HEAT OF RESPIRATION OF HIGH MOISTURE SPANISH PEANUTS

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SPANISH PEANUTS

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PREFACE

This study was concerned with the heat of respiration of high moisture Spanish peanuts. The primary objective of the study was to measure the effect of storage temperature, initial moisture content, and time in storage on the rate of heat produced by the peanuts and any micro-organisms present during the test. A respiration calorimeter was designed and constructed for the study.

The research reported in this study was partially supported by funds from the Oklahoma Agricultural Experiment Station.

The author is especially grateful to his major adviser, Dr. Bobby L. Clary, for his capable guidance and encouragement during this study. His leadership has been an inspiration from the initiation of the study through the preparation of the manuscript.

Appreciation is extended to other members of the Advisory Committee. Professor Jay G. Porterfield, Chairman of the Advisory Committee and Professor of Agricultural Engineering, Dr. Glenn W. Todd, Professor of Botany, Dr. John A. Wiebelt, Professor of Mechanical and Aerospace Engineering served in this manner. Their suggestions and criticisms have been very valuable throughout this study.

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For their sacrifices, patience and encouragement throughout this study, I dedicate this thesis to my wife Carol and my children, Deborah, Linda and Susan.

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LIST OF SYMBOLS

Symbol	Quantity	Units
β_0, β_1, β_2 β_3, β_4	Regression coefficients of polynomial equation	---
C_p	Specific heat at constant pressure	cal/(gm-^oC)
C_v	Specific heat at constant volume	cal/(gm-^oC)
C_{pp}	Specific heat of peanut pods	cal/(gm-^oC)
C_{ps}	Specific heat of sulfur lumps	cal/(gm-^oC)
C_{pw}	Specific heat of water	cal/(gm-^oC)
dE	Change in internal stored energy	cal
dQ_{C_x}	Convected heat at x	cal
$dQ_{C_{x+dx}}$	Convected heat at x+dx	cal
dQ_g	Total heat generated in volume element	cal
dQ_x	Quantity of heat conducted at x	cal
dQ_{x+dx}	Quantity of heat conducted at x+dx	cal
dQ_y	Quantity of heat conducted at y	cal
dQ_{y+dy}	Quantity of heat conducted at y+dy	cal
dQ_z	Quantity of heat conducted at z	cal
dQ_{z+dz}	Quantity of heat conducted at z+dz	cal
G_x	Mass velocity or mass flux at x	gm/(sec-cm^2)
g	Gravitational acceleration standard	cm/sec^2
g_c	Newton constant	(cm-gm)/(dyne-sec^2)
H_c	Heat capacity constant	cal/^oC

Symbol	Quantity	Units
i	Enthalpy	cal/gm
J	Mechanical-to-thermal energy conversion factor	(dyne-cm)/cal
K_T	Thermal conductivity, a function of temperature	cal/(sec-cm-^{o}C)
ϕ	Angle	---
M	Moisture content, dry basis, decimal	---
MC	Moisture content, wet basis, percent	---
Q	Total energy transfer in conductor	cal
Q_a	Energy stored in air	cal
Q_f	Energy stored in flask	cal
Q_g	Energy generated	cal
Q_p	Energy stored in peanuts	cal
Q_s	Total energy stored	cal
q_a	Rate of energy storage in air	cal/sec
q_f	Rate of energy stored in flask	cal/sec
q_g	Rate of energy generated	cal/sec
q_p	Rate of energy stored in peanuts	cal/sec
q_s	Rate of total energy stored	cal/sec
q'''_T	Rate of internal heat generated per unit volume, a function of temperature	cal/(sec-cm^3)
q'_θ	Heat of respiration rate at time θ	cal/(gm-hr)
R	Regression correlation coefficient	---
r	Radius	cm
R_c	Rate of temperature rise of mixture after equilibrium temperature is reached	^{o}F/min

Symbol	Quantity	Units
ρ	Density	gm/cm^3
RQ	Respiratory quotient	---
S	Standard deviation	---
S_{pn}	Specific heat of peanuts	$cal/gm-^oC$
T	Temperature	^oC
T_K	Temperature	^oK
T_θ	Temperature at time θ	^oF
T_p	Peanut temperature	$^oC/100$
T_i	Initial bulk peanut temperature	^oF
T_{ic}	Initial peanut temperature	^oC
T_A	Bulk peanut temperature at time A	^oC
T_B	Bulk peanut temperature at time B	^oC
T_e	Equilibrium temperature	^oC
T_∞	Free stream temperature	^oC
ΔT_c	Difference between cold water temperature and final equilibrium temperature	^oF
ΔT_f	Initial flask temperature minus equilibrium temperature of mixture	^oF
ΔT_h	Difference between initial temperature of hot water and equilibrium temperature of mixture	^oF
ΔT_p	Equilibrium temperature of mixture minus initial peanut temperature	^oF
ΔT_s	Difference between initial sulfur and equilibrium temperatures	^oF
ΔT_w	Initial water temperature minus equilibrium temperature of mixture	^oF
θ	Hour of test	hr
θ_A	Time A	hr

Symbol	Quantity	Units
θ_B	Time B	hr
θ_P	Maximum peanut temperature	$^oC/100$
u	Fluid velocity	cm/sec
V_a	Volume of effluent	ml
V	Volume	cm^3
V_c	Per cent by volume of CO_2	---
x	Distance parallel to flask axis	cm
W	Weight	gm
W_b	Weight of $BaCO_3$	gm
W_c	Weight of cold water	gm
W_h	Weight of hot water	gm
W_p	Initial weight of peanuts	gm
W_w	Weight of water used in specific heat tests	gm

CHAPTER I

INTRODUCTION

The Problem

Peanuts and their by-products are important sources of food. Both the protein and oil content of peanuts are of particular importance to the developing countries of the world. However, present harvesting, transporting, storage, and processing equipment and techniques are often inadequate to maintain the field quality of the peanuts.

A significant cause of deterioration of peanut quality is that caused by fungi, yeast, or bacteria in the peanut mass. Fungal development can be prevented in stored peanuts if the moisture content and temperature throughout the mass are correctly controlled throughout the storage period.

In order to design equipment to economically maintain safe levels of temperature and moisture throughout the peanut mass, the rate of heat production liberated in the respiration process by peanuts and any micro-organisms present at various moisture content and temperatures must be known. The respiration of any fungi present will add to the internal heat generated in the mass. However, no attempt was made in this study to measure the heat of respiration of the peanuts separately from fungal heat production. In order to attempt to insure a meaningful correlation between the results of this study and average field conditions, farmer stock peanuts from the Oklahoma State

University Agricultural Experimental Station farm at Perkins, Oklahoma were used.

Objectives

The objectives of this study were:

1. Design and construct a respiration calorimeter.
2. Measure the effect of storage temperature, initial moisture content, and time in storage on the rate of heat produced by the peanuts and any micro-organisms present during the test.

Limitations of the Study

Several factors are known to have an effect on the respiration of biological materials. Some of the factors are discussed in Chapter II.

Although the respiration of any microorganisms present may have considerable effect on the rate of heat generated, no attempt was made to separate this effect from the heat of respiration of the peanuts. Since the soil was removed from the peanut hulls by washing them, many microorganisms were probably removed by washing.

Numerous researchers have reported the effect of temperature on the heat of respiration of living tissues. A lower limit of $40^{\circ}F$ and an upper limit of $70^{\circ}F$ were chosen for the initial peanut bulk temperatures. A storage temperature of $35^{\circ}F$ had been used successfully in previous tests conducted by Manbeck, Moseley, Barnes, and Nelson at Oklahoma State University (20). Maximum duration of five days was selected for each test. Some of the equipment used in the study had

an upper limit of 100°F. It was estimated that an initial peanut bulk temperature of 70°F would result in at least a 30°F temperature rise in the peanuts during the five day test duration. Therefore, the upper level for the initial peanut bulk temperature was established as 70°F.

The upper level of the peanut moisture content was selected as that resulting from blotting the washed peanuts with paper towels to remove the excess water. A lower moisture content level of 30 per cent, wet basis, was selected. Loads of peanuts brought to dryer plants have been frequently noted to be approximately 30 per cent, wet basis.

An extensive study of the rate of respiration of high moisture Spanish peanuts was not made. Therefore, considerable further study will be required to determine the effect of storage temperature, moisture content, and time in storage on respiration.

CHAPTER II

REVIEW OF THE LITERATURE

Considerable research on the heat produced during respiration of various biological materials is reported in the literature. However, most of the work reported describes how the heat of respiration is estimated by assuming that the heat produced in the respiration activity is essentially due to a given and known chemical reaction. Very little literature was found in which it was reported that the heat of respiration was measured directly by some temperature sensing system.

Respiration

When seeds germinate in a dark environment, the total weight of the developing seedlings increases for a number of days, but their dry weight consistently decreases. If seedlings developing in the dark are enclosed in a chamber which is constructed such to permit a slow continuous stream of air to pass through it and over the seedlings, frequent analysis of the air will show that the air emerging from the chamber contains a lower percentage of oxygen and a higher percentage of carbon dioxide than the air which entered.

All of the above phenomena - disappearance of food resulting in a decrease in dry weight, absorption of oxygen, evolution of carbon dioxide, and liberation of energy - are different external mani-

festations of the process of respiration. Respiration occurs not only in germinating seeds and seedlings but in living cells generally.

Carbon dioxide is not always released nor is oxygen always used in respiration. Therefore, plant physiologists use the term respiration primarily to refer to the oxidation of foods in living cells with the resulting release of energy. Part of the energy released is transferred to compounds other than those which are oxidized and some is used in the activation of certain cell processes.

Respiration is one of the more important metabolic processes. To accomplish the various kinds of work in the plant, a supply of kinetic energy must be furnished continually to the different parts of the plant concerned in the performance of the various functions. Also, important life processes such as the synthesis of proteins, fats, and carbohydrates require a certain expenditure of energy. The energy necessary for the performance of any function by a living organism or part of an organism is obtained by the process of respiration in the protoplasm. At least two conditions are necessary for cells to perform the functions of life: (a) there must be substances present that can readily be oxidized and from the oxidation of which the available energy can be obtained; and (b) there must be oxygen present with which to oxidize these materials. Most organisms can perform some work in the absence of free oxygen, but usually it is only a limited amount and for a limited time.

During the process of respiration under normal conditions, oxygen is absorbed, organic compounds such as carbohydrates and fats are oxidized and carbon dioxide and water are formed. One can observe the beginning conditions of the respiration process and the end

products but all the intermediate steps are not known.

The degradation of sugar to carbon dioxide and water with the absorption of oxygen is the simplest form of respiration (32). In the presence of oxygen with a hexose being the substrate, the summary chemical equation for aerobic respiration is:

$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + 673 \text{ kg-cal.}$$

Mechanism of Energy Transfer

When the sugar molecule is degraded to smaller fragments in respiration, chemical bonds are broken and the energy that was incorporated is released (32). However, the energy is not dissipated immediately as heat but it is in a sense trapped into another chemical compound in which it is stored. There is a variety of chemical compounds which fulfill this function of storage centers.

Adenosine triphosphate is the principal device through which energy is metabolized in respiration and transferred to synthetic reactions (32). The rate at which it is formed is likewise of decisive importance and is likely to affect the entire activity of the system.

Cellular Respiration

The oxidation of organic compounds by molecular oxygen is considered as cellular respiration (32). The situation is essentially that of transfer of electrons from organic through a series of organic catalyses (enzymes and coenzymes) to molecular oxygen, with the reduction of the oxygen to water. Usually, but not always, the oxidation of the organic compounds results in the formation of carbon

dioxide.

Cellular respiration is essentially a mechanism for the release of potential energy of organic compounds in forms which can be utilized by the cell. Part of the energy released in the respiration process is in the form of heat and is lost to useful work while other energy is channeled into useful work by the very enzymatic mechanisms which catalyze the energy release. The latter energy portion is used to drive uphill (endergonic) reactions which store the energy in chemical compounds in forms immediately available in the life of the cell.

Methods for Measuring Respiration

Any quantitative measurements of respiration should ideally include data on the initial and final products concerning (a) substrate disappearing, (b) oxygen used, (c) carbon dioxide liberated, (d) water formed and (e) heat generated. However, it is not possible to obtain all of the above since a growing system or one where synthesis is occurring, two-thirds to four-fifths of the hexose which disappears may be converted to higher molecular weight compounds. However, the usual alternative is to determine the oxygen consumed and the carbon dioxide produced and calculate the respiratory coefficient.

The method used extensively in England and Europe for measuring respiration has been that of Pettenkofer method. In this method, carbon dioxide is removed from the air by passing it through absorption towers. The air is then passed by the respiring plant parts. The respiratory carbon dioxide is then removed by absorption in sodium hydroxide and the carbon dioxide present is determined by titration. Blackman (7) improved on the Pettenkofer method by improving on the

apparatus to collect the carbon dioxide.

Newton (26) developed still another method of absorbing the carbon dioxide. In his method the carbon dioxide is absorbed in 0.050 normal sodium hydroxide in a tower which contains platinized platinum electrodes, and the decrease in conductivity that results from the conversion of sodium hydroxide to sodium carbonate is read on a 1000-cycle Wheatstone bridge.

Bailey (5) developed an apparatus to force the carbon dioxide free air through the respiration calorimeter. Accumulated carbon dioxide from the respiration chamber was forced through measured quantities of standard barium hydroxide solution contained in specially constructed absorption vessels.

Milner and Geddes (23) used a Haldane-Henderson gas analysis apparatus essentially following the technique outlined by Peters and Van Slyke (28). Young and Holley used an apparatus similar to that of Bailey (43) to trap the carbon dioxide.

Todd (37) (38) used a Liston-Becker Infra-red Carbon Dioxide Analyzer (Model 15) to measure carbon dioxide content of the air for determining plant respiration. The above analyzer permits continuous and rapid determination of the carbon dioxide in the air.

Heat of respiration of fresh produce in a controlled atmosphere storage was measured by Toledo, et al. (36). Heat of respiration in air at same temperature was also measured to enable direct comparison with the heat of respiration in controlled atmosphere.

Respiratory Quotient

During respiration tests, it is usually desirable to determine

both the oxygen consumed and the carbon dioxide evolved. The ratio of volume of carbon dioxide produced to volume of oxygen consumed is called the respiratory quotient (RQ).

$$RQ = \frac{CO_2}{O_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Oxygen Tension

Many researchers have studied the effect of oxygen on the respiratory rate. The relation of the respiratory rate to the percentage of oxygen in the surrounding atmosphere (32) is illustrated in Figure 1.

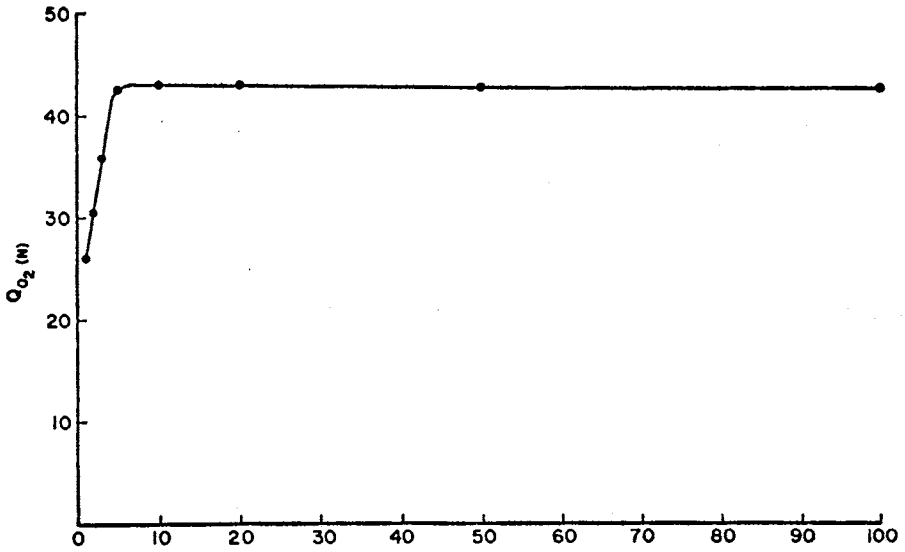


Figure 1. Relation of Respiratory Rates to Volume Per cent Oxygen; Etiolated Black Valentine bean hypocotyls. Unpublished Results of Susan Smith and W. D. Bonner, Jr. (From Steward (32)).

