THE DEVELOPMENT OF A CONTINUOUS PEANUT DRIER

By

BUFORD MULLIS CANNON

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APPROVED:

Director of Graduate Studies

Dean of Engineering

APPROVED:

Head of Department

Supervisor

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INTRODUCTION

Peanuts are a vital commodity in a small area in southeastern Virginia and northeastern North Carolina. The production in this area is 24% of the total value of the peanut crop in the United States. In 1948 this production was 568 million pounds of peanuts having a cash value of 62 million dollars. Peanuts are utilized in two distinct forms in this section - shelled and unshelled. About 80% of the crop is shelled before being utilized in peanut butter, salted peanuts and candy. In this form only the kernel is considered in determining the value of the peanut. However, in the remaining 20% a thick, good textured hull which is free from holes and has a bright color is essential since these nuts are marketed in the hull as roasted peanuts. These are premium nuts and should demand premium prices.

In 1948 the total production of peanut vine hay in this Virginia-North Carolina area was 219,000 tons having a cash value of four million dollars. Due to the method of curing and its poor quality, over 50% of the hay that could mean extra cash in the pockets of farmers is being spread back on the land and utilized as a soil conditioner. During the present method of curing, most of the leaves are lost, thereby reducing the value and the amount of hay harvested. By improving the hay that is now being saved and saving the hay that is now being lost, the income from the total crop of peanuts could be increased considerably.

There are three important phases in the production of peanuts: planting and cultivating; harvesting and curing; and marketing. During recent years great strides have been made toward mechanizing the planting and cultivating phase, but, today the same method of curing peanuts is employed as that used by farmers a hundred years ago. Today a man can plant and cultivate about three times as many peanuts as he can harvest. This causes an unbalanced labor requirement which results in high labor costs. The present method of curing requires that peanuts remain in the field in stacks from three to five weeks under optimum conditions. During this period they are subjected to inclement weather and damage by small animals and birds. The principal need for engineering research in harvesting and curing is the development of methods and machines which will enable farmers to harvest their crops more efficiently with as little labor as possible and with a minimum amount of time. This method should increase the proportion of peanuts suitable for premium use and greatly improve the value of the peanut vine hay.

Several organizations have done work on the mechanization of peanut harvesting (1, 2, 3) with the aim of developing a peanut combine. There is a need for some method of drying the green nuts if they are to be harvested with a combine. Peanut drying investigations are now in progress in most of the peanut producing areas (4, 5, 6, 7).

Engineering research is needed in Virginia because of the special conditions which do not exist in other areas. The variety of peanuts grown in Virginia is determined by market demands. The market requires a large type peanut with a bright colored, fine textured hull. The method of curing these nuts should enhance their appearance. It is very difficult to remove the large type peanuts from the soils of Virginia without leaving a large portion of them in the soil. Harvesting equipment which is utilized efficiently in other peanut producing areas is not necessarily adaptable to the Virginia area because of the variety of nuts, which embraces both nut and vine formation, type soil and the climatic differences. The harvesting season is in the fall when the weather conditions are often quite unfavorable for curing; therefore some form of artificial conditioning appears feasible. From previous experiments, in which the nuts and vines were dried together, it was found that a method was needed whereby the peanuts could be picked soon after digging, while still wet, and the nuts and vines could be dried separately (8).

OBJECTIVES

The objectives of this study were:

1. To design and construct a small column type drier and conduct fundamental tests using this drier.
2. To design, construct and test a continuous peanut drier using optimum conditions as obtained from fundamental tests.
3. To determine the quality of the peanuts cured in the fundamental and continuous driers.

FACILITIES

Records of the peanut drying studies carried on by the Virginia Agricultural Experiment Station and the Farm Electrification Division, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, previous to this study, were available.

The Department of Agricultural Engineering, Virginia Polytechnic Institute, furnished office equipment, small tools, laboratory facilities, and transportation from Blacksburg to Holland, Virginia.

The peanuts and the housing space needed for this study were furnished by the Tidewater Field Experiment Station.

Supplies for this study were secured with State and Federal funds.

MATERIALS AND EQUIPMENT

FUNDAMENTAL COLUMN DRIER

The following is a list of the equipment that made up the fundamental drying system, a brief description of each and their uses.

Drier Ducts

The fundamental duct system, Fig. 1, consisted of a main duct 8 ft 8 in long with an area of 1.4 sq ft and two smaller ducts 2 ft long with an area of .56 sq ft, branching off each side perpendicular to the main duct. An air baffle for regulating air flow was inserted in each of the small columns.

Columns

Columns for containing peanuts were made of furnace pipe 8-3/4 in in diameter by 43 in long with mesh wire bottoms. These columns were fastened air-tight to the small ducts.

Heater Strips

Heater strips of 500 watts, with maximum sheath temperature of 750 F,and 750 watts, with maximum sheath temperature of 1200 F were used to heat the entering air. See Fig. 2 for circuit diagram.

Thermostat

A metallic strip thermostat with a capacity of 10 amp 115 volt, 5 amp 230 volt, manufactured by Fenwald Inc., Ashland, Massachusetts, was used to regulate temperatures during the fundamental drying studies.

Fan

A forward curved blade, 10 in centrifugal type fan, manufactured by American Blower Corporation, Detroit, Michigan, was used to force air through the column of nuts in the fundamental drying studies.

Pulley

A variable speed 7 in pulley, manufactured by the Toledo Timer Company, Toledo, Ohio, was used to regulate the fan speed in the fundamental drying studies.

Motor

The motor used to rotate the centrifugal fan for these studies was a 3 hp, repulsion start, induction run, 110-220 volt, 37 - 18.5 amp, single phase motor, manufactured by the Fairbank Morse Company. It was designed for continuous duty at a full load speed of 1745 rpm.

Scales

A Hanson type "C" scale, model 8910, range 0 - 100 by 1 lb was used to determine the weights of the column at regular intervals.

CONTINUOUS DRIER

The following is a list of the equipment that made up the continuous drying system, a brief description of each and their uses.

Drier Structure

The continuous drier structure, Fig. 6, was made up of three major parts: the base consisting of the air duct, plenum chamber, horizontal conveyors, driving mechanism, and supports; the grate-bottom; and the drier bin.

1. Base

The overall dimensions of the base, Fig. 9, were 9 ft 1-3/4 in wide by 12 ft 10 in long with a height of 4 ft 1-3/4 in. A triangular air duct formed the center of the base. The top of the air duct was covered with mesh wire so that air could pass up through the plenum chamber and into the drier bin. The bottom of the air duct was covered with canvas at one end but open at the other to permit the entrance of heated air from a crop drier. A 6 in rubber belting conveyor was on either side of the triangular air duct, Figs. 9 and 11. The belt was driven by a 6 in steel pulley 2 in in diameter and idled on a similar pulley. A manually operated screw-type tension adjustment was on the idling pulley. Power for driving the conveyors was transmitted from a 1 hp motor through a series of reduction gears to a 1/2 in tempered steel driving shaft with chains and sprockets. This driving mechanism was integrally mounted to the base of the drier in such a location as to furnish power to both the conveyors and the shaker. The base was constructed so as to support the grate-bottom and bin.

2. Grate-bottom

The grate-bottom, Figs. 9 and 10, was made up of a series of stationary inverted "V" sections spaced 9-5/8 in on center. A 2 in by 4 in rocker was spaced between each inverted "V" and was pivoted at each end. These rockers were caused to oscillate by a 1/4 by 1 in strap-iron rocker arm working off a cam actuated by the driving mechanism. The grate-bottom was framed with 2 in by 12 in plank which rested on edge between the base and the drier bin. The overall dimensions of the grate-bottom were 8 ft by 12 ft 6 in.

3. Drier Bin

The drier bin, Fig. 6, was constructed of 3/8 in plyboard on 2 in by 4 in framework. Its dimensions were 8 ft 4 in wide, 12 ft 6 in long, and 6 ft 1-1/2 in deep, with a total volume of 581.25 cu ft. Bolts 1/2 in in diameter and 15 in long were used to secure the bin to the base and bolts 1/2 in in diameter and 4 in long were used at corners and joints.

Peirson-Moore All Crop Drier

A dual burner Peirson-Moore All Crop Drier, manufactured in Lexington, Kentucky, was used as the source of supplemental heat to preheat the entering air. See Fig. 5B.

Loading Platform

A loading platform, Figs. 5B and 6, with an area of 24 sq ft was constructed in the field to receive peanuts before cleaning.

Cleaner

A custom-built cleaner, Figs. 6 and 7A, was fabricated by the Pittman Wood and Metal Products Company, Courtland, Virginia, for the purpose of removing peanut stems, leaves, and foreign material. This cleaner used four rows of saw blades, a six-blade centrifugal fan and pan agitation as its principle of cleaning.

Vertical Elevator

A custom-built cup-type elevator, Figs. 6 and 7B, was fabricated by the Pittman Wood and Metal Products Company, Courtland, Virginia, to convey the peanuts from the peanut cleaner into the drying bin.

Inclined Elevator

A custom-built inclined elevator, Figs. 6 and 11B, was fabricated by the Pittman Wood and Metal Products Company, Courtland, Virginia, and was used to convey the dry peanuts from the drier into a temporary storage bin.

Storage Bin

A temporary storage bin, for the purpose of receiving the dry peanuts from the drier until they could be bagged, was built of 3/8 in plyboard on a 2 in by 4 in frame. An inclined false floor made unloading through side openings possible. The volume of this storage bin was 256 cu ft. See Figs. 6 and 11B.

Motor

The driving motor for the shaker and horizontal conveyor was a 1 hp, single phase capacitor motor operating on 110-220 volt and 14-7 amps, manufactured by the Westinghouse Corporation. A variable cone-shaped pulley was used on the driving shaft.

Reducing Gears

A variable speed reducer, Turner model 204-24, 1 hp, with an input speed of 300 rpm and output speeds of 102, 138, 183, and 247 was used with a 100-1 speed reducer.

INSTRUMENTS AND MACHINERY

Digger

A Goodrich type peanut digger was used to dig peanuts for these studies. The digger used had been modified by adding shaker bars to obtain more agitation of the peanuts.

Picker

Several pickers were observed throughout this study; however, the type used to pick the peanuts for these tests was a carding-type picker manufactured by the Benthall Corporation, Suffolk, Virginia.

Potentiometer

A Brown recording potentiometer with a thermocouple switching assembly (9) was used to record temperatures throughout this study. This potentiometer, model no. 153X60P16-X-IN, Ser. No. 5145 with a range of -50 to + 300 F operating on 110-125 volts, 60 cycle, 55 amps, 55 watts, was manufactured by Minneapolis Honeywell Regulator Company.

Recording Thermometer

Wet and dry bulb temperatures were recorded with a Brown recording thermometer having a range of 0 to + 200 F, using seven-day charts.

Hygro-thermographs

Dry bulb temperatures and percent relative humidity of air were recorded by a Friez hygro-thermograph, model 594 which was manufactured by Friez Instrument Division, Bendix Aviation Corporation, Baltimore, Maryland.

Inclined Tube Monometer

Four inclined tube monometers were constructed in the Rural Electrification Research Laboratory, Virginia Polytechnic Institute. These monometers were used to indicate the air flow in each small duct.

Micro-monometer

A type C micro-monometer, reading from 0 to 6 in of water and manufactured by E. Vernon Hill of Chicago, Illinois, was used to calibrate the inclined tube monometer.

Psychrometer

A motor driven psychrometer, Serial No. 206-39, 110 volt, 60 ohms, 0.4 amp with a range of 0 to 130 F was used to calibrate the recording hygro-thermographs.

Anemometer

A Taylor anemometer, Serial No. 1922, range 0 - 10,000 fpm, manufactured by the Taylor Instrument Company, Rochester, New York, was used to determine the air velocity.

Thermometers

Palmer mercury-bulb thermometers, range of 0 to 220 F, were used in this study.

Plotting Machine

A plotting machine constructed by the Agricultural Engineering Department, Virginia Polytechnic Institute (10) was used for converting values from the recording potentiometer to curves.

Scales

The Holland Gin Company, Holland, Virginia, furnished platform scale service for weighing peanuts.

Balances

Cenco Balancing Scales, Fig. 4, manufactured by Central Scientific Company, Chicago, Illinois, were used throughout these studies for weighing samples.

Steinlite

The Steinlite moisture tester, Fig. 4, 110 volt, 60 cycles, manufactured by the Fred Stein Laboratories, Atchison, Kansas, was used to determine immediately the moisture content of peanut samples.

Oven

Samples of peanuts were placed in the Aminco Electric Oven, Fig. 4, no. 4-148A, Serial No. 020064, 60 cycles, 147-215 volt, in order to determine the moisture content of peanuts. The oven method of moisture determination is considered more accurate than the Steinlite method and was used in this study for all final determinations.

PROCEDURE

The major subdivisions of this study involve the design, construction and testing of a fundamental drier and a continuous drier and the determination of quality of the peanuts dried. These driers were erected and tests were conducted at the Tidewater Field Experiment Station, Holland, Virginia, whereas all design and fabrication was done in the Virginia Polytechnic Institute Agricultural Engineering Laboratories. Quality determinations were made in the laboratories listed in tables 8, 8A, 8B, as well as in the Virginia Polytechnic Institute Home Economics Laboratory and the Rural Electrification Laboratory.

FUNDAMENTAL COLUMN DRIER

A fundamental drier, Fig. 1, was designed and constructed so that a number of small tests could be made under closely controlled conditions in an effort to formulate linear prediction drying equations and to ascertain the optimum temperature and air flow to be used in drying peanuts in the continuous drier.

Design and Construction

Two points were stressed in the design and construction of the fundamental drier; close control of testing conditions and ease of varying these conditions.

Main Duct

The main duct, Fig. 1, was fabricated of 3/8 in plyboard on 1 in by 2 in framework, with the exception of the heating chamber which

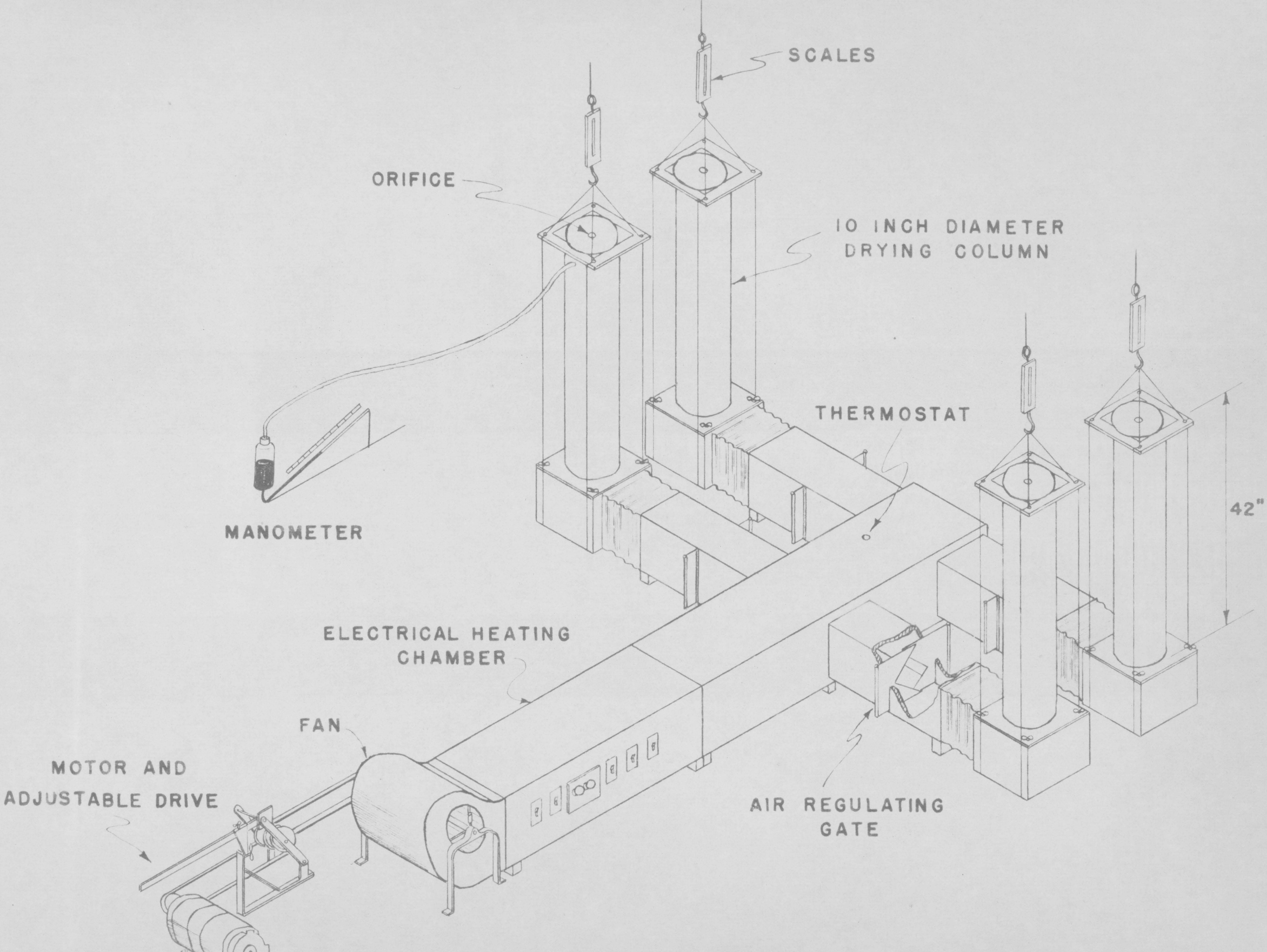


Fig. 1 -Column drier used in fundamental drying studies.

was lined with 1/4 in asbestos sheet board. The duct was open on one end for the entering air. Four openings, two on each side, were left on the end opposite the heater unit. These openings were to exhaust air into the small ducts.

Small Ducts

The small ducts had the same construction as the main duct. They were fastened to the main duct with 1 in screws and the joint was made air-tight by the use of weather-stripping. Formed metal sheets were used in each duct as air baffles. The small ducts were extended with a canvas which allowed the column to be flexible for obtaining the weight of the column.

Columns

The columns for containing the peanuts were furnace pipes 8-3/4 in in diameter and 43 in long. The furnace pipes were fastened to a base attached to the small ducts. The peanuts were supported with a mesh-wire bottom at the base. Each column had a metal cap made with an orifice and a pressure tube included. A plenum chamber of approximately 4 in could be obtained when a sample of peanuts was limited to approximately 50 lbs.

Temperatures

Temperatures varying from 80-120 F in 10 F increments were used in the fundamental studies. Supplemental heat was furnished by electric heater strips mounted on a steel frame. The heater strips were arranged in banks running parallel to the length and inside the main duct.

Fig. 2 illustrates the heater and motor wiring diagram used in the fundamental investigations.

Air Flow

A forward curved centrifugal fan, Fig. 1, furnished the air for drying the peanuts. The fan outlet was sealed to the open end of the main duct with a tar compound. Lag screws secured the fan to the frame. Power for the fan was furnished by a 3 hp electrically driven motor through a 7 in variable pulley. The quantity of air was regulated by the variable speed pulley and the louver on the fan. Air flows of 15, 30, 35, 60, and 75 cfm per sq ft were used during fundamental studies. Orifice calibrations are shown in Appendix B.

Fundamental Tests

Data obtained in the fundamental tests covers a period of two peanut seasons, 1949 and 1950, and is listed in Tables 1, 2, and 2A.

Peanut samples (Virginia runner and jumbo varieties) consisting of about 50 lbs were placed in the vertical columns. Each column was then suspended from spring scales and air was blown up through each sample, Fig. 3, at the temperatures and velocities as shown in Tables 2 and 2A. The drying of peanuts in each test was continued until the nuts in each column reached equilibrium, that is, to the point where no further moisture could be driven off at existing temperatures. The weight loss was recorded at regular intervals in each test. After drying had been completed, samples were taken from the bottom and top of each column for the determination of quality.

