0372	0.1314	0.161
0.250	0.0175	0.0372	0.1314	0.161
0.225	0.0175	0.0372	0.1314	0.161
0.200	0.0175	0.0372	0.1314	0.161
0.175			0.1314	0.161
0.150			0.1314	0.161
0.125			0.1314	0.161
0.100			0.127	0.155
0.075			0.075	0.0925
0.050			0.038	0.0417

DRY MATERIAL 5.0 LB.
TRAY AREA 400 SA. IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 2.12

ROTARY VACUUM DRYING DATA

RUN NO. R 1

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER LOST	LBS.WATER PER LB.DRY MATERIAL
11:30	352.4	397.8	45.4	30.08	14.6	0.474
12:00	352.1	415.6	63.5	42.97	20.53	0.471
12:30	352.9	406.1	53.2	39.14	14.06	0.359
1:05	349.6	404.6	55.0	46.72	8.28	0.177
1:30	358.9	400.1	41.2	37.91	3.29	0.0868
2:00	349.4	400.6	51.2	48.62	2.58	0.0552
2:30	354.9	409.3	54.4	52.19	2.21	0.0424
3:00	354.8	398.6	43.8	43.31	0.49	0.0113
3:30	353.2	419.4	66.2	66.5		0
4:00	355.1	397.4	42.3			0

VACUUM 29.0 IN. OF MERCURY

RUN NO. R 2

4:20	355.8	440.0	84.2	61.27	22.93	0.374
4:50	353.7	416.4	62.7	49.56	13.14	0.265
5:20	339.7	414.5	74.8	65.09	9.71	0.149
6:50	338.8	398.4	59.6	59.44	0.16	0.00269

VACUUM 18 IN. OF MERCURY

ROTARY VACUUM DRYING DATA

RUN NO. R 3

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER LOST	LBS.WATER PER LB.DRY MATERIAL
11:35	339.0	365.2	26.2	19.63	5.57	0.335
11:05	338.1	392.0	53.9	41.39	12.51	0.302
12:35	332.5	408.0	70.5	56.12	14.38	0.256
1:05	345.5	390.0	55.5	45.38	10.12	0.223
1:40	336.4	389.3	52.9	47.57	5.33	o.112
2:20	331.4	367.3	35.9	32.87	2.83	0.086
2:55	332.0	368.7	36.7	33.92	2.78	0.0821
3:55	337.2	391.7	54.3	53.02	1.28	0.0241
4:10	336.7	392.4	55.7	55.15	0.55	0.0100

VACUUM 10 IN. OF MERCURY

RUN NO. R 4

12:25	339.2	400.6	61.4	47.35	14.05	0.297
12:55	338.5	392.7	54.2	42.45	11.75	0.277
1:25	337.5	402.2	64.7	56.05	8.65	0.154
2:10	336.1	367.1	31.0	30.02	1.00	0.0333
2:40	336.5	381.3	44.8	44.25	0.55	0.0125
3:10	334.8	393.6	58.8	58.97		
3:40	332.2	373.4	41.2	41.42		
4:20	337.3	338.4	56.2	57.27		

VACUUM 29.5 IN. OF MERCURY

ROTARY VACUUM DRYING DATA

RUN NO. R 5

TIME	BOTTLE TARE WEIGHT GM.	TOTAL WET WEIGHT GM.	SAMPLE WET WEIGHT GM.	SAMPLE DRY WEIGHT GM.	WATER LOST	LBS.WATER PER LB.DRY MATERIAL
11:10	331.2	393.3	62.1	41.57	20.53	0.493
11:40	339.2	398.6	59.4	41.56	17.90	0.432
12:10	338.5	394.4	55.9	41.52	14.38	0.346
1:10	337.5	400.9	63.4	55.57	7.62	0.137
1:40	334.8	391.5	56.7	54.30	2.40	0.0443
2:10	336.5	388.1	51.6	50.90	0.70	0.0138
2:50	337.3	392.3	60.0	59.81	0.15	0.00318
3:50	332.2	376.7	44.5	44.63		

VACUUM 23 IN. OF MERCURY

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 1

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB.DRY MATERIAL
11:40	163.5284	46.16	0.442
12:00	161.6603	44.29	0.427
12:20	159.7900	42.42	0.409
12:40	158.2134	40.84	0.304
1:40	153.7786	35.91	0.346
2:00	152.0160	34.64	0.334
2:20	151.1262	33.76	0.325
2:40	150.0937	32.72	0.315
3:00	149.1212	31.75	0.306
3:20	147.7561	30.39	0.293
3:40	146.9336	29.56	0.285
4:00	145.8757	28.51	0.275
6:10	140.0631	22.69	0.210

STEAM PRESSURE	20 LB. psi.
CRUMB SIZE	AS RECEIVED
CRUMB DEPTH	2.0 IN.
TRAY TARE	13.56 GM.
DRY MATERIAL	103.8 GM.
AIR VELOCITY	400 FT. PER MIN.
BOTTLE TARE WEIGHT	17.4400 GM.
TOTAL WET WEIGHT	24.7319 GM.
TOTAL DRY WEIGHT	22.4926 GM.
DRY CRUMB	5.0526 GM.
WATER LOST	2.2393 GM.
LB.WATER PER LB.D.M.	0.442

TIME	TEMPERATURE- DEGREES FAHRENHEIT							HUMIDITY LB.WATER PER LB. DRY AIR	
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	OUTLET WETBULB	INLET	OUTLET
11:40									
12:00	108	97	97		97.5	120	101.0		0.039
12:20	108	97	96	98.6	91.4	117.5	96.8	0.031	0.034
12:40	108	97	97	95.9	91.7	118.	96.8	0.032	0.034
1:40	111	100	100	96.8	94.3	120	95.8	0.0344	0.032
2:00	111	102	102	98.8	93.5	121	96.8	0.0345	0.032
2:20	115	102	104	100.4	93.5	121	97.6	0.0330	0.035
2:40	117	106	106	100.7	95.3	121	97.3	0.0365	0.035
3:00	117	109	109	100.4	95.3	122	97.9	0.036	0.035
3:20	117	109	109	100.4	94.6	122	97.6	0.035	0.035
3:40	120	109	109	99.3	94.6	122	97.6	0.035	0.035
4:00	120	109	109	98.6	95.7	121	96.8	0.037	0.032
6:10	120	113	113	96.8	92.5	123	96.8	0.038	0.032

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 2

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
2:00	156.6464	45.58	0.517
2:30	150.1012	42.05	0.445
3:00	145.9369	37.87	0.401
3:30	141.9473	33.88	0.359
4:00	138.5682	30.50	0.323
4:30	135.5192	27.45	0.290
5:00	132.8772	24.80	0.269
5:30	130.7200	22.65	0.240
6:00	127.4670	19.40	0.205
7:00	124.9926	16.92	0.179

STEAM PRESSURE	5 LB. psi.
CRUMB SIZE	AS RECEIVED
CRUMB DEPTH	2.0 IN.
TRAY TARE	13. GM.
DRY MATERIAL	94.5 GM.
AIR VELOCITY	400 FT. PER MIN.
BOTTLE TARE WEIGHT	14.2605 GM.
TOTAL WET WEIGHT	20.7332 GM.
TOTAL DRY WEIGHT	18.6437 GM.
DRY CRUMB	4.0232 GM.
WATER LOST	2.0895 GM.
LB.WATER PER LB.D.M.	0.517

TIME	TEMPERATURE- DEGREES FAHRENHEIT							HUMIDITY LB.WATER PER LB. DRY AIR	
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	OUTLET WET BULB	INLET	OUTLET
2:00									
2:30	81	72	84	79.5	58.1	104	67.1	0.0056	0.0058
3:00	88	75	84	79.5	58.1	104	67.5	0.0055	0.0060
3:30	93	84	86	80.2	58.3	104	67.5	0.0054	0.0060
4:00	97	90	86	80.2	58.3	104	67.1	0.0054	0.0058
4:30	99	95	90	80.2	58.6	104	67.5	0.0055	0.0061
5:00	100	99	95	80.6	59.0	104.2	67.5	0.0057	0.0061
5:30	102	100	100	80.6	59.0	104	68	0.0057	0.0064
6:00	102	100	100	80.6	59.0	104	68	0.0057	0.0064

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 3

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
11:20	154.0510	36.48	0.349
11:50	146.6224	29.05	0.279
12:20	141.1584	23.59	0.226
12:50	136.1780	18.61	0.179
1:20	132.1730	15.40	0.148
1:50	131.2412	13.67	0.131
2:20	128.9200	11.35	0.109
3:00	126.0302	8.46	0.0811
3:30	124.5770	7.50	0.0720
4:00	123.4315	5.86	0.0562

STEAM PRESSURE	20 LB. psi.
CRUMB SIZE	AS RECEIVED
CRUMB DEPTH	20.0 IN.
TRAY TARE	13.56 GM.
DRY MATERIAL	109.5 GM.
AIR VELOCITY	400 FT.PER MIN
BOTTLE TARE WEIGHT	18.0770 GM.
TOTAL WET WEIGHT	25.8437 GM.
TOTAL DRY WEIGHT	23.8022 GM.
DRY CRUMB	5.7252 GM.
WATER LOST	2.0415 GM.
LB.WATER PER LB D.M.	0.349

TIME	TEMPERATURE- DEGREES FAHRENHEIT							HUMIDITY LB.WATER PER LB DRY AIR	
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	OUTLET WET BULB	INLET	OUTLET
11:20									
11:50	138	96.8	109	101.3	71.6	167	89.6	0.0097	0.012
12:20	138	102.2	104		71.6	168.8	89.2		0.012
12:50	142	124	137	102.2	71.6	161.6	89.6	0.0096	0.0137
1:20	145	138	140	102.2	71.6	161.6	91.4	0.0096	0.016
1:50	145	139	140	105.8		161.6		0.0103	0.013
2:20	147	142	140	105.8		163.4	89.2	0.0126	0.013
3:00	147	142	141	105.8		163.4	89.6	0.011	0.0144
3:30	147	145	144	105.8		163.4	90.	0.0108	0.011
4:00	147	147	146	104		161.6	88.8	0.0103	0.0125