Factors Affecting Respiration

Temperature

As with most chemical reactions, the chemical reactions of respiration are sensitive to temperature changes. Since the respiration reactions are controlled by various enzymes, the temperature range in which the reactions may occur is actually rather narrow. However, the actual effects of temperature on the rate of respiration are rather complex and for most biological processes, not well defined. Within certain limits, an increase in temperature generally results in an increase in the respiration rate.

The relation among time, temperature and the rate of respiration of pea seedlings (11) is shown in Figure 2. Note that in the temperature range between $0^{o}C$ and $45^{o}C$, an increase in temperature resulted in an increase in the initial rate of respiration of the pea seedlings. However, at temperatures of $30^{o}C$ and above, the respiration rate decreased with time, which became most predominate at the highest temperature tested. Apparently, at temperatures above $30^{o}C$, factors leading to denaturation of enzymes involved in respiration begin to have an adverse effect. Since denaturation at these temperatures is not immediate, there will be an initial increase in the respiration rate. Apparently, the optimum temperature for a rather constant rate of respiration for the pea seedlings used in the above respiration is approximately at $30^{o}C$. However, the results of experiments with other materials indicate that the optimum temperature for respiration is not the same for all plant tissues.

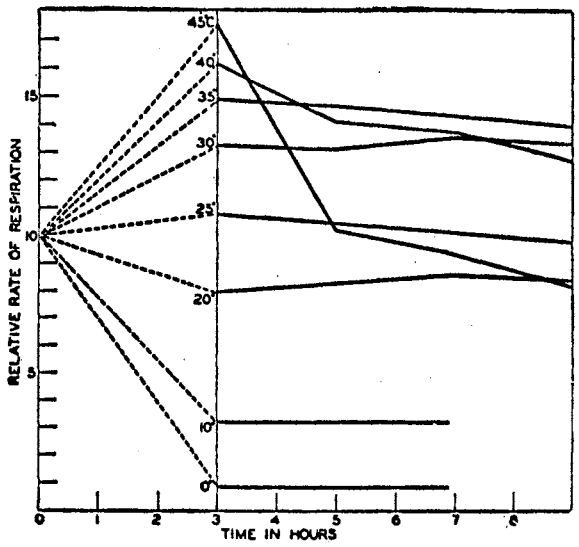


Figure 2. Relation Among Time, Temperature, and Rate of Respiration of Pea Seedlings. Dotted Lines Represent Period During which Temperature of Seedlings was Changed from 25°C to Indicated Temperatures. Data of Fernandes (1923). (From Devlin (11)).

The exact nature of the "time factor" and why it becomes increasingly effective in causing reduction in the rate of respiration with a rise in temperature is not known. Possibly this effect results from a progressively more pronounced inactivation of enzymes with an increase in temperature. However, other possibilities are: (a) the rate at which oxygen may not diffuse into the cell fast

enough at higher temperatures to permit maintenance of respiration rate, (b) the concentration of carbon dioxide which accumulates in the cell at higher temperatures may inhibit the rate of respiration, and (c) the supply of oxidizable foods stored in the cell may be inadequate to maintain high rates of respiration.

Although measurable rates of respiration have been recorded in some plant tissues at temperatures as low as -20°C, as the temperature is decreased to 0°C or below, the rate of respiration diminishes until it is almost imperceptible. Again, possibly the most probable reason for the pronounced decrease in the rate of respiration is due to the significant inactivation of the enzymes affecting respiration.

Moisture

Maintaining the quality of stored grain depends greatly on the moisture content of grain. Under favorable storage conditions, the moisture content of the grain may be sufficiently high to permit heating and other types of damage such as discoloration, development of musty odors, loss of viability, increase in fat acidity, and deterioration in nutritive qualities. The value of the grain is therefore reduced according to the extent of these changes and, in extreme cases, the grain may deteriorate to the point where it may be unfit for food purposes.

It has, therefore, long been recognized that moisture content is one of the most critical of all factors influencing the respiration, heating, and deterioration of stored grain. As the moisture content of dry grain is increased, there is a small increase in the respiratory rate until a critical moisture range is reached. This critical

moisture content is characteristic of the seed species and is influenced by various factors related to the commercial quality of the grain. Above the critical range, a rapid acceleration in respiration occurs. The "critical moisture content" of seeds may be associated with minimum moisture levels at which certain common molds will develop and grow.

Milner and Geddes (25) studied the relation among moisture content, mold growth, and respiration of soybeans. They studied the respiratory rates of six samples of Illini soybeans containing from 8.5 per cent to 14.6 per cent moisture at 37.8°C over an 11 day period with samples weighing 250 grams. Two aeration rates were used to prevent inhibitory carbon dioxide concentrations in the interseed atmosphere, namely, 1000 ml per day for samples containing 14.0 per cent moisture and more, and 500 ml per day for the samples of lower moisture content. The results of the study are presented in Figure 3.

Milner, Christensen, and Geddes (23) conducted respiration trials at 30°C on Regent wheat at various moisture content values. One of the experiments covered a moisture range of 12.3 to 16.3 per cent with intermediate increments, over a time interval of 20 days. The other trial involved moisture increments of from 16.8 to 38.6 per cent for a period of 17 days.

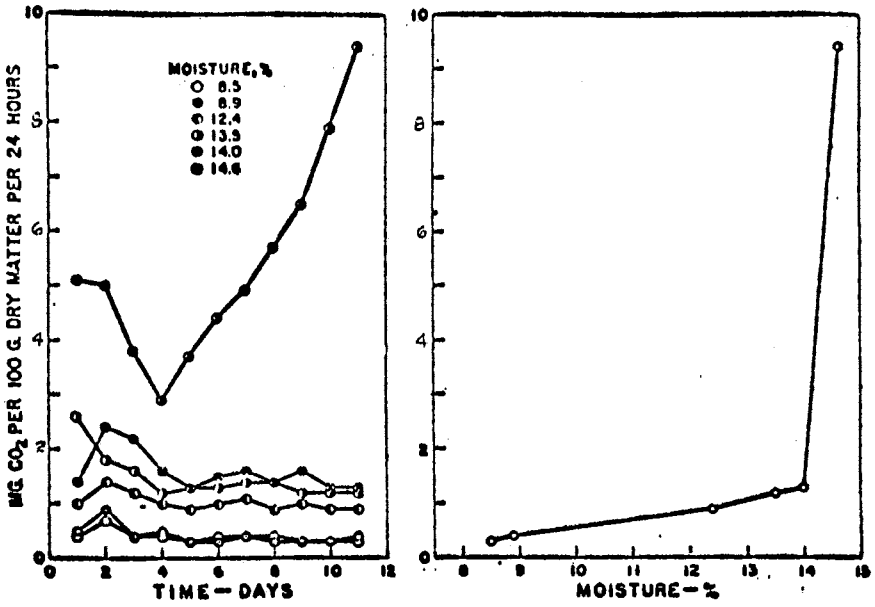


Figure 3. Time and Moisture Content versus Respiratory Rate of Naturally Moist Illini Soybeans at 37.8°C. (From Milner and Geddes (25)).

The results of the daily respiratory rates are graphically presented in Figure 4 showing the influence of moisture content on respiratory rate for the lower moisture range. They reported that subsequent studies indicated that marked inhibition of respiration is to be expected at interseed carbon dioxide concentrations in excess of 12 percent, so that the respiratory rate of the sample containing 25.2 per cent moisture is doubtless an underestimation of the respiratory rate attainable under adequate aeration conditions.

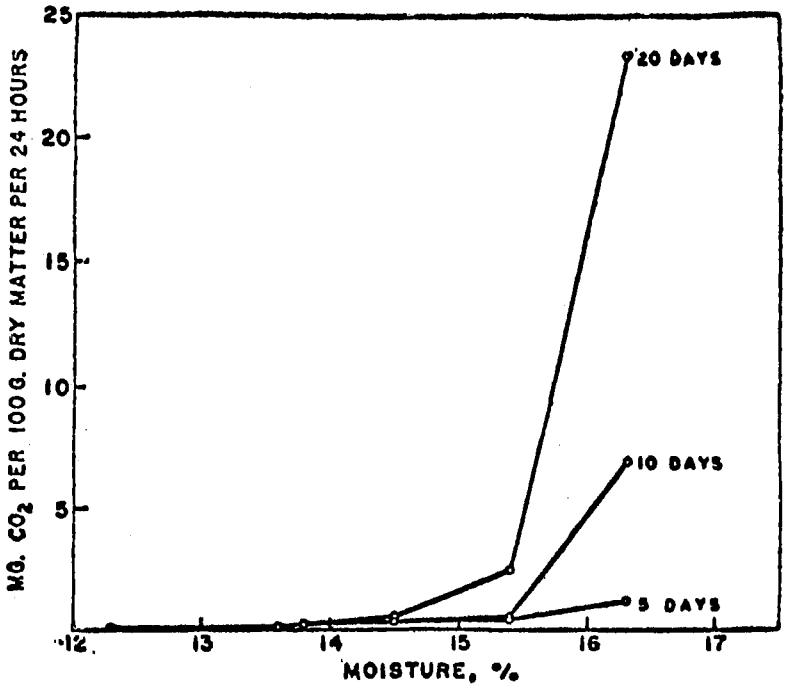


Figure 4. Moisture Content and Time Versus Respiratory Rate of Regent Wheat at 30°C. (From Milner, Christenson and Geddes (23)).

It was observed that the respiratory activity of the wheat at moisture values at equilibrium with relative humidity values below 74 per cent was virtually constant over the entire period of the 20 day test. However, beginning with moisture contents of 14.5 per cent (75 per cent relative humidity), respiratory rates increased with time, following an induction period the length of which was inversely proportional to the moisture content. Probably the induction period represents the time required for mold spores to germinate and for mycelia to become established. It is important to note that the number of mold colonies per gram at the end of the respiration trial appeared to be correlated with the ultimate respiratory rates. Also, the

respiration-time curves for moisture values at which mold growth occurs assume the form of a microbiological growth curve. The curves in Figure 4 relating respiratory activity to moisture content assume increasingly sharper inflections with time in the critical moisture range (14.5 per cent to 15 per cent), corresponding to a relative humidity of 74 to 75 per cent.

The release of energy through the biochemical oxidation of the carbohydrates, proteins, fats, and other organic nutrients is common to all living organisms. If it is generated in the stored grain faster than it is being removed, the temperature of the grain rises and heat damage may occur.

Microorganisms are usually present on the surfaces and within the seed of coats of grain. It has been frequently noted that the heating of moist grain and other biological materials is usually accompanied by the growth of molds. It is not commonly recognized that the heat produced in stored moist grain is due both to the respiration of the grain itself and to the growth of the fungi.

Within a certain range, the moisture content in the tissue is one of the determining factors in the intensity of respiration. This is particularly true for seeds and grains. Seeds which have been dried to extremely low values, will begin to respire more rapidly if their moisture content is increased sufficiently.

Oxygen

The general effect of a reduction in the concentration of oxygen in the environment below a certain limit (the extinction point) is to bring about anaerobic respiration or fermentation such that the carbon

dioxide evolved is due partly to aerobic respiration and partly from anaerobic respiration. The proportion of anaerobic respiration increases with the decreasing of the oxygen concentration until, in complete absence of oxygen, the carbon dioxide is all produced anaerobically.

In general, both aerobic and anaerobic respiration can be expected to occur in the plant at low oxygen concentrations. Under completely anaerobic conditions, the carbon dioxide produced would be a product of anaerobic respiration (fermentation) exclusively. As the oxygen concentration is increased, anaerobic production of carbon dioxide falls off rapidly, aerobic respiration increases, and the respiratory quotient approaches unity. When the respiratory quotient reaches unity at a certain oxygen concentration, this point is referred to as the extinction point. It is at this point that anaerobic respiration ceases. A typical example of the above relationship is illustrated in Waton's work with Bramley seedling apples (11) in Figure 5. Oxygen consumption gives a measure of aerobic respiration as does carbon dioxide production after the extinction point has been passed.

As the concentration of oxygen increases from zero, the rate of aerobic respiration increases. This increase is usually hyperbolic for most plants. However, for some plants, the increase in the rate of aerobic respiration is linear over a range of oxygen concentrations.

The per cent by volume necessary to produce a certain respiration rate will depend in many cases upon the permeability of the membranes it must penetrate in reaching the point of its utilization. This is illustrated by the seed coats through which oxygen diffuses with considerable difficulty. The structure of the seed coats may influence

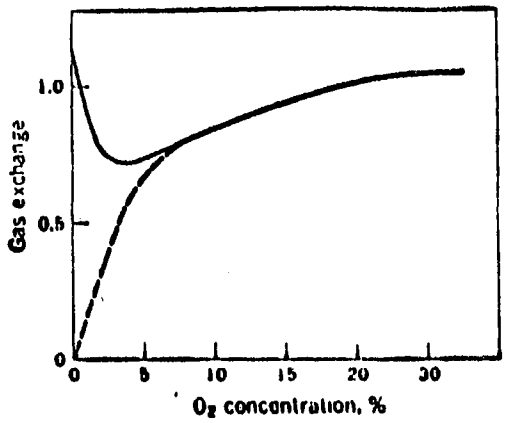


Figure 5. Production of CO_2. (From Devlin (11)).

the respiration rate in the following manner: (a) In the initial phase of germination, the presence of the unbroken testa around the seed prevents the free diffusion of gases, so that a relatively small amount of oxygen enters and anaerobic respiration occurs. (b) The rupture of the seed coats causes a quick rise in the absorption of free oxygen and a slow down in the rate of carbon dioxide production, thus the value of the respiratory quotient decreases.

The substance in the intercellular spaces can have an effect on the respiratory rate indirectly by affecting the diffusion rate of oxygen. In pure water, oxygen diffusion is nearly 300,000 times slower than in air.

Milner and Geddes (25) studied the effect of aeration and temperature on the respiration, respiratory quotient, mold growth, and chemical characteristics on Wisconsin Manchu soybeans. The results are presented in Figure 6.

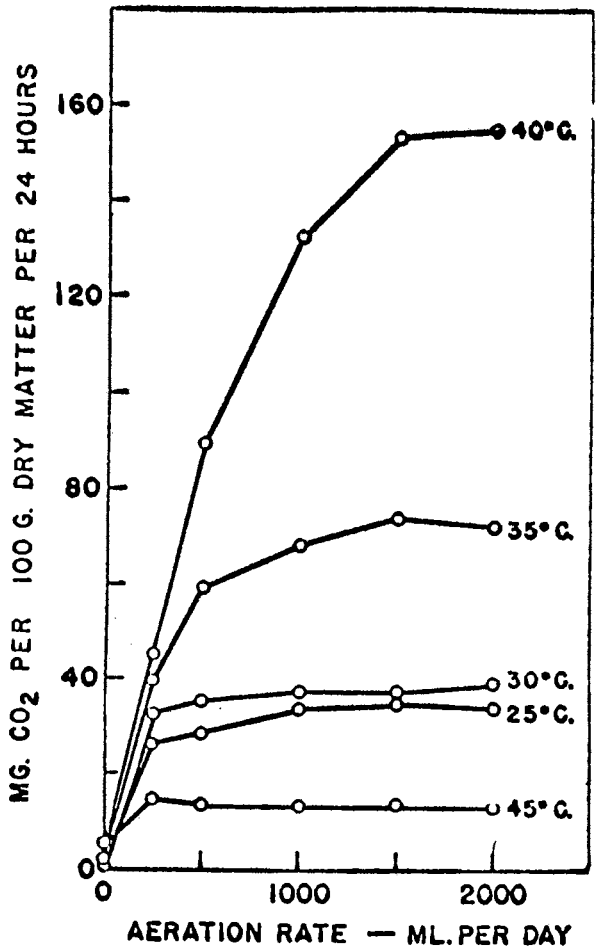


Figure 6. Aeration versus respiratory rate of Wisconsin Manchu soybeans at high storage moisture at various temperatures. (From Milner and Geddes (24)).