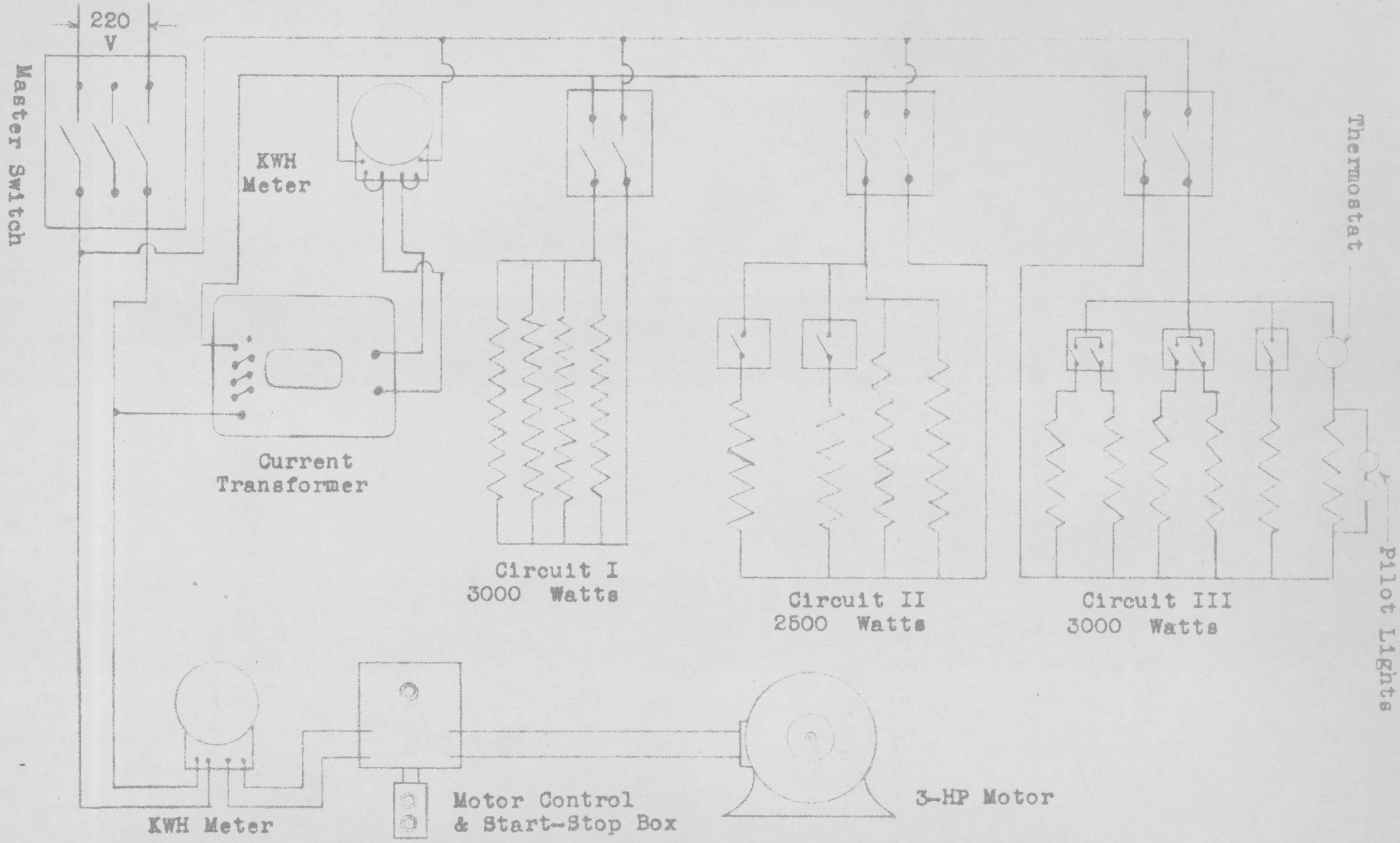


Figure 2 Instruments & Circuit Diagrams For Heater & Fan Motor

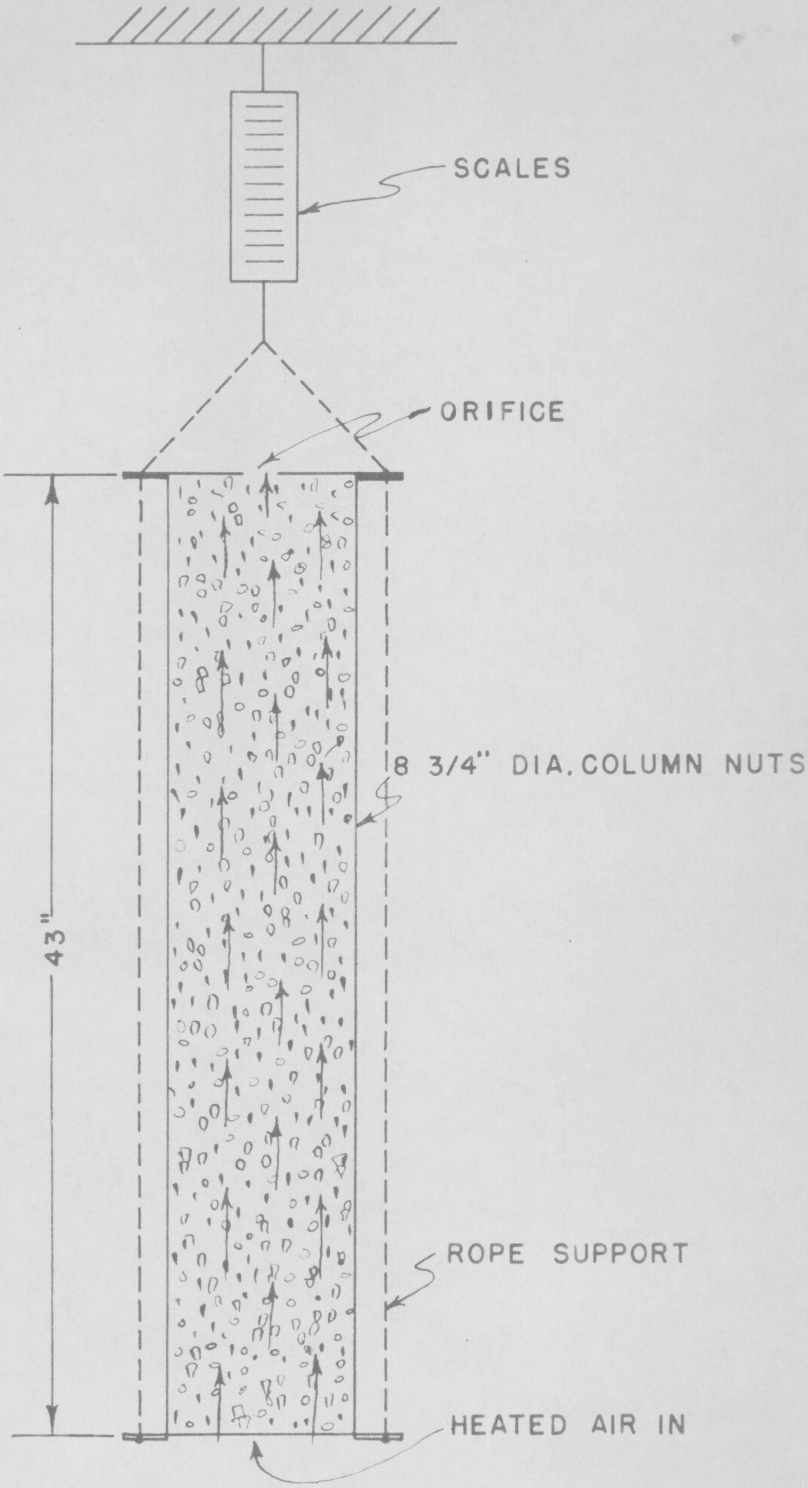


Fig. 3 - A sketch of the column of nuts is shown. The columns of nuts were mounted on scales and data were taken at regular intervals in order to determine the rate at which water was removed from the column of nuts.

Temperature Measurements and Recordings

Temperatures were recorded by the Brown recording potentiometer and switching assembly (9) with the use of copper constantan thermocouples placed at the following points: ambient or room, below and above each column of nuts, and inside the columns at 1/4, 1/2, and 3/4 the height of the peanuts. The thermocouples were placed inside wooden pegs replicating peanuts in order to get a temperature reading approximating that of the peanut and not the passing air. With temperature patterns recorded by the recording potentiometer, drying rates could be determined. See Charts 2-8.

In addition to the recording potentiometer, recording thermometers and recording hygro-thermographs were used to record wet bulb temperatures, dry bulb temperatures, and percent relative humidity. See Fig. 4.

Analysis of X and Y Values in Table 1

The X values shown in Table 1 were measured with the experimental apparatus, that is X_1, initial moisture content (dry basis), was determined by the oven method. X_2, average entering air temperature, was recorded with a thermocouple and a recording potentiometer. X_3 is the average relative humidity for the entire test and was obtained by entering the psychrometric chart with the average wet bulb and dry bulb temperature readings that were recorded for each test. X_4, the amount of air used in each test, was measured with an orifice and manometer.

In an effort to obtain straight line relationships between the various factors in the drying process, the following method of analysis

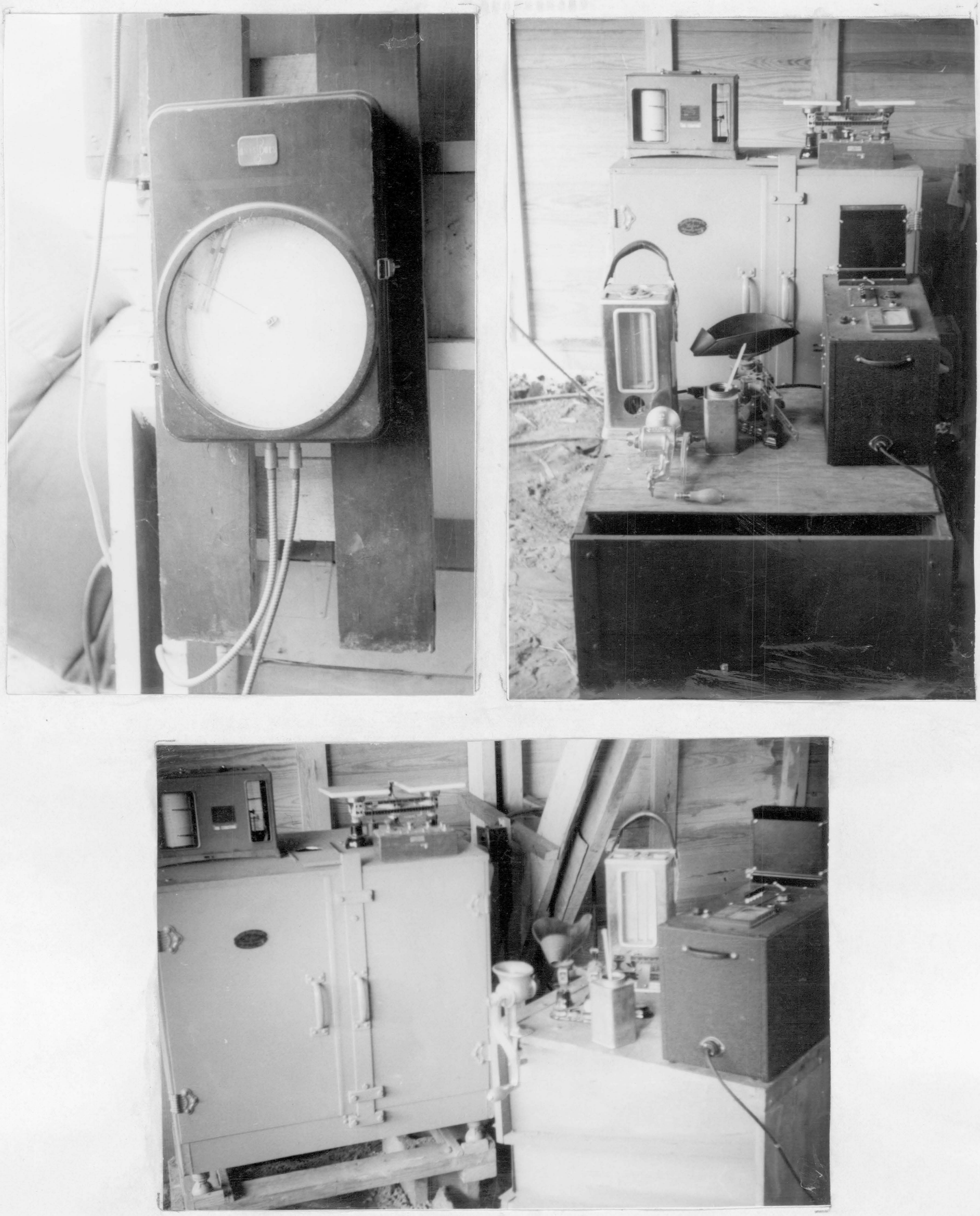


Fig. 4 - Instruments used in measuring temperatures, percent relative humidity and moisture content in fundamental and continuous drying studies.

was used to determine the Y values in Table 1. Since the X values could be measured directly, it was necessary to develop a technique for determining the Y values. Due to faulty operation of the recording potentiometer during the second season, only 16 tests conducted during the first season have been analyzed in Table 1.

Y_1 in Table 1, the thickness of drying layer in inches, was secured by obtaining the difference in ordinate values of the trailing and leading drying edges after the equilibrium drying layer had been reached, assuming adiabatic drying. In the leading drying edge curve, Charts 13-16, the time in hours that the temperatures at the different thermocouples located in the column of nuts began to rise was plotted as the abscissa and the depth of the peanuts at the different times was plotted as the ordinate. The trailing drying edge curve was obtained by plotting the time that the various thermocouples located in the column of nuts became equal tc or approached the entering air temperature. All of the time values and temperature values were taken from the Brown potentiometer temperature recorder chart after the data on the recorder chart had been mechanically transferred to coordinate paper (10).

Y_2, the rate of movement of the trailing drying edge in inches per hour, is the slope of the trailing drying edge curve. See Charts 13-16.

Y_3, time of departure of trailing drying edge, was obtained by reading the time value where each trailing edge curve intersected the time axis on the depth of nuts versus time curves, Charts 13-17, as each thermocouple point reached or approached the entering temperature, assuming that the thermocouple placed in the air surrounding a group of nuts actually measures the temperature of the nuts.

Y_4 is expressed in terms of hours and is the time required for the weight of the peanuts in the entire column drier to go from a weight at any time (t) half-way to the equilibrium weight. Drying rate curves were first plotted for each test and then moisture ratio curves were plotted using values taken from the drying rate curves. In order to obtain a linear set of drying rate graphs, the data for each test was plotted on semi-logarithmic graph paper where the abscissa was time and the ordinate was the weight ratio, Charts 17-20. This ratio is defined as the ratio of the weight of the nuts in the drier at the time of the observation minus the equilibrium weight, divided by the initial weight minus the equilibrium weight. The curves resulting when this information was plotted were straight lines on semi-logarithmic graph paper in most every case. The slope of these curves was determined for that portion of their length that they were straight or the falling drying rate period, and where it is felt that internal differences of moisture in the peanuts was a controlling factor. Since the surface moisture on the nuts was allowed to evaporate in the field before the nuts were picked, the constant drying rate period should not be a factor. Accepting this, the slope of the falling rate curves should give some idea of the effect of the drying conditions on this portion of the drying process.

Y_5, the final moisture content of the bottom layer, dry basis, was determined by the oven method.

Prediction Equations for Column Drier Data

In order to make a rough evaluation of the relative importance of (X_1, X_2, X_3, X_4) upon $(Y_1, Y_2, Y_3, Y_4, Y_5)$ the latter taken singly, the multiple regression technique (11) was used to find the best linear estimates of these effects. It might be noted that there are no theoretical conditions placed on the X's, i.e., they may take any value and these estimates are valid under the simple criterion of minimum variance (12). Exhibited below are the five regression equations.

$Y_1 = -468.363 + 3.35X_{mc} + 1.96X_t + 3.07X_{rh} + 0.323X_q$ = Thickness of drying layer in inches.

$Y_2 = -3.941 + 0.028X_{mc} + 0.029X_t + 0.0013X_{rh} + 0.0130X_q$ = Rate of movement trailing drying edge inches per hr.

$Y_3 = -67.840 + 1.279X_{mc} + 0.189X_t - 0.101X_{rh} - 0.228X_q$ = Time of departure of trailing drying edge in hrs.

$Y_4 = -77.467 + 1.230X_{mc} + 0.168X_t + 0.365X_{rh} - 0.228X_q$ = Hrs. of entire mass of nuts to reach one-half equilibrium.

$Y_5 = 12.485 - 0.032X_{mc} - 0.059X_t + 0.083X_{rh} - 0.066X_q$ = Final moisture content (dry basis) bottom layer.

When considering time of departure and hours to reach one-half equilibrium, note that the equations show very well, within limits of the number of observations, that three factors (mc, t, and q) have the same over-all effect; whereas, the factor of R.H. changes appreciably from positive to negative. The use of the equations will give "good" predictions within bands determined by range of sample points.

CONTINUOUS DRIER

Data obtained in the continuous drier, Figs. 5 and 6, include investigations for three years, 1949-50-51, and are listed in Tables 3-4B inclusive.

Design and Construction

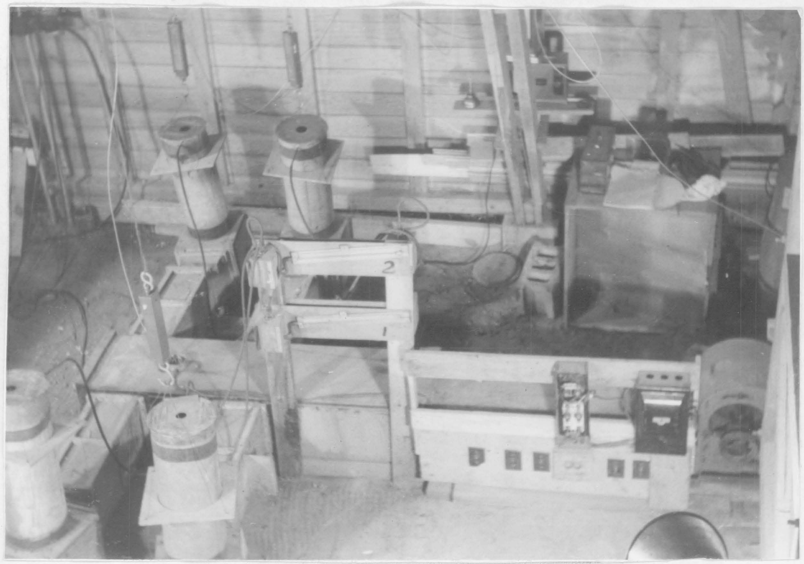
The continuous drier, Fig. 6, was designed to have a capacity equal to about one harvesting crew. It was constructed in the Virginia Polytechnic Institute Agricultural Engineering Laboratory and assembled, together with the component parts of the continuous system, at the Tidewater Field Experiment Station, Holland, Virginia.

Operation

By referring to the peanut flow chart of Appendix E the procedure from the digging through the drying operation may be seen. This shows the peanuts in the field before they were dug; then the peanuts as they were being shaken before being put through the picker. Following this, the peanuts were brought in from the field on a truck, weighed on platform scales and loaded into the loading platform. From the loading platform the peanuts were fed by an operator into the cleaner where the stems and leaves were removed before the nuts were lifted by the vertical elevator into the drying bin.

Heated air from the Peirson-Moore All Crop Drier was forced into the drier duct through the grate-bottom and up through the column of peanuts where it picked up moisture adiabatically.

After the peanuts were dried and ready for unloading, the



A

B

Fig. 5 - A. Fundamental drier in operation.
B. General view of continuous drying installation.

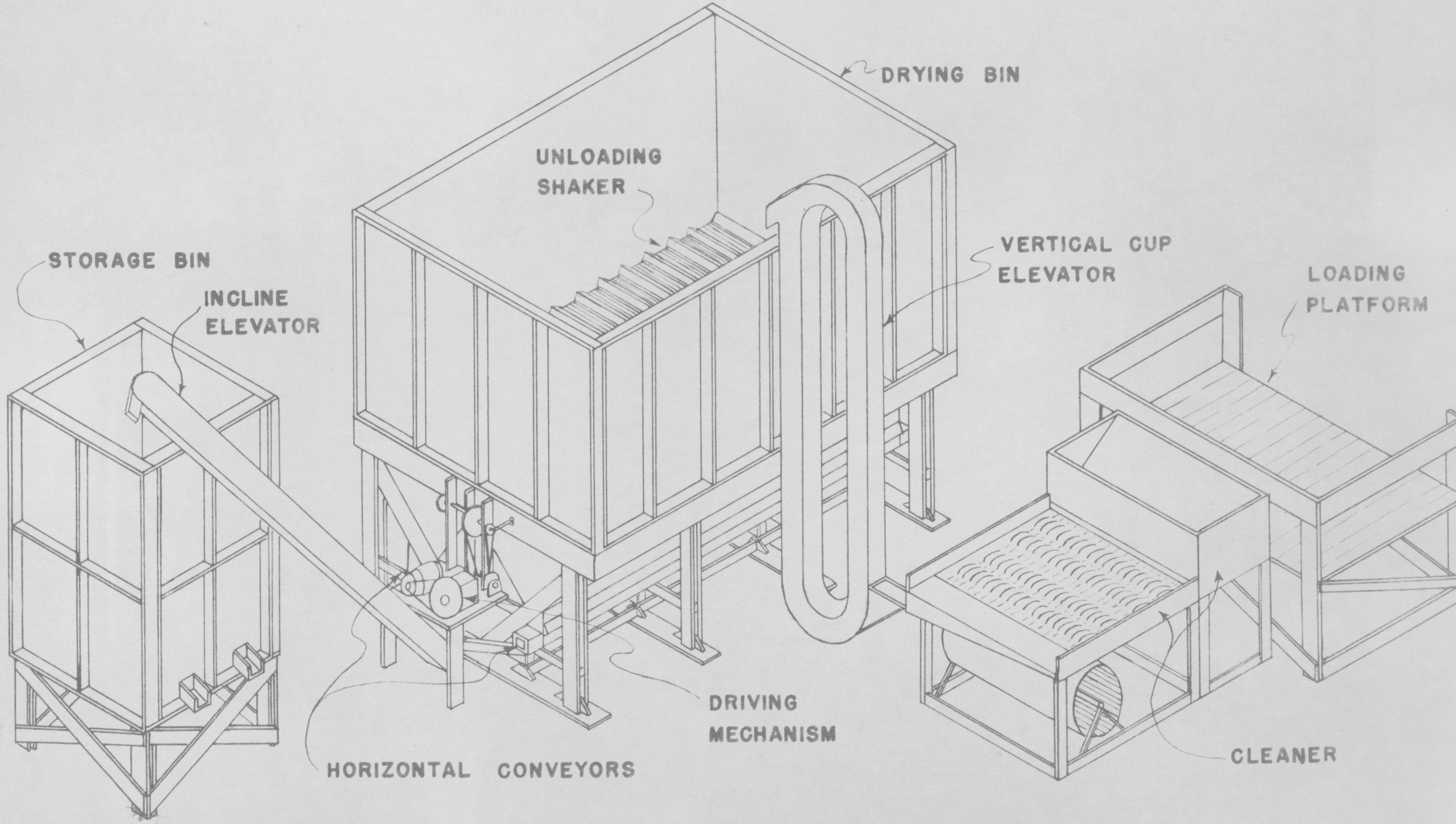


Fig. 6 -General isometric sketch of continuous drier, cleaner, elevators and storage bin.

oscillating mechanism of the grate-bottom would rock slowly to allow them to fall between the oscillating member and the edge of the inverted "V" section. When the peanuts were shaken through the grate-bottom, they would fall onto a conveyor belt which carried them to an elevator where they were lifted into a temporary storage bin until they could be bagged. Figs. 7-11 further illustrate this operation.