AIR DRYING DATA
AIR ACROSS CRUMB
RUN NO. A 4

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB.DRY MATERIAL	OUTLET DRY BULB °F	OUTLET WET BULB °F	HUMIDITY LB. WATER PER LB. DRY AIR OUTLET
12:00	155.498	40.26	0.395			
12:30	146.339	31.31	0.308	211	101	0.022
1:00	140.090	24.86	0.244	212		
1:30	133.020	17.79	0.175			
2:00	129.533	14.29	0.140	214	102	0.022
2:30	129.534	10.70	0.1051	213	100	0.021
3:00	123.114	2.88	0.0775	212	101	0.023
3:30	120.781	5.55	0.0545	215	102	0.025
4:00	118.900	3.67	0.0361	214	102	0.026

STEAM PRESSURE	50 psi.	
AIR VELOCITY	120 FT. PER MIN.	
CRUMB SIZE	THROUGH	0.371 IN.
	ON	0.185 IN
CRUMB DEPTH	2 IN.	
CONTAINER TARE	13.43	GM
DRY MATERIAL	101.8	GM

INITIAL MOISTURE CONTENT DETERMINATION:

BOTTLE TARE WEIGHT	13.2736 GM.
TOTAL WET WEIGHT	18.6370 GM.
TOTAL DRY WEIGHT	17.1174 GM.
DRY CRUMB	3.8438 GM.
WATER LOST	1.5196 GM.
LB. WATER PER LB. D.M.	0.395

DRYING RATE DATA

RUN NO. A 1 (Cont'd)

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.450		
0.425	0.74	0.219
0.400	0.63	0.187
0.375	0.51	0.151
0.350	0.46	0.136
0.325	0.40	0.118
0.300	0.34	0.101
0.275	0.34	0.101
0.250	0.23	0.0681
0.225	0.105	0.0547
0.200		
0.175		

TRAY AREA 9 SQ. IN.
CONVERSION FACTOR 0.296

RUN NO. A 2 (Cont'd)

SLOPE OF CURVE	DRYING RATE LB. WATER PER SQ. FT. PER HOUR
1.60	0.399
1.34	0.334
1.16	0.299
1.04	0.259
0.098	0.245
0.91	0.228
0.82	0.205
0.72	0.180
0.66	0.165
0.57	0.143
0.51	0.127
0.93	0.116

TRAY AREA 9 SQ.IN.
CONVERSION FACTOR 0.249

RUN NO. A 3 (Cont'd)

0.375		
0.350		
0.325	2.08	0.574
0.300	1.78	0.493
0.275	1.58	0.437
0.250	1.35	0.374
0.225	1.25	0.348
0.200	1.00	0.276
0.175	0.88	0.253
0.150	0.71	0.196
0.125	0.60	0.166
0.100	0.50	0.138
0.075	0.42	0.115
0.050	0.36	0.0991
0.025		

TRAY AREA 9 SQ. IN
CONVERSION FACTOR 0.368

RUN NO. A 4 (Cont'd)

1.70	0.611
1.64	0.589
1.60	0.574
1.57	0.546
1.40	0.503
1.30	0.467
1.20	0.431
1.08	0.388
0.98	0.352
0.82	0.295
0.68	0.244
0.55	0.197
0.48	0.172
0.43	0.154
0.37	0.133

TRAY AREA 9 SQ. IN.
CONVERSION FACTOR 0.359

AIR DRYING DATA
AIR ACROSS CRUMB
RUN NO. A 5

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB.DRY MATERIAL	INLET DRY BULB °F	INLET DRY BULB °F	HUMIDITY LB.WATER PER LB. DRY AIR INLET
4:20	149.7924	40.57	0.422			
4:40	141.5790	32.18	0.334	133	82.4	0.0130
6:10	119.279	9.88	0.103	131	80.8	0.011
6:40	116.501	7.10	0.0739	131	80.8	0.011
7:10	114.135	4.74	0.0493	133		
7:40	112.682	3.28	0.0342	133	80.8	0.011
8:10	111.334	1.03	0.0201	133	78.8	0.0098
9:10	110.020	0.62	0.00645	131	78.8	0.010

STEAM PRESSURE	42 LB. psi.
AIR VELOCITY	400 Ft Per Min.
CRUMB SIZE	THROUGH 0.371 IN.
	ON 0.185 IN.
CRUMB DEPTH	2 IN.
CONTAINER TARE	13.34 GM.
DRY MATERIAL	96.1 GM.

INITIAL MOISTURE CONTENT DETERMINATION:

BOTTLE TARE WEIGHT	13.5720	GM.
TOTAL WET WEIGHT	19.1478	GM.
TOTAL DRY WEIGHT	17.4915	GM.
DRY CRUMB	3.9195	GM.
LB.WATER PER LB.D.M.	0.422	
WATER LOST	1.6563	GM.

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 6

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
11:04	160.077	52.07	0.550
11:24	152.706	44.71	0.472
11:44	145.890	37.89	0.400
12:04	140.464	37.46	0.343
12:34	133.794	25.79	0.272
1:04	127.900	19.90	0.210
1:40	123.682	15.68	0.165
2:04	121.543	13.54	0.143
2:34	119.546	11.55	0.122
3:04	116.955	8.96	0.0947
3:34	115.140	7.14	0.0753

STEAM PRESSURE	42 LB. psi.
CRUMB SIZE	THROUGH 0.371 IN ON 0.185 IN
CRUMB DEPTH	2.0 IN
TRAY TARE	13.35 GM.
DRY MATERIAL	94.60 GM.
AIR VELOCITY	400 FT. PER MIN
BOTTLE TARE WEIGHT	13.2946 GM.
TOTAL WET WEIGHT	19.0174 GM.
TOTAL DRYWEIGHT	17.1654 GM.
DRY CRUMB	3.3708 GM.
WATER LOST	1.8520 GM.
LB.WATER PER LB D.M.	0.0550

TIME	TEMPERATURE- DEGREES FAHRENHEIT						HUMIDITY LB.WATER PER LB. DRY AIR
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	INLET
11:04							
11:24	127	106	120	134	85.8	180	0.0151
11:44	144	117	122	134	86.7	181	0.0153
12:04	147	126	126	131	85.5	180	0.0153
12:34	158	144	144	132	85.7	180	0.0152
1:04	176	167	165	133	86.7	182	0.0154
1:40	181	178	178	133	86.7	182	0.0154
2:04	185	181	181	134	87.8	182	0.0155
2:34	187	185	183	133	86.0	180	0.0152
3:04	188	187	185	135	82.8	183	0.0156
3:34	188	187	185	136	82.0	183	

DRYING RATE DATA

RUN NO. A 5(Cont'd) RUN NO. A 6 (Cont'd)

MOISTURE CONTENT LB.WATER PER LB. DRY MATERIAL	SLOPE OF CURVE (A 5)	DRYING RATE LB.WATER PER SQ. FT PER HOUR (A 5)	SLOPE OF CURVE (A 6)	DRYING RATE LB.WATER PER SQ. FT. PER HOUR (A 6)
0.500			2.33	0.775
0.475			2.33	0.775
0.450			2.22	0.739
0.425			2.08	0.694
0.400	2.78	0.94	1.92	0.629
0.375	2.63	0.89	1.67	0.556
0.350	2.50	0.846	1.63	0.543
0.325	2.44	0.825	1.50	0.500
0.300	2.32	0.785	1.40	0.467
0.275	2.13	0.720	1.35	0.450
0.250	2.00	0.677	1.22	0.407
0.225	1.67	0.565	1.06	0.353
0.200	1.54	0.521	0.88	0.293
0.175	1.40	0.474	0.68	0.226
0.150	1.15	0.389	0.58	0.193
0.125	1.00	0 338	0.49	0.163
0.100	0.78	0:264	0.43	0.143
0.075	0.55	0.186	0.34	0.113
0.050	0.36	0.122		
0.025	0.22	0.0745		

TRAY AREA 9 SQ. IN.
CONVERSION FACTOR 0.338

TRAY AREA 9 SQ. IN.
CONVERSION FACTOR 0.333

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 7

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB.DRY MATERIAL
4:10	164.999	54.24	0.563
4:30	160.673	50.11	0.517
4:50	154.653	44.39	0.458
5:30	144.530	34.27	0.354
6:00	138.192	27.93	0.288
6:30	134.983	24.72	0.255
7:00	131.748	21.49	0.222
7:30	129.068	18.81	0.194
8:00	126.700	16.44	0.170
8:30	124.085	13.73	0.142
9:00	122.351	12.09	0.125

STEAM PRESSURE	45 LB. psi.
CRUMB SIZE	THRU 0.371 IN.
	ON 0.185 IN.
CRUMB DEPTH	2.0 IN.
TRAY TARE	13.36 GM.
DRY MATERIAL	96.90 GM.
AIR VELOCITY	400 FT.PER MIN.
BOTTLE TARE WEIGHT	13.2736 GM.
TOTAL WET WEIGHT	18.8590 GM.
TOTAL DRY WEIGHT	16.8412 GM.
DRY CRUMB	3.5676 GM.
WATER LOST	2.0178 GM.
LB.WATER PER LB. D.M.	0.563

TIME	TEMPERATURE- DEGREES FAHRENEITH						HUMIDITY
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	LB.WATER PER LB. DRY AIR INLET
4:10							
4:30	122	118	144	115	103	177	0.048
4:50	138	126	147	115	103	178	0.049
5:30	165	133	143	118	107	181	0.051
6:00	172	146	143	114	107.5	181	0.052
6:30	176	147	149	115	109.4	181	0.057
7:00	176	154	156	113	107.5	181	0.052
7:30	178	162	162	114	107.5	181	0.047
8:00	181	169	176	114	104	181	0.047
8:30	187	171	169	111	104	182	0.047
9:00	183	176	176	113	105.8	186	0.049

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 8

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL
11:45	150.337	46.67	0.519
12:05	144.007	40.34	0.447
12:25	138.152	34.48	0.382
12:50	132.572	28.90	0.320
1:15	127.150	23.48	0.260
1:45	122.165	18.50	0.205
2:15	118.824	14.15	0.156
2:45	116.271	12.60	0.139
3:15	113.670	10.00	0.1108
3:45	111.400	7.73	0.0856
4:15	109.586	5.92	0.0656

STEAM PRESSURE	45 LB. psi.
CRUMB SIZE	THRU 0.371 IN.
	ON 0.185 IN.
CRUMB DEPTH	2.0 IN.
TRAY TARE	13.37 GM.
DRY MATERIAL	90.3 GM.
AIR VELOCITY	400 FT PER MIN
BOTTLE TARE WEIGHT	13.2106 GM.
TOTAL WET WEIGHT	17.1660 GM.
TOTAL DRY WEIGHT	15.8149 GM.
DRY CRUMB	2.6043 GM.
WATER LOST	1.3511 GM.
LB. WATER PER LB. D.M.	0.519