The aeration rate influenced significantly the respiratory activity when insufficient to maintain concentrations of carbon dioxide in the interseed air below approximately 12 to 14 per cent.

Carbon Dioxide

The amount of carbon dioxide around the plant material may have

a significant effect on the rate of respiration. After a certain level, increasing the concentration of carbon dioxide has a definite repressing effect on respiration.

Type and Age of Plant

The rate of respiration varies with the kind and age of the tissues. This difference in the rate of respiration of different tissues has been especially studied in seeds and seedlings by determining the relative respiratory intensity of the embryo and endosperm. Sometimes the respiratory activity in the embryo of wheat is as much as twenty times that of the endosperm.

Since there are large morphological differences among members of the plant kingdom, it should be assumed that differences in metabolism also exist. It has been noted that in general, bacteria and fungi have a much higher respiration rate than that of higher plants.

Peanut Respiration Studies

Schenk (29) measured the respiration of Dixie Spanish peanuts in Warburg constant volume respirometer flasks containing one percent potassium hydroxide solution for the absorption of carbon dioxide. He measured oxygen absorption at 30°C for approximately three hours and then calculated the respiration rate based on standard methods as described by Umbreit, Burris and Stauffer (39).

The respiratory quotient of the developing peanut fruits and separated kernels was well above unity during the period of rapid oil synthesis. The maximum respiratory quotient measured was 1.77.

The respiratory quotient declined very rapidly as the peanut

fruits reached maturity. However, the respiratory quotient of the embryos declined more slowly.

Respiratory quotients of 0.8 and lower were observed when net fat synthesis had ceased. Such a low respiratory quotient indicates the possibility of a metabolic breakdown of the lipids.

Whitaker (40) studied the effect of curing treatment upon the respiration of peanuts. He used both mature and immature freshly dug peanuts. The peanuts were shelled and the whole kernels were cured at temperatures of 95°F and 125°F. During the curing process, the carbon dioxide liberation and oxygen consumption by 240 grams of kernels were measured in a closed system. Whitaker reported the following effects of curing treatment on relative levels* of respiration and off-flavor:

Measurements and Computations	Immature 125°F	Immature 95°F	Mature 125°F	Mature 95°F
Rate of respiration	4	2	3	1
Respiration ratio	4	3	2	1
Anaerobic index	4	3	2	1
Off-flavor	4	3	2	1

*4 = highest and 1 = lowest

Specific Heat of Spanish Peanuts

A review of the literature revealed only one published report on the specific heat of Spanish peanuts, which was by Wright and Porterfield (42). They measured the specific heat of Spanish peanuts both on a batch basis and of individual peanuts.

The batch test calorimeter used by Wright is shown schematically

in Figure 7. The results of the tests are presented in Figure 8.

The following multiple regression equation for specific heat of the peanuts was determined using all the data from the batch tests:

$$S_{pn} = -0.0128 + 2.9141\ P - 5.2705\theta P^2 + 1.1927M$$
$$-0.4345M^2 - 1.9441\theta PM \quad [2]$$

The results from the single peanut tests are illustrated in Figure 9. The following multiple regression equation was determined for the single peanut tests:

$$S_{pn} = 2.5568 - 6.0921\theta P + 5.0151\theta P^2 + 0.9497M$$
$$-0.6906M^2 + 0.0892\theta PM \quad [3]$$

Chakrabarti and Johnson (9) measured the specific heat of flue cured tobacco leaves using a Perkin-Elmer Differential Scanning Calorimeter. Moisture content of the leaves ranged from zero per cent to 400 per cent, dry basis. Results of the study are presented graphically in Figure 10.

General Differential Equation for the Temperature Field

The general differential equation describing the temperature field in a three-dimensional body will be developed in the cartesian coordinate system and then be presented in cylindrical coordinate form. The cylindrical coordinate system will be used exclusively in this thesis.

Consider an infinitesimal rectangular parallelpiped porous conducting material of a volume V = dxdydz, with an internal heat generating source as a function of the local temperature in the amount of q_T''', Btu/(hr-ft^3), and where the thermal conductivity of the conducting

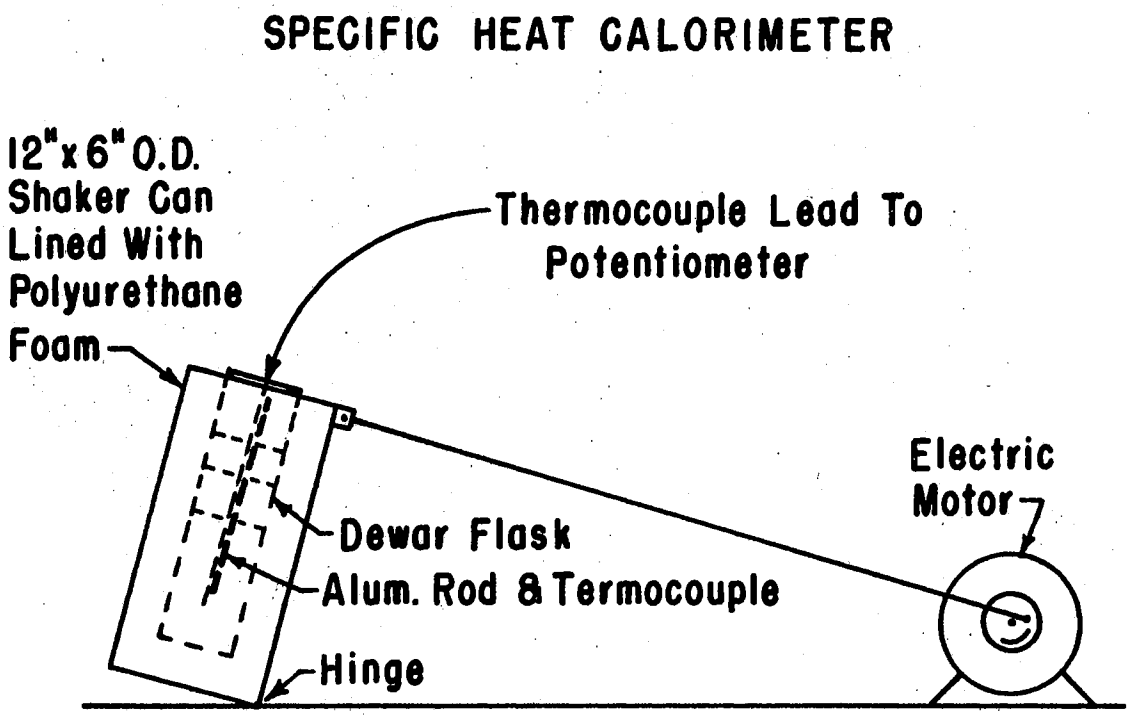


Figure 7. Schematic diagram of specific heat calorimeter. (From Wright and Porterfield (42)).

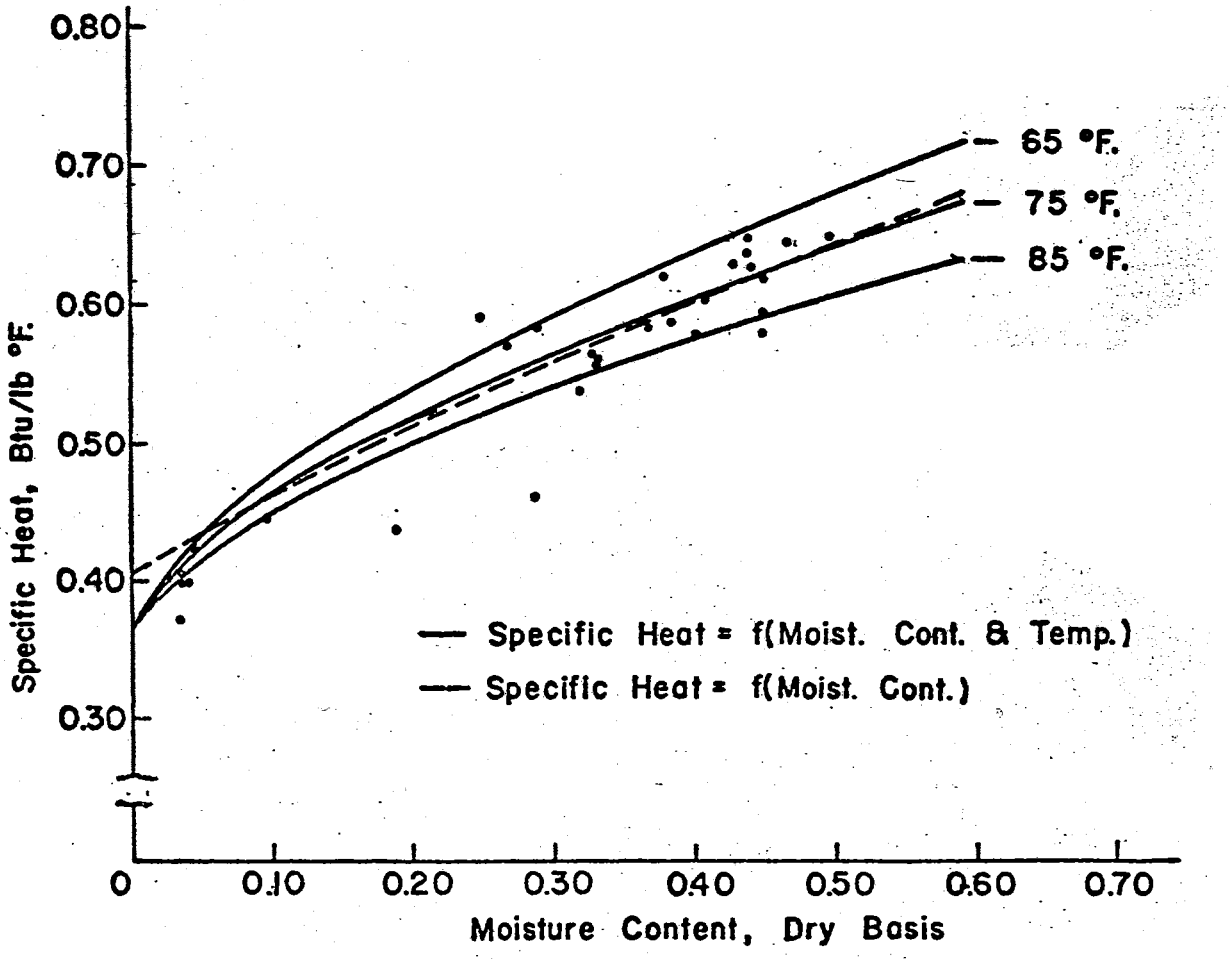


Figure 8. Specific Heat Versus Moisture Content for Spanish Peanuts Determined from Batch Tests by Method of Mixtures. (From Wright (41)).

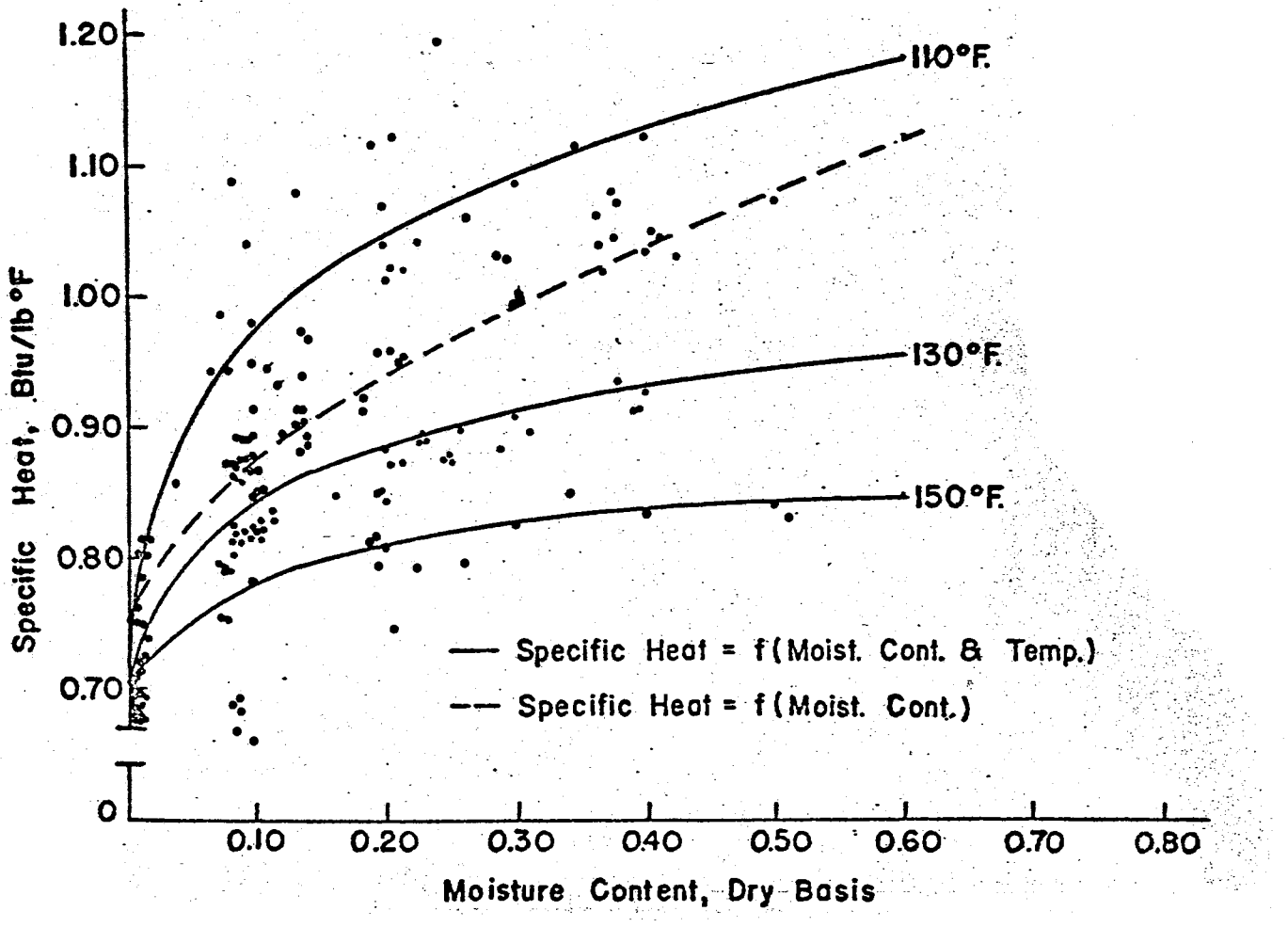


Figure 9. Specific Heat Versus Moisture Content for Spanish Peanuts Determined from Single Peanut Tests with Dry Heat. (From Wright (41)).