By referring to Fig. 12, the transmission of power for the shaking assembly can be followed. Power was furnished by an electric motor operating at a speed of 1800 rpm. This speed was reduced to 300 rpm with pulleys before entering the variable speed reducing gear. By adjusting a lever on the speed reducer, output speeds of 102, 138, 183, and 247 rpm were obtained. These speeds were further reduced by a 100-1 speed reducer to 1.02, 1.38, 1.83, and 2.47 rpm driving shaft speeds. Sprockets with a ratio of 3.75 to 1 further reduced this speed for the shaking mechanism. Assuming an output speed of 2.47 rpm for the driving shaft, a cam speed of .659 rpm was obtained. Also, as shown in Fig. 12, by using sprockets with a 1 to 5 ratio and a drive shaft speed of 2.47 rpm a conveyor belt speed of 3.23 fpm was obtained. As previously stated, by varying the output speed, the cam and conveyor speeds were varied accordingly.

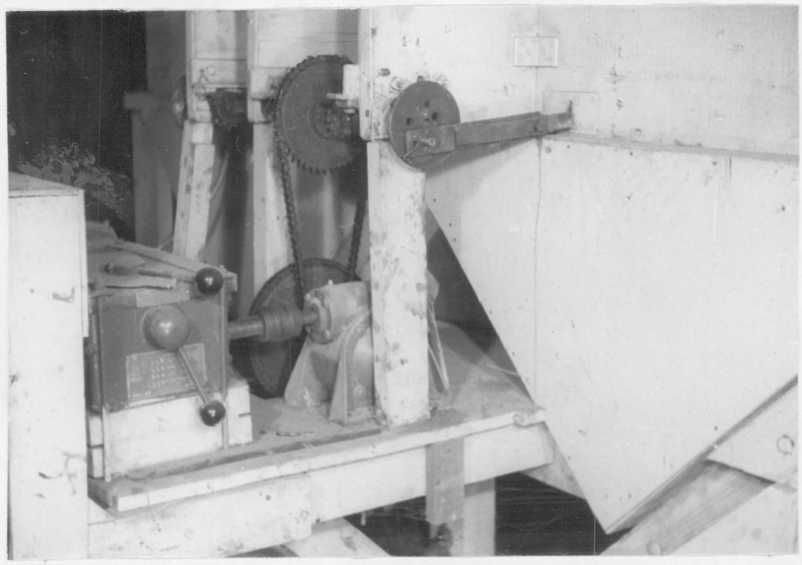
During 1949 the peanuts were picked wet immediately after digging and then placed into the continuous drier. In order to reduce the cost of drying, this practice was abandoned in 1950 for that of allowing the peanuts to wilt in the field before picking.

The investigators felt that greater efficiency would be obtained

A

B

Fig. 7 - A. Peanuts being put through the cleaner.
B. Peanuts being emptied from the vertical elevator into the drying bin.



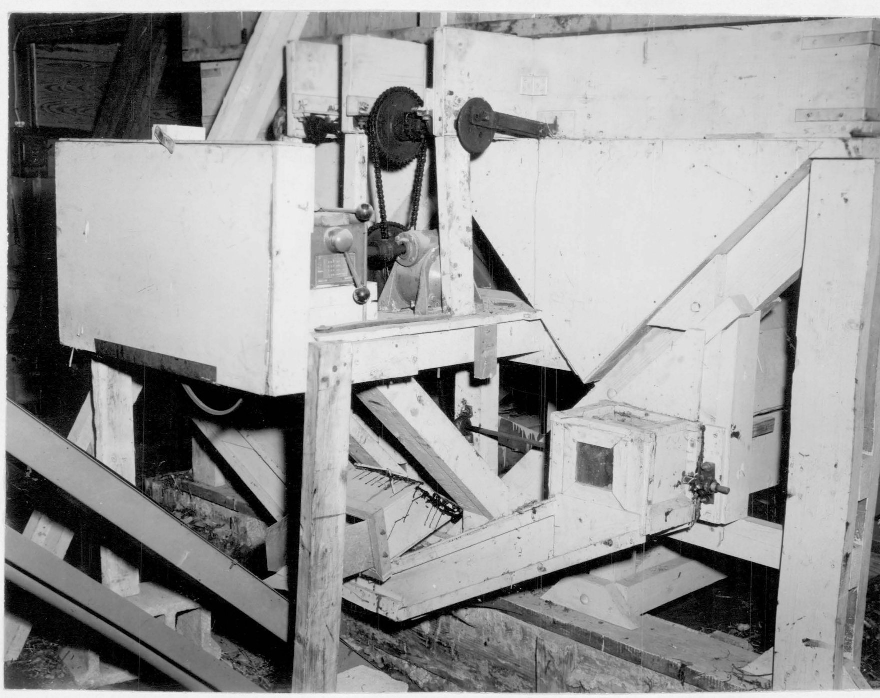


Fig. 8 - Front views of the continuous drier showing the driving mechanism for the shaker and conveyors. Note: Chute to inclined elevator removed for storage.

A

B

Fig. 9 - A. Bottom view of the shaker grate. Note the oscillating arms fastened to the cams at top.
B. Continuous drier with bin and grate removed. Note inverted V forming the air duct and the space on each side for the nuts to drop on the horizontal conveyors.

A

B

Fig. 10 - View of grate-bottom in drying bin. Note inverted V-section and 2 in by 4 in members in between.

A

B

Fig. 11 - A. Peanuts being conveyed to inclined elevator.
B. Inclined elevator and storage bin.

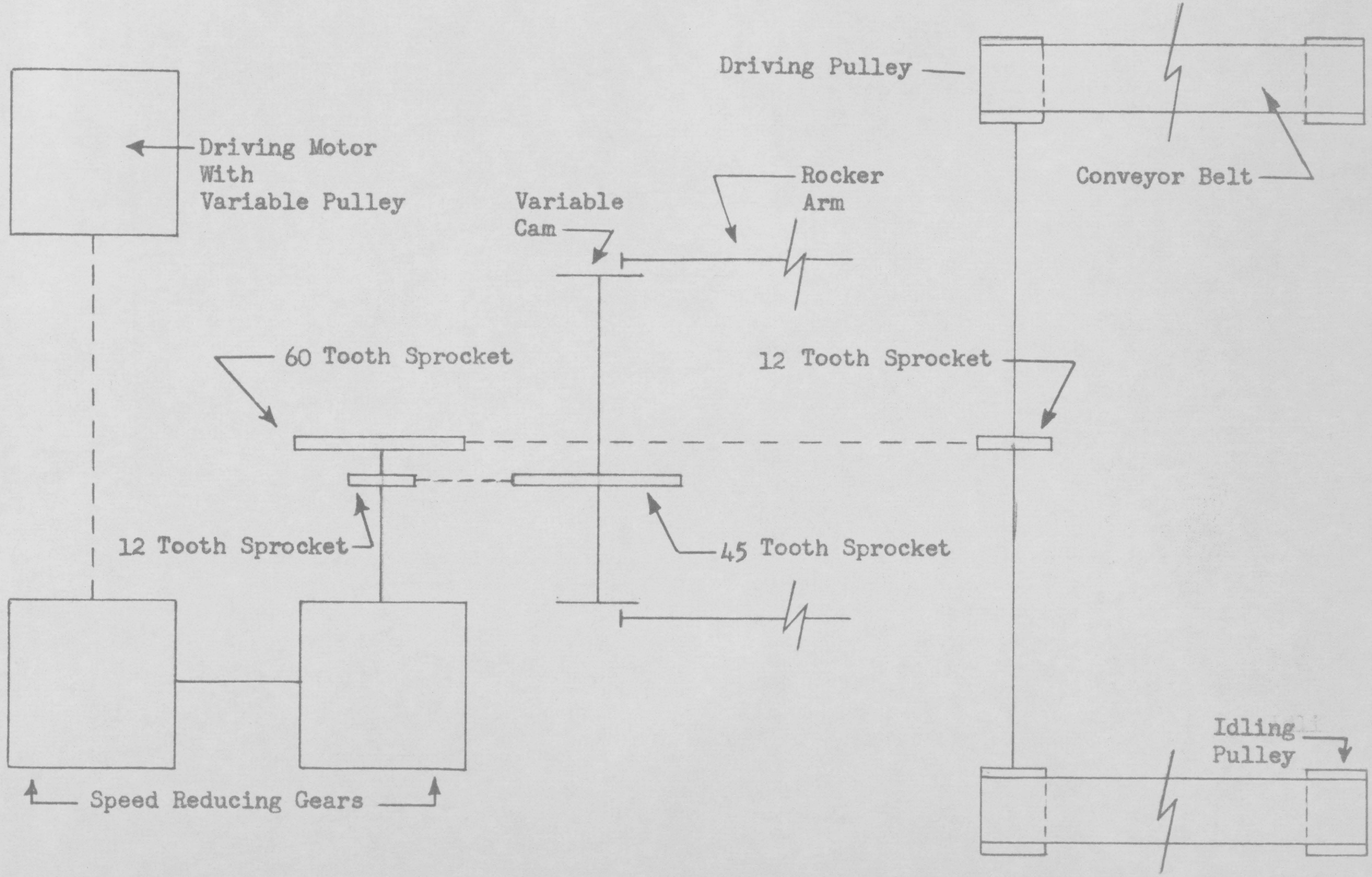


Fig. 12 - Power transmission block diagram for the continuous drier.

if the drier was loaded intermittently; that is, load the first foot or two and then begin drying. This procedure would fit into the harvesting operations as well as utilize the drying air most efficiently. When the relative humidity of the air leaving the top of the nuts began to drop below 100%, more peanuts could be loaded onto the drier, which would bring the relative humidity back to 100%. This would indicate that the air leaving the peanuts had reached the saturation point. Efficiency calculations for the continuous drier are shown in Appendix C.

Temperature

Results from fundamental drying studies indicated that temperatures of 120 F caused a detrimental effect on the taste, quality, and slippage and breakage percent of the peanuts. Consequently, the minimum and maximum temperatures were established at 70 and 110 F.

Air Flow

Throughout the series of continuous drier tests, air flow of 60 cfm per sq ft was used. This air flow was selected (13, 14) on the basis of the air flow resistance curve shown in Chart 1 and on the results of the fundamental drying studies.

Duration

The duration of each continuous drying test was determined by moisture content of the peanuts. Intermittent samples were checked for moisture content on the Steinlite moisture tester in order to determine when the peanuts were sufficiently dry for removal.

Temperature Measurements and Recordings

Temperature patterns throughout the drier bin were recorded by the Brown recording potentiometer and switching assembly with the use of copper-constantan thermocouples placed at the bottom of the bin, at a depth of 6 in and at every 1 ft depth to the top of the nuts. In order to replicate a peanut, the thermocouples were placed inside wooden pegs and sealed with tape. The Brown recording thermometers gave a constant check on the average entering dry bulb and wet bulb temperatures. Recording hygro-thermographs were placed in the ambient air and 6 in above the bin of peanuts in order to record the dry bulb temperature and relative humidity of the air exhausting from the nuts, as well as ambient conditions.

QUALITY DETERMINATIONS

The quality determinations included taste, germination, rancidity, skin slippage and breakage tests.

Germination

Germination tests for each sample taken in 1950 were conducted in the Farm Electrification Laboratory at Virginia Polytechnic Institute. One hundred peanuts from each sample were hand-shelled, wrapped in a paper towel and placed in a warm, dark location. These samples were kept moist and inspected periodically. Duplicate samples were made in each case. A record of germinated kernels was kept on a percentage basis and is shown in Table 5.

Taste Tests

The taste tests for the 1949-50 peanut drying studies were conducted by the Home Economics Department, Virginia Polytechnic Institute and consisted of a taste panel under the supervision of Miss L. J. Harper, Associate Professor of Home Economics. A Peanut Butter Score Chart, Table 6, was set up on the basis of 100% with the taste constituting 60%, texture 20%, spreadability 10%, and color 10%. A taste test summary is given in Tables 7 and 7A. Peanut butter made from field cured samples was included and used as the basis for comparison in this as well as other quality tests made. The peanut butter was prepared by the Division of Fruits and Vegetables, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, Beltsville, Maryland.

Quality Report from Planters Nut and Chocolate Company, Suffolk, Virginia

Samples of peanuts from each test were sent to the Planters Nut and Chocolate Company, Suffolk, Virginia, for peroxide tests; determination of butter flavor and odor; and to determine to what extent the peanuts would hand blanch. A report from this laboratory is listed in Table 8.

Quality Report from Division of Fruits and Vegetables, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, Beltsville, Maryland

The Division of Fruits and Vegetables, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, Beltsville, Maryland, conducted a slippage and breakage test and a test to determine the quality of the peanut butter for all samples taken. See Table 8A. Duplicate samples were prepared by the Agricultural Engineering Department, Division of Farm Electrification, Virginia Polytechnic Institute, and forwarded for taste tests.

Quality Report from Agricultural Chemistry Laboratory, Virginia Polytechnic Institute

Samples of peanuts from each of the 1950 tests were sent to the Agricultural Chemistry Laboratory, Virginia Polytechnic Institute where they were subjected to a rancidity test, Table 8B. The percent protein dry basis and percent ether extract dry basis were also determined.

GENERAL DISCUSSION

FUNDAMENTAL DRYING STUDIES

Discussion of Prediction Equations

The relatively good fit of the equations to data seems to lend credence to the hypothesis of linearity of effects. Accepting this, estimates of expected results for given conditions of moisture, etc. should be tested on further research and better estimates obtained. The use of this statistical technique is relatively new in its engineering application. It does extract useful information when the main interest is interpolation, close extrapolation, and prediction of performance. It may be that further study will suggest non-linear effects which also may be used in this technique to yield more reliable estimates. In order to determine the value of this analysis for extrapolated conditions beyond the limits of this data, values for the different X's were substituted in the equations that would possibly be obtained in the field. If the Y value (with a given set of X's) comes out negative, this is an indication that the regression equations will not predict with this set of X values. With these equations under a given set of conditions, approximate predictions of the maximum thickness of drying layer, the rate of movement of this drying layer, the time after drying started that the trailing drying edge would begin to move up through a column of nuts, and the final moisture content in the bottom layer could be determined.

Discussion of Drying Operation

The fundamental drier, in general, performed a satisfactory job of drying four columns of nuts using a constant temperature and four different air flows. The entering air temperature was regulated by a bi-metallic thermostat which controlled a 1500 watt electric heater. The air flow for each column was kept constant by adjusting air baffles regulating the static pressure under the nuts. A careful setting was required at the beginning of the tests, but close control was obtained thereafter with only minor adjustments.

Drying rate curves for the fundamental drier, Appendix A, indicate that a smaller air flow differential than the 15 cfm per sq ft increment used should be chosen in the future because of the wide variations of drying time between the upper and lower air flow limits used.

Data obtained during this study indicate that when peanuts are dried in a column 43 in high, an air flow greater than 15 cfm per sq ft is required to dry the peanuts on the top before mold develops.

CONTINUOUS DRYING STUDIES

Discussion of Operation

The continuous drier operated satisfactorily. However, the design of the shaker assembly was such that some of the peanuts in certain positions being shaken over the drier would move out faster than those in other positions. This caused the wet nuts on the top layer to be unloaded before they were dry. This was due to the bridging action of the peanuts and the variation of the spacings in the shaker assembly.

When peanuts were allowed a wilting period in the field, the moisture content was reduced from approximately 50 to approximately 35 percent w.b. This reduced both the drying load of the drier and the drying time considerably.

Some of the problems confronted during this study were: (1) The inability to correct the cause for slippage on the kernel. Cause of skin slippage had proved to be one of the principal problems in curing of peanuts. From discussions with chemists, pathologists, air conditioning engineers, and agricultural engineers, a number of hypotheses have been presented. A few of the most common have been drying rate, uneven drying, physiological effect, humidity and temperature. Of all the tests run thus far, not one has been absolutely free of slippage. (2) It was impossible to remove all immature and diseased nuts before the drying process which added extra load on the drying unit. Much of the cleaning problem was eliminated with the installation of the Pittman cleaner.

By varying the speed of the driving mechanism, the following four shaker outputs were obtained using mixed, runner and jumbo peanuts with a wet basis moisture content of 11.5 percent - 156, 231, 312, and 387 lbs per hr.

It was noted during the 1950 operation that the shaker assembly was only oscillating through a one-half stroke. By making the necessary adjustments to obtain a complete shaker stroke, the output could be increased considerably.

The most desirable results were obtained in the continuous drier where the peanuts used were allowed to wilt in the field and then dry slowly at a dry bulb temperature range of 80 - 90 F with an air flow of 60 cfm per sq ft. Any temperature above this maximum caused excessive skin slippage and, if the temperature was held at over 110 F during a test, a detrimental effect was noted in the taste quality.

QUALITY DETERMINATIONS

In determining the quality of the dried peanuts as well as the processed product, the following variables should be considered: (a) Type of soil (b) Varieties (c) Weather (d) Date of digging (e) Time remaining in field after dug (f) Rate of drying (g) Method of processing (h) Consistency of samplers

Germination

Results from germination tests conducted in 1950, Table 5, indicate that in the operating range used the temperature and air flow did not significantly affect the germinating quality of the kernels. At low air flows, 15 and 30 cfm, the drying rate was so slow that mold developed in the upper layers of the column and was detrimental to the germination of the peanuts.

Taste

Taste is one of the most important factors in the quality of peanuts and peanut products. This factor has no standard for judging since every judge may have a different sense of taste. The requisites for a good taste judge include the ability to differentiate in taste, to be able to determine which taste is the best, and to be consistent in judgement. Methods of choosing and eliminating judges have been studied and reported in a thesis by Lombardi (15).

Quality reports vary somewhat from individual laboratories, as was expected. However, data in Tables 7 and 7A indicate that peanuts can be dried using supplemental heat and still retain a palatable flavor. By referring to Table 7A it can be seen that eleven samples of peanuts dried artificially were ranked above the field cured sample by the taste panel for 1950. Results from Planters Nut and Chocolate Company for the 1951 tests, which are not listed in this study, indicate that a good flavor was obtained from the continuous drier samples. However, samples from the top of the bin had a sweeter and more natural taste than those from the bottom.

Rancidity

In an effort to determine the effect of temperature and air flow on the rancidity of the peanuts, the Kreis and peroxide tests were used. The Agricultural Chemistry Laboratory, Virginia Polytechnic Institute, conducted the Kreis tests which were negative in every case. Planters Nut and Chocolate Company reported no apparent correlation between the temperature and amount of air and the peroxide values obtained.

Skin Slippage and Breakage

Skin slippage and breakage has been the most significant problem encountered while drying peanuts with supplemental heat. The red skin around each kernel serves as a protective covering and when this covering is destroyed the meat of the kernel tends to absorb the moisture and odors which are detrimental to its quality. If this skin is destroyed to an extent that the two halves of the kernel separate, the over-all quality will be lowered because these half kernels will pass through the grading equipment with the shriveled kernels as oil stock rather than with the larger kernels where they would go if the halves remained together. This is important in the Virginia-North Carolina area where a premium is placed on large kernels. Hence, it is desirable for this skin to remain on the kernel throughout the processing. The exact cause of this slippage, which occurs on artificially dried peanuts, has not been fully determined, although data obtained by the United States Department of Agriculture, Division of Fruits and Vegetables, and Planters Nut and Chocolate Company from samples of peanuts cured in 1950 indicate that temperature and amount of air has marked effect on skin slippage and breakage. By referring to the fundamental test data, Table 8A, it can be seen that as the temperature increases, the percent breakage and slippage increases. Also as the air flow increases, the percent breakage and slippage increases. The continuity of these results lends credence to the hypothesis that rate of drying affects skin slippage and breakage. A nomenclature given this slippage, or removal of the red skin on the kernel, is "blanching". The Planters Nut and Chocolate Company conducted a slippage test by rolling the kernel between the thumb and forefinger while the peanut was raw to see if the kernel would hand-blanch while raw. The results of the 1950 tests are shown in Table 8.

"Blanching" tests conducted by Planters Nut and Chocolate Company for three samples from the 1951 continuous drier indicate that skin on nuts from the two samples taken from the bottom of the drier would slip slightly at a moisture content of 7.32 and 7.95 percent; whereas the skin would not slip from a sample at 13.78 percent moisture taken from the top of the drier.