TIME	TEMPERATURE- DEGREES FAHRENHEIT						HUMIDITY LB. WATER PER LB DRY AIR INLET
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	
11:45							
12:05	122	113	127	120	92.3	184	0.0265
12:25	149	113	127	136	94.4	186	0.0262
12:50	165	129	129	127	93.0	182	0.0260
1:15	172	151	144	131	95	180	0.0280
1:45	176	162	154	127	95	180	0.029
2;15	178	171	165	127	94.1	180	0.029
2:45	185	179	172	129	92	183	0.028
3:15	185	181	181	129	91.4	184	0.022
3:45	185	181	180	126	92.3	182	0.025
4:15	185	183	181	128	93.4	184	0.024

DRYING RATE DATA

	RUN NO. A 7 (Cont'd)		RUN NO. A 8 (Cont'd)	
MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB. WATER PER SQ. FT PER HOUR	SLOPE OF	DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.500	1.67	0.57	2.40	0.750
0.475	1.67	0.57	2.24	0.695
0.450	1.67	0.57	2.10	0.664
0.425	1.57	0.535	1.92	0.606
0.400	1.54	0.525	1.80	0.569
0.375	1.43	0.488	1.70	0.537
0.350	1.30	0.443	1.61	0.507
0.325	1.18	0.403	1.51	0.474
0.300	1.01	0.344	1.40	0.443
0.275	0.89	0.304	1.31	0.414
0.250	0.75	0.256	1.14	0.360
0.225	0.60	0.204	1.02	0.322
0.200	0.53	0.181	0.80	0.253
0.175	0.49	0.167	0.70	0.221
0.150	0.45	0.153	0.58	0.183
0.125	0.36	0.123	0.56	0.177
0.100	0		0.53	0.167
0.075			0.46	0.146
0.050			0.46	0.146

TRAY AREA 9 SQ. IN.
CONVERSION FACTOR 0.341

TRAY AREA 9 SQ. IN.
CONVERSION FACTOR 0.316

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 9

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WAER PER LB. DRY MATERIAL
11:55	164.9076	46.54	0.445
12:25	157.3646	38.99	0.390
12:55	151.9422	33.57	0.322
1:25	146.7197	28.35	0.270
1:55	143.1289	24.76	0.246
2:25	140.7859	22.42	0.204
2:55	138.0237	19.65	0.187
3:25	136.0522	17.68	0.169
3:55	134.7124	11.44	0.157
4:25	133.0330	14.66	0.140

STEAM PRESSURE	5 LB. psi.
CRUMB SIZE	AS RECEIVED
CRUMB DEPTH	2.0 IN.
TRAY TARE	13.3694 GM.
DRY MATERIAL	104.8 GM.
AIR VELOCITY	400 FT.PER MIN
BOTTLE TARE WEIGHT	13.6813 GM.
TOTAL WET WEIGHT	19.0402 GM.
TOTAL DRY WEIGHT	17.4233 GM.
DRY CRUMB	3.7420 GM.
WATER LOST	1.6169 GM.
LB.WATER PER LB D.M.	0.445

TIME	TEMPERATURE- DEGREES FAHRENHEIT							HUMIDITY LB.WATER PER LB.DRY AIR	
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	OUTLET WET BULB	INLET	OUTLET
11:55									
12:25	111	86	99	80.6	59.9	129.8	77.9	0.0062	0.008
12:55	118	93	99	80.6	59.9	129.2	79.5	0.0062	0.011
1:25	118	102	104	80.6	59.9	129.2	78.6	0.0062	0.0095
1:55	122	108	102	81.7	81.5	130.0	80.4	0.0071	0.0125
2:25	126	111	106	81.5	80.6	131.0	78.8	0.0064	0.011
3:25	127	122	117	80.4	80.4	130.9	78.1	0.0066	0.009
3:55	128	124	120	80.6	80.4	131.0	79.2	0.0060	0.012
4:25	129	126	124	80.6	41.5	131.0			

AIR DRYING DATA - AIR ACROSS CRUMB
RUN NO. A 10

CRUMB DEPTH 1 IN.

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL
10:50	92.0605	25.78	0.450
11:10	84.6924	18.41	0.324
11:30	79.9884	13.71	0.242
11:50	76.9194	10.64	0.187
12:20	73.4012	7.12	0.125
1:50	69.4118	3.13	0.0551
2:20	68.3552	2.48	0.0437
2:50	68.3502	2.07	0.0364
3:20	68.0766	1.80	0.0316
3:50	67.9100	1.63	0.0287

DRY MATERIAL 57.2 GM.
TRAY TARE 9.45 GM.

CRUMB DEPTH 1.5 IN.

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL
10:50	129.5317	36.65	0.450
11:10	122.5192	29.63	0.363
11:30	116.3305	23.44	0.287
11:50	113.2508	20.37	0.248
12:20	107.9380	15.06	0.185
1:50	100.4872	7.61	0.0931
2:20	99.0028	6.12	0.0748
2:50	97.8945	5.10	0.0613
3:20	97.0050	4.12	0.0504
3:50	96.3808	3.50	0.0428

DRY MATERIAL 81.60 GM.
TRAY TARE 11.08 GM.

AIR DRYING DATA- AIR ACROSS CRUMB

CRUMB DEPTH 2 IN. RUN NO. A 10 (Cont'd)

TIME	TOTAL WEIGHT GM.	WEIGHT PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
10:50	174.0500	49.76	0.450
11:10	166.1263	41.84	0.378
11:30	159.6652	35.37	0.319
11:50	154.9187	30.63	0.277
12:20	148.1396	23.85	0.216
1:50	136.9111	12.62	0.1140
2:20	134.7576	10.47	0.0945
2:50	133.0366	8.75	0.0791
3:20	131.6661	7.38	0.0666
3:50	130.6093	6.32	0.0571

STEAM PRESSURE	28 LB. psi.
CRUMB SIZE	AS RECEIVED
DRY MATERIAL	110.4 GM.
TRAY TARE	13.69 GM.
AIR VELOCITY	400 FT PER MIN.
BOTTLE WARE WT.	13.2734 GM.
TOTAL WET WT.	18.1461 GM.
TOTAL DRY WT.	16.6350 GM.
DRY CRUMB	3.3 616 GM.
WATER LOST	1.5111 GM.
LB.WATER PER LB D.M.	0.450

TIME	TEMPERATURE- DEGREES FAHRENHEIT TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	HUMIDITY LB.WATER PER LB. DRY AIR INLET
10:50							
11:10	151	126	108	122	73.0	168	0.0064
11:30	158	144	115	122	73.0	169	0.0064
11:50	165	156	118	125	73.4	170	0.0062
12:20	167	162	149	124	73.4	169	0.0063
1:50	179	171	163	126	74.6	170	0.0067
2:20	174	172	167	129	74.7	170	0.0060
2:50	176	172	167	129	73.4	171	0.0056
3:20	171	171	167	123	73.4	168	0.0063
3:50	171	172	167	127	73.4	168	0.0060

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. A 9 (Cont'd) SLOPE OF CURVE	RUN NO. A 9 (Cont'd) DRYING RATE LB.WATER PER SQ. FT PER HOUR	RUN NO. A 10 (Cont'd) SLOPE OF CURVE	RUN NO. A 10 (Cont'd) DRYING RATE LB.WATER PER SQ. FT PER HOUR
0.425	1.70	0.461	4.08	0.822
0.400	1.70	0.461	3.80	0.765
0.375	1.60	0.434	3.70	0.745
0.350	1.51	0.409	3.68	0.740
0.325	1.49	0.404	3.20	0.644
0.300	1.28	0.348	2.80	0.563
0.275	1.00	0.271	2.32	0.467
0.250	0.91	0.246	2.10	0.427
0.225	0.78	0.211	1.78	0.360
0.200	0.67	0.181	1.60	0.322
0.175	0.54	0.145	1.40	0.282
0.150	0.325	0.0878	1.18	0.237
0.125			0.94	0.189
0.100			0.74	0.149
0.075			0.40	0.0805
0.050			0.205	0.0412

RUN NO. A 9:
TRAY AREA 9 SQ. IN.
CRUMB DEPTH 2 IN.
CONVERSION FACTOR 0.361

RUN NO. A 10:
TRAY AREA 9 SQ. IN.
CRUMB DEPTH 1. IN.
CONVERSION FACTOR 0.201

DRYING RATE DATA

RUN NO. A 10 (Cont'd)			RUN NO. A 10 (Cont'd)	
MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB.WATER PER SQ.FT. PER HOUR	SLOPE OF CURVE	DRYING RATE LB.WATER PER SQ. FT PER HOUR
0.425	2.60	0.749	2.10	0.819
0.400	2.48	0.713	2.02	0.738
0.375	2.42	0.696	1.96	0.765
0.350	2.42	0.696	1.79	0.698
0.325	2.35	0.676	1.55	0.605
0.300	2.11	0.606	1.30	0.507
0.275	1.73	0.497	1.30	0.507
0.250	1.40	0.403	1.20	0.468
0.225	1.17	0.336	1.12	0.437
0.200	0.96	0.276	0.98	0.381
0.175	0.81	0.233	0.80	0.311
0.150	0.68	0.196	0.60	0.253
0.125	0.57	0.164	0.45	0.175
0.100	0.42	0.121	0.38	0.150
0.075	0.34	0.098		
0.050	0.16	0.046		

TRAY AREA 9 SQ. IN.
CRUMB DEPTH 1.5 IN.
CONVERSION FACTOR 0.288

TRAY AREA 9 SQ.IN.
CRUMB DEPTH 2 IN.
CONVERSION FACTOR 0.389

AIR DRYING DATA- AIR ACROSS CRUMB

CRUMB DEPTH 1 IN. RUN NO. A 11

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
1:55	103.1793	27.21	0.408
2:25	95.0824	19.12	0.287
2:55	90.1535	14.19	0.213
3:25	86.4052	10.44	0.157
3:55	83.8200	7.86	0.118
4:25	81.8167	5.82	0.0876
4:55	80.2163	4.12	0.0618
5:55	78.0248	2.06	0.0309
7:35	75.9633	0	0

DRY MATERIAL 66.56 GM.
TRAY TARE 9.40 GM.

CRUMB DEPTH 1.5 IN.