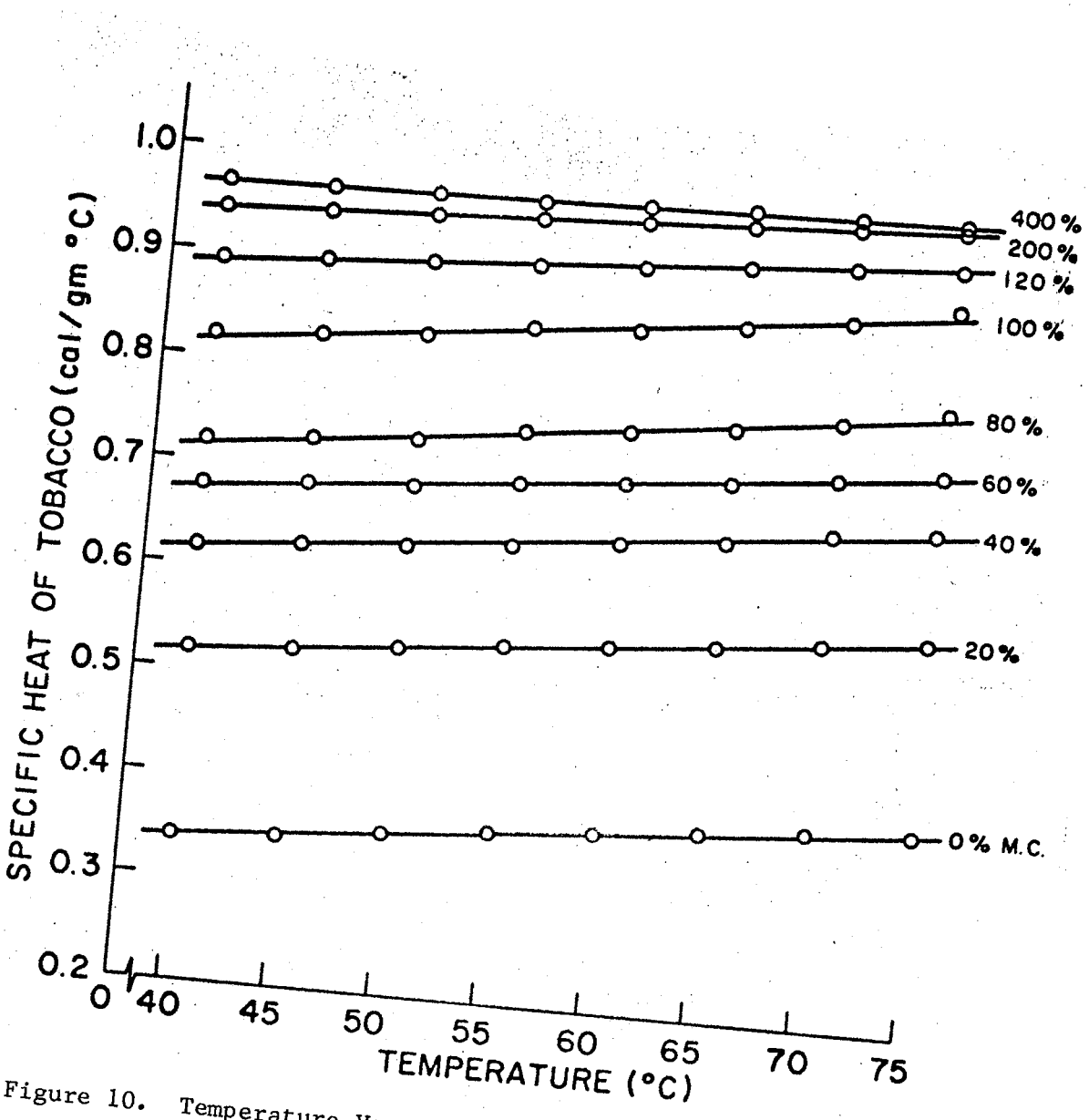
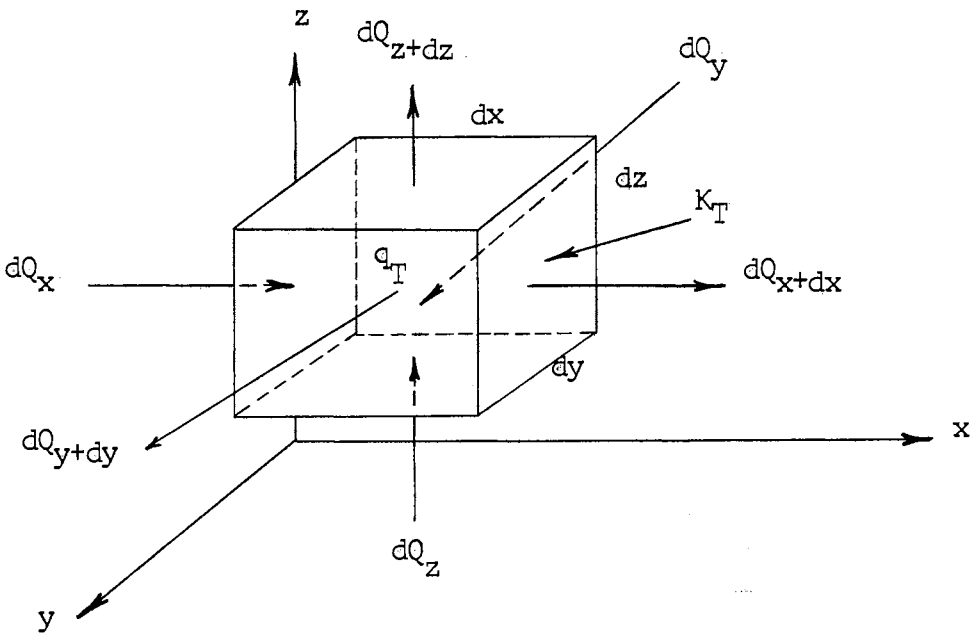


Figure 10. Temperature Versus Specific Heat of Tobacco. (From Chakrabarti and Johnson (9)).

material, K_T, is also nonuniform. Assume that there is no mass flow across the boundaries of the parallelpiped.



The total quantity of heat representing the change in the internal stored energy of the volume element is given by

$$dE = C_v \rho dx dy dz \frac{\partial T}{\partial \theta} d\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [4]$$

The total heat dQ_g generated in the volume element is

$$dQ_g = q'''_T V d\theta = q'''_T dx dy dz d\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots [5]$$

Schneider (30) combines the eight heat components in such a way that the total energy is conserved, equation [6].

$$dQ_x + dQ_y + dQ_z + dQ_g = dQ_{x+dx} + dQ_{y+dy} + dQ_{z+dz} + dE \quad \ldots [6]$$

Now assume a constant mass flow rate entering the volume element across the differential face surface of dydz at x with convected energy rate (16) dQ_{C_x} of

$$dQ_{C_x} = dydzG_x \left(i + \frac{u^2}{2g_c J} \right) d\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots [7]$$

For constant volume conditions, the mass flow rate leaving the volume element across the differential face surface dydz at x + dx must equal the mass flow rate entering the volume element differential face surface dydz at x. Then

$$dQ_{c_{x+dx}} = dydz \left\{ G_x \left(i + \frac{u^2}{2g_c J} \right) + \frac{\partial}{\partial x} \left[G_x \left(i + \frac{u^2}{2g_c J} \right) \right] dx \right\} d\theta \quad [8]$$

since $\frac{\partial G_x}{\partial x} \approx 0$, assume $dQ_{c_x} = dQ_{c_{x+dx}}$

Then the above energy balance equation remains

$$dQ_x + dQ_y + dQ_z + dQ_g = dQ_{x+dx} + dQ_{y+dy} + dQ_{z+dz} + dE. \quad [9]$$

For adiabatic uniform heating, i.e., no heat crossing the volume element boundaries and no temperature gradient in the volume element, the above energy balance equation becomes

$$q'''_T = C\rho \frac{\partial T}{\partial \theta} \quad [10]$$

since $q'''_T = f(T)$

$$\frac{\partial q'''_T}{\partial T} = C\rho \frac{\partial T}{\partial \theta} \quad [11]$$

From chain rule differentiation

$$\frac{\partial q'''_T}{\partial T} \frac{\partial T}{\partial \theta} = C\rho \frac{\partial T}{\partial \theta}$$

Then $$\frac{\partial q'''_T}{\partial T} = C\rho \quad [12]$$

And for the entire volume

$$\frac{dq_T}{dT} = C\rho V \quad [13]$$

CHAPTER III

EXPERIMENTAL DESIGN

Range of Variables in Respiration Tests

The range of variables used in the respiration tests are tabulated in Table I. Two replicates for each treatment combination were planned.

TABLE I

EXPERIMENTAL DESIGN

Initial Temperature, T_i		Moisture Content Level, MC	
^{o}F	^{o}C	% Wet Basis	% Dry Basis
40.0	4.4	45	82
40.0	4.4	30	43
50.0	10.0	45	82
50.0	10.0	30	43
70.0	21.1	45	82
70.0	21.1	30	43

Due to malfunction of some of the equipment used in the study, the treatment combination of initial temperature of $50^{o}F$ and 45 percent moisture content level wet basis was not studied before severe

cold weather killed the peanut vines in the field. The vines from which the peanuts were taken for the second replicate of 50°F initial temperature and 30 per cent moisture content wet basis were still in fair shape and no appreciable deterioration of the peanuts was noted.

Specific Heat Measurements

Specific heat of peanuts placed in the companion flask of the respiration calorimeter was measured (1) at the beginning of each respiration test, (2) every day at approximately 8:00 P.M., and (3) at the end of each respiration test.

Farmer stock peanuts were obtained from the Oklahoma State University Experiment Farm at Perkins, Oklahoma, for both the respiration tests and additional specific heat tests. All specific heat data obtained in the respiration study were lumped together to obtain a polynomial equation for specific heat as a function of bulk moisture content and bulk temperature.

CHAPTER IV

EQUIPMENTAL PROCEDURE AND EQUIPMENT

Field Cover of Peanut Vines

In order to extend the testing period to complete as many tests as possible, peanut vines were covered with black plastic sheets in the field when the weather forecast predicted over-night temperatures less than $40^{o}F$. Each plastic sheet was 6 mil thickness, 16 ft. width, and 100 ft. length, Figure 11.

When a long cold spell was predicted, the plastic was supported by aluminum pipes placed on concrete hollow blocks, Figure 11, in order to prevent physical contact between the plastic and peanut plants.

If the daytime temperature increased above $40^{o}F$, the plastic sheets were removed to prevent excessive heat buildup under the plastic sheets. However, removal of the sheets was done only after the temperature increased above $40^{o}F$ and the weather forecast indicated that the daytime temperature would not go below $35^{o}F$.

Harvesting

Peanut vines were hand pulled and hauled to the laboratory where peanuts were handpicked from the vines. The peanuts were thoroughly washed with tap water to remove soil. Peanuts were carefully sorted to remove split or badly damaged pods and any pods which appeared to

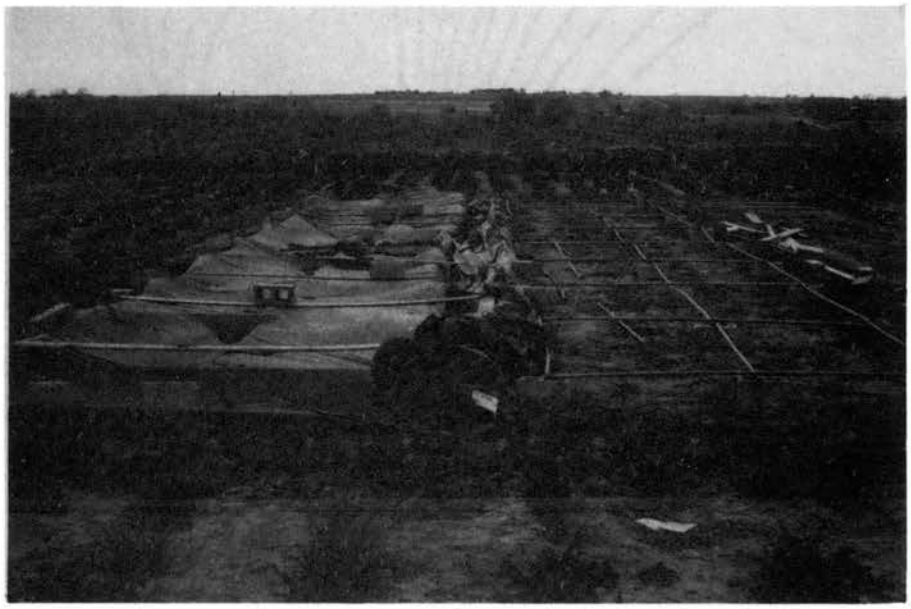


Figure 11. Peanut Vines Covered for Protection Against Frost or Freezing

be immature.

Drying

Upon completion of sorting, pods were thinly placed on paper towels spread over a table, located in the laboratory, Figure 12. Drying of pods used in the higher moisture content tests were dried by simply removing the excess surface moisture from the hulls by paper towels. Peanuts used in the lower moisture content tests (30 per cent, wet basis) were left covered by paper towels under one of the overhead heaters in the laboratory for one overnight period.

Temperature Conditioning of Peanut Samples

Since temperature of peanuts brought from the field was different than the desired temperature for the beginning of the test, it was necessary to change the peanut temperature. This temperature change was accomplished using either the walk-in cooler or the respiration calorimeter environment chamber.

Approximately 1000 grams of peanuts were placed in each of three plastic bags. A 36 gauge copper-constantan thermocouple was placed at the center of each of six peanuts. A small hole, the size of the thermocouple lead, was made by the use of a syringe needle to the estimated center of the kernel. Fingernail polish was placed around the thermocouple lead at the hole entrance to prevent heat transfer by convection. Six peanuts with inserted thermocouples are shown in Figure 13. Two peanuts in which a thermocouple had been inserted, were placed in each of three plastic bags at the approximate center of the sample.

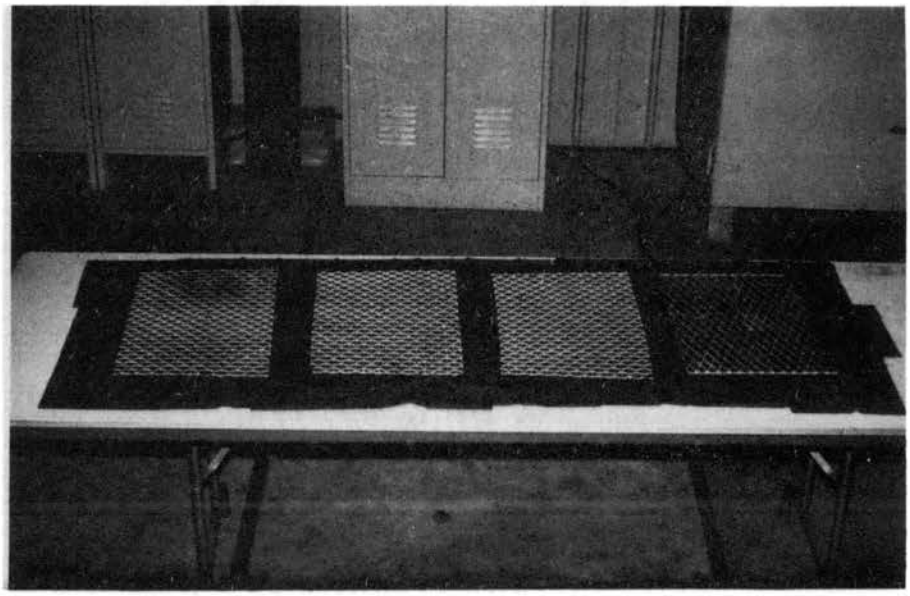


Figure 12. Drying of Peanuts to Designed Moisture Content

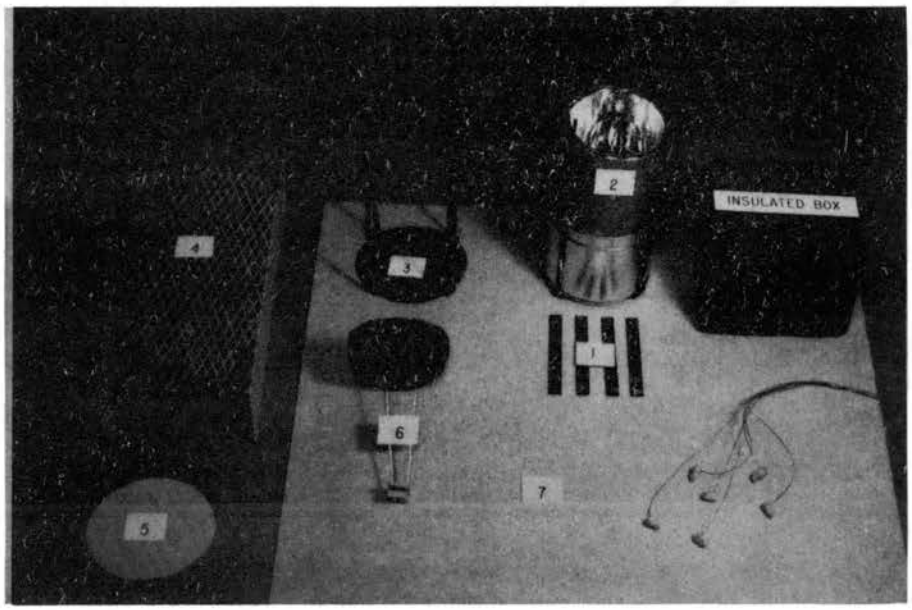


Figure 13. Miscellaneous Equipment Used in the Study

When the six peanuts used in temperature monitoring were in place, each plastic bag was sealed around the two thermocouple leads by use of rubber bands. The three samples were placed in the environment chamber on top of the air bath chamber. This placed the samples in the convective air stream of the environment chamber.