CONCLUSIONS

The ultimate objective in developing a continuous drying method for peanuts is to open the way for mechanization of peanut production. With this objective in mind, the following conclusions appear credible.

1. A fundamental column drier was designed and constructed whereby small samples of peanuts could be dried under controlled conditions.

2. Data was obtained and evaluated statistically in an effort to determine optimum conditions under which to dry peanuts.

3. A continuous drier was designed to have the capacity of 481.25 cu ft.

4. The continuous drier was fabricated in the Virginia Polytechnic Institute Agricultural Engineering Laboratory and assembled at the Tidewater Field Experiment Station, Holland, Virginia.

5. The continuous drier operated satisfactorily in all mechanical details with only minor attention.

6. The method of removing peanuts from the continuous drier caused a channeling effect in the bin, allowing some wet peanuts to be unloaded together with the dry ones.

7. Germination was not affected by temperatures of 70 to 120 F as used in this study.

8. Germination was not affected by air flow so long as the air flow was sufficient to prevent mold.

9. Taste was affected by drying rate as well as variety of peanuts and method of handling.

10. The skin slippage and breakage of the peanuts increased as the drying rate increased.

11. The degree of skin slippage and breakage varied inversely as to the moisture content at time of sampling.

12. There was no indication of rancidity using temperatures of 70 to 120 F.

13. There was no indication of rancidity using air flows of 15 to 75 cfm per sq ft.

SUGGESTIONS FOR FUTURE STUDY

This study indicates that peanuts can be dried continuously using supplemental heat and still retain a palatable flavor. It has brought to focus many problems heretofore unrecognized. With these problems in mind, it is recommended that the following suggestions be used as a basis for future research.

1. Continue fundamental studies with relative humidity being controlled as well as air flow and temperature.

2. Conduct a physiological study of the peanut during its curing process in order that the engineer might attempt to duplicate those conditions.

3. Make a study of the economics of drying peanuts using supplemental heat.

4. Simplify the design of the continuous drier for its adaptation on the farm.

5. Design another shaking assembly for the continuous drier whereby a more direct method of unloading may be obtained.

6. Design a metal bin-type drier and conduct tests whereby peanuts and small grain can be dried at small depths. Dampers and ducts should be arranged so that drying air can be forced through the peanuts or grain from the bottom or the top during the same operation in order to achieve a more uniform drying pattern.

7. Study the effects that aging might have on the curing of peanuts.

8. Investigate the possibility of intermittent drying of peanuts.

9. Design a machine whereby the testing of slippage and breakage can be standardized and accomplished mechanically.

10. Contact buyers and processors in an effort to determine what factors are involved in determining quality of peanuts.

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APPENDIX A

CHARTS OF RESISTANCE OF DRY UNSHELLED PEANUTS TO AIR FLOW, DRYING RATE, DRYING LAYER, DRYING EDGES, AND MOISTURE RATIO

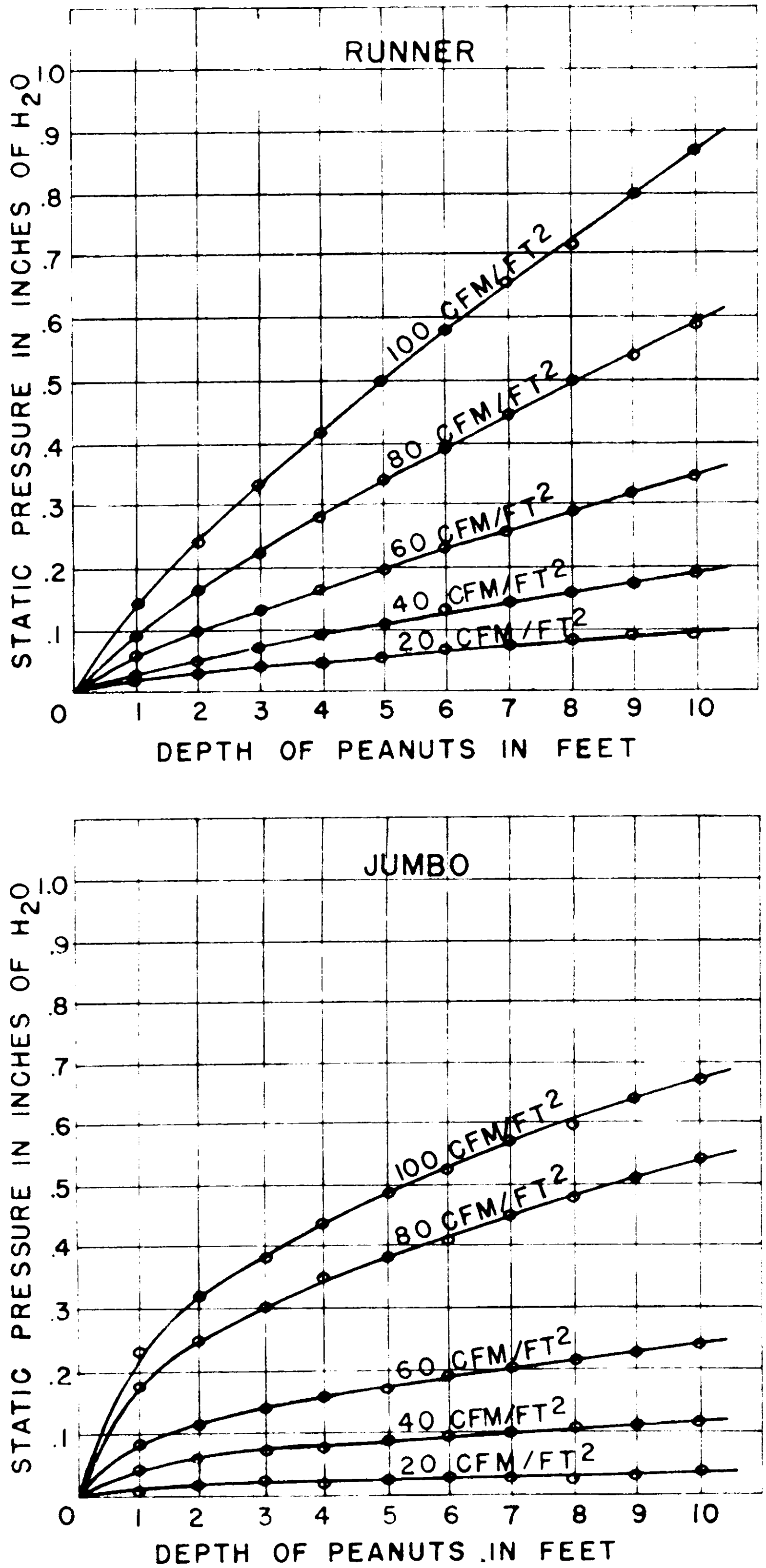


Chart 1 - The resistance of dry unshelled runner and Jumbo peanuts to air flow.