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
1:55	135.7242	36.12	0.408
2:25	129.6246	30.00	0.339
2:55	124.1724	24.57	0.278
3:25	119.2352	20.64	0.233
3:55	115.6764	16.08	0.182
4:25	112.8066	13.20	0.144
4:55	109.8621	10.26	0.116
5:55	106.3803	6.78	0.0767
7:35	102.6500	3.05	0.0344

DRY MATERIAL 88.60 GM.
TRAY TARE 11.00 GM.

AIR DRYING DATA - ACIR ACROSS CRUMB
RUN NO. A 11 (Cont'd)

CRUMB DEPTH 2. IN.

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
1:55	177.0128	47.44	0.408
2:25	168.3700	38.80	0.345
2:55	162.0385	32.47	0.280
3:25	156.7759	27.21	0.235
3:55	152.5733	23.00	0.195
4:25	148.3955	18.83	0.162
4:55	144.6882	15.12	0.1305
5:55	140.1352	10.57	0.0914
7:35	134.2747	4.47	0.0406

STEAM PRESSURE	15 LB. psi.
CRUMB SIZE	AS RECEIVED.
TRAY TARE	13.5694 GM.
DRY MATERIAL	16 GM.
AIR VELOCITY	400 FT.PER MIN.

TIME	TEMPERATURE- DEGREES FAHRENHEIT						HUMIDITY LB.WATER PER LB. DRY AIR INLET
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	
1:55							
2:25	109	111	111	111	77.0	158	0.0122
2:55	131	124	113	112	77.4	158	0.0124
3:25	144	136	116	112	77.0	158	0.0121
3:55	147	142	135	112	77.4	158	0.0124
4:25	151	147	140	111	77	158	0.0122
4:55	153	149	145	111	77	159	0.0122
5:55	158	154	151	111	77	159	0.0122
7:35	158	156	156	111	77	157	0.0122

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 12

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL
2:00	164.000	49.20	0.430
2:20	159.060	44.26	0.385
2:40	155.760	40.96	0.357
3:00	152.712	37.97	0.331
3:20	150.191	35.39	0.008
3:40	147.295	32.49	0.283
4:00	144.939	30.14	0.262
4:20	143.066	28.26	0.246
4:40	140.823	26.02	0.227
5:00	138.840	24.04	0.210
5:20	137.687	22.89	0.200

STEAM PRESSURE	20 LB. psi.
CRUMB SIZE	AS RECEIVED
CRUMB DEPTH	2. IN.
TRAY TARE	13.5694 GM.
DRY MATERIAL	114.8 GM.
AIR VELOCITY	400 FT.PER MIN.

TIME	TEMPERATURE- DEGREES FAHRENHEIT							HUMIDITY LB.WATER PER LB. DRY AIR	
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	INLET DRY BULB	INLET WET BULB	OUTLET DRY BULB	OUTLET WET BULB	INLET	OUTLET
2:00									
2:20	131	115	138	102	96.8	163	96.8	0.037	0.023
2:40	140	126	126	100	97.7	163	102.0	0.039	0.031
3:00	145	135	127	104	95.0	165	101.0	0.034	0.027
3:20	147	142	135	100	98.6	163	104.0	0.041	0.0345
3:40	145	147	144	98.6	93.2	165	102.0	0.035	0.031
4:00	147	145	145	104	89.9	159	100.0	0.027	0.0286
4:20	145	145	145	104	91.4	165	102.0	0.034	0.031
4:40	145	145	145	103	94.6	165	107.0	0.034	0.0306
5:00	151	149	145	100	94.6	165	107.0	0.0345	0.031
5:20	154	153	153	100	94.6	165	107.0	0.034	0.0306

DRYING RATE DATA

RUN NO. A 11 (Cont'd)			RUN NO. A 11(Cont'd)	
MOISTURE CONTENT LB.WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB.WATER PER SQ.FT. PER HOUR	SLOPE CURVE	DRYING RATE LB.WATER PER SQ. FT. PER HOUR
0.400	2.86	0.67	1.43	0.449
0.375	2.76	0.641	1.41	0.440
0.350	2.50	0.586	1.36	0.424
0.325.	2.17	0.510	1.30	0.406
0.300	2.00	0.469	1.26	0.393
0.275	1.72	0.404	1.19	0.371
0.250	1.50	0.352	1.03	0.321
0.225	1.30	0.305	1.00	0.312
0.200	1.20	0.282	0.90	0.286
0.175	1.10	0.258	0.80	0.250
0.150	0.90	0.212	0.69	0.216
0.125	0.70	0.165	0.55	0.172
0.100	0.635	0.149	0.40	0.125
0.075	0.55	0.129	0.315	0.0984
0.050	0.325	0.0762	0.22	0.0687
0.025	0.24	0.0563		

TRAY AREA 9. SQ. IN.
CRUMB DEPTH 1.0 IN.
CONVERSION FACTOR 0.234

TRAY AREA 9.SQ. IN.
CRUMB DEPTH 1.5 IN.
CONVERSION FACTOR 0.312

DRYING RATE DATA

RUN NO. A 11 (cont'd) | RUN NO. A12 (Cont'd)

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	A11 SLOPE OF CURVE	A11 DRYING RATE LB. WATER PER SQ. FT PER HOUR	A12 SLOPE OF CURVE	A12 DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.425			2.00	0.809
0.400	1.43	0.585	1.35	0.545
0.375	1.41	0.577	0.95	0.389
0.350	1.36	0.536	0.79	0.320
0.325	1.30	0.533	0.75	0.309
0.300	1.19	0.487	0.70	0.288
0.275	1.08	0.442	0.68	0.275
0.250	0.90	0.368	0.60	0.242
0.225	0.81	0.331	0.50	0.202
0.200	0.77	0.314	0.37	0.091
0.175	0.70	0.286		
0.150	0.62	0.254		
0.125	0.50	0.204		
0.100	0.36	0.145		
0.075	0.30	0.122		
0.050	0.30	0.122		

Run A 11:
TRAY AREA 9 SQ. IN.
CRUMB DEPTH 2 IN.
CONVERSION FACTOR 0.409

Run A12:
TRAY AREA 9 SQ. IN.
CRUMB DEPTH 2 IN.
CONVERSION FACTOR 0.303

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 13

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
2:45	153.493	42.82	0.441
3:05	148.720	38.05	0.392
3:25	141.300	30.72	0.316
3:45	135.382	24.71	0.2545
4:15	128.780	18.11	0.186
4:45	123.972	13.30	0.137
5:15	120.353	9.68	0.0996
6:15	114.575	3.90	0.0406
6:45	113.372	2.70	0.0276

STEAM PRESSURE	50 LB. psi
CRUMB SIZE	THRU 0.371 IN.
	ON 0.181 IN.
CRUMB DEPTH	2.0 IN.
TRAY TARE	13.467 GM.
DRY MATERIAL	97.2 GM.
AIR VELOCITY	240 FT.PER MIN.
BOTTLE TARE WEIGHT	13.4995 GM.
TOTAL WET WEIGHT	18.5098 GM.
TOTAL DRY WEIGHT	16.9768 GM.
DRY CRUMB	4.4773 GM.
WATER LOST	1.3330 GM.
LB.WATER PER LB D.M.	0.441

TIME	TEMPERATURE- DEGREES FAHRENHEIT					HUMIDITY
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	OUTLET DRY BULB	OUTLET WET BULB	LB. WATER PER LB.DRY AIR OUTLET
2:45						
3:05	153	142	156	221.4	145.4	
3:25	167	145	162	224.6	143.6	
3:45	181	156	162	222.8	140.0	0.1275
4:15	190	176	176	224.2	140.0	0.1270
4:45	205	192	203	222.0	136.4	0.109
5:15	212	208	207	223.4	138.2	
6:45	215	215	212	223.8	138.2	

AIR DRYING DATA
AIR ACROSS CRUMB
RUN NO. A 14

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	OUTLET DRY BULB °F	OUTLET WET BULB °F	HUMIDITY LB.WATER PER LB. DRY AIR
12:00	162.860	42.86	0.395			
12:30	157.101	37.10	0.345	217.4	0.022	0.022
1:00	152.753	32.75	0.305			
1:30	147.490	27.50	0.256			
2:00	144.270	24.27	0.226	214.	0.024	0.024
2:30	140.758	20.76	0.193	213.	0.021	0.021
3:00	137.745	17.75	0.165	212.	0.025	0.025
3:30	135.030	15.03	0.140	215.	0.027	0.027
4:00	132.488	12.49	0.114	214.	0.026	0.026

STEAM PRESSURE	50 LB psi.
AIR VELOCITY	15 FT. PER MIN.
CRUMB SIZE	THROUGH 0.371 IN.
	ON 0.185 IN.
CRUMB DEPTH	2.0 IN.
CONTAINER TARE	12.128 GM.
DRY MATERIAL	107.4 GM

INITIAL MOISTURE CONTENT DETERMINATION:

BOTTLE TARE WEIGHT	13.2736 GM.
TOTAL WET WEIGHT	18.6370 GM.
TOTAL DRY WEIGHT	17.1174 GM.
DRY CRUMB	3.8438 GM.
WATER LOST	1.5196 GM.
LB.WATER PER LB. D.M.	0.395

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. A 13 (Cont'd) SLOPE OF CURVE	RUN NO. A 13 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR	RUN NO. A 14 (Cont'd) SLOPE OF CURVE	RUN NO. A 14 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.425	1.90	0.65		
0.400	1.90	0.65		
0.375	1.90	0.65	0.94	0.355
0.350	1.90	0.65	0.92	0.348
0.325	1.86	0.636	0.90	0.340
0.300	1.72	0.587	0.88	0.332
0.275	1.66	0.567	0.80	0.202
0.250	1.52	0.52	0.77	0.291
0.225	1.36	0.465	0.70	0.264
0.200	1.20	0.410	0.61	0.230
0.175	1.02	0.349	0.56	0.212
0.150	0.90	0.312	0.52	0.196
0.125	0.78	0.267	0.46	0.174
0.100	0.70	0.240	0.45	0.170
0.075	0.60	0.206		
0.050	0.45	0.154		
0.025	0.27	0.0958		

TRAY AREA 9 SQ. IN
CRUMB DEPTH 2 IN
CONVERSION FACTOR 0.342

TRAY AREA 9 SQ. IN.
CRUMB DEPTH 2 IN.
CONVERSION FACTOR 0.265

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 15

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
4:50	152.732	4.455	0.488
6:00	124.890	17.71	0.189
6:50	119.673	12.49	0.133
7:00	118.153	8.97	0.0957
7:30	112.850	5.67	0.0805
8:00	110.730	3.57	0.0381

STEAM PRESSURE	50 LB. psi.
CRUMB SIZE	THRU 0.371 IN. ON 0.185 IN.
CRUMB DEPTH	2.0 IN.
TRAY TARE	13.38 GM.
DRY MATERIAL	93.8 GM.
AIR VELOCITY	240 FT. PER MIN.
BOTTLE TARE WT.	13.7946 GM.
TOTAL WET WT.	18.8642 GM.
TOTAL DRY WT.	17.2004 GM.
DRY CRUMB	3.4058 GM.
WATER LOST	1.6638 GM.
LB.WATER PER LB. D.M.	0.488

TIME	TEMPERATURE- DEGREES FAHRENHEIT					HUMIDITY LB.WATER PER LB. DRY AIR
	TOP OF CAKE	MIDDLE OF CAKE	BOTTOM OF CAKE	OUTLET DRY BULB	OUTLET WET BULB	OUTLET
4:50						
6:00	208	176	178	210	104	0.023
6:30	213	185	183	210	104	0.023
7:00	217	201	194	210	104	0.023
7:30	223	212	205	217	104	0.022
8:00	223	214	208	215	104	0.022

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 16

CRUMB SIZE ON 0.371 IN.