It was assumed that, since each of the six monitored peanuts were at the center of their respective peanut sample, the bulk temperature of all three samples would be the same when steady state temperature was reached for the six monitored peanuts.

Moisture Content Determination

Peanuts selected for a given respiration test were divided into three samples of approximately equal size. One sample was placed in the main flask of the respiration calorimeter, a second sample was for the calorimeter companion flask and the third sample was used to estimate the initial bulk moisture content of the peanuts and specific heat of the peanuts at initial bulk temperature.

Three samples were obtained from peanuts of the calorimeter main flask at the end of each test for moisture content determination. The moisture content was expressed as a percent, wet basis. An average moisture content, wet basis, was calculated for a given respiration test, using the moisture content of the three samples obtained at the beginning of the test and the three samples from the respiration main flask when the respiration test was stopped.

The equipment used in the moisture content determination were the following:

1. Torsion balance weighing scales, 2 kilogram capacity,

with 0.1 gram divisions

2. Forced convection electric oven. The oven was a Precision Scientific Company, 2600 watts, with a temperature control of $1^{\circ}F$ sensitivity, range of $260^{\circ}C$
3. Drying screen
4. Metal cans with plastic air-tight covers

Approximately 100 grams of peanuts were used for each moisture content determination sample. Temperature of the oven was maintained at approximately $190^{\circ}F$ and peanuts were dried for about 24 hours.

Environment Chamber

The environment chamber is shown in Figure 14. It maintained the temperature inside at an accuracy of $\pm 1^{\circ}F$ within a range of $40^{\circ}F$ to $100^{\circ}F$. Breakdown of the refrigeration unit invalidated three tests. Not all of the planned tests could therefore be completed before peanut vines were killed by exposure to cold weather.

Aeration and Air Quality Control Equipment

Aeration and air quality control equipment is shown in Figures 15, 16, and 17. An air flow diagram is shown in Figure 18.

Air passing through the main flask was conditioned to remove all its carbon dioxide and to raise its relative humidity as near to equilibrium moisture content as possible. The plan called for the inlet air to be supersaturated air from the top of the hot water heater (Figure 15) to pass through the air bath chamber with sodium crystals to lower the relative humidity of the air to about 95 per

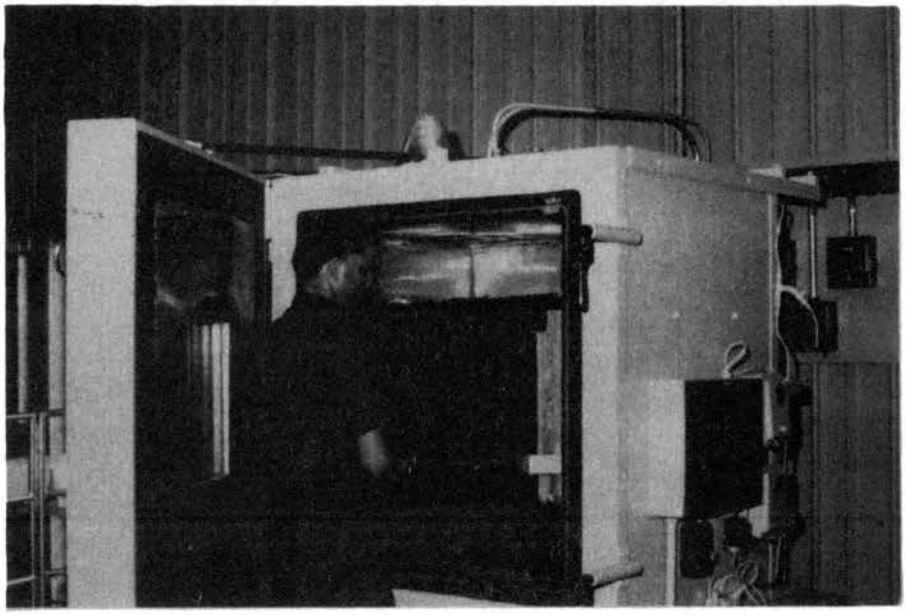


Figure 14. Environment Chamber

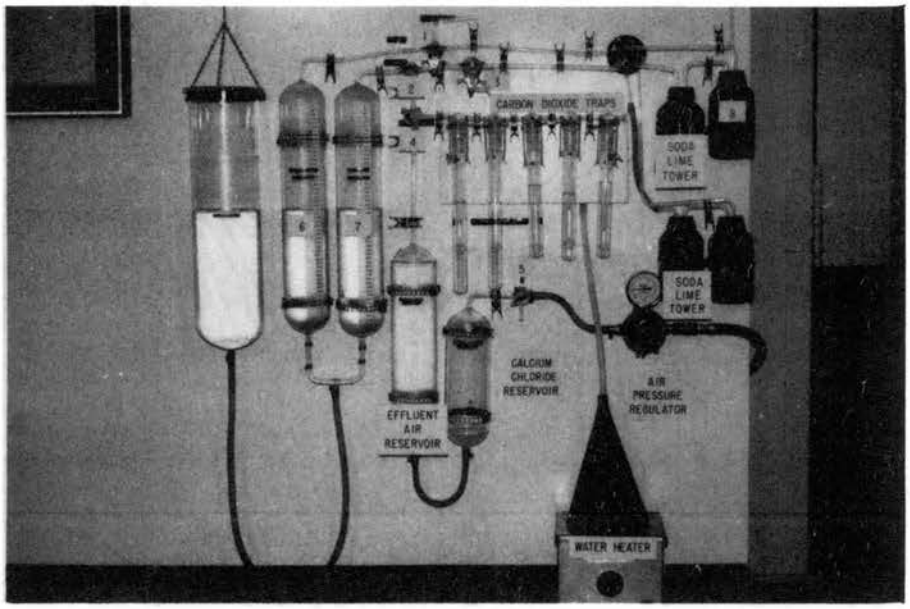


Figure 15. Aeration and Air Quality Control and Analysis Equipment

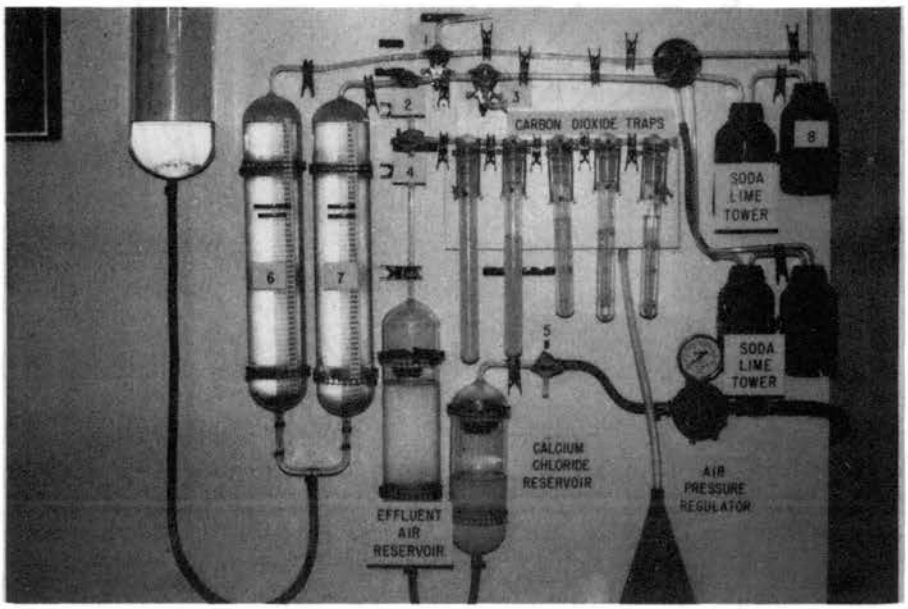


Figure 16. Passing Effluent Through CO_2 Traps

CROSS SECTION OF AIR BATH CHAMBER (SIDE VIEW)

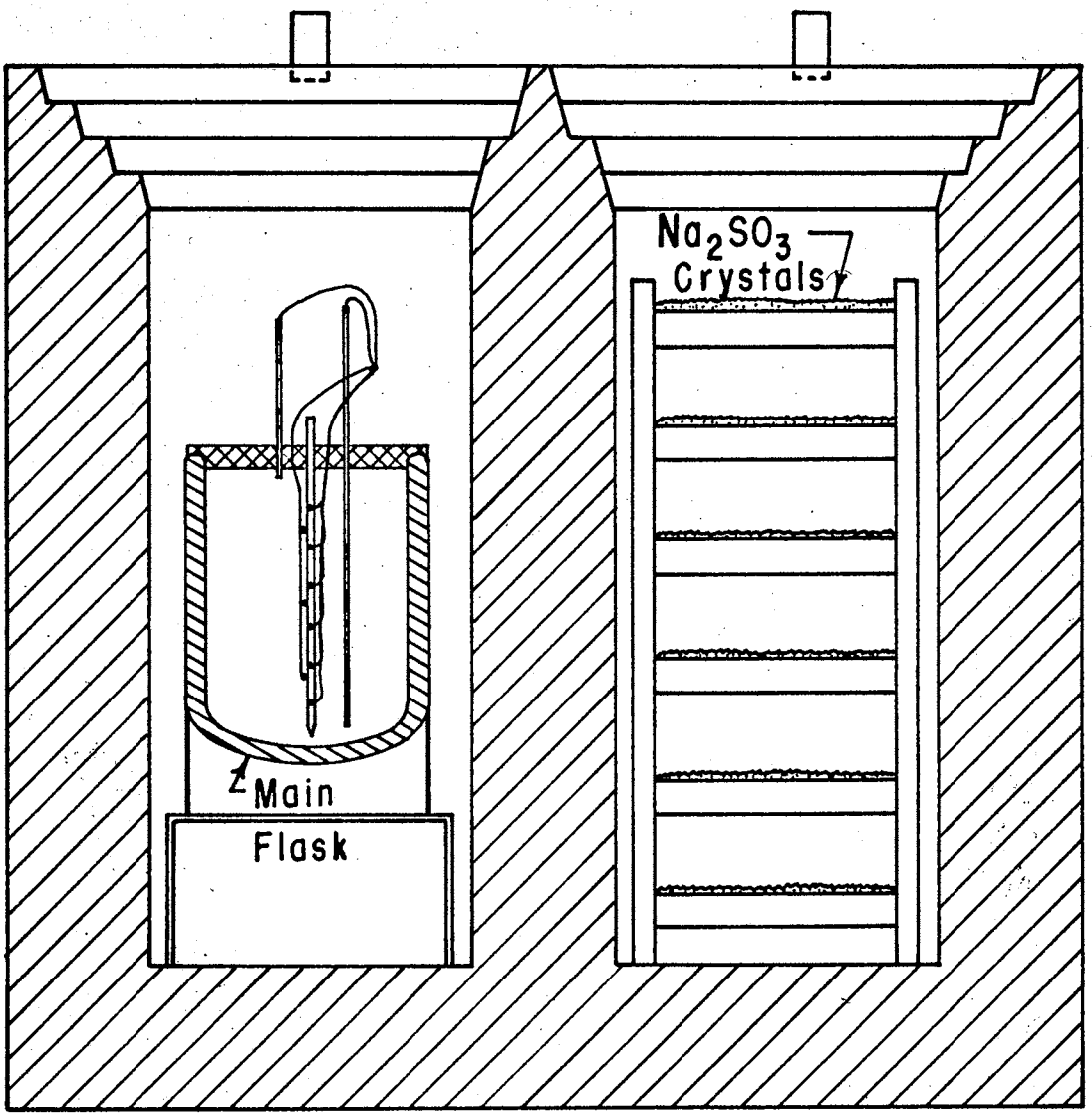


Figure 17. Cross Section of Air Bath Chamber, Side View.

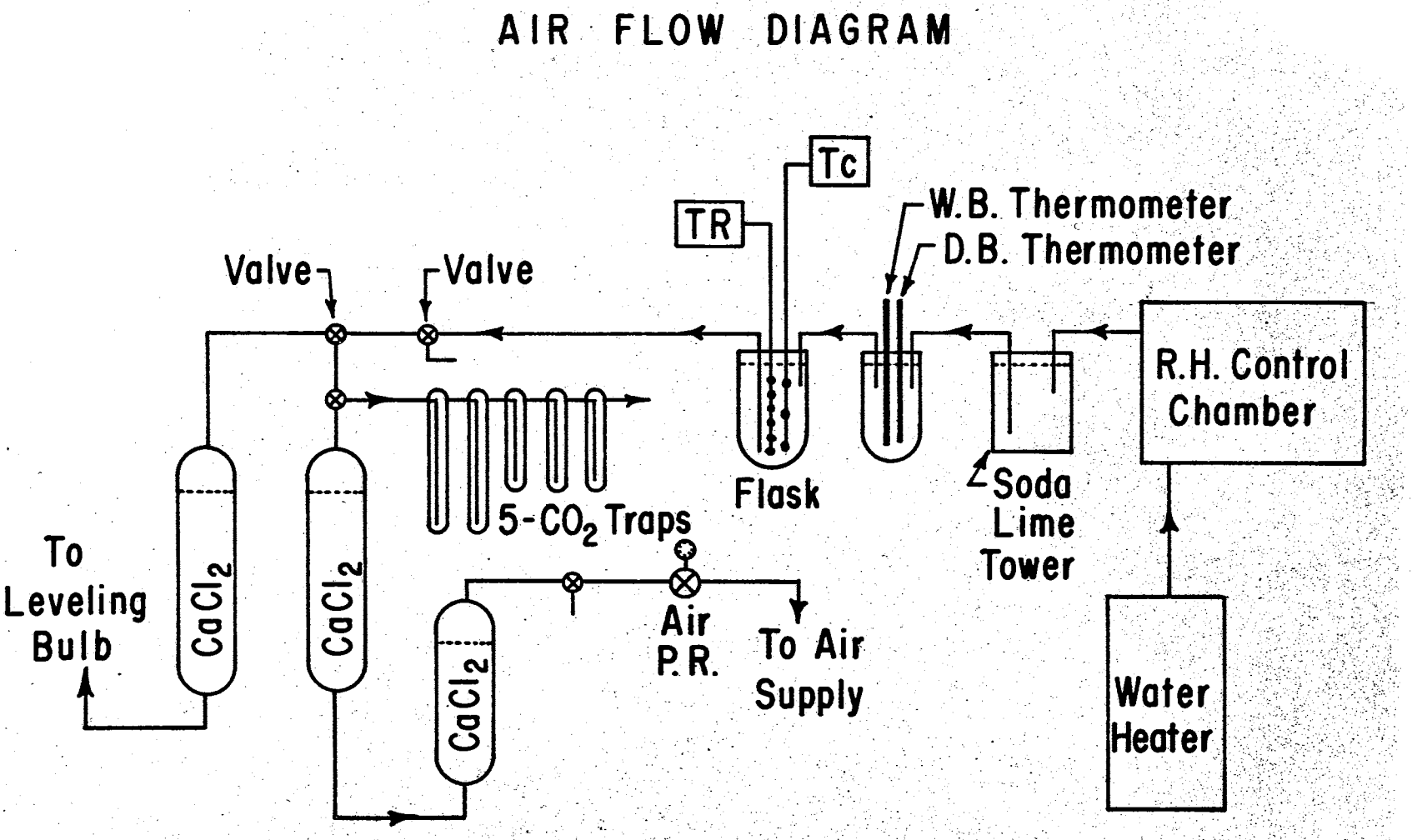


Figure 18. Air Flow Diagram of Respiration Calorimeter.

cent. The air passed through the soda lime tower to remove any carbon dioxide present in the air. From the soda lime tower, the air passed through a jar in which is placed dry bulb and wet bulk thermometers for determining relative humidity of air. Air then passed through the main flask, entering at the top and being removed by an air line extending to near the bottom of the flask.