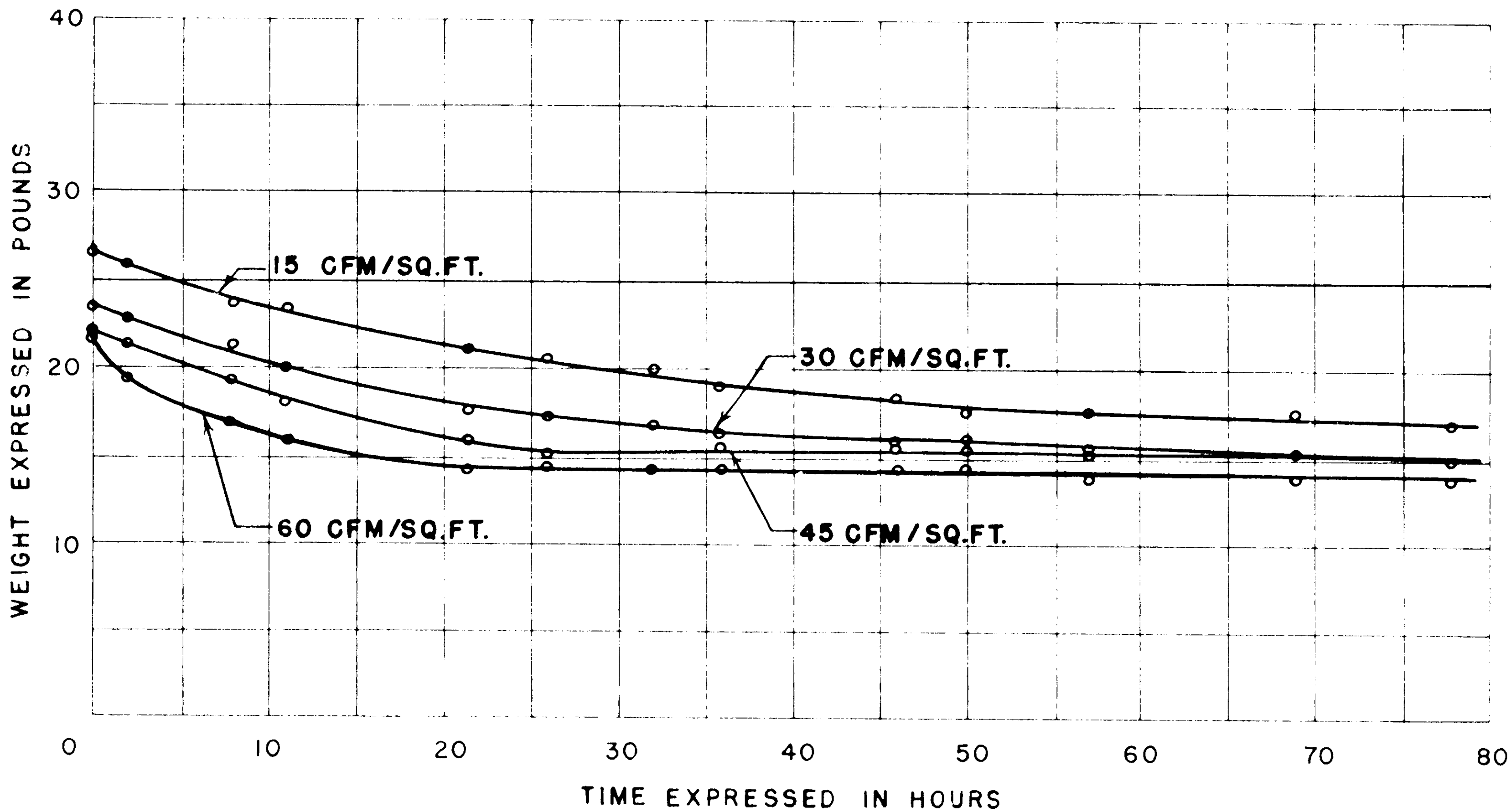


Chart 2 - Drying Rate of Peanuts, 1949 Fundamental Studies, Test 1, Temp. 96 F

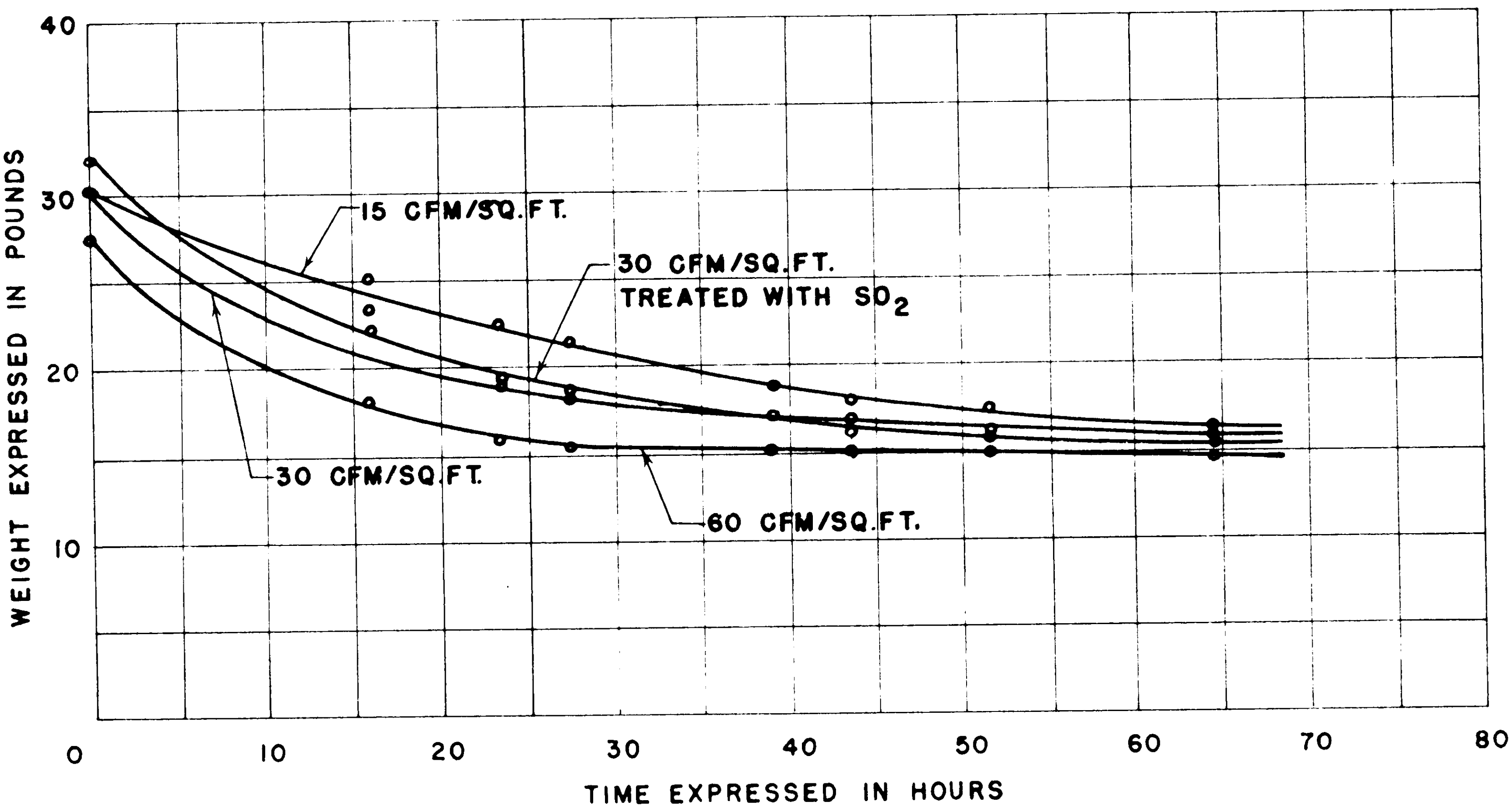


Chart 3 - Drying Rate of Peanuts, 1949 Fundamental Studies, Test 2, Temp. 120 F

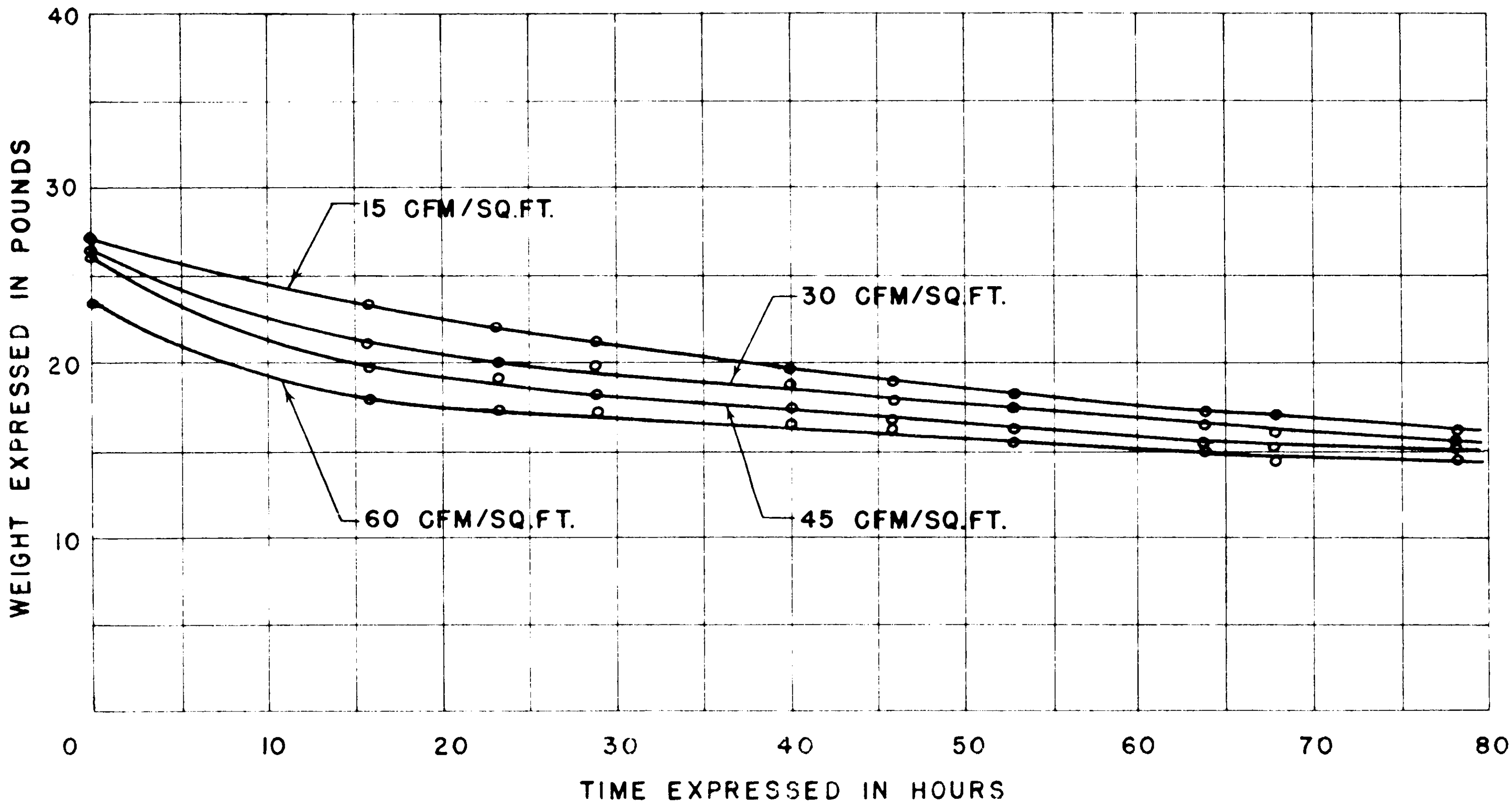


Chart 4 - Drying Rate of Peanuts, 1949 Fundamental Studies, Test 3, Temp. 90 F

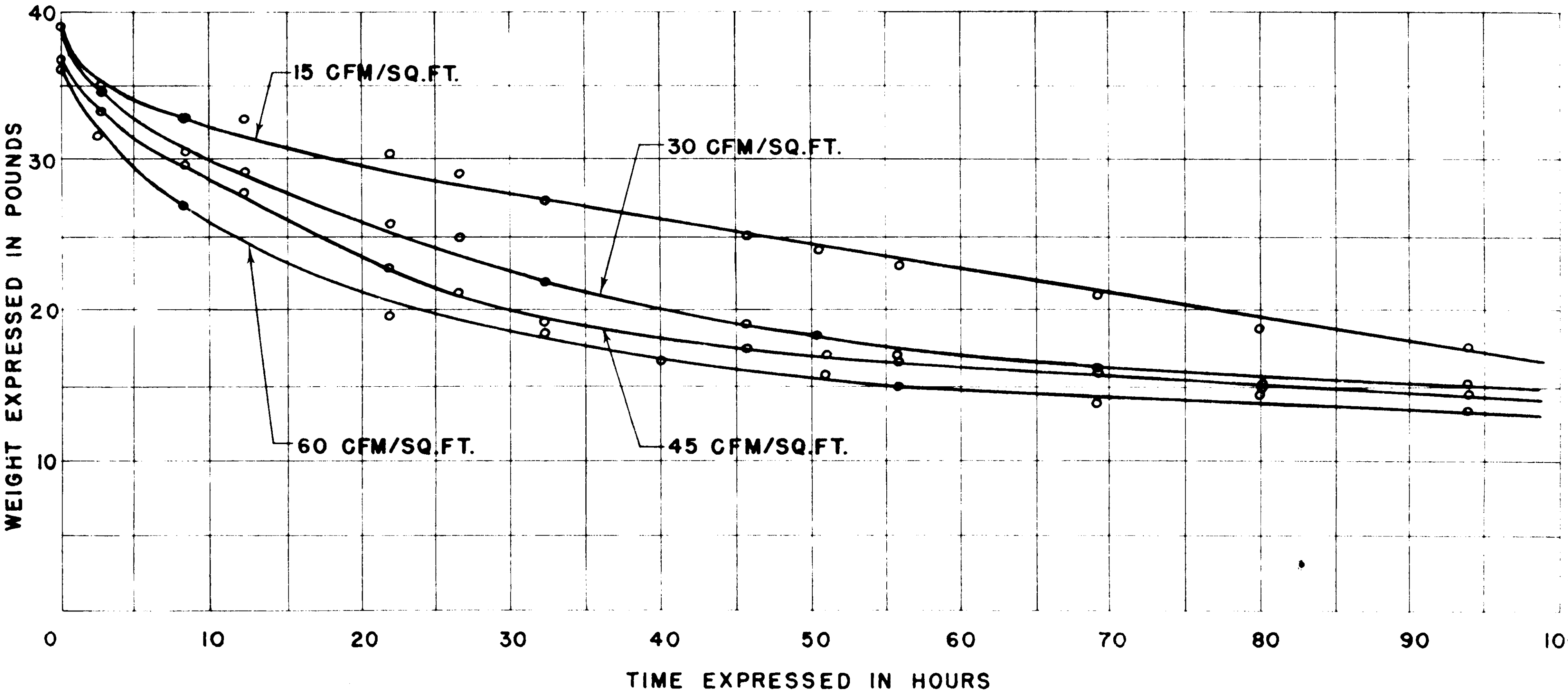


Chart 5 - Drying Rate of Peanuts, 1949 Fundamental Studies, Test 4, Temp. 80 F

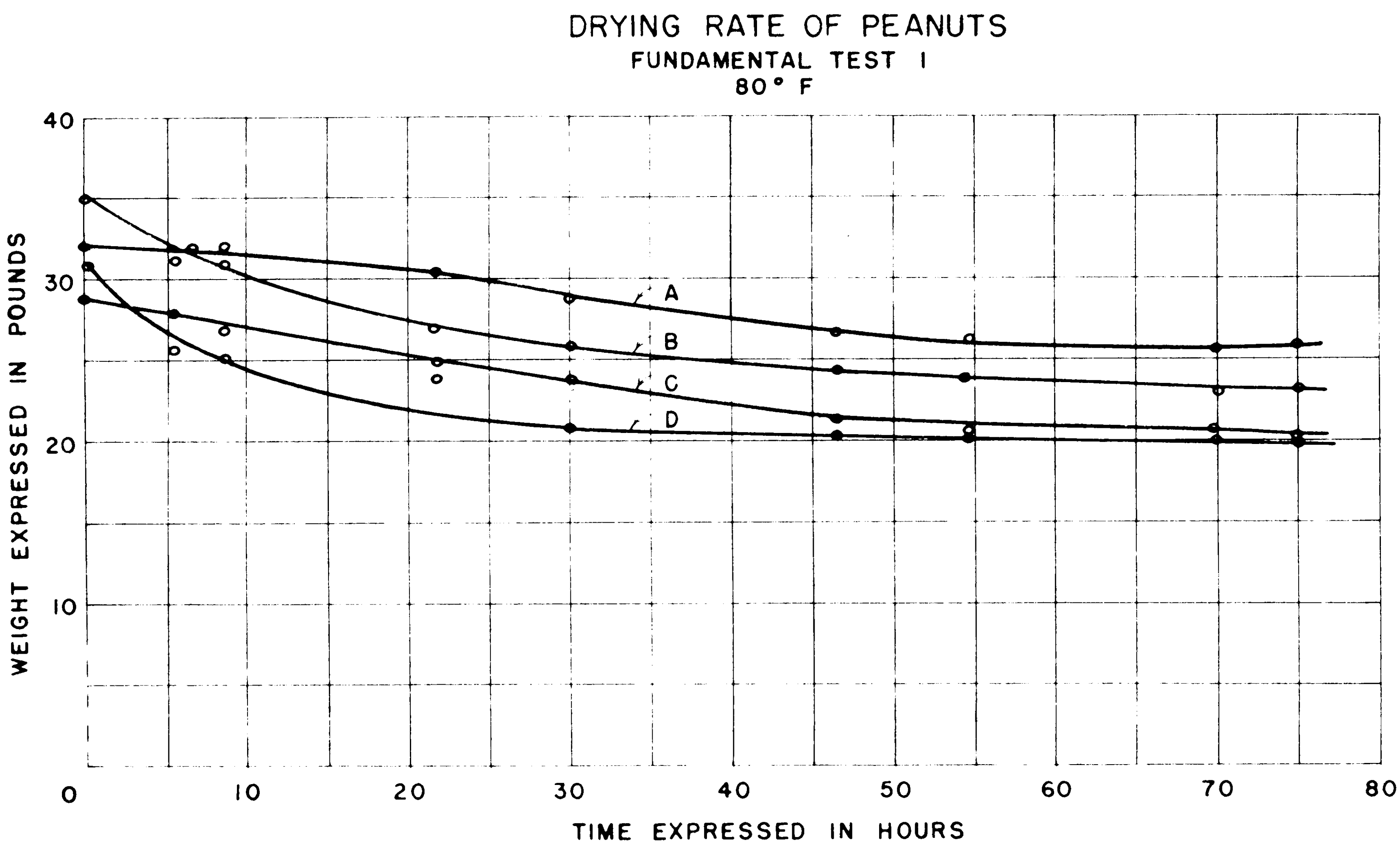


Chart 6 - Drying Rate of Peanuts, 1950 Fundamental Studies, Test 1, Temp. 80 F

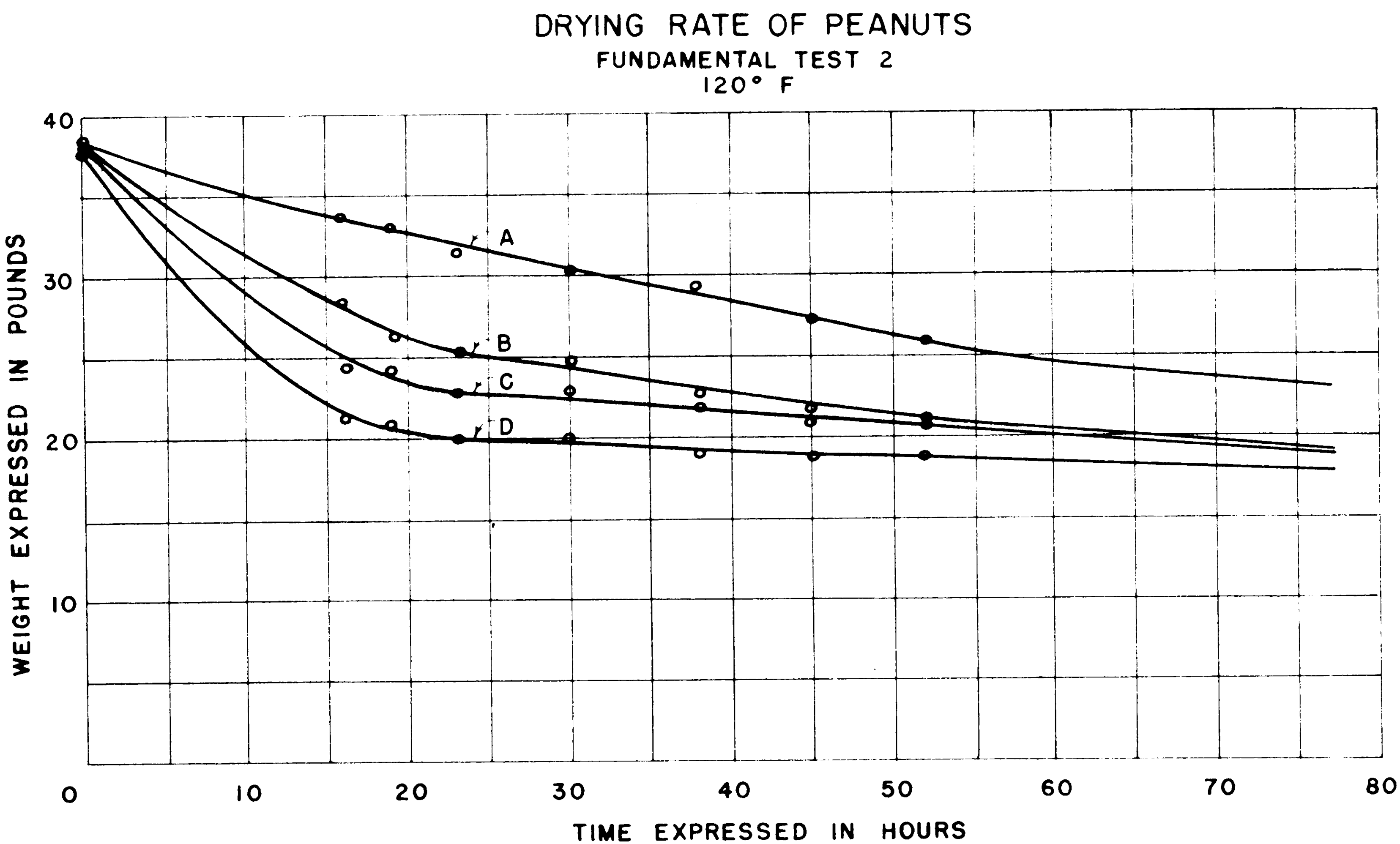


Chart 7 - Drying Rate of Peanuts, 1950 Fundamental Studies, Test 2, Temp. 120 F

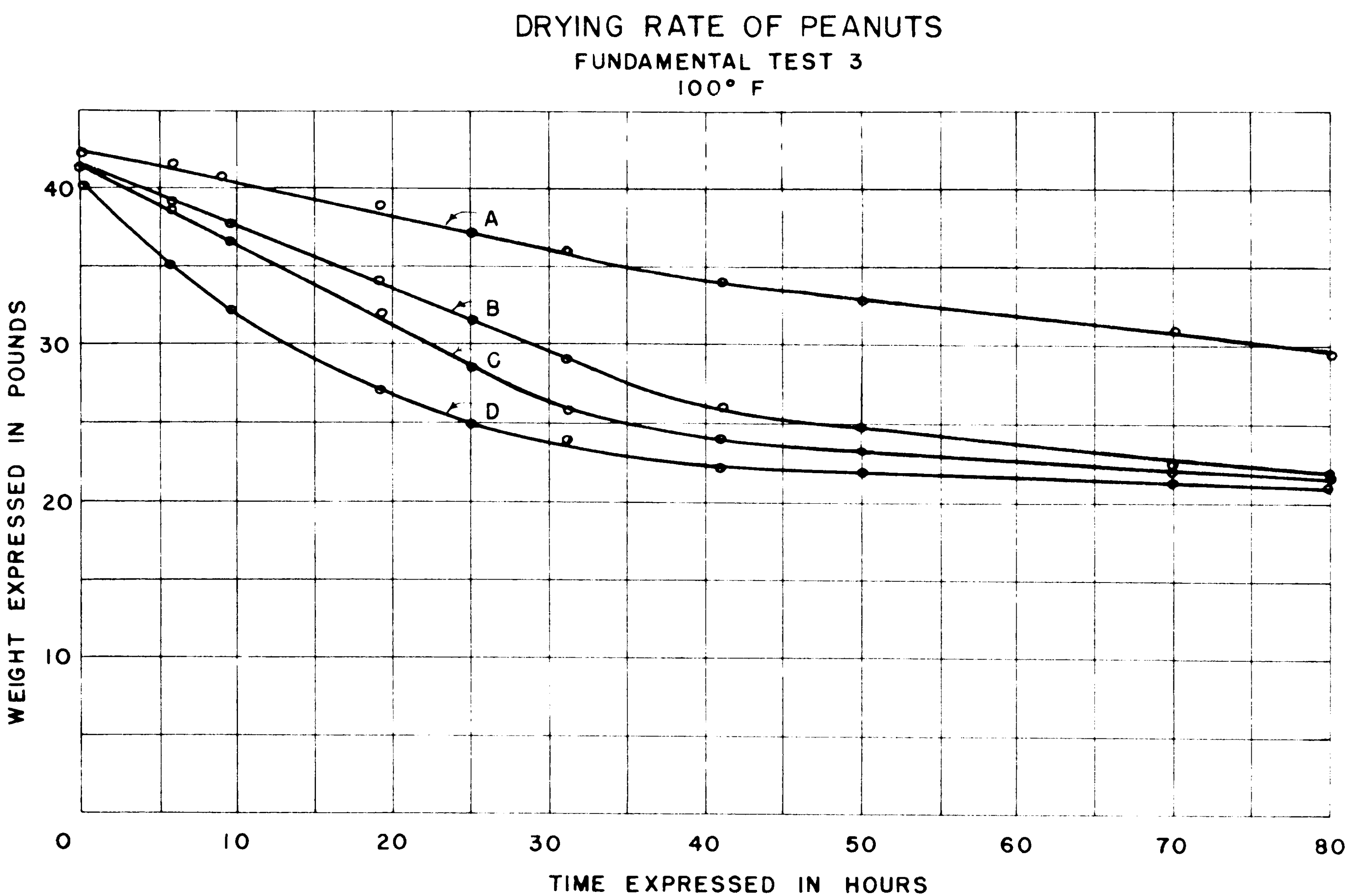


Chart 8 - Drying Rate of Peanuts, 1950 Fundamental Studies, Test 3, Temp. 100 F

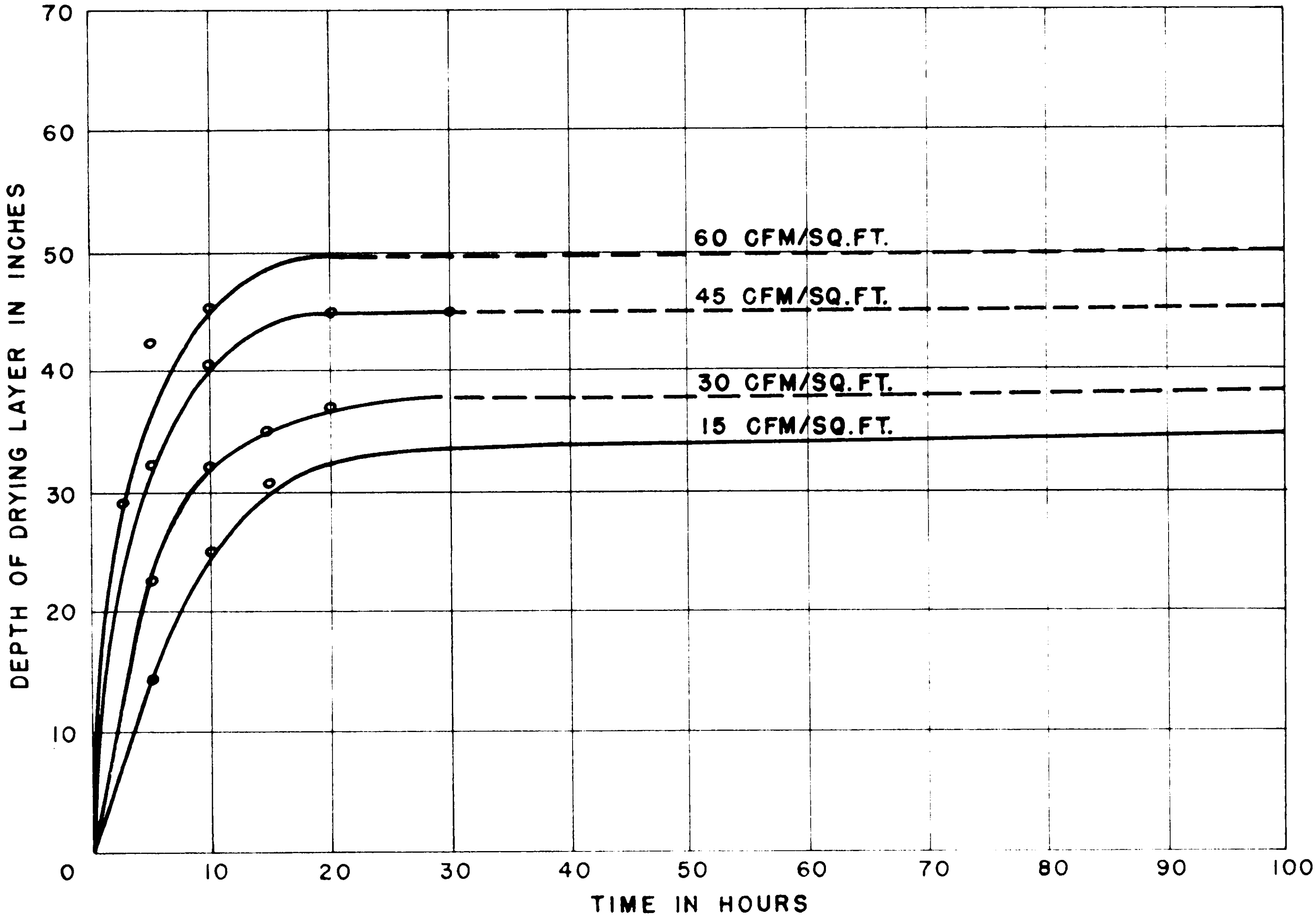


Chart 9 - Drying Layer of Peanuts, 1949 Fundamental Studies, Test 1, Temp. 96 F

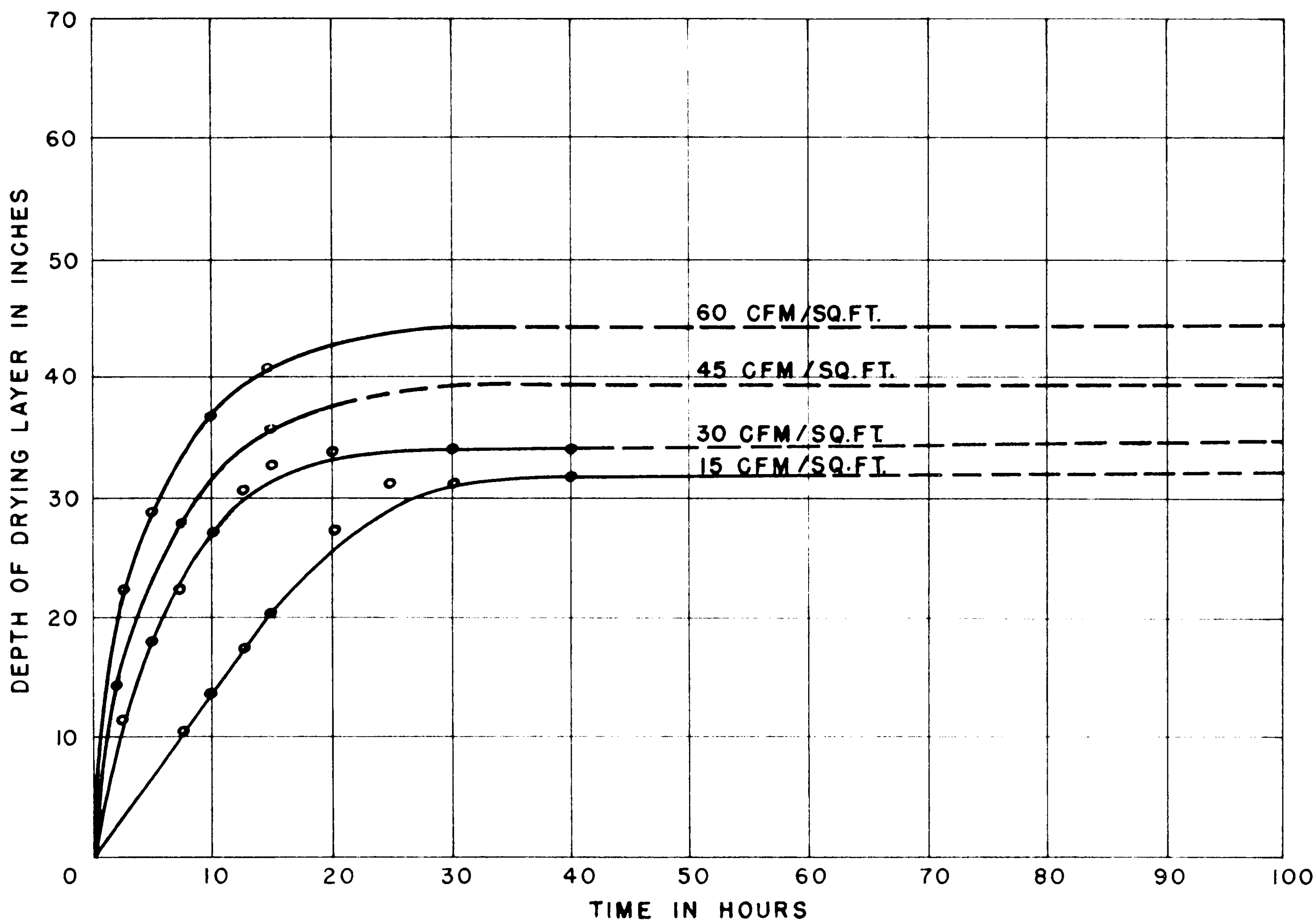


Chart 10 - Drying Layer of Peanuts, 1949 Fundamental Studies, Test 2, Temp. 120 F