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL
11:30	146.562	39.48	0.422
12:00	135.169	28.09	0.300
12:30	126.545	19.47	0.208
1:00	120.373	13.29	0.142
1:30	115.925	8.85	0.0945
2:00	113.968	6.89	0.0735
2:30	112.029	4.95	0.0528
3:00	110.650	3.57	0.0381
3:30	109.702	2.62	0.0280
4:00	109.074	1.99	0.0212

DRY MATERIAL 93.7 GM.
TRAY TARE 13.382 GM.
CRUMB DEPTH 2.0 IN.

CRUMB SIZE THRU 0.371 IN.
ON 0.263 IN.

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL
11:30	162.324	44.10	0.422
12:00	151.505	33.29	0.313
12:30	141.665	23.45	0.219
1:00	135.355	17.14	0.161
1:30	129.020	10.80	0.1015
2:00	126.988	8.77	0.0825
2:30	124.414	6.19	0.0582
3:00	122.479	4.26	0.0400
3:00	121.200	2.98	0.0280
4:00	120.170	1.95	0.0183

DRY MATERIAL 106.4 GM.
TRAY TARE 11.819 GM.
CRUMB DEPTH 2.0 IN.

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 16 (Cont'd)

CRUMB SIZE THRU 0.263 IN.
ON 0.131 IN.

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL
11:30	174.923	48.48	0.422
12:00	165.239	38.81	0.340
12:30	158.386	31.96	0.279
1:00	153.750	27.32	0.238
1:30	148.205	21.78	0.191
2:00	144.058	17.63	0.154
2:30	140.190	13.76	0.1204
3:00	137.319	10.89	0.0955
3:30	134.969	8.54	0.0747
4:00	133.115	6.68	0.058

DRY MATERIAL 114.3 GM.
TRAY TARE 12.128 GM.
CRUMB DEPTH 2.0 IN.

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. A 15 (Cont'd) SLOPE OF CURVE	RUN NO. A 15 (Cont'd) DRYING RATE LB. WATER PER SQ. FT PER HOUR	RUN NO. A 16 (Cont'd) SLOPE OF CURVE	RUN NO. A 16 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.475	3.60	1.19		
0.450	3.54	1.17		
0.425	3.36	1.11		
0.400	3.20	1.06	2.70	0.891
0.375	3.00	0.99	2.60	0.858
0.350	2.90	0.957	2.28	0.753
0.325	2.70	0.891	2.04	0.673
0.300	2.50	0.826	2.00	0.660
0.275	2.26	0.746	1.90	0.627
0.250	2.05	0.676	1.76	0.581
0.225	1.74	0.575	1.68	0.554
0.200	1.47	0.485	1.54	0.508
0.175	1.22	0.403	1.30	0.429
0.150	1.00	0.330	1.04	0.345
0.125	0.83	0.274	0.84	0.278
0.100	0.76	0.251	0.61	0.202
0.075	0.61	0.202	0.48	0.159
0.050	0.46	0.157	0.32	0.106
0.025	0.29	0.096		

RUN NO. A 15:
TRAY AREA 9 SQ.IN.
CRUMB DEPTH 2.0 IN.
CONVERSION FACTOR 0.330

RUN NO. A 16:
TRAY AREA 9 SQ. IN.
CRUMB DEPTH 2.0 IN.
CONVERSION FACTOR 0.330

DRYING RATE DATA

RUN NO. A 16 (Cont'd)			RUN NO. A 16 (Cont'd)	
MOISTURE CONTENT LB.WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB.WATER PER SQ. FT PER HOUR	SLOPE OF CURVE	DRYING RATE LB.WATER PER SQ. FT PERHOUR
0.400	2.24	0.84	1.70	0.658
0.375	2.24	0.84	1.60	0.620
0.350	2.20	0.825	1.48	0.573
0.325	2.14	0.805	1.36	0.527
0.300	2.02	0.757	1.10	0.426
0.275	1.96	0.735	1.00	0.385
0.250	1.68	0.630	0.86	0.333
0.225	1.54	0.577	0.80	0.310
0.200	1.25	0.469	0.76	0.294
0.175	1.07	0.401	0.72	0.279
0.150	0.90	0.308	0.68	0.254
0.125	0.74	0.278	0.58	0.225
0.100	0.67	0.252	0.50	0.194
0.075	0.50	0.187	0.39	0.151
0.050	0.34	0.127	0.30	0.116

TRAY AREA 9 SQ.IN.
CRUMB DEPTH 2.0 IN.
CONVERSION FACTOR 0.375

TRAY AREA 9 SQ. IN.
CRUMB DEPTH 2.0 IN.
CONVERSION FACTOR 0.387

AIR DRYING DATA
AIR ACROSS CRUMB
RUN NO. A 16
(Cont'd)

CRUMB SIZE THRU 0.131 IN.

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	OUTLET DRY BULB °F	OUTLET WET BULB °F	HUMIDITY LB. WATER PER LB. DRY AIR OUTLET
11:30	166.060	45.36	0.422			
12:00	159.820	39.12	0.362	172.4	92.3	0.015
12:30	155.109	34.40	0.319	172.4	91.0	0.013
1:00	151.330	30.60	0.284	173.0	91.4	0.0135
1:30	148.715	28.02	0.260	174.0	91.7	0.0135
2:00	144.173	23.40	0.217	174.0	89.7	0.0115
2:30	141.386	20.69	0.192	172.4	89.6	0.0115
3:00	138.730	18.03	0.167	172.4	89.7	0.0115
3:30	136.179	15.48	0.143			
4:00	134.008	13.31	0.123	171.0	89.7	0.0115

STEAM PRESSURE	22 LB. psi.
AIR VELOCITY	230 FT. PER MIN.
CRUMB DEPTH	2.0 IN
CONTAINER TARE	12.800 GM.
DRY MATERIAL	107.9 GM.

INITIAL MOISTURE CONTENT DETERMINATION:

BOTTLE TARE WEIGHT	13.2736 GM.
TOTAL WET WEIGHT	18.8348 GM.
TOTAL DRY WEIGHT	17.1909 GM.
DRY CRUMB	3.9173 GM.
WATER LOST	1.6439 GM.
LB.WATER PER LB. D.M.	0.422

AIR DRYING DATA- AIR ACROSS CRUMB
RUN NO. A 17

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	OUTLET DRY BULB °F	OUTLET WET BULB °F	HUMIDITY LBS. WATER PER LB. DRY AIR OUTLET
11:30	155.500	43.32	0.438	217.0	115.0	0.043
11:50	148.108	35.93	0.3620	216.0	113.0	0.034
12:10	141.382	29.20	0.296	218.6	113.0	0.039
12:30	135.287	23.11	0.234	220.0	114.8	0.042
1:00	129.082	16.90	0.171	222.0	115.7	0.045
1:30	124.425	12.24	0.124	222.0	115.7	0.045
2:00	120.000	7.82	0.079	222.0	115.9	0.038
2:30	117.000	5.49	0.0556	217.0	111.2	0.035
3:00	115.575	3.40	0.0340	217.0	111.2	0.035
3:30	114.209	2.03	0.0205	216.0	111.2	0.035

STEAM PRESSURE	52 LB. psi.
AIR VELOCITY	330 FT. PER MIN.
CRUMB SIZE	THRU 0.371 IN.
	ON 0.185 IN.
CRUMB DEPTH	2.0 IN.
CONTAINER TARE	13.38 GM.
DRY MATERIAL	98.8 GM.

INITIAL MOISTURE CONTENT DETERMINATION:

BOTTLE TARE WEIGHT	13.4580 GM.
TOTAL WET WEIGHT	18.2077 GM.
TOTAL DRY WEIGHT	16.7635 GM.
DRY CRUMB	3.3055 GM.
WATER LOST	1.4442 G M.
LB. WATER PER LB. D.M.	0.438

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. A 16 (Cont'd) SLOPE OF CURVE	RUN NO. A 16 (Cont'd) DRYING RATE LB.WATER PER SQ.FT. PER HOUR	RUN NO. A 17 (Cont'd) SLOPE OF CURVE	RUN NO. A 17 (Cont'd) DRYING RATE LB.WATER PER SQ. FT. PER HOUR
0.425			2.24	0.780
0.400	1.17	0.444	2.14	0.745
0.375	1.00	0.380	2.02	0.703
0.350	0.87	0.331	2.00	0.696
0.325	0.84	0.391	1.98	0.689
0.300	0.74	0.281	1.90	0.661
0.275	0.72	0.273	1.74	0.606
0.250	0.66	0.251	1.64	0.571
0.225	0.58	0.220	1.37	0.477
0.200	0.50	0.190	1.22	0.424
0.175	0.48	0.182	1.02	0.355
0.150	0.42	0.159	0.90	0.315
0.125	0.40	0.152	0.90	0.313
0.100			0.72	0.251
0.075			0.63	0.219
0.050			0.42	0.146

RUN NO. A 16:
TRAY AREA 9 SQ. IN.
CRUMB DEPTH 2.0 IN
CONVERSION FACTOR 0.380

RUN NO. A 17:
TRAY AREA 9 SQ. IN.
CRUMB DEPTH 2.0 IN.
CONVERSION FACTOR 0.348

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 1

TIME	TOTAL WEIGHT GM.	WATER PRESENT	LB.WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB.WATER PER LB. DRY AIR	AIR VELOCITY FT.PER MIN.
2:04	1047.0	205.0	0.469				295
2:09	908.0	66.0	0.151	179.6	92.4	0.0130	330
2:14	883.0	41.0	0.0936				275
2:19	869.0	27.0	0.0616				430
2:24	861.0	19.0	0.0433	180.6	93.2	0.0140	390
2:29	855.0	13.0	0.0397				320
2:44	845.0	3.0	0.00685				340
2:59	843.0	1.0	0.0023	179.6	93.6	0.0150	370
3:14	842.0	0.	0.				315

TRAY TARE WEIGHT 404 GM. DRY MATERIAL 438.GM. STEAM PRESSURE 52 LB. psi.
CRUMB SIZE THROUGH 0.131 IN. CRUMB DEPTH 2.0 IN.