Since the specific gravity of carbon dioxide is slightly greater than that of air, it was assumed that the greatest concentration of carbon dioxide would be at the bottom of the flask. No attempt was made to determine if a gradient in carbon dioxide concentration existed within the interseed air of the main flask.

The air quality control equipment did not accomplish the objective of maintaining a relative humidity of the interseed air at 95 per cent. As the air passed through the wall of the environment chamber just before entering the air bath chamber, it was cooled to the temperature of the environment chamber. Thus, some of the moisture in the air vapor was removed by condensation. As the temperature of the air was again raised as it passed through the air bath chamber, before entering the main flask, the relative humidity was thus lowered.

However, the failure of the air quality control equipment to accomplish all of its objectives does not present a serious problem. Aeration rate was held at approximately 2000 milliliters per 24 hours. At that rate, no significant drying of the peanuts should occur. It should be noted that water is liberated in the respiration process; thus adding water to the peanuts.

Little difference was found between the moisture content of the peanuts determined at the beginning of each test and that measured at

the end of said test. It is possible that variation between moisture content values obtained is due primarily to random effects rather than due to an actual significant change in the moisture content of the peanuts during respiration.

Peanuts in the calorimeter flasks were aerated with conditioned air at a constant rate. Aeration rate was controlled by a pumping (lowering) mechanism shown in Figures 15 and 19. Various parts of the pumping mechanism are as follows:

1. A one revolution per hour synchronous electric motor with a rating of 1/20 horsepower, Figure 19.
2. Gear reduction drive constructed to reduce the speed from one revolution per hour to one revolution per 24 hours
3. The motor-gear drive mounting bracket and sliding guide
4. The line shaft on which is located the different size pulleys. The spikes are spaced to permit the holding of the leveling bulb in a fixed position
5. Two sets of pulleys with diameters of 3", 2", and 1.5". The pulleys are of various sizes in order to vary the aeration rate
6. The cable connected to the leveling bulb
7. The counter balance, Figure 24

The balance of the equipment involved in the aeration system, as shown in Figure 15, is the following:

1. The leveling bulb, which is the reservoir of the chloride solution. The inside diameter of the

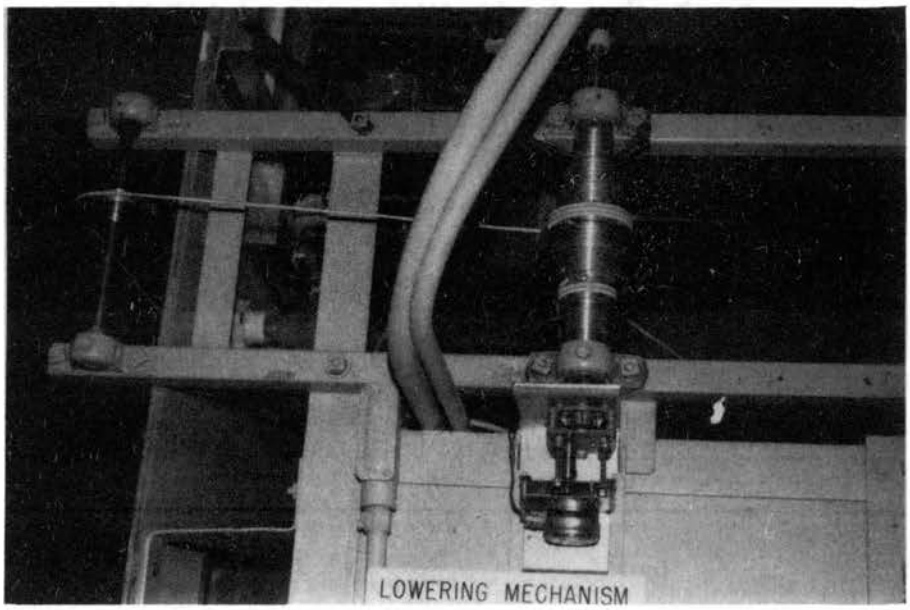


Figure 19. Lowering Mechanism of Aeration System

leveling bulb is 124 centimeters.

2. Two spirometers with inside diameters of 85 centimeters each and graduated to measure air flow during a given time
3. The flexible line connecting the leveling bulb and the two spirometers
4. Valve numbers one, two and three
5. Glass connecting lines

As the leveling bulb is lowered by the pumping mechanism, conditioned air is drawn through the aeration system as indicated in Figure 18. Although various aeration rates are possible with the aeration system, the approximate rate of 2000 milliliters per 24 hours was used throughout all the tests.

Air Bath Chamber

The air bath chamber was located inside the environment chamber to control the environment around the main flask, in which peanuts were placed. Various views of the air bath chamber are shown in Figures 17, 20, 21 and 22.

The air bath chamber was constructed of Polyurethane foam. A mold was constructed of lumber to form the air bath chamber. When the foam had hardened sufficiently, the forms were removed and the surface holes of the foam were filled with a ceramic plaster to minimize surface damage of the chamber. The surfaces of the chamber were sprayed with a non-gloss black paint to add additional protection to the chamber surfaces.

A plexiglass shield was placed between the air bath chamber and

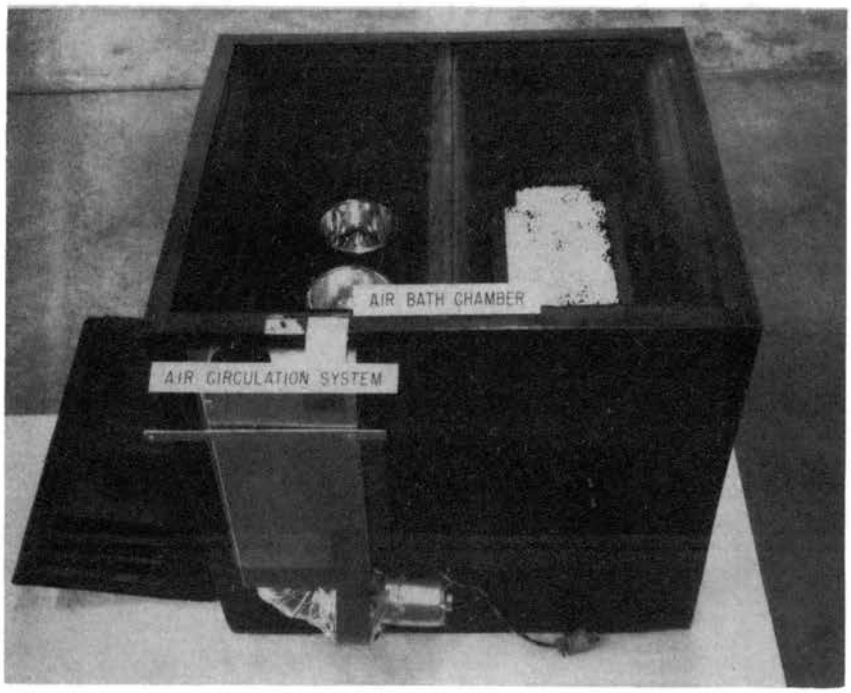


Figure 20. Air Bath Chamber and Air Circulation System

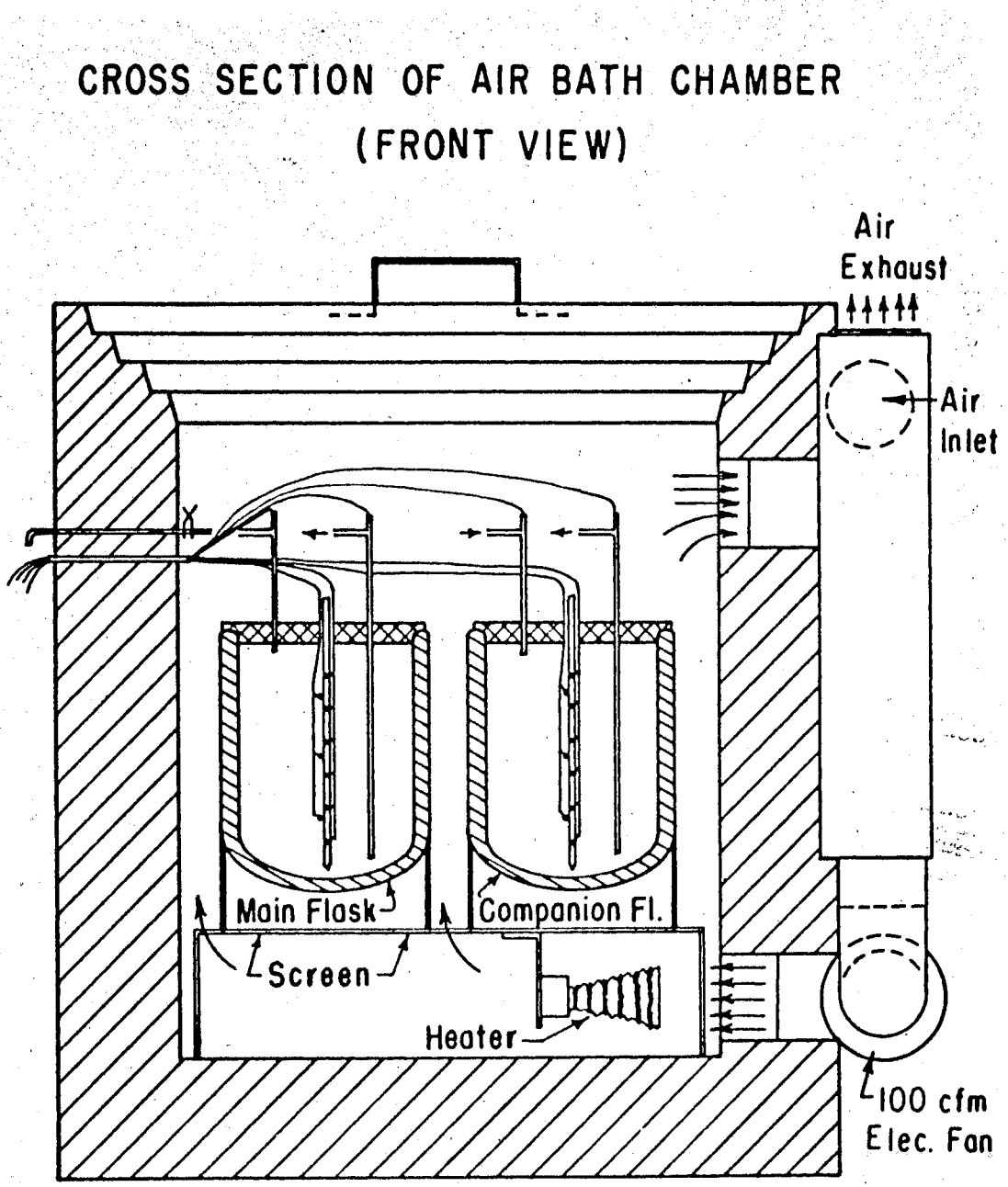


Figure 21. Cross Section of Air Bath Chamber, Front View.

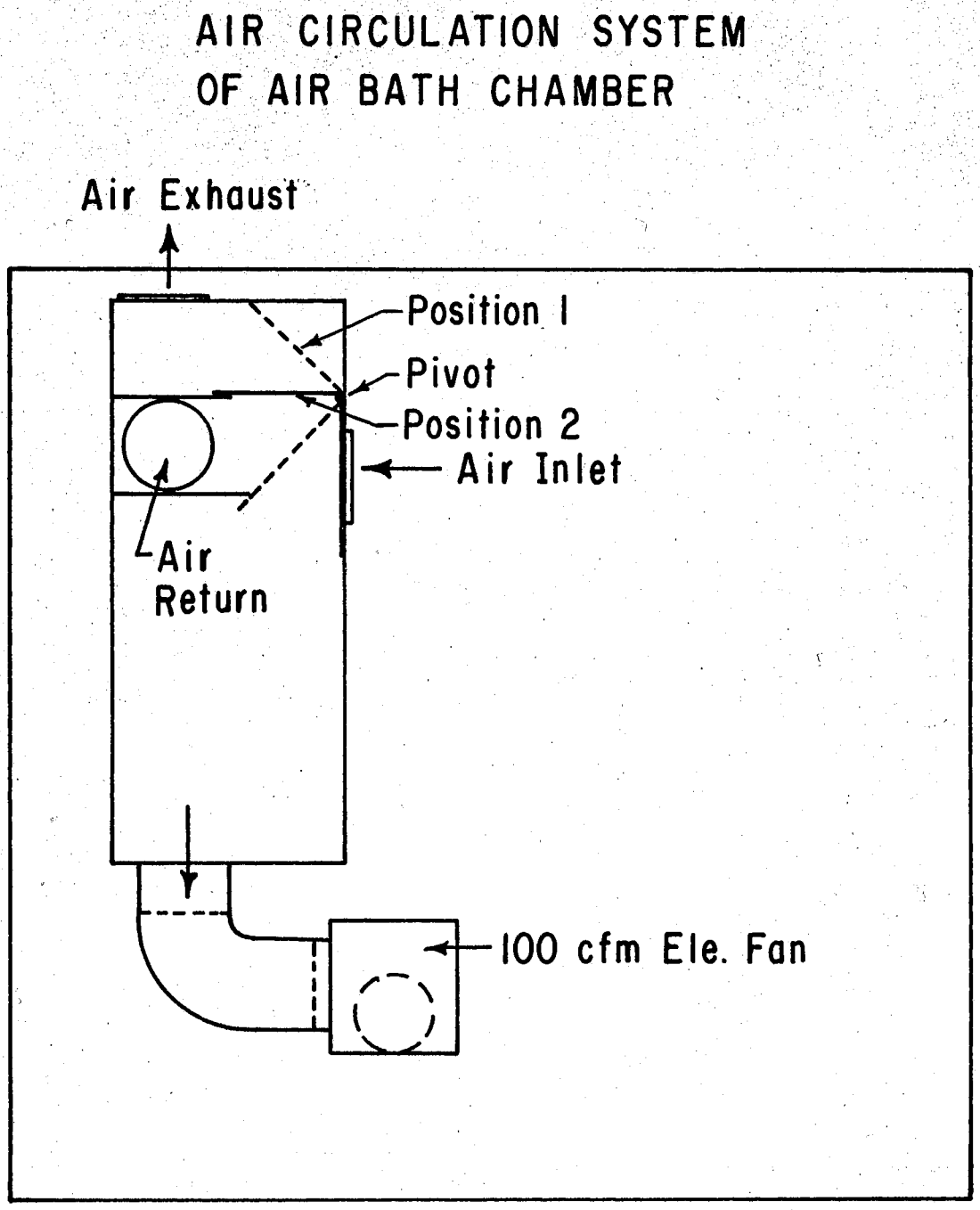


Figure 22. Schematic Diagram of Air Circulation System of Air Bath Chamber.

the environment chamber door to prevent drastic change in the air temperature of the environment chamber when the door was opened. If such drastic change should suddenly occur in the environment chamber, the environment in the air bath chamber would be changed so fast that the temperature control system could not adequately perform its function.