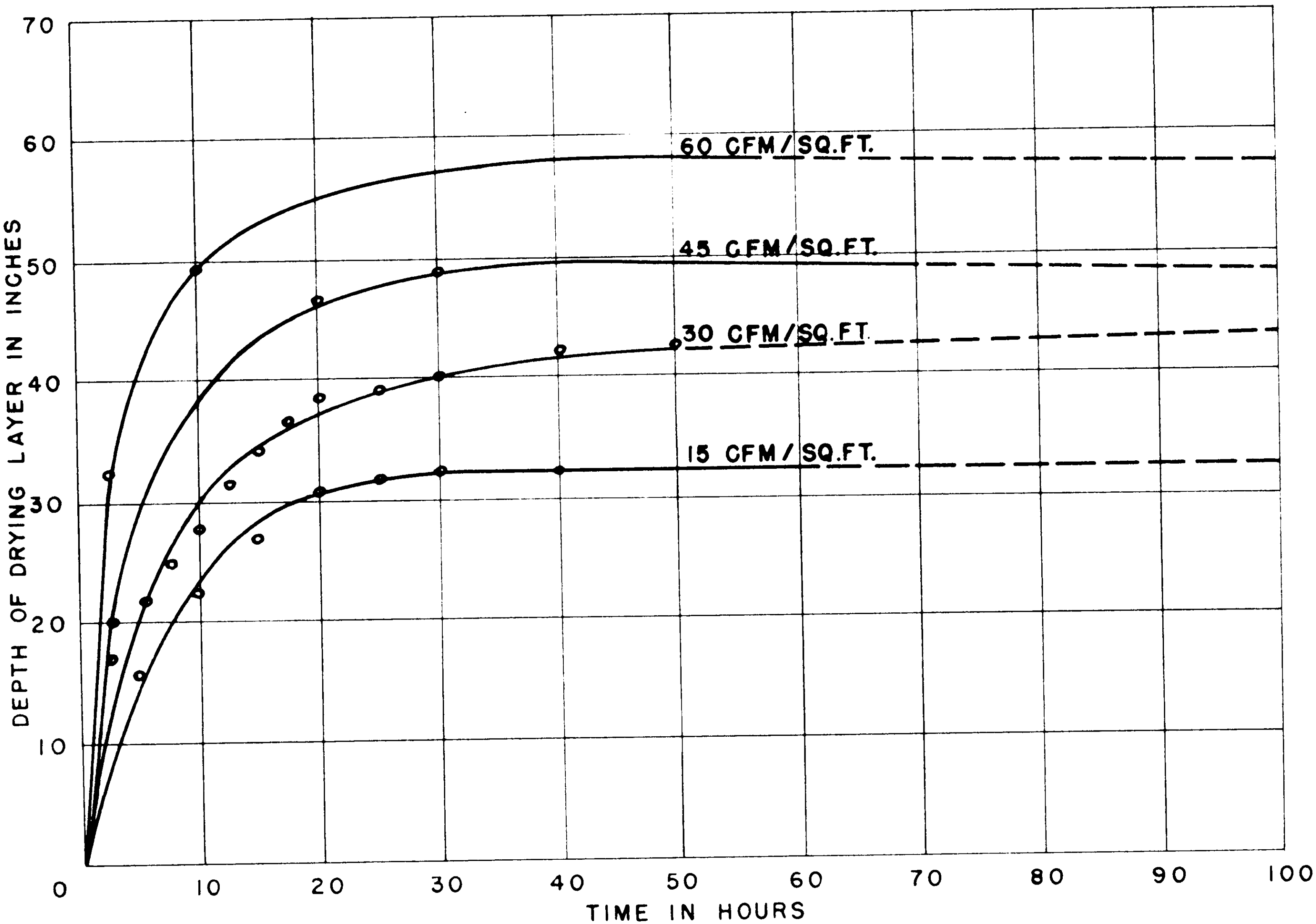


Chart 11 - Drying Layer of Peanuts, 1949 Fundamental Studies, Test 3, Temp. 90 F

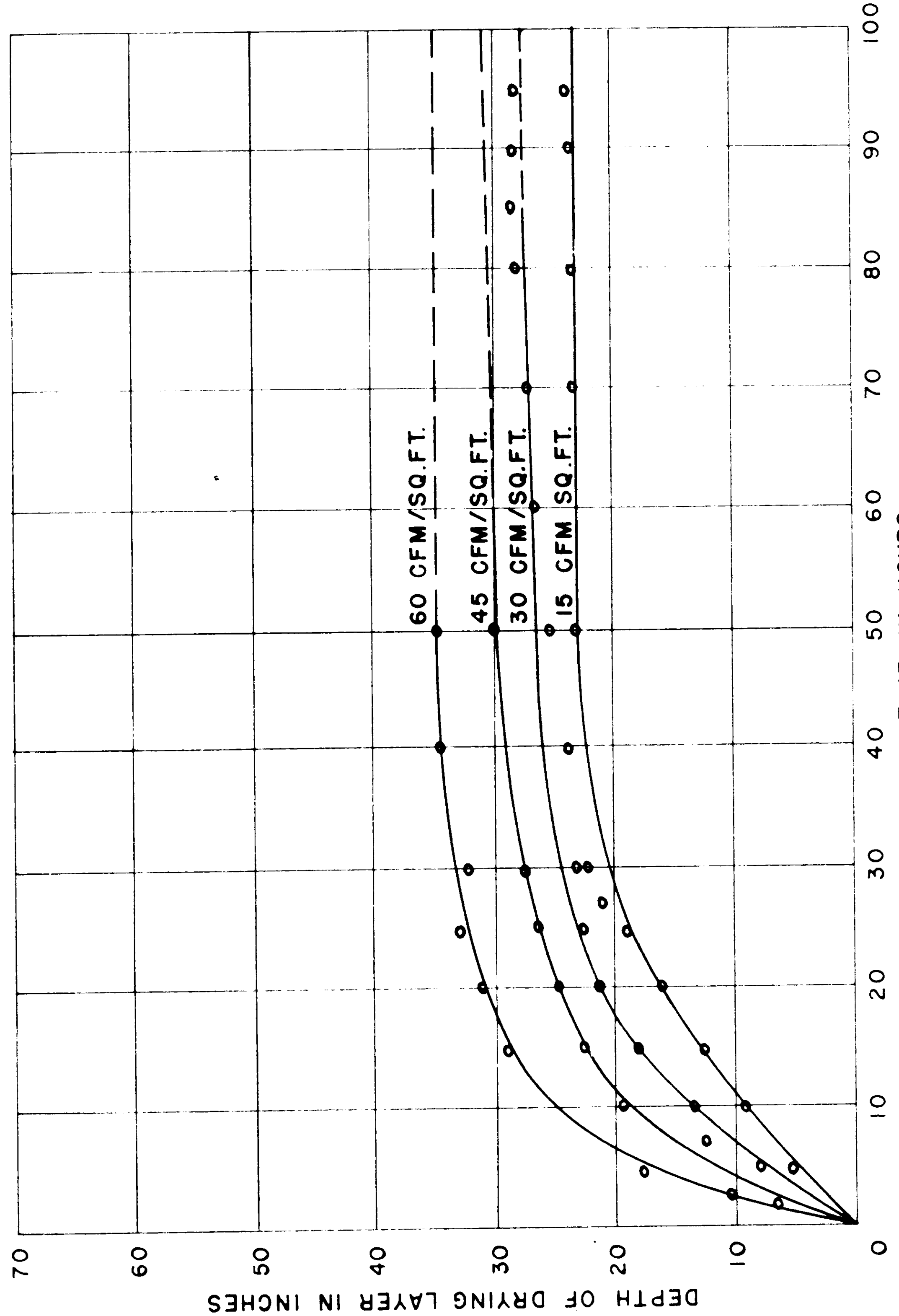


Chart 12 - Drying Layer of Peanuts, 1/40 Fundamental Studies, Test 4, Temp. 80 F

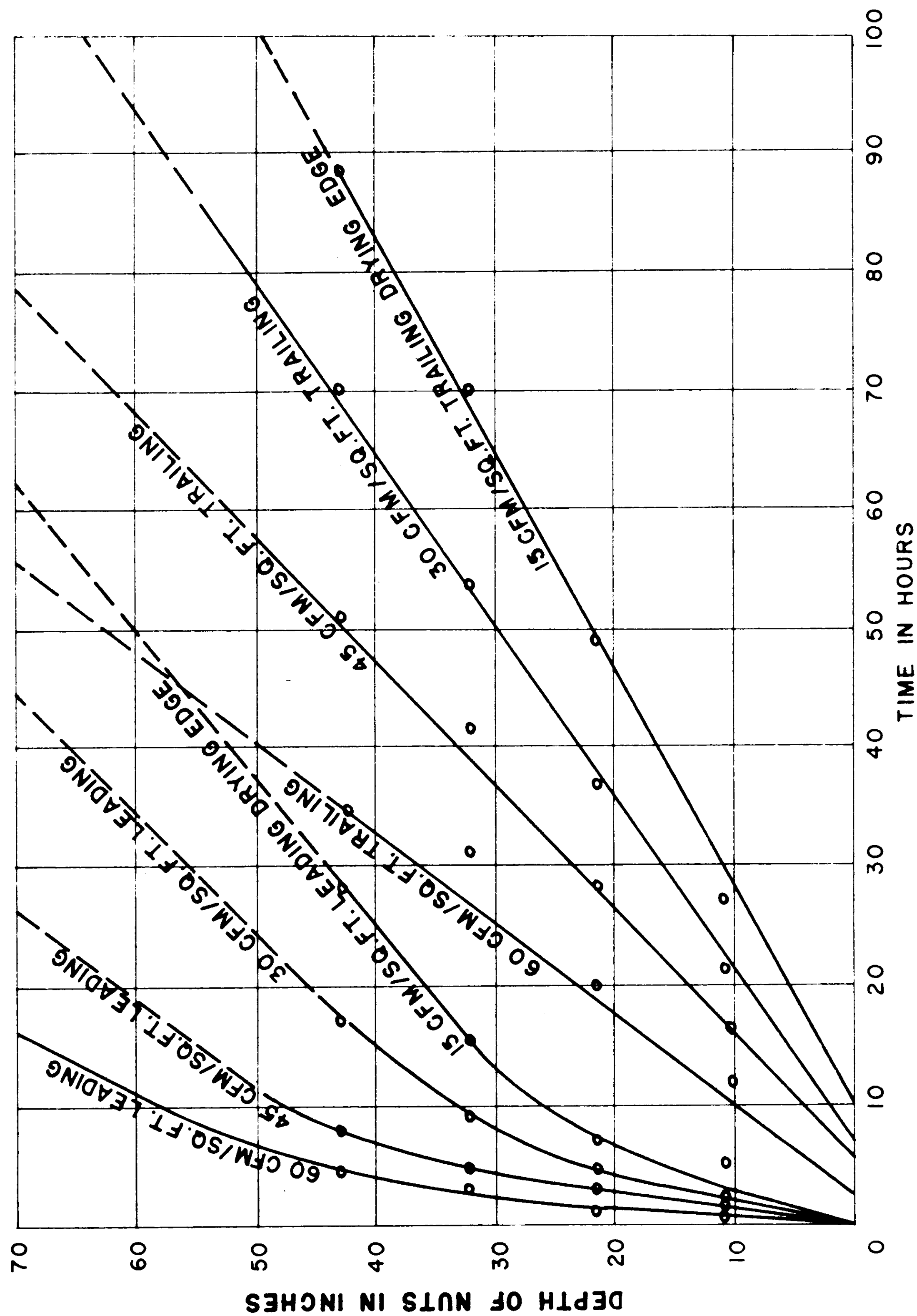


Chart 13 - Drying Edges of Peanuts, 1949 Fundamental Studies, Test 1, Temp. 96 F

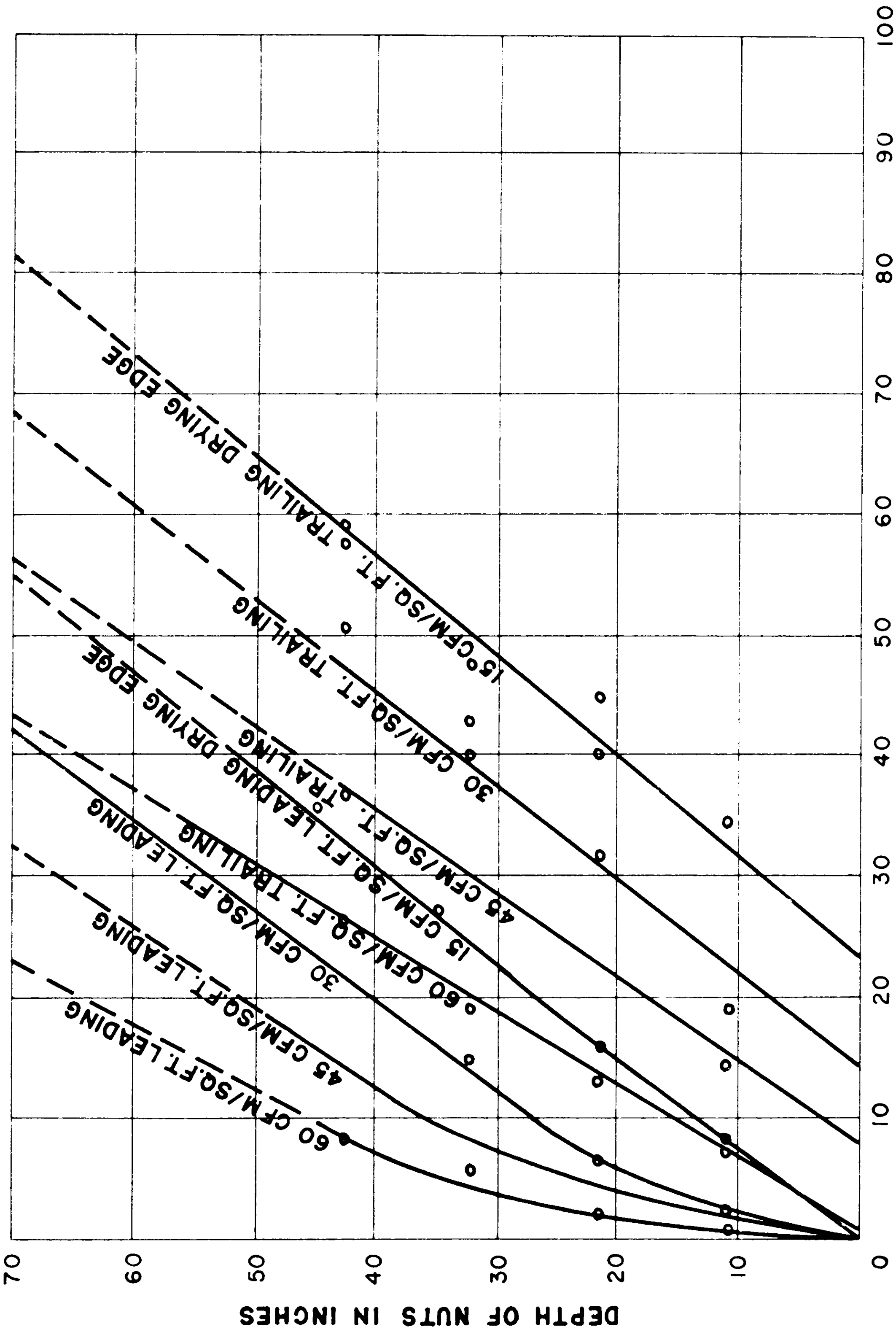


Chart 14 - Drying Edges of Peanuts, 1949 Fundamental Studies, Test 2, Temp. 120 F