RUN NO. T 2

TIME	TOTAL WEIGHT GM.	WATER PRESENT	LB.WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB.WATER PER LB. DRY AIR	AIR VELOCITY FT.PER MIN.
3:22	1021.10	185.0	0.426				490
3:27	895.8	59.8	0.138	179.6	93.2	0.0140	400
3:32	877.0	41.0	0.0943				360
3:42	855.6	19.6	0.0451	181.4	93.5	0.0145	370
3:52	844.2	8.2	0.0189				375
4:07	837.4	1.4	0.0032	180.6	93.2	0.0141	380
4:17	836.0	0.	0.	181.4	93.5	0.0145	

TRAY TARE WEIGHT 401 GM. DRY MATERIAL 435 GM. STEAM PRESSURE 52 LB. psi.
CRUMB SIZE THROUGH 0.263 IN. ON. 0.131 IN. CRUMB DEPTH 2.0 IN.

DRYING RATE DATA

MOISTURE CONTENT LB.WATER PER LB.DRY MATERIAL	RUN NO. T 1 (Cont'd) SLOPE OF CURVE	RUN NO. T 1 (Cont'd) DRYING RATE LB.WATER PER SQ. FT. PER HOUR	RUN NO. T 2 (Cont'd) SLOPE OF CURVE	RUN NO. T 2 (Cont'd) DRYING RATE LB.WATER PER SQ. FT. PER HOUR
0.425	7.90	14.70	7.90	14.70
0.400	7.90	14.70	7.90	14.70
0.375	7.90	14.70	7.90	14.70
0.350	7.90	14.70	7.90	14.70
0.325	7.90	14.70	7.90	14.70
0.300	7.90	14.70	7.90	14.70
0.275	7.90	14.70	7.90	14.70
0.250	7.90	14.70	7.90	14.70
0.225	7.90	14.70	7.90	14.70
0.200	4.00	7.44	6.00	11.10
0.175	2.60	4.87	3.02	5.09
0.150	1.64	3.05	1.76	3.26
0.125	1.20	2.23	0.99	1.83
0.100	0.90	1.68	0.70	1.30
0.075	0.65	1.21	0.51	0.944
0.050	0.41	0.713	0.38	0.703
0.025	0.23	0.428	0.23	0.426

TRAY AREA 48.1 SQ.IN.   TRAY AREA 48.1 SQ.IN.

CONVERSION FACTOR 1.86   CONVERSION FACTOR 1.85

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 3

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB. WATER PER LB. DRY AIR	AIR VELOCITY FT. PER MIN.
4:23	965.2	165.2	0.414	183.2	93.2	0.0135	480
4:28	862.5	62.5	0.156				440
4:35	845.8	45.8	0.113	183.2	93.2	0.0135	
4:43	828.8	26.8	0.0674				
4:53	817.2	17.2	0.0433				410
5:08	810.2	10.2	0.0256				
DRY	800.0	0.	0.				

TRAY TARE WEIGHT 402 GM. DRY MATERIAL 398 GM. STEAM PRESSURE 52 LB psi.
CRUMB SIZE ON 0.263 IN. CRUMB DEPTH 2.0 IN.

RUN NOT. T 4

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB. WATER PER LB. DRY AIR	AIR VELOCITY FT. PER MIN.
3:28	1051.7	167.7	0.343				204
3:33	982.3	98.3	0.203	177.8	96.8	0.020	200
3:38	943.6	59.6	0.123				170
3:48	918.0	34.0	0.0703				188
3:58	905.8	21.8	0.0451	179.6			175
4:13	896.3	12.3	0.0254	185.2	96.8	0.018	165
4:28	891.0	7.0	0.0145	181.4			170

TRAY TARE WEIGHT 400.0 GM. DRY MATERIAL 488.0 GM. STEAM PRESSURE 35 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 5

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB. WATER PER LB. DRY AIR	AIR VELOCITY FT. PER MIN.
11:12	969.5	113.1	0.252				
11:19	909.8	53.4	0.119	147.0	80.6	0.007	495
11:22	900.4	44.0	0.098				440
11:32	890.7	34.3	0.0763				
11:42	885.2	28.8	0.0642	142.0	79.7	0.008	445
11:57	877.0	20.6	0.0481	142.9	80.5	0.008	440
12:12	872.6	16.2	0.0361	143.5			
1:45	856.4						

TRAY TARE WEIGHT 408.8 GM. DRY MATERIAL 447.6 GM. STEAM PRESSURE 16 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

RUN NO. T 6

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB. WATER PER LB. DRY AIR	AIR VELOCITY FT. PER MIN.
3:02	1014.3	121.3	0.252				470
3:07	946.7	53.7	0.111		88.1		480
3:12	925.7	32.7	0.0673	141.0	87.8	0.016	440
3:22	916.6	23.6	0.0486	141.0	88.7	0.018	430
3:32	911.2	18.9	0.0390	141.0	88.7	0.018	400
3:47	904.3	11.3	0.0232	141.0			360
DRY	893.0						

TRAY TARE WEIGHT 408.0 GM. DRY MATERIAL 485.0 GM. STEAM PRESSURE 16 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. T 3 (Cont'd) SLOPE OF CURVE	RUN NO. T 3 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR	RUN NO. T 4 (Cont'd) SLOPE OF CURVE	RUN NO. T 4 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.400	7.20	12.40		
0.375	7.20	12.40		
0.350	7.20	12.40		
0.325	7.20	12.40	3.20	6.66
0.300	7.20	12.40	3.20	6.66
0.275	7.20	12.40	3.20	6.66
0.250	7.20	12.60	3.20	6.66
0.225	6.80	11.50	3.20	6.66
0.200	3.60	6.10	2.94	6.12
0.175	2.10	3.53	2.00	4.61
0.150	1.02	1.73	1.40	2.91
0.125	0.72	1.22	0.96	2.00
0.100	0.52	0.880	0.60	1.25
0.075	0.35	0.593	0.38	0.790
0.050	0.19	0.322	0.20	0.416

RUN NO. T 3: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 1.69

RUN NO. T 4: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 2.08

	RUNNNO. T 5 (Cont'd)		RUN NO. T 6 (Cont'd)	
0.250	5.20	9.92		
0.225	4.80	9.16	4.00	8.25
0.200	3.88	7.40	3.58	7.38
0.175	2.60	4.96	2.80	5.77
0.150	1.88	3.54	2.32	4.78
0.125	1.42	2.71	1.59	3.28
0.100	0.36	0.687	1.10	2.27
0.075	0.17	0.324	0.65	1.34
0.050	0.07	0.134	0.10	0.206
0.025			0.10	0.206

RUN NO. T 5: TRAY AREA 48.1 SQ. IN.
CONVERSION FACTOR 1.908

RUN NO. T 6: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 2.06

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 7

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB.WATER PER LB.DRY AIR	AIR VELOCITY FT. PER MIN.
2:14	1011.1	163.0	0.370				
2:19	915.9	67.8	0.154	153.5	85.1	0.011	400
2:24	895.7	47.6	0.108	155.6	85.3	0.011	390
2:34	882.1	34.0	0.0773	155.3	85.2	0.011	330
2:44	872.2	24.1	0.0548	155.3	85.2	0.011	350
2:59	862.9	14.8	0.0336	155.8	85.4	0.011	350
3:14	858.0	9.9	0.0225	155.8			340
3:44	851.1	3.1	0.00705	154.4	89.1	0.015	350
4:04	848.1						

TRAY TARE WEIGHT 408.5 GM. DRY MATERIAL 439.6 GM. STEAM PRESSURE 21 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

RUN NO. T 8

11:01	1017.1	158.9	0.353	159.8	101.3	0.031	420
11:06	922.2	64.0	0.142	159.8	100.4	0.030	410
11:11	897.0	38.8	0.0863	158.3	99.5	0.028	390
11:21	884.4	26.2	0.0583	159.2	99.9	0.029	350
11:31	876.0	17.8	0.0396	158.3	88.4	0.014	360
11:46	868.1	9.9	0.022	157.1	88.4	0.014	330
12:01	861.6	3.4	0.00755	158.0	88.4	0.014	340
12:21	858.2						

TRAY TARE WEIGHT 409.0 GM. DRY MATERIAL 449.2 GM. STEAM PRESSURE 25 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 9

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB.WATER PER LB DRY AIR	AIR VELOCITY FT. PER MIN.
11:15	1007.2	177.9	0.424	190.4			200
11:20	925.5	96.2	0.230		99.5	0.022	180
11:25	883.4	54.1	0.119	180.5			190
11:30	867.5	38.2	0.0912		99.5	0.024	160
11:40	850.4	21.1	0.0503	184.1	99.5	0.022	150
11:50	845.4	16.1	0.0384				150
12:00	840.0	10.7	0.0256	186.8	99.5	0.022	
1:15	829.3						

TRAY TARE WEIGHT 410.0 GM. DRY MATERIAL 419.3 GM. STEAM PRESSURE 50 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

RUN NO. T 10

0	1064.7	183.8	0.386				68
5	1022.1	141.2	0.297				
10	944.6	113.7	0.237		95.0		70
15	963.9	83.0	0.174	168.8	95.0	0.019	78
20	945.6	64.7	0.136	172.4	95.0	0.018	50
30	918.3	37.5	0.0788	176.0	96.8	0.020	70
50	902.2	21.3	0.0447	181.4	98.6	0.021	62
80	886.0	5.1	0.0107	181.4	98.6	0.021	77
100	881.6	0.7	0.0015	181.4	98.6	0.021	76
120	880.9	0.	0.00	182.3			74