Temperature Control and Recording Equipment

Control of temperature of the air surrounding the main flask to insure that it was the same as that inside the flask, was maintained by the use of a Honeywell Cascade control system. It was necessary to maintain identical air temperatures both inside and outside the main flask to prevent heat transfer through the flask walls.

The temperature control equipment is shown in Figures 23 and 24. A description of the temperature control equipment is as follows:

1. Two Honeywell Vutronik MV/I transmitters, 120 volt AC with a span continuously adjustable from 2.0 to 60.0 mv, an output of 4-20 mv DC, an accuracy of $\pm$ 0.1 per cent of span, operative limits of 40°F to 120°F temperature and 5 to 90 percent relative humidity, and step response of rise time of one second for a minimum of 99 per cent recovery of a step change from 10 to 90 percent. One of the MV/I transmitters served as the set point and the second the process variable. The accuracy of the process variable is $\pm$ 1 per cent full scale, and the set point accuracy of $\pm$ 0.5 per cent of full scale. The accuracy of the MV/I transmitters is $\pm$ 0.1 per cent of full span of 0°-100°F.

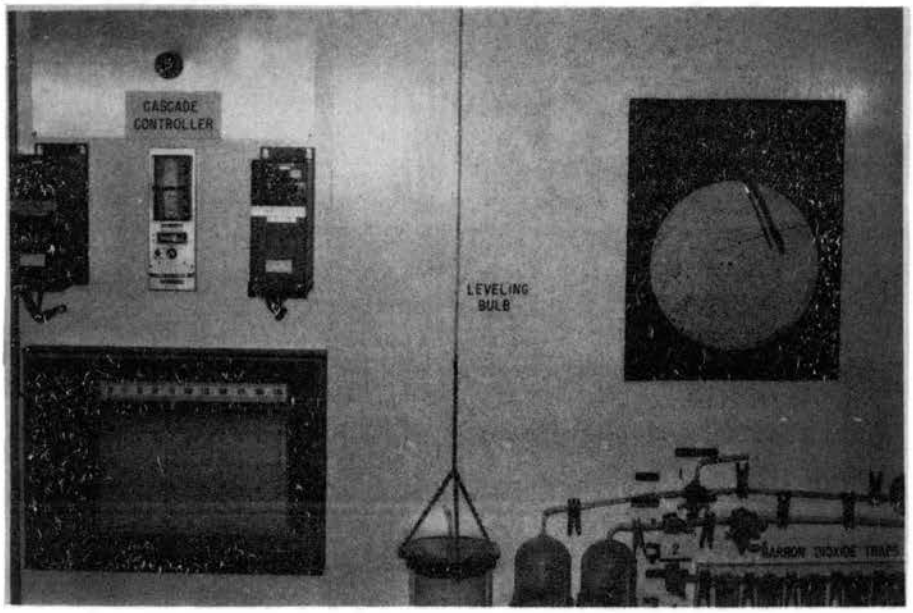


Figure 23. Temperature Control and Recording Equipment Located on Control Panel

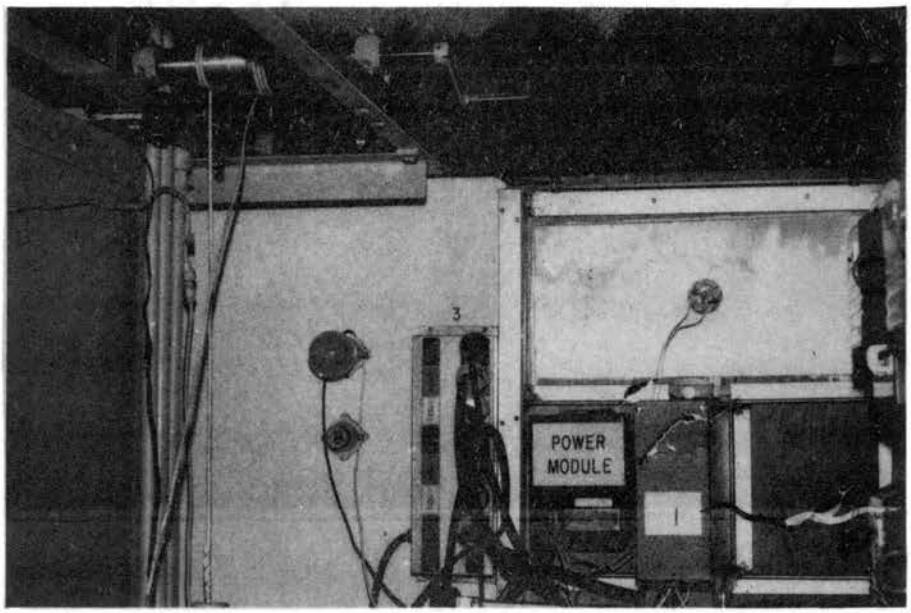


Figure 24. Balance of Temperature Control Equipment

2. Inside the air bath chamber is located, under the base of the two flasks, a 100 watt electrical resistance heater. The heater is to provide the quantity of heat inside the air bath chamber required to raise the temperature of the air bath chamber air circulating around the exterior surfaces of the flask to be exactly the same as that of the interseed air inside the flask.
3. The location of the three parallel thermocouples connected to the set point MV/I transmitter and the three connected to the process variable is shown in Figure 25. The three process variable thermocouples were spaced equi-distance around the top of the flask.
4. One Honeywell Currentronik vertical scale indicator and electronic controller with accuracy on the process variable of $\pm$ 1 per cent of full scale and an accuracy on the set point of $\pm$ 0.5 per cent of full scale.
5. One Honeywell SCR power module
6. Six premium grade copper-constantan thermocouples, ten feet in length

The temperature at various places in the calorimeter were recorded by a Honeywell 24 point recorder, Figure 23. The location of the six thermocouples used to monitor the temperature along the vertical center line of the main flask is shown in Figure 25.

Carbon Dioxide Measurement

The measurement of the carbon dioxide included the equipment to collect the carbon dioxide and that to measure it. The equipment

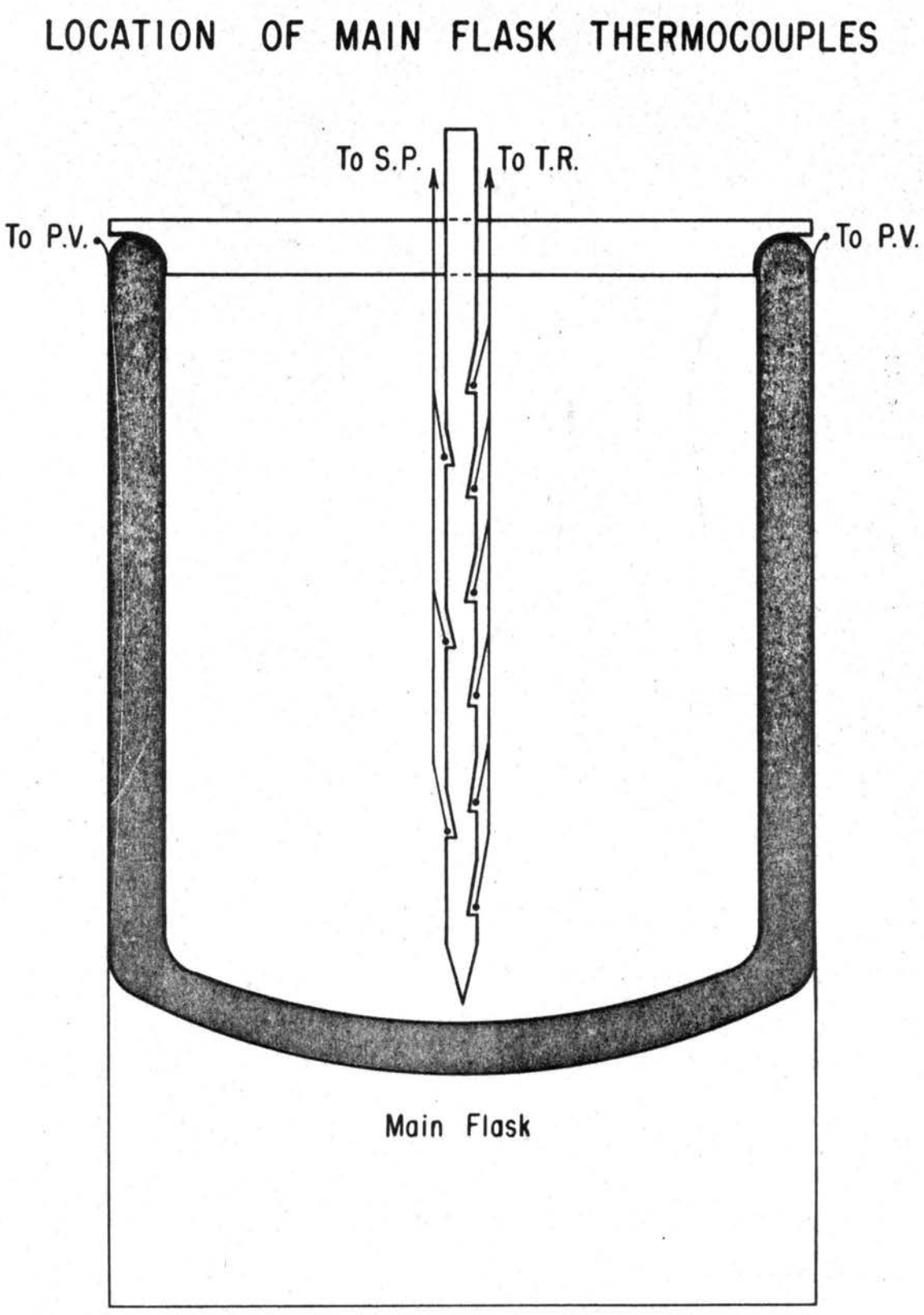


Figure 25. Location of Main Flask Thermocouples.

to collect the carbon dioxide is shown in Figures 16 and 18.

At the end of each 12 hour period, the pumping mechanism was stopped. By regulating various valves, the effluent air was transferred to the effluent air reservoir. A detailed description of the procedure followed at the end of each 12 hour period is presented in Appendix A.

A calcium chloride solution with specific gravity of 1.4 was used since carbon dioxide is only slightly soluble in it. The carbon dioxide reacts with barium hydroxide to form calcium carbonate and water. Five carbon dioxide traps were adequate to trap all the carbon dioxide since the carbon dioxide measured in the fifth trap was negligible.

After the effluent air has passed through the barium hydroxide, the solution in each trap was passed through number 40 filters to remove the precipitate. The filters were dried in an electric convection type oven at 190^{o}F for four to five hours.

When the filters were dried, they were placed in cans, sealed with plastic tops and placed in the weighing room to allow their temperature to reach ambient room temperature. The filters were then weighed with a Mettler precision balance to the nearest 0.0001 gram.

The method used in the computation of the carbon dioxide by volume in the interseed air is presented in Appendix B. The computation is made on a volume basis since it is the method most widely reported in the literature.

Since the barium hydroxide was placed in the carbon dioxide traps in an environment not free of carbon dioxide, some carbon

dioxide probably diffused into the barium hydroxide. In order to estimate the amount of carbon dioxide diffused into the barium hydroxide in each trap, a sixth trap was filled with 60 milliliters of barium hydroxide and the precipitate was determined in the same manner as that of the other five traps. The amount of the precipitate in the sixth trap was considered a base value for that day and the amount was deducted from the precipitate value obtained in each of the other five traps. Some of the carbon dioxide measurement equipment is shown in Figure 26.

Maturity Measurement Screens

A sample of approximately 100 grams of peanuts was obtained from the main flask at the end of each respiration test to estimate the percentage of immature kernels in said test. The peanuts were hand shelled and placed on a screen having 15/64 inch by 3/4 inch perforations. The percentage of immature kernels was calculated on the basis of percent by weight.

Specific Heat Calorimeter and Auxiliary Equipment

Specific heat of the peanuts was determined by the method of mixtures. The specific heat calorimeter and auxiliary equipment used in the tests are shown in Figure 27. A schematic diagram of the calorimeter published by Wright and Porterfield (42), described in Chapter II, illustrates the calorimeter used in this study.

The peanut sample to be used in the specific heat test was removed from the companion flask about three to four hours prior to the test, sealed in a plastic bag and placed inside the air bath chamber

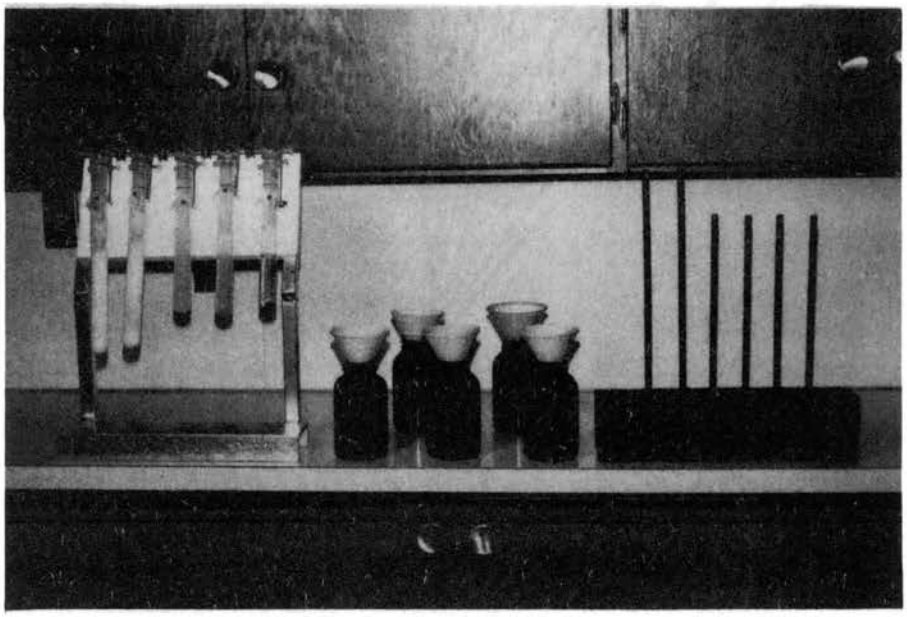


Figure 26. Filtration Equipment

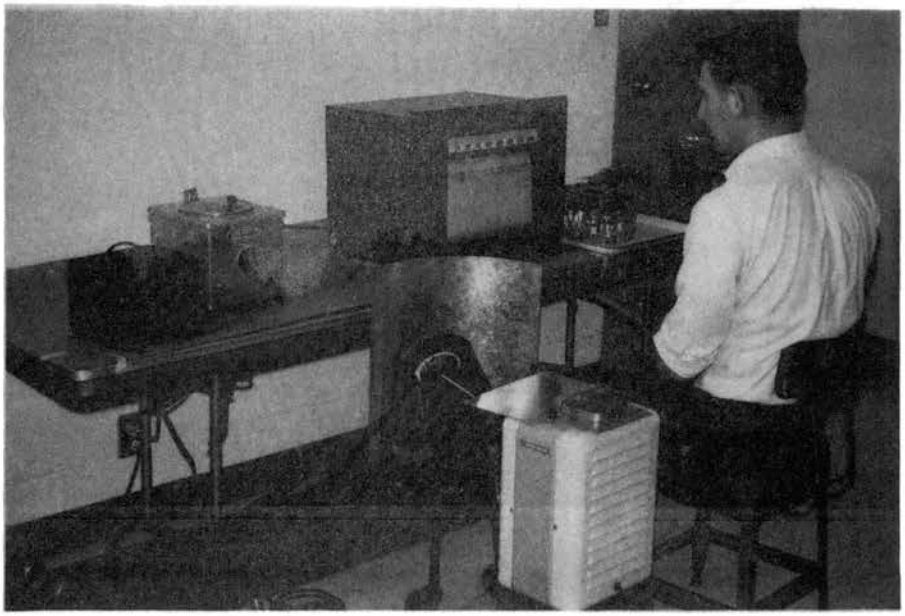


Figure 27. Specific Heat Calorimeter

so that the temperature of the peanuts in the plastic bag was the same as that inside the flask at the time of the test.