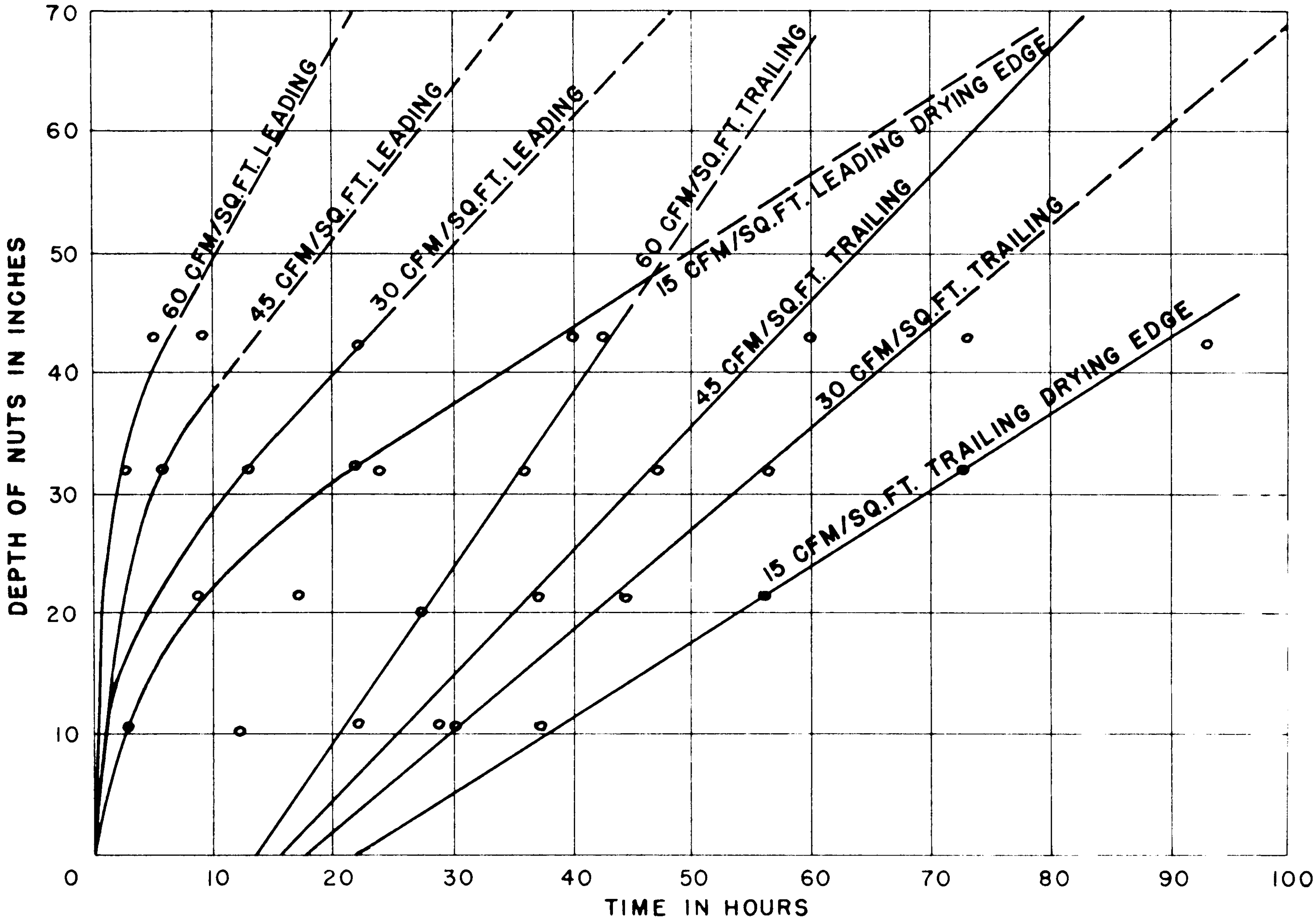


Chart 15 - Drying Edges of Peanuts, 1949 Fundamental Studies, Test 3, Temp. 90 F

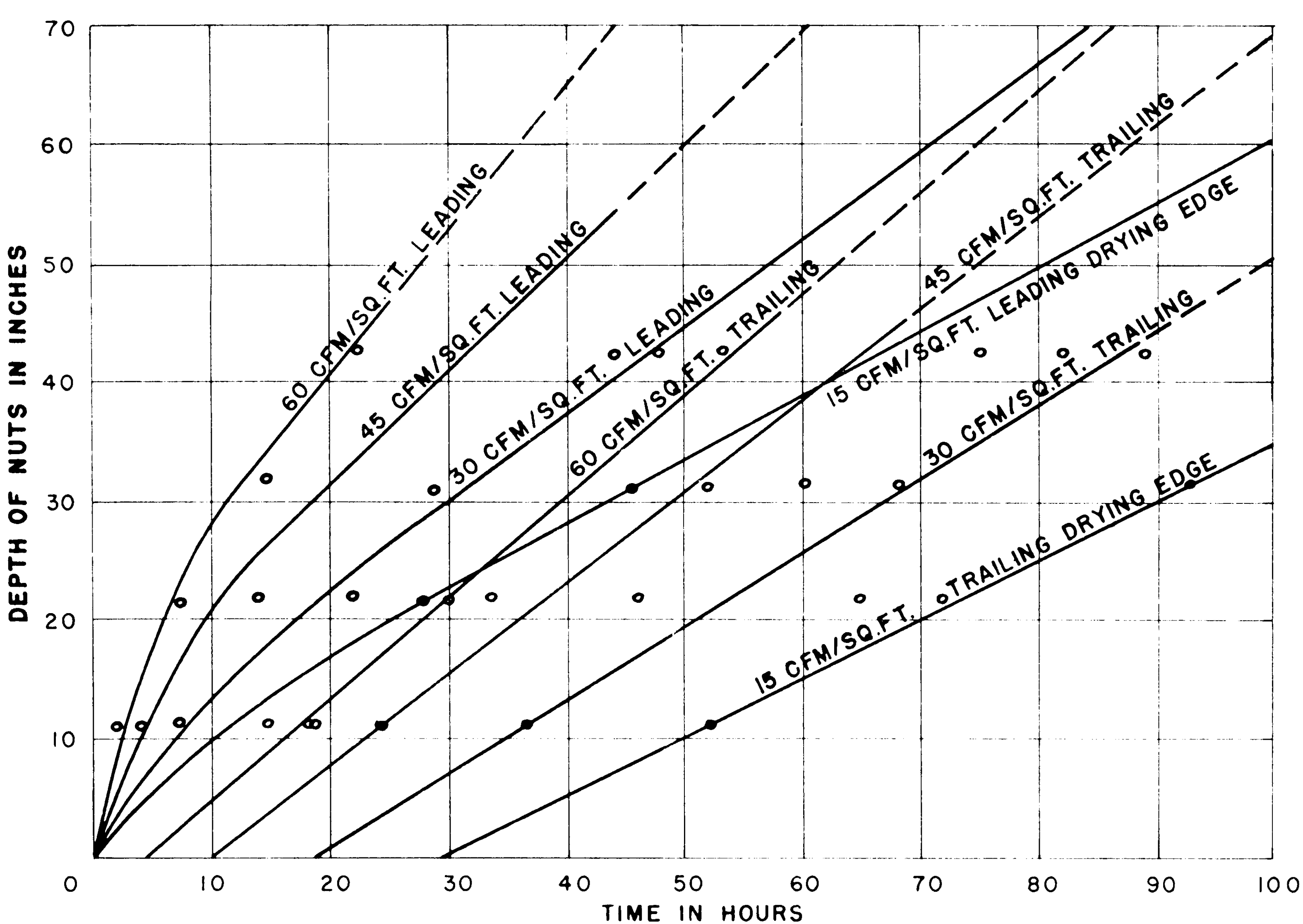


Chart 16 - Drying Edges of Peanuts, 1949 Fundamental Studies, Test 4, Temp. 80 F

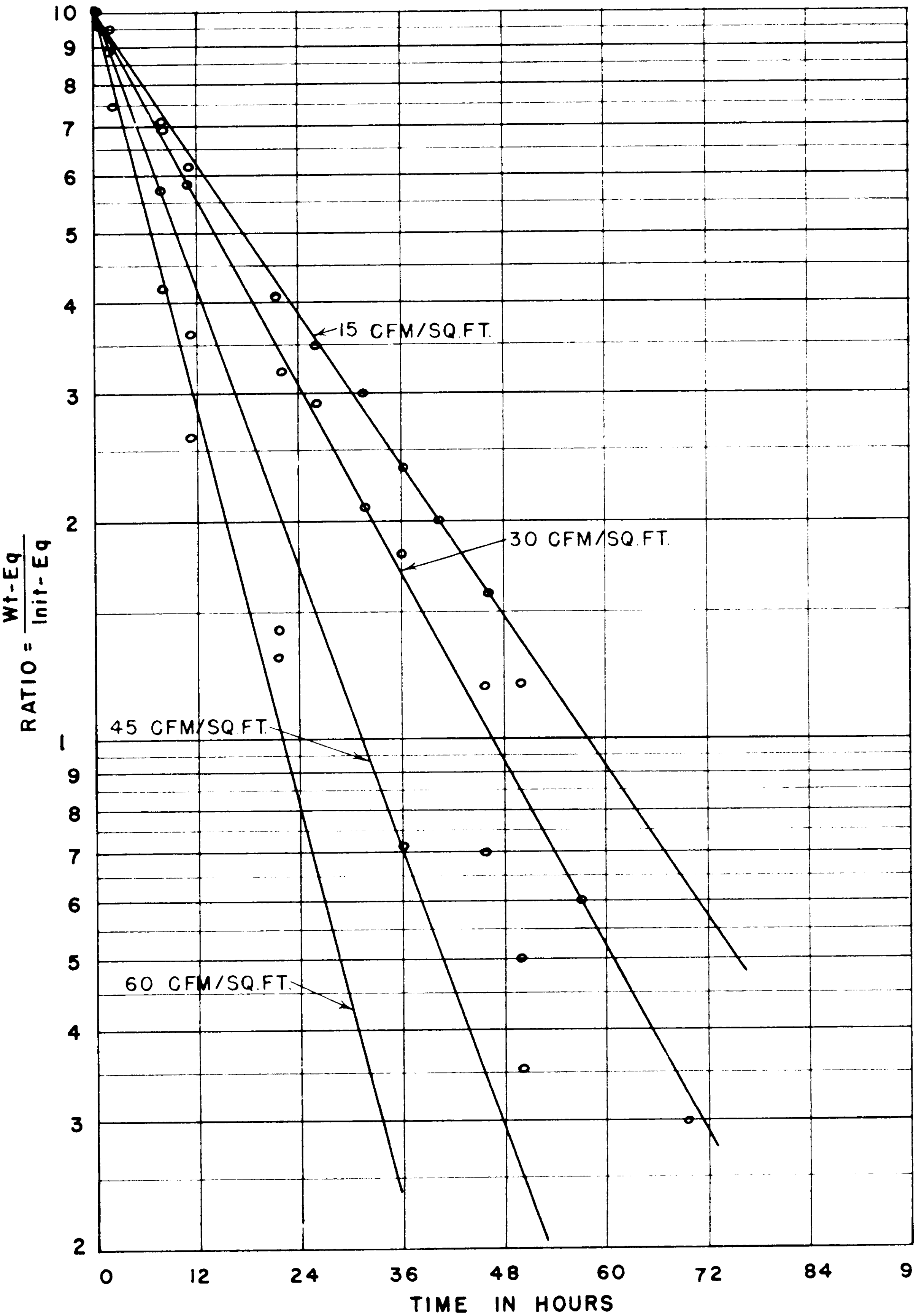


Chart 17 - Moisture Ratio of Peanuts, 1949 Fundamental Studies,
Test 1, Temp. 96 F

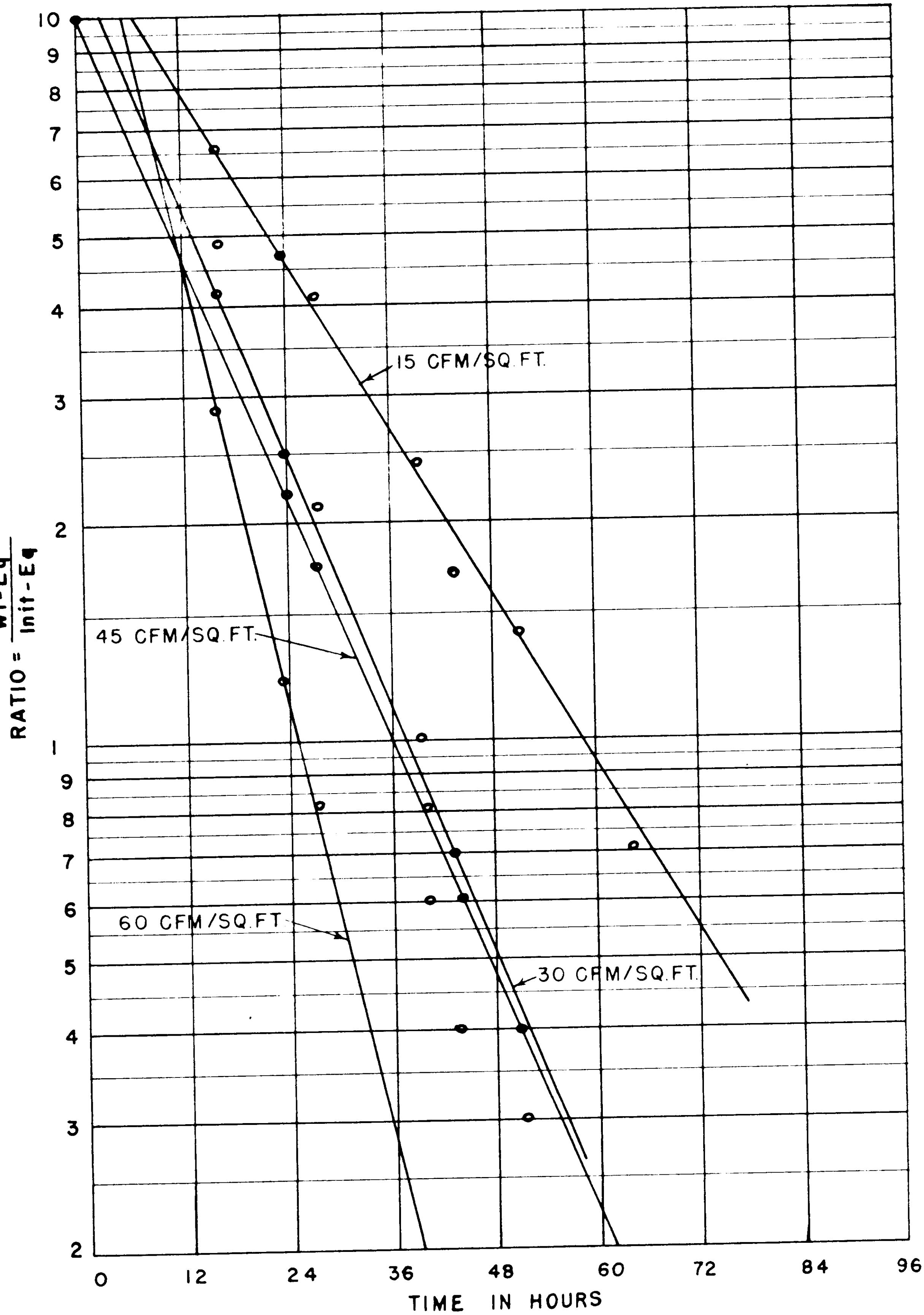


Chart 13 - Moisture Ratio of Peanuts, [illegible] Fundamental Studies,
Test 2, Temp. 10[illegible]

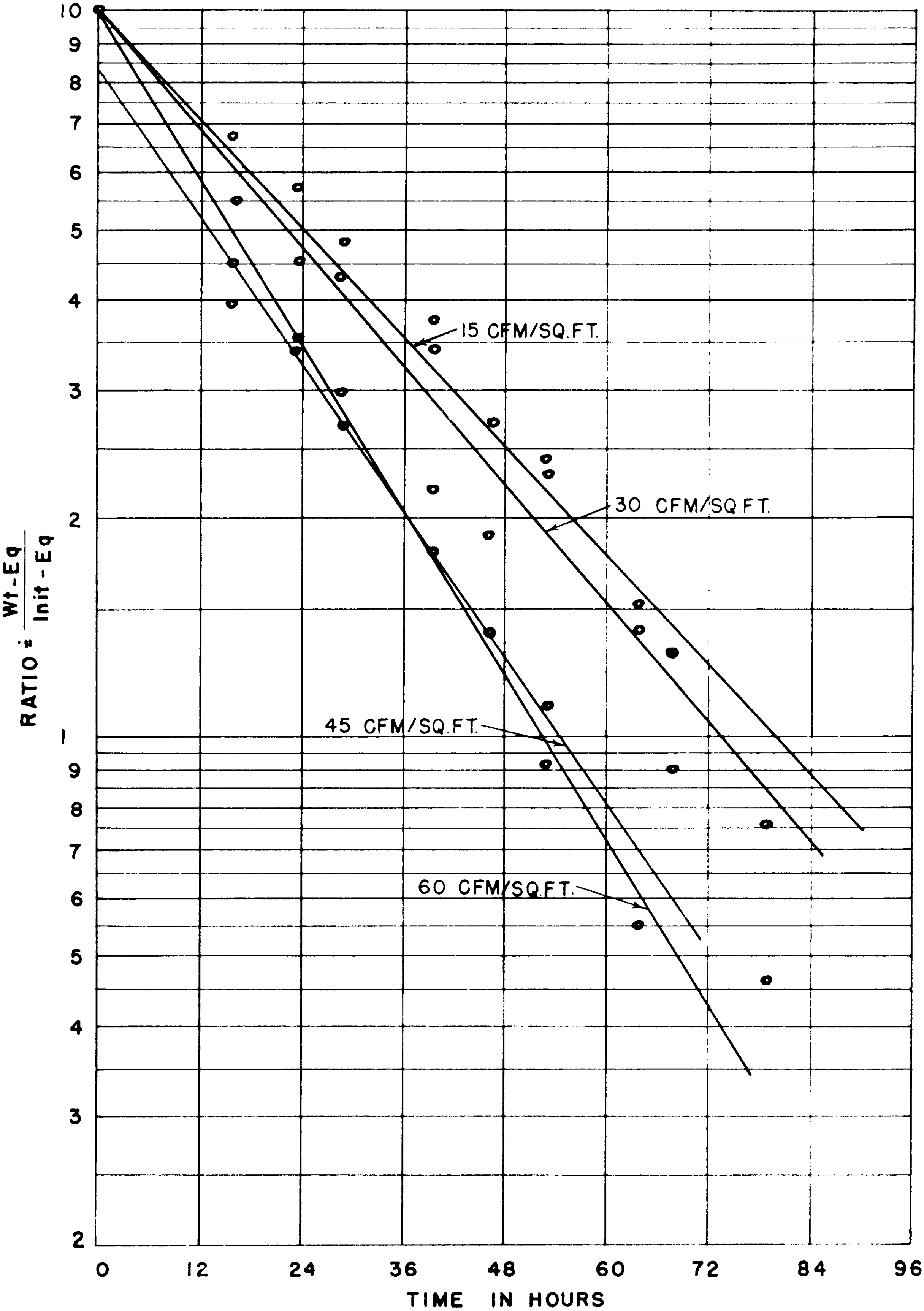


Chart 19 - Moisture Ratio of Peanuts, 1949 Fundamental Studies, Test 3, Temp. 90 F

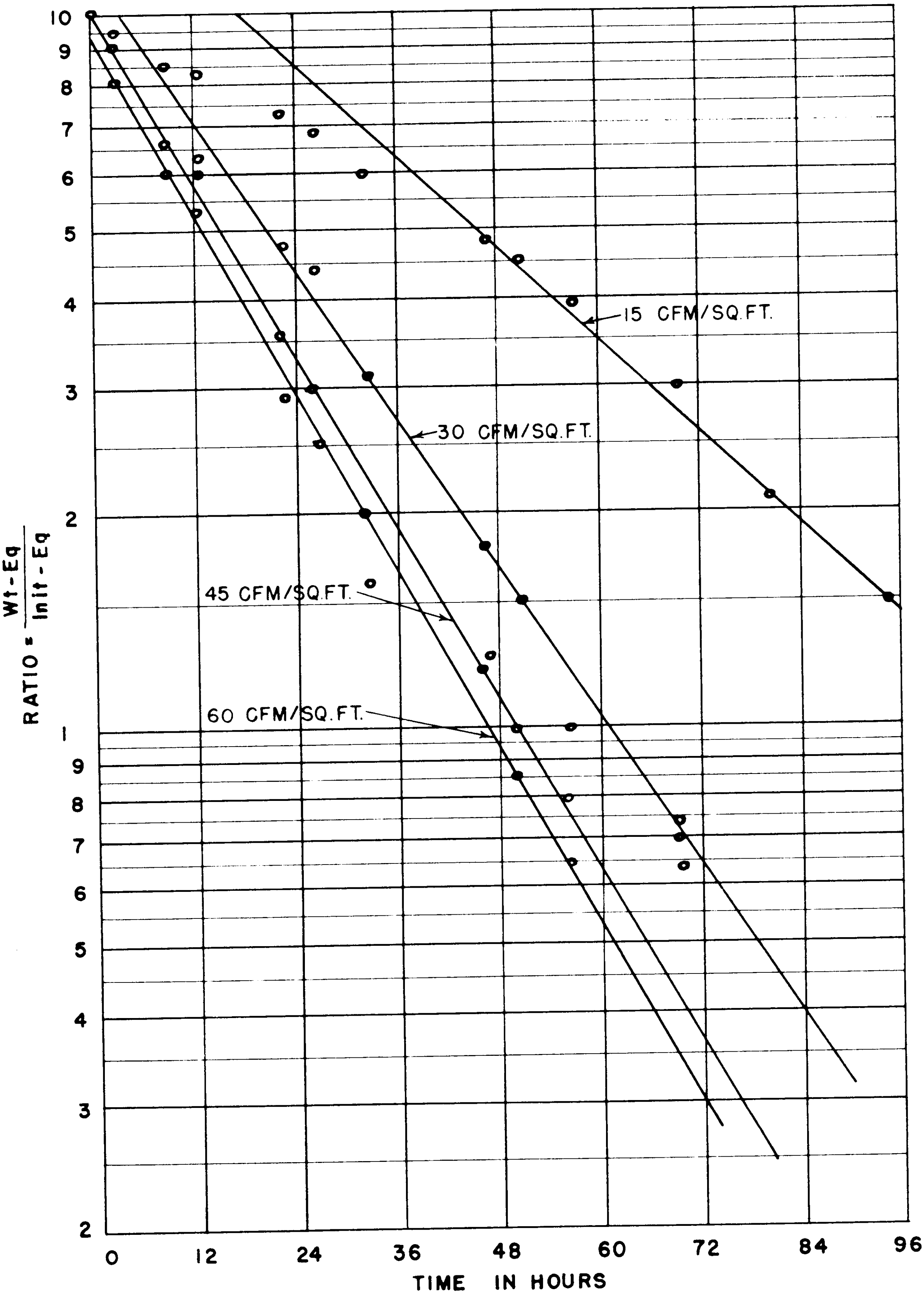


Chart 20 - Moisture Ratio of Peanuts, 1949 Fundamental Studies, Test 4, Temp. 80 F

APPENDIX B

ORIFICE CALCULATIONS

ORIFICE CALCULATIONS FOR FUNDAMENTAL COLUMN DRIER

Basic Conditions

1.	Diameter of duct, ft	0.7290
2.	Area of duct, sq ft	0.4200
3.	Diameter of orifice, ft	0.1250
4.	Area of orifice, sq ft	0.0122
5.	Air flow, cfm per sq ft	45.0000

Static Pressure for 45 cfm per sq ft Air Flow

$$q = 4005\ C\ A\ (p)^{\frac{1}{2}}$$

$$p = \left(\frac{q}{4005\ C\ A} \right)^2$$

Where q = cu ft of air per min

C = coefficient of discharge assuming standard air

A = area of orifice in sq ft

p = pressure difference in inches of water between the pressure in the duct before the orifice and the pressure after the orifice

$$p = \left(\frac{45 \times 0.42}{0.0122 \times 0.60 \times 4005} \right)^2$$

p = 0.42 in of water

Orifice Calibrations for Fundamental Column Drier

Air Flow cfm per sq ft	Static Pressure inches of water 1½ in orifice	Static Pressure inches of water 2 in orifice
30	0.18	0.06
45	0.42	0.13
60	0.74	0.23
75	1.15	0.36

APPENDIX C

CONTINUOUS DRIER EFFICIENCY CALCULATIONS

EFFICIENCY CALCULATIONS FOR CONTINUOUS DRIER

Basic Conditions: Values taken from Test 1, 1951 season

1.	Dry bulb temperature of entering air, F	78.7
2.	Dry bulb temperature of exhaust air, F	69.0
3.	Dry bulb temperature difference between entering and exhaust air, F	9.7
4.	Mean outside dry bulb temperature, F	60.0
5.	Dry bulb temperature difference between outside and entering air, F	18.7
6.	Mean relative humidity of entering air, percent	36.0
7.	Mean relative humidity of exhaust air, percent	63.0
8.	Mean relative humidity of outside air, percent	71.5
9.	Wet bulb temperature of entering air, F	61.5
10.	Wet bulb temperature of exhaust air, F	61.0
11.	Weight of wet nuts loaded, lbs	7709.0
12.	Moisture content of peanuts loaded, percent	36.9
13.	Weight of moisture removed, lbs	2479.0
14.	Moisture content of peanuts unloaded, percent	9.3
15.	Duration of test, hrs	72.0
16.	Amount of fuel used, gals	190.0
17.	Higher heating value of fuel, Btu per gal	135000.0
18.	Amount of air, cfm	10000.0

Heat Added to The Air

$$H = \frac{q \times 60 \times t_d \times c \times T}{c_v}$$

Where H = Heat added to air, Btu

q = Air flow, cu ft per min

t_d = Dry bulb temperature difference between entering and exhaust air, F

c = Specific heat of air

c_v = Specific volume of air

T = Duration of test, hrs

$$H = \frac{10000 \times 60 \times 9.7 \times .24 \times 72}{13.75}$$

$$H = 7.3 \times 10^6 \text{ Btu}$$

Heat Given up by The Fuel

$$H_f = HHV \times F$$

Where H_f = Heat given up by the fuel

HHV = Higher heating value of fuel, Btu per gal

F = Total amount of fuel used, gals

$$H_f = 135000 \times 190 = 2.562 \times 10^7$$

Efficiency of The Burner

$$E_b = \frac{H}{H_f} \times 100$$

Where E_b = Efficiency of the burner, percent

H = Heat added to the air

H_f = Heat given up by the fuel

$$E_b = \frac{7.3 \times 10^6}{2.57 \times 10^7} \times 100$$

$$E_b = 28.4$$

Heat Utilized

$$H_u = 1050\ W_w$$

Where H_u = Heat used for evaporating water

1050 = Amount of heat required to vaporize one unit of water at standard conditions

W_w = Weight of water evaporated

$$H_u = 1050 \times 2479$$

$$H_u = 2.6 \times 10^6$$

Heat Available for Drying

$$H_d = \frac{q \times 60 \times c \times T \times t_{dw}}{c_v}$$

Where H_d = Heat available for drying, Btu

q = Air flow, cfm

c = Specific heat of air

T = Total time of test, hrs

t_{dw} = Temperature difference between entering dry bulb and exhaust wet bulb

c_v = Specific volume of air

$$H_d = \frac{10000 \times 60 \times .24 \times 72 \times 17.2}{13.75}$$

$$H_d = 1.29 \times 10^7$$

Efficiency of Drying

$$E_d = \frac{H_u}{H_d} \times 100$$

Where E_d = Efficiency of drying, percent

H_u = Heat utilized, Btu

H_d = Heat available for drying, Btu

Efficiency of Drying Continued

$$E_d = \frac{2.6 \times 10^6}{1.29 \times 10^7} \times 100$$

$$E_d = 20.2$$

APPENDIX D

TABLES OF FUNDAMENTAL DRYING DATA, SUMMARY OF CONDITIONS USED IN FUNDAMENTAL DRYING STUDIES, LOADING SCHEDULE AND SUMMARY FOR CONTINUOUS DRYING STUDIES, DATA OBTAINED IN CONTINUOUS STUDIES, SUMMARY OF GERMINATION DATA, PEANUT BUTTER SCORE CARD, SUMMARY AND RANK OF PEANUT BUTTER TASTE TESTS, AND QUALITY REPORTS