TRAY TARE WEIGHT 404.0 GM. DRY MATERIAL 476.9 GM. STEAM PRESSURE
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. T 7 (Cont'd) SLOPE OF CURVE	RUN NO. T 7 (Cont'd) DRYING RATE LB. WATER PER SQ. FT PER HOUR	RUN NO. T 8 (Cont'd) SLOPE OF CURVE	RUN NO. T 8 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.350	7.00	13.10		
0.325	7.00	13.10	9.00	17.2
0.300	6.50	12.20	7.00	13.4
0.275	5.40	10.10	5.80	11.1
0.250	5.10	7.56	5.10	9.76
0.225	4.60	8.63	4.80	9.18
0.200	3.00	5.63	3.28	6.27
0.175	2.20	4.13	2.60	4.97
0.150	1.60	3.00	1.94	3.71
0.125	0.81	1.52	1.34	2.56
0.100	0.47	0.881	0.88	1.68
0.075	0.18	0.337	0.33	0.631
0.050	0.16	0.300	0.21	0.401
0.025			0.10	0.191

RUN NO. T 7: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 1.873

RUN NO. T 8: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 1.91

MOISTURE CONTENT	RUN NO. T 9 (Cont'd) SLOPE OF CURVE	RUN NO. T 9 (Cont'd) DRYING RATE	RUN NO. T 10 (Cont'd) SLOPE OF CURVE	RUN NO. T 10 (Cont'd) DRYING RATE
0.400	3.90	6.95		
0.375	3.90	6.95	1.69	3.44
0.350	3.90	6.95	1.69	3.44
0.325	3.90	6.95	1.62	3.29
0.300	3.90	6.95	1.50	3.05
0.275	3.90	6.95	1.48	3.00
0.250	3.90	6.95	1.42	2.88
0.225	3.30	4.89	1.26	2.56
0.200	2.86	5.10	1.10	2.24
0.175	2.37	4.25	0.97	1.97
0.150	1.78	3.18	0.80	1.62
0.125	1.22	2.18	0.69	1.40
0.100	0.73	1.30	0.51	1.04
0.075	0.40	0.713	0.36	0.736
0.050	0.18	0.321	0.10	0.203

RUN NO. T 9: TRAY AREA 48.1 SQ.IN
CONVERSION FACTOR 1.784

RUN NO. T 10: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 2.03

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 11

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB. WATER PER LB. DRY AIR	AIR VELOCITY FT. PER MIN.
0	581.2	47.0	0.366				
5	549.2	15.0	0.1169	182.3	98.2	0.021	206
10	544.6	10.4	0.0813	180.5	100.4	0.024	207
15	541.7	7.5	0.0584	180.5			207
25	538.0	3.8	0.0296	182.3	98.6	0.021	210
35	536.1	1.9	0.0148	186.8	97.7	0.019	210
55	534.2	0.		186.8	98.2	0.021	211

TRAY TARE WEIGHT 405.7 GM. DRY MATERIAL 128.5 GM. STEAM PRESSURE 53 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON. 0.185 IN. CRUMB DEPTH 0.5 IN.

RUN NO. T 12

0.	770.6	78.1	0.273				
5	725.8	31.3	0.1095	184.1	101.3	0.025	190
10	712.1	19.6	0.0685	179.6	98.2	0.021	175
15	706.7	14.2	0.0496				170
25	700.0	7.5	0.0263	185.0	98.6	0.020	180
40	694.8	2.3	0.0080	186.8	99.5	0.020	180
60	692.5	0.		186.8	99.5	0.020	185

TRAY TARE WEIGHT 406.0 GM. DRY MATERIAL 286.5 GM. STEAM PRESSURE 46 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 1.0 IN.

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 13

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	TEMPERATRE DEGREES FAHRENHEITH INLET DRY BULB	INLET WET BULB	HUMIDITY LB. WATER PER LB. DRY AIR	AIR VELOCITY FT. PER MIN.
2:04	1047.0	205.0	0.469				295
2:09	908.0	66.0	0.151	179.6	92.4	0.0130	330
2:14	883.0	41.0	0.0936				275
2:19	869.0	27.0	0.0616				430
2:24	861.0	19.0	0.0433	180.6	93.2	0.0140	390
2:29	855.0	13.0	0.0397				320
2:44	845.0	3.0	0.00685				340
2:50	843.0	1.0	0.0023	179.6	93.6	0.0150	370
3:14	842.0	0.0	0.0				3.15

TRAY TARE WEIGHT 404 GM. DRY MATERIAL 438. GM. STEAM PRESSURE 52 LB. psi.
CRUMB SIZE THROUGH 0.131 IN. CRUMB DEPTH 2.0 IN.

RUN NO. T 14

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	INLET DRY BULB	INLET WET BULB	HUMIDITY	AIR VELOCITY
12:01	1006.2	196.2	0.486	221.0	113.0	0.037	200
12:06	894.0	84.0	0.208	221.0	111.2	0.035	182
12:11	842.0	32.0	0.0795	221.0	114.8	0.043	
12:21	814.5	4.5	0.0112	222.8	108.5	0.028	365
12:31	812.0	2.0	0.00496	222.7	113.0	0.038	152
1:01	811.0	1.0	0.00248	222.4	113.5	0.038	
1:45	810.0						

TRAY TARE WEIGHT 407.5 GM. DRY MATERIAL 402.5 GM. STEAM PRESSURE 56 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. T 11 (Cont'd) SLOPE of CURVE	RUN NO. T 11 (Cont'd) DRYING RATE LB. WATER PER SQ. FT PER HOUR	RUN NO. T 12 (Cont'd) SLOPE OF CURVE	RUN NO. T 12 (Cont'd) DRYING RATE LB. WATER PER SQ. FT. PER HOUR
0.350	9.00	4.45		
0.325	9.00	4.45		
0.300	9.00	4.45		
0.275	9.00	4.45		
0.250	6.30	3.46	4.76	6.09
0.225	6.00	3.30	4.76	6.09
0.200	5.20	2.86	4.04	5.18
0.175	3.82	2.10	3.40	4.36
0.150	2.38	1.31	2.48	3.18
0.125	1.44	0.792	1.83	2.36
0.100	0.89	0.489	1.13	1.44
0.075	0.50	0.275	0.50	0.640
0.050	0.31	0.171	0.31	0.397
0.025	0.18	0.099	0.21	01258

RUN NO. T 11: TRAY AREA 48.1 SQ. IN.
CONVERSION FACTOR 0.56

RUN NO. T 12: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 1.218

MOISTURE CONTENT	RUN NO.T 13 (Cont'd) SLOPE	RUN NO.T 13 (Cont'd) DRYING RATE	RUN NO. T 14 (Cont'd) SLOPE	RUN NO. T 14 (Cont'd) DRYING RATE
0.350	5.44	9.34	5.20	9.36
0.325	5.20	8.91	5.00	9.00
0.300	5.00	8.56	4.90	8.82
0.275	4.80	8.33	4.80	8.64
0.250	4.50	7.71	4.50	8.10
0.225	4.00	6.86	4.00	7.20
0.200	3.60	6.16	3.60	6.48
0.175	3.20	5.49	3.30	5.94
0.150	3.00	5.14	3.20	5.76
0.125	2.40	4.12	2.90	5.22
0.100	1.80	3.08	2.20	3.06
0.075	1.29	2.21	1.56	2.81
0.050	0.88	1.51	1.00	1.80
0.025	0.54	0.926	0.50	0.900

RUN NO. T 13: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 1.715

RUN NO. T 14: TRAY AREA 48.1 SQ.IN.
CONVERSION FACTOR 1.80

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 15

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB.WATER PER LB DRY AIR	AIR VELOCITY FT. PER MIN.
3:35	1015.5	178.4	0414	219.0	119.9	0.055	185
3:40	927.2	90.1	0.210	220.0	120.5	0.055	161
3:45	875.1	38.0	0.0886				174
3:55	824.7	5.6	0.0131	220.5	121.4	0.059	
4:10	837.1			221.0	122.0	0.061	235
4:35	837.1			221.0			120

TRAY TARE WEIGHT 408.0 G M. DRY MATERIAL 429.1 GM. STEAM PRESSURE 56 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

RUN NO. T 16

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB. DRY MATERIAL	INLET DRY BULB	INLET WET BULB	HUMIDITY	AIR VELOCITY
2:06	933.0	141.0	0.367				
1:11	871.7	79.7	0.208	138.2	78.0	0.008	190
2:16	841.7	49.7	0.129	140.0	79.7	0.008	190
2:26	818.1	26.1	0.068	141.6	80.2	0.008	180
2:36	808.9	16.0	0.0417	143.6	80.9	0.009	180
2:51	801.1	9.1	0.0237	143.6	80.6	0.009	180
3;06	794.4	2.0	0.00521	141.6	78.8	0.007	175
3:21	792.0	0.0					

TRAY TARE WEIGHT 408.0 GM. DRY MATERIAL 384.0 GM. STEAM PRESSURE 18 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

DRYING RATE DATA

	RUN NO. T 15 (Cont'd)		RUN NO. T 16 (Cont'd)	
MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	SLOPE OF	DRYING RATE LB.WATER PER SQ. FT PER HOUR	SLOPE OF	DRYING RATE LB.WATER PER SQ.FT. PER HOUR
0.400	4.50	8.26		
0.375	4.30	7.84		
0.350	4.00	7.32	3.60	6.00
0.325	3.98	6.91	3.60	6.00
0.300	3.60	6.57	3.40	5.68
0.275	3.50	6.39	3.30	5.51
0.250	3.20	5.88	2.85	4.76
0.225	3.00	5.46	2.60	4.34
0.200	2.80	5.16	2.25	3.92
0.175	2.50	4.54	1.75	2.92
0.150	2.20	4.02	1.34	2.24
0.125	2.00	3.64	1.02	1.70
0.100	1.80	3.29	0.69	1.15
0.075	1.35	2.46	0.44	0.735
0.050	0.90	1.651	0.22	0.368
0.025	0.49	0.897	0.12	0.200

TRAY AREA 48.1 SQ. IN
CONVERSION FACTOR 1.826

TRAY AREA 48.1 SQ. IN.
CONVERSION FACTOR 1.670

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 17

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB. WATER PER LB DRY AIR	AIR VELOCITY FT. PER MIN.
3:43	935.9	132.6	0.336	158.0	84.2	0.008	
3:48	874.6	70.3	0.180	149.0	82.4	0.009	180
3:53	845.3	40.0	0.0116				190
4:03	826.8	23.5	0.0595	152.0	83.3	0.009	180
4:13	815.8	12.5	0.0317	154.0	83.5	0.009	175
4:26	809.9	6.6	0.167	154.0	83.7	0.009	170
4:43	803.3			156.0	84.2	0.009	185

TRAY TARE WEIGHT 408.0 GM. DRY MATERIAL 395.3 GM. STEAM PRESSURE
CRUMB SIZE THROUGH 0.371 IN ON. 0.185 IN. CRUMB DEPTH 2.0 IN.

RUN NO. T 18

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	INLET DRY BULB	INLET WET BULB	HUMIDITY	AIR VELOCITY
11:40	920.4	154.9	0.427				370
11:45	817.5	52.0	0.144				385
11:50	786.9	21.4	0.0593	176.0	102.2	0.028	380
12:00	772.2	6.7	0.0185	176.0	102.2	0.028	350
12:10	767.9	2.4	0.00665	177.8	102.2	0.027	370
12:20	766.6	1.1	0.00304	176.9	102.2	0.027	330
DRY	765.5						

TRAY TARE WEIGHT 405.5 GM. DRY MATERIAL 360.5 GM. STEAM PRESSURE 49 LB. psi.
CRUMB SIZE THROUGH 0.371 IN. ON 0.185 IN. CRUMB DEPTH 2.0 IN.

DRYING RATE DATA

MOISTURE CONTENT LB. WATER PER LB. DRY MATERIAL	RUN NO. T 17 (Cont'd) SLOPE OF CURVE	RUN NO. T 17 (Cont'd) DRYING RATE LB.WATER PER SQ. FT PER HOUR	RUN NO. T 18 (Cont'd) SLOPE OF CURVE	RUN NO. T 18 (Cont'd) DRYING RATE LB.WATER PER SQ. FT PER HOUR
0.400			7.50	11.5
0.375			7.50	11.5
0.350			7.50	11.5
0.325	3.70	6.30	7.50	11.5
0.300	3.60	6.12	7.50	11.5
0.275	3.50	5.95	7.00	10.8
0.250	3.40	5.78	6.60	10.3
0.225	2.90	4.93	5.70	8.76
0.200	2.60	4.42	4.30	6.61
0.175	2.10	3.58	3.40	5.23
0.150	1.64	2.78	2.56	3.94
0.125	1.25	2.12	2.30	3.54
0.100	0.80	1.36	1.80	2.76
0.075	0.42	0.714	1.20	1.84
0.050	0.29	0.493	0.76	1.17
0.025	0.12	0.204	0.29	0.446

TRAY AREA 48.1 SQ. IN.
CONVERSION FACTOR 1.7000

TRAY AREA 48.1 SQ. IN.
CONVERION FACTOR 1.535

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 19

TIME	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB. WATER PER LB. DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	TEMPERATURE DEGREES FAHRENHEIT INLET WET BULB	HUMIDITY LB. WATER PER LB. DRY AIR	AIR VELOCITY FT. PER MIN.
3:10	1458.5	288.0	0.401				180
3:15	1417.4	247.0	0.342				180
3:20	1373.9	203.0	0.283	179.6	102.0	0.027	180
3:25	1337.2	167.0	0.232	181.4	104.0	0.030	180
3:35	1266.4	96.0	0.133	182.3	105.0	0.032	180
3:45	1214.7	44.0	0.0613	183.2	105.8	0.035	180
4:00	1180.0	10.0	0.0139	181.0	104.0	0.030	180
4:15	1172.8	2.0	0.00278	180.5	105.0	0.032	180
4:30	1170.4	0.		181.4	104.0	0.031	180

TRAY TARE WEIGHT 452.5 GM. DRY MATERIAL 718.0 GM. STEAM PRESSURE 58. LB. psi.
CRUMB SIZE THROUGH 0.371 IN. ON 0.185 IN. CRUMB DEPTH 4.0 IN.

DRYING RATE DATA

RUN NO. T 19
(Cont'd)

MOISTURE CONTENT LB.WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB.WATER PER SQ. FT. PER HOUR
0.375	1.20	3.66
0.350	1.20	3.66
0.325	1.20	3.66
0.300	1.20	3.66
0.275	1.10	3.36
0.250	1.08	3.30
0.225	1.02	3.12
0.200	1.00	3.05
0.175	0.96	2.93
0.150	0.91	2.78
0.125	0.86	2.62
0.100	0.79	2.41
0.075	0.66	2.01
0.050	0.45	1.37
0.025	0.23	0.703

TRAY AREA 48.1 SQ. IN.
CONVERSION FACTOR 3.050

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 20

TIME MIN.	TOTAL WEIGHT GM.	WATER PRESENT GM.	LB.WATER PER LB.DRY MATERIAL	TEMPERATURE DEGREES FAHRENHEIT INLET DRY BULB	INLET WET BULB	HUMIDITY LB.WATER PER LB. DRY AIR	CRUMB DEPTH IN.	AIR VELOCITY FT.PER MIN.
0	944.3	144.3	0.376	152.6			2.0	350
5	861.9	61.9	0.161	162.5	93.2	0.018	1.76	350
10	845.2	45.2	0.1173	161.4	92.3	0.017	1.67	330
15							1.66	
20	828.7	28.7	0.0746	163.7	92.7	0.017	1.61	310
25							1.57	
30	824.4	24.4	0.0635	163.4	93.2	0.018	1.55	310
45	809.6	9.6	0.0250	166.1	94.1	0.018	1.51	360
60	805.2	5.2	0.0135	165.2	93.6	0.018	1.50	320
80	802.5	2.5	0.0065	164.3	94.1	0.018	1.49	

TRAY TARE WEIGHT 415.8 GM.
DRY MATERIAL 384.2 GM.
TRAY AREA 48.1 SQ.IN.

STEAM PRESSURE 20 LB. psi.
CRUMB SIZE THROUGH 0.381 IN. ON 0.185 IN
CRUMB DEPTH 2.0 IN. (At start)

DRYING RATE DATA

RUN NO. T 20
(Cont'd)

MOISTURE CONTENT LB.WATER PER LB. DRY MATERIAL	SLOPE OF CURVE	DRYING RATE LB.WATER PER SQ.FT PER HOUR.
0.375	4.60	7.52
0.350	4.60	7.52
0.325	4.60	7.52
0.300	4.60	7.52
0.275	4.60	7.52
0.250	4.60	7.52
0.225	3.90	6.38
0.200	3.20	5.24
0.175	2.20	3.60
0.150	1.33	2.18
0.125	0.73	1.19
0.100	0.43	0.704
0.075	0.23	0.376
0.50	0.18	0.294
0.025	0.14	0.229

TRAY AREA 48.1 SQ.IN.

CONVERSION FACTOR 1.634

SHRINKAGE RATE DATA

RUN NO. T 20
(Cont'd)

CRUMB DEPTH	SLOPE OF CURVE	SHRINKAGE RATE IN.PER HR.
2.00		
1.95	3.20	3.84
1.90	3.00	3.60
1.85	2.30	2.76
1.80	1.62	1.95
1.75	1.08	1.298
1.70	0.68	0.816
1.65	0.43	0.516
1.60	0.32	0.384
1.55	0.22	0.264

SCALE FACTOR 1.2

AIR DRYING DATA
AIR THROUGH CRUMB
RUN NO. T 21

TIME — TEMPERATURE- DEGREES CENTIGRADE

MIN.	TOP OF LAYER	MIDDLE OF LAYER	BOTTOM OF LAYER	AIR DRY BULB	AIR WET BULB	EXIT AIR	AIR VELOCITY FT. PER MIN.
0	65.0	20.0	20.0	83.0		90.0	
5	76.0	74.0	72.0		36.0	91.7	350
10	77.0	75.0	72.5	83.0	36.0	91.7	
15	77.0	75.5	73.0	83.3	36.0	91.1	310
20	77.0	76.0	76.0	83.5	36.0	91.1	
25	77.5	76.5	76.5	84.0	36.5	91.7	300
30	78.0	77.0	76.5	84.0	36.5	91.7	
35	77.0	76.5	76.0	83.8	36.2	91.7	300
40	77.0	77.0	77.0	83.0	36.0	91.1	
45	77.5	77.5	77.0	83.0	36.0	91.7	
50	78.0	77.5	77.0	83.3	36.0	91.7	
60	79.0	78.0	78.0	83.5	36.0	92.2	275
75	80.0	79.0	79.0	84.0		92.8	
100	80.0	80.0	80.0	84.5		93.3	

STEAM PRESSURE 55 LB. psi.
CRUMB DEPTH 2.0 IN.

CRUMB SIZE THROUGH 0.371 IN.
ON 0.185 IN.

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VITAE

George W. Williams, the third of three children, was born on December 4, 1922, in Cincinnati, Ohio, to Bess Williams and Fred J. Williams.

His pre-college education was started at Kilgore Grade School in Cincinnati but was interrupted after attaining the second grade, at which time he moved to Louisville, Kentucky. Here he completed his basic education at W. R. Belknap Grade School, at Highland Junior High School and at Louisville Male High School from which he graduated in June, 1940. His undergraduate studies were taken at the Speed Scientific School of the University of Louisville and were completed on August 27, 1943, whereupon he was granted the degree of Bachelor of Chemical Engineering.

In further pursuance of Chemical Engineering he enrolled in the Graduate School of the University of Louisville and was accepted on a fellowship with the Rubber Reserve to study the drying characteristics of synthetic rubber under the guidance of W. R. Barnes, assistant professor in the Chemical Engineering department.

Richard L. Harvin was born on October 15, 1922, in Louisville, Kentucky, to Odessa Harvin and Milford C. Harvin.

His pre-college education was started at I. N. Bloom Grade School in Louisville. He attended the Highland Junior High School and du Pont Manual Training High School from which he was graduated in June, 1940. His undergraduate studies were taken and completed at the Speed Scientific School of the University of Louisville. The degree of Bachelor of Chemical Engineering was conferred upon him by the University of Louisville on August 27, 1943.

In further pursuance of Chemical Engineering he enrolled in the Graduate School of the University of Louisville and was accepted for a fellowship with the Rubber Reserve to study the drying characteristics of synthetic rubber under the guidance of W. R. Barnes, assistant professor in the Chemical Engineering department.