Table 1

Fundamental Drying Data of The Small Peanut Samples Used
In The Statistical Analysis for The Determination
Of The Prediction Equations
1949

Y_1	Y_2	Y_3	Y_4	Y_5	X_1	X_2	X_3	X_4
Maximum Thickness of Drying Layer Inches	Rate of Movement of Drying Zone Inches/Hr.	Time of Departure of Y_2 in Hrs.	Hrs. to Reach 1/2 Equilibrium Weight	Final MC Bottom Layer (Dry basis)	Initial MC Dry Basis	Av. Temp. Entering Air Deg. F.	Av. RH Entering Air	Air Flow CFM Per Sq. Ft.
25.0	0.49	27.0	27.00	8.20	65.0	80.1	50	15
27.0	0.65	11.0	17.25	5.50	65.0	80.1	50	30
30.0	0.76	10.0	17.50	6.50	65.0	80.1	50	45
34.0	0.84	4.0	14.50	5.50	65.0	80.1	50	60
32.0	0.65	22.0	25.50	6.90	62.8	90.2	57	15
42.0	0.84	10.0	22.00	5.05	62.8	90.2	57	30
[illegible]	0.96	15.5	13.00	5.15	62.8	90.2	57	45
36.0	1.44	15.5	14.00	5.90	62.8	90.2	57	60
31.5	0.96	11.0	17.50	8.50	54.0	96.0	42	15
[illegible]	0.71	7.0	14.00	8.30	54.0	96.0	42	30
44.0	1.00	5.5	9.50	1.50	54.0	96.0	42	45
50.0	1.32	2.8	6.50	5.60	54.0	96.0	42	60
36.5	1.27	25.5	17.75	3.50	54.1	115.3	28	15
[illegible]	1.29	14.5	10.25	9.30	54.1	115.3	28	30
37.5	1.46	8.0	8.15	1.00	54.1	115.3	28	45
40.4	1.76	1.0	6.25	1.60	54.1	115.3	28	60

Table 2

Summary of The Conditions Used in The Fundamental Drying Work at Holland in 1949

Test 1			
Sample	Air Flow CFM/ Sq. Ft.	Deg. F	Initial MC
1B1	15	96	35.0
1T1	15	96	35.0
1B2	30	96	35.0
1T2	30	96	35.0
1B3	45	96	35.0
1T3	45	96	35.0
1B4	60	96	35.0
1T4	60	96	35.0

Test 2			
Sample	Air Flow CFM/ Sq. Ft.	Deg. F	Initial MC
2B1	15	115	35.1
2T1	15	115	35.1
2B2	30	115	35.1
2T2	30	115	35.1
2B3	45	115	35.1
2T3	45	115	35.1
2B4	60	115	35.1
2T4	60	115	35.1

Test 3			
Sample	Air Flow CFM/ Sq. Ft.	Deg. F	Initial MC
3B1	15	90	38.45
3T1	15	90	38.45
3B2	30	90	38.45
3T2	30	90	38.45
3B3	45	90	38.45
3T3	45	90	38.45
3B4	60	90	38.45
3T4	60	90	38.45

Test 4			
Sample	Air Flow CFM/ Sq. Ft.	Deg. F	Initial MC
4B1	15	80	38.5
4T1	15	80	38.5
4B2	30	80	38.5
4T2	30	80	38.5
4B3	45	80	38.5
4T3	45	80	38.5
4B4	60	80	38.5
4T4	60	80	38.5

Table 2-A

Summary of The Conditions Used in The Fundamental
Drying Work at Holland in 1950

Test 1				Test 2			
Sample	Air Flow CFM / Sq. Ft.	Deg. F	Initial MC	Sample	Air Flow CFM / Sq. Ft.	Deg. F	Initial MC
1B1	15	80	33.3	2B1	15	120	45
1T1	15	80	33.3	2T1	15	120	45
1B2	30	80	33.3	2B2	30	120	45
1T2	30	80	33.3	2T2	30	120	45
1B3	45	80	33.3	2B3	45	120	45
1T3	45	80	33.3	2T3	45	120	45
1B4	60	80	33.3	2B4	60	120	45
1T4	60	80	33.3	2T4	60	120	45

Test 3			
Sample	Air Flow CFM / Sq. Ft.	Deg. F	Initial MC
3B1	15	100	47.3
3T1	15	100	47.3
3B2	30	100	47.3
3T2	30	100	47.3
3B3	45	100	47.3
3T3	45	100	47.3
3B4	60	100	47.3
3T4	60	100	47.3

Table 3

Loading Schedule and Summary for
Continuous Drying Studies 1949

Test	Date	Time	Loaded Lbs.	Unloaded Lbs.
1	10/3/49	1800	2003	
	10/4/49	1700	1525	
	10/5/49	1100	4099	
	10/6/49	1000	2349	
	10/7/49	0900		786
	10/10/49	1400		1727
	10/12/49	0800		2707
2	10/13/49	1200	2089	
	10/14/49	1600	4798	
	10/15/49	1000	1303	
	10/18/49	1600	3985	
	10/19/49	1000	4852	
	10/20/49	1400		2659
	10/21/49	1000		1315
	10/24/49	2000		1532
	10/26/49	0800		2751
3	10/18/49	1600	3984	
	10/19/49	0800	4852	
	10/24/49	2000		836
	10/25/49	1300		766
	10/26/49	0800		2751

Summary

Test 1	Lbs.	Test 2	Lbs.	Test 3	Lbs.
Peanuts Loaded	9976	Peanuts Loaded	17024	Peanuts Loaded	8836
Trash Removed	0	Trash Removed	0	Trash Removed	0
Wet Nuts Dried	9976	Wet Nuts Dried	17024	Wet Nuts Dried	8836
Peanuts Unloaded	5220	Peanuts Unloaded	8257	Peanuts Unloaded	4353
Water Lost	4756	Water Lost	8767	Water Lost	4483

Table 3-A

Loading Schedule and Summary for
Continuous Drying Studies 1950

Test	Date	Time	Loaded Lbs.	Unloaded Lbs.
1	10/4/50	1300	6634	
	10/5/50	0900	1882	
	10/7/50	1000	3365	
	10/9/50	2000		5875
	10/19/50	0800		2135
2	10/19/50	1650	241	
	10/19/50	1300	6225	
	10/20/50	1000	8845	
	10/23/50	1900		7648
3	10/23/50	2000	8470	
	10/24/50	2000		6089

Summary

Test 1	Lbs.	Test 2	Lbs.	Test 3	Lbs.
Peanuts Loaded	11881	Peanuts Loaded	15311	Peanuts Loaded	8470
Trash Removed	300	Trash Removed	660	Trash Removed	350
Net Nuts Dried	11581	Net Nuts Dried	14651	Net Nuts Dried	8120
Peanuts Unloaded	8010	Peanuts Unloaded	7648	Peanuts Unloaded	6089
Water Lost	3571	Water Lost	7003	Water Lost	2031

Table 3-B

Loading Schedule and Summary for
Continuous Drying Studies 1951

Test	Date	Time	Loaded Lbs.	Unloaded Lbs.
1	10/8/51	1000	2500	
		1300	2609	
		1500	1500	
		1800	1900	
	10/11/51	0800		2000
		1700		1500
		2100		2049
2	10/20/51	0900	2300	
		1300	2000	
		1700	2550	
		2000	1962	
	10/22/51	1000		1000
		1400		2000
		1900		500
		2300		1834

Summary

Test 1	Lbs.	Test 2	Lbs.
Peanuts Loaded	8109	Peanuts Loaded	8812
Trash Removed	400	Trash Removed	450
Wet Nuts Dried	7709	Wet Nuts Dried	8362
Peanuts Unloaded	5549	Peanuts Unloaded	5334
Water Lost	2160	Water Lost	3028

Table 4

Data Obtained in Continuous Drying Studies
Holland, Virginia, 1949

Test	1	2
Entering air, dry bulb temperature, deg. F	82.5	85.5
Exhaust air, dry bulb temperature, deg. F	74.3	67.9
Ambient air, dry bulb temperature, deg. F	73.4	64.3
Entering air, relative humidity, percent	53.1	44.8
Exhaust air, relative humidity, percent	73.0	75.0
Ambient air, relative humidity, percent	73.7	72.1
Entering air, wet bulb temperature, deg. F	69.5	69.2
Exhaust air, wet bulb temperature, deg. F	67.3	62.5
Duration of test, hours	157.5	241.0
Fuel used, gallons	134.0	316.0
HHV of fuel used, 1000 Btu per gallon	135.0	135.0
Air delivered, cubic feet per minute	5900.0	5440.0
Weight of water removed from nuts, pounds	4757.0	8768.0
Heat available for drying, 1000 Btu	12900.0	22800.0
Heat used for drying, 1000 Btu	4110.0	7550.0
Efficiency of drying, percent	31.8	33.1

Table 4-A

Data Obtained in Continuous Drying Studies
Holland, Virginia, 1950

Test	1	2	3
Entering air, dry bulb temperature, deg. F	83.1	88.3	95.1
Exhaust air, dry bulb temperature, deg. F	67.0	73.3	81.6
Ambient air, dry bulb temperature, deg. F	70.2	72.1	70.5
Entering air, relative humidity, percent	37.0	49.0	42.0
Exhaust air, relative humidity, percent	87.0	98.2	74.0
Ambient air, relative humidity, percent	85.5	89.6	89.6
Entering air, wet bulb temperature, deg. F	64.5	72.8	75.8
Exhaust air, wet bulb temperature, deg. F	64.5	72.8	75.8
Duration of test, hours	80.0	84.3	25.0
Fuel used, gallons	131.0	165.5	81.3
HHV of fuel used, 1000 Btu per gallon	135.0	135.0	135.0
Air delivered, cubic feet per minute	10037.0	9850.0	9875.0
Weight of water removed from nuts, pounds	3494.0	7522.0	666.0
Heat available for drying, 1000 Btu	15880.0	13700.0	5000.0
Heat used for drying, 1000 Btu	3670.0	7900.0	700.0
Efficiency of drying, percent	23.1	57.6	13.8

Table 4-3

Data Obtained in Continuous Drying Studies
Holland, Virginia, 1951

Test	1	2
Entering air, dry bulb temperature, deg. F	78.7	87.8
Exhaust air, dry bulb temperature, deg. F	69.0	75.8
Ambient air, dry bulb temperature, deg. F	60.0	68.2
Entering air, relative humidity, percent	36.0	38.0
Exhaust air, relative humidity, percent	63.0	69.2
Ambient air, relative humidity, percent	71.5	74.5
Entering air, wet bulb temperature, deg. F	61.5	68.5
Exhaust air, wet bulb temperature, deg. F	61.0	69.0
Duration of test, hours	72.0	46.0
Fuel used, gallons	190.0	125.0
HHV of fuel used, 1000 Btu per gallon	135.0	135.0
Air delivered, cubic feet per minute	10000.0	10000.0
Weight of water removed from nuts, pounds	2479.0	3044.0
Heat available for drying, 1000 Btu	12700.0	8890.0
Heat used for drying, 1000 Btu	7320.0	3215.0
Efficiency of drying, percent	20.2	43.0

Table 5.

Summary of Germination Data
Peanut Drying Studies 1950

Temp. Deg. F	Air Flow CFM/sq. ft.	Date Started	Number of Nuts	Number Sprouted	Date Ended	% Germ.
83.1	60	11/21	400	370	12/12	92.50
88.3	60	11/21	400	397	12/12	99.25
95.1	60	11/21	300	221	12/12	73.67
80.0	15	11/21	400	359	12/12	89.75
80.0	30	11/21	400	393	12/12	98.25
80.0	45	11/21	400	367	12/12	91.75
80.0	60	11/21	400	343	12/12	85.75
100.0	15	11/21	400	263	12/12	65.75
100.0	30	11/21	400	354	12/12	88.50
100.0	45	11/21	400	300	12/12	75.00
100.0	60	11/21	400	332	12/12	83.00
120.0	15	11/21	400	311	12/12	77.75
120.0	30	11/21	400	387	12/12	96.75
120.0	45	11/21	400	301	12/12	75.25
120.0	60	11/21	400	256	12/12	64.0
Field	Cured	12/11	400	363	1/11/51	90.75

Table 6

Peanut Butter Score Card

CODE

A.	Taste	60%
B.	Texture	20% oil and butter well mixed smooth
C.	Spreadability	10% relative value of spreading
D.	Color	10%

Temp.	Air Flow CFM/ Sq. Ft.	Taste	Texture	Spreadability	Color
120	15	50	20	9	8
120	30	45	20	10	6
120	45	45	18	5	6
120	60	45	20	10	6
100	15	60	10	4	7
100	30	50	18	10	9
100	45	55	18	10	7
100	60	50	18	9	9
80	15	45	10	7	6
80	30	58	18	9	8
80	45	45	18	9	6
80	60	40	18	9	6
Continuous Test #1		55	16	8	10
Continuous Test #2		60	19	9	9
Continuous Test #3		50	19	9	6
Field Cured		58	20	7	7

(Signature and Title of Taster)

Table 7

Summary and Rank of Peanut Butter Taste Test Data
1949

Rank	Score Total	Initial M.C.(WB)	Hrs. of Test	Temp. Deg. F	Air Flow CFM / Sq. Ft.
1	1027	Commercial Sample No. 1			
2	929	Field Cured Sample No. 1			
3	924	35.0	78.0	96	60
4	898	Field Cured Sample No. 2			
5	840	35.0	78.0	96	15
6	836	Field Cured Sample No. 1			
7	821	Commercial Sample No. 2			
8	776	38.5	78.5	90	60
9	768	38.5	78.5	90	30
10	762	Field Cured Sample No. 1			
11	760	38.5	102.0	80	60
12	720	38.5	102.0	80	45
13	705	38.5	102.0	80	15
14	651	38.5	102.0	80	30
15	541	35.1	64.5	115	15
16	479	35.1	64.5	115	60

Table 7-A

Summary and Rank of Peanut Butter Taste Test Data
1950

Rank	Score Total	Initial M.C.(WB)	Hrs. of Test	Temp. Deg. F	Air Flow CFM/ Sq. Ft.
1	530	55	84.3	Continuous Test No. 2	
2	513	43	52.0	120.0	15
3	488	33.3	75.5	80.0	30
4	485	34.2	80.0	Continuous Test No. 1	
5	480	47.3	96.2	100.0	45
6	468	47.3	96.2	100.0	30
7	454	33.3	75.5	80.0	15
8	450	47.3	96.2	100.0	60
9	450	33.3	75.5	80.0	45
10	439	43.0	52.0	120.0	60
11	436	47.3	96.2	100.0	15
12	434	Field Cured Sample			
13	424	43.0	52.0	120.0	45
14	420	43.0	52.0	120.0	[illegible]
15	391	33.3	75.5	80.0	60
16	371	17.8	25.0	Continuous Test No. 3	

Table 8

1950 Peanut Quality Report From
Planters Nut and Chocolate Company
Suffolk, Virginia

Temp. Deg. F	Air Flow CFM / Sq.Ft.	Moisture Content	Hand Blanch Raw	Butter Flavor	Butter Odor	Peroxide Value
80	15	5.3	No	Over cooked	Over cooked	0.410
80	30	5.7	No	Slightly off	Slightly off	0.461
80	45	5.7	No	Slightly off	Slightly off	0.52[illegible]
80	60	5.7	No	Over cooked	Over cooked	0.632
120	15	7.7	No	Good	Good	0.632
120	30	5.7	No	Good	Good	0.316
120	45	5.3	Slightly	Off	Off	0.614
120	60	5.3	Yes	Off	Off	0.351
100	15	5.7	Yes	Over cooked	Over cooked	0.526
100	30	5.7	No	Good	Good	0.474
100	45	5.3	Yes	Slightly off	Fair	0.410
100	60	5.3	Yes	Off	Off	0.474
Field Cured		8.5	No	Good	Good	0.175
Continuous Test #1		5.7	Slightly	Good	Good	0.794
Continuous Test #2		6.7	Slightly	Off	Off	0.263
Continuous Test #3		6.0	Yes	Good	Good	0.316

Table 8-A

1950 Peanut Quality Report From U.S.D.A.
Division of Fruits and Vegetables
Beltsville, Maryland

Temp. Deg. F	Air Flow CFM / Sq. Ft.	Percent Breakage or Slippage	Quality of Peanut Butter Made From The Sample
80	15	8.97	Flat, but no off flavor.
80	30	12.08	Flat, a little off flavor.
80	45	14.99	Flat, a little off flavor.
80	60	11.65	Flat, and distinctly off flavor.
120	15	17.80	Flat and off flavor.
120	30	37.77	Flat, disagreeable taste.
120	45	32.10	Flat, disagreeable taste.
120	60	51.14	Flat, disagreeable taste.
100	15	12.80	Flat and off flavor.
100	30	34.22	Flat and distinctly off flavor.
100	45	24.52	Badly off flavor; inedible.
100	60	34.74	Badly off flavor; inedible.
Field	Cured	5.70	No off flavor, but lacks aroma.
Continuous Test #1		13.70	Lacks desirable flavor
Continuous Test #2		8.69	Lacks desirable flavor
Continuous Test #3		11.45	Lacks desirable flavor

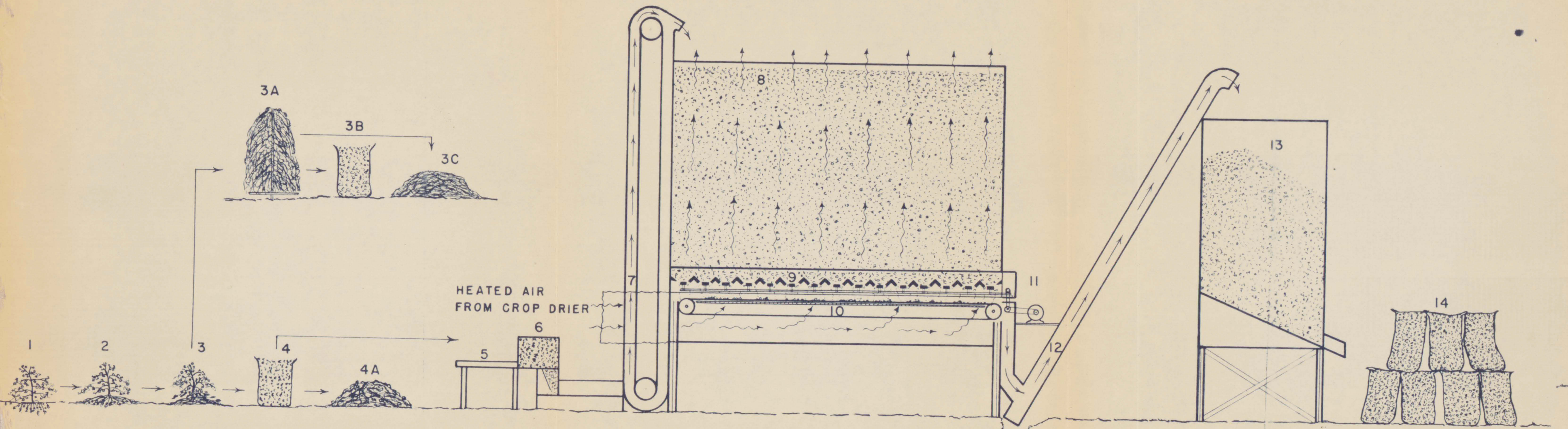
Table C-3

1950 Peanut Quality Report From Chemical Department
Virginia Agricultural Experiment Station
Virginia Polytechnic Institute
Blacksburg, Virginia

Temp. Deg. F	Air Flow CFM/ Sq. Ft.	Percent Moisture after Additional Drying	Percent Protein Dry Basis	Percent Ether Extract Dry Basis	Rancidity Test
80	15	1.38	29.81	47.17	Negative
80	30	1.62	29.44	47.13	Negative
80	45	1.19	30.00	47.11	Negative
80	60	1.65	30.00	46.63	Negative
120	15	1.47	31.06	45.17	Negative
120	30	1.46	30.38	44.78	Negative
120	45	1.54	30.38	45.71	Negative
120	60	1.21	29.38	46.68	Negative
100	15	1.27	30.31	44.70	Negative
100	30	1.73	30.31	44.65	Negative
100	45	1.47	30.19	45.63	Negative
100	60	1.65	30.44	45.89	Negative
Field	Cured	1.90	30.88	45.54	Negative
Continuous	Test #1	1.45	29.56	46.72	Negative
Continuous	Test #2	1.58	30.13	45.33	Negative
Continuous	Test #3	1.32	30.13	45.32	Negative

APPENDIX E

PEANUT FLOW CHART



Flow diagram of peanut harvesting and drying process with cross-section of continuous drier. 1.- Nuts on vine before dug 2. -Nuts and vine after nuts have been removed from soil 3. -Nuts and vine after soil has been shaken from nuts. 3A -Conventional field stack of nuts and vines 3B -Field cured nuts 3C -Field cured hay 4. -Wet nuts removed from wet vines 4A. 5. -Loading platform 6. -Cleaner 7. -Vertical cup elevator 8. -Drying bin 9. - Unloading shaker 10. -Horizontal dry nut conveyor 11. -Driving mechanism for unloading shaker 12. -Incline dry nut elevator 13. -Dry nut storage 14. -Sacks of dry nuts ready for market.