The sample was placed in an insulated box (Figure 13) for transferring from the air bath chamber to the specific heat calorimeter. The insulated box was constructed of Polyurethene foam, one inch thick walls throughout.

For each specific heat test, 220 grams of distilled water were heated to a temperature of at least $30^{o}F$ above that of the peanut sample. The hot water was placed in the flask. The shaker mechanism was started and the water and the flask were allowed to reach temperature equilibrium.

The temperature of the environment around the calorimeter was maintained at a temperature approximately the same as that of the water and flask interior by the space heater. The air shield placed behind the shaker can, Figure 27, acts as a heat diffuser to minimize a temperature gradient around the can.

The peanut sample was placed in the flask, with the shaker mechanism stopped. As soon as the peanuts were inserted and the stopper was in place, the shaker mechanism was again started and the agitation of the mixture was continued until temperature equilibrium was again reached.

The heat balance for each of the peanut tests is written as follows:

$$C_{pp}W_{p}(\Delta T_{p} - \theta R_{c}) = C_{pw}W_{w}(\Delta T_{w} + \theta R_{c}) + H_{c}(\Delta T_{f} + \theta R_{c}) \quad . \quad . \quad . \quad [14]$$

Since the water and the flask are at the same temperature just prior to placing the peanuts in the flask, ΔT_{w} is equal to ΔT_{f}. If the equilibrium temperature was below room temperature, R_{c} will be the

rate of temperature rise of mixture after equilibrium was reached. The determination of R_c is illustrated in Figure 28.

The specific heat was measured of peanut pods and kernels individually in order to compare the specific heat of each with the peanut pods. Farmer stock Spanish peanuts stored in the walk-in cooler at 40°F were used in the study.

Peanuts were rewetted to a bulk moisture content of approximately 30 per cent wet basis. The peanuts were hand shelled, and divided into samples of approximately 120 grams of kernels and 35 grams of hulls. The samples were sealed in plastic bags and placed in the walk-in cooler at about 40°F until ready for the test.

The mean moisture content of the hulls and kernels was approximately 30 per cent and 26 per cent, wet basis, respectively. Four replicates were run at 40°F, 60°F, 80°F and 100°F of each pods and kernels.

Calibration of Equipment

Heat Capacity Constant of Specific Heat Calorimeter

The specific heat calorimeter flask was calibrated to determine the flask heat capacity constant, H_c, a constant which defines the amount of heat stored by the flask and attached auxiliary equipment. The heat capacity constant was determined by the method of mixtures.

Approximately 475 grams of distilled water with a temperature of approximately 95°F was used in each test. After the hot water and the flask reached equilibrium, approximately 590 grams of distilled water at a temperature of about 45°F was added to the hot water.

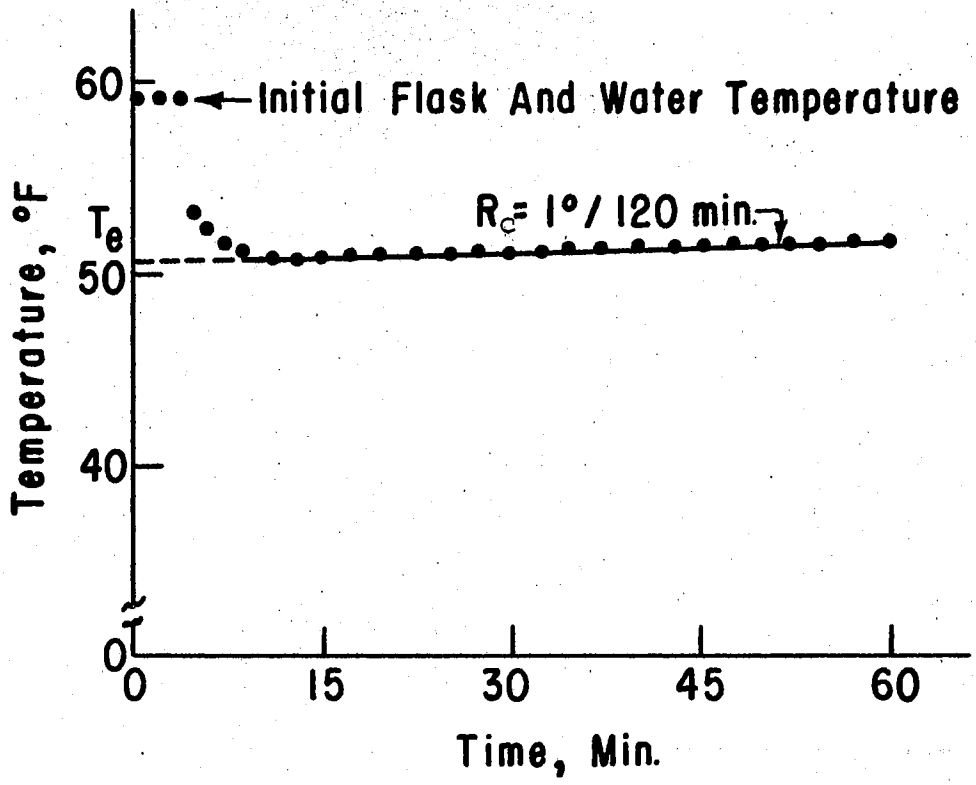


Figure 28. Calculation of Temperature Correction Factor, R_c.

The shaker mechanism, as described in the previous section, was used to insure thorough mixing of the two amounts of water of different temperature. The agitation was continued until temperature equilibrium was again reached.

Since the equilibrium temperature was usually approximately the same as that of the room temperature, the equation for the heat capacity constant is given by the following:

$$H_c = \frac{W_c \Delta T_c - W_h \Delta T_h}{\Delta T_f} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [15]$$

The heat capacity constant of the specific heat calorimeter flask was determined to be 21.20 cal./^{o}C. The results of the calibration tests are summarized in Table II. The mean percent difference between the eight measured values and the mean value of 21.20 cal./^{o}C. was 2.6. The data used in determining the heat capacity constant of the specific heat calorimeter flask are presented in Table XIX, Appendix F.

Validation Tests of Specific Heat Calorimeter

Rhombic and Monoclinic sulfur lumps were used to validate the accuracy of the specific heat calorimeter. The specific heat of Rhombic sulfur (10) is given by equation [16].

$$C_{ps} = \frac{3.63 + 0.00640T_k}{32} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [16]$$

The specific heat of Monoclinic sulfur (10) is given by equation [17].

$$C_{ps} = \frac{4.38 + 0.00440T_k}{32} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [17]$$

The data used in the specific heat calorimeter tests are given in Table XX, Appendix F.

Results of the validation tests are summarized in Table III. The maximum percent difference between the measured and calculated values was 4.0.

Heat Capacity Constant of Respiration Calorimeter

The heat capacity constant of the respiration calorimeter was determined in the same manner as that used to determine the specific heat calorimeter flask heat capacity constant. The only essential difference between the two calibration tests was the different amounts of water and sulfur lumps used in each case.

The heat capacity constant of the respiration calorimeter main flask was measured to be 51.2 calories per degree centigrade. Results of the calibration tests are summarized in Table IV. The mean percent differences between the six measured values and the mean value of 51.2 calories per degree centigrade was 4.2. The data in determining H_c of the respiration calorimeter are given in Table XXI, Appendix F.

Validation Tests of Respiration Calorimeter

Measurement of the rate of heat generated by the peanuts in the respiration calorimeter was validated by measuring the rate of heating in the respiration calorimeter flask with three heaters of known electrical source. The three heaters consisted of 1 1/2 inch O. D., 5 1/4 inch thin wall pipe of wall thickness of 1/16 inch; wrapped with 26 gauge nichrome wire. The heaters were connected in series to insure uniform heating. The flask cover was constructed of Polyurethene form.

Leads to the power source and oscillioscope, used as a voltmeter,

TABLE II

DETERMINATION OF HEAT CAPACITY CONSTANT, H_c
OF SPECIFIC HEAT CALORIMETER FLASK

Test No.	H_c (cal/°C)	Diff. From Mean (cal./°C)	Percent Difference
1	21.86	+ 0.66	3.1
2	21.93	+ 0.73	3.4
3	20.02	- 1.18	5.6
4	21.27	+ 0.07	0.3
5	20.46	- 0.74	3.5
6	21.55	+ 0.35	1.6
7	20.86	- 0.34	1.6
8	21.62	+ 0.42	2.0
Mean	21.20		2.6

TABLE III

VALIDATION TESTS OF SPECIFIC HEAT CALORIMETER
WITH SULFUR LUMPS

Test No.	Measured (cal./gm.-°C)	Calculated (cal./gm.-°C)	Difference (cal./gm.-°C)	Percent Difference
1	0.178	0.178	-	-
2	0.178	0.178	-	-
3	0.173	0.171	0.002	1.6
4	0.178	0.178	-	-
5	0.173	0.175	0.002	1.6
6	0.173	0.180	0.007	4.0

were two copper wires, number 12. Since the thermal conductivity of copper is high, it was essential to minimize any temperature difference between the two sides of the flask top, through which passed the copper leads. Three set point thermocouples were placed adjacent to the power leads and approximately 1/16 inch below the flask cover. Three process variable thermocouples were placed adjacent to the power leads and within 1/16 inch of the flask cover top surface.

The wiring circuit used in the validation tests is shown in Figure 29. The variable resistors were set to maintain an 8.1 volt potential with 0.3 amps current.

It was necessary to determine the specific heat of all the materials used in the validation tests which were within the interior of the flask. The specific heat calorimeter was used and the same procedure as that used with the peanuts was followed.

Results of the validation tests are summarized in Table V. The maximum percent difference between the calculated and measured values was 5.3 percent. Data used in the validation tests are presented in Table XXII, Appendix F.

Estimation of Interseed Air of Main Flask of Respiration Calorimeter

The volume of the interseed air of the main flask was estimated at various intervals during the growing season. Freshly harvested peanuts which had been washed and sorted for using in one of the respiration tests were placed in a 1900 milliliter Dewar flask to a level normally used in the tests. The flask was filled with water until all of the peanuts were barely covered.

TABLE IV

DETERMINATION OF HEAT CAPACITY CONSTANT, H_c, OF MAIN FLASK OF RESPIRATION CALORIMETER

Test No.	H (cal./°C)	Diff. From Mean (cal./°C)	Percent Difference
1	51.5	0.2	3.9
2	51.3	0.1	1.9
3	50.9	0.3	5.9
4	51.1	0.1	1.9
5	50.9	0.3	5.9
6	51.5	0.3	5.9
Mean	51.2		4.2

TABLE V

VALIDATION TESTS OF RESPIRATION CALORIMETER

Test No.	Calculated Electrical Energy Output (cal.)	Calculated Thermal Energy Measured (cal.)	Difference Between Thermal And Electrical Energy (cal.)	Percent Difference (%)
1	2282.4	2213.7	68.7	3.2
2	2099.1	2213.7	114.6	5.3
3	2143.0	2213.7	70.7	3.2

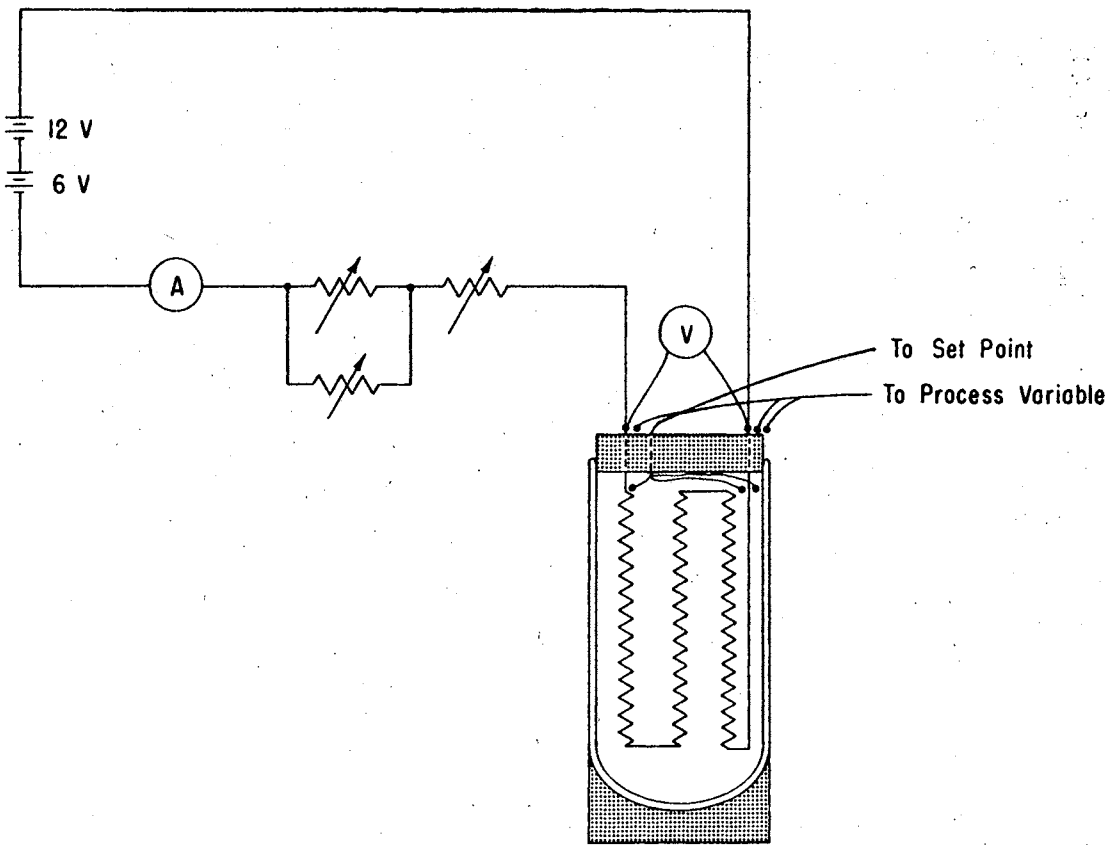


Figure 29. Wiring Circuit Used in the Validation Test.

With the flask cover in place, the flask was drained through a small hole in the cover until no more water could be removed by gravitational forces. The water drained off was weighed and its gram weight was used as an estimate of the air voids in the sample in cubic centimeters. The average value obtained in the above tests was 770 milliliters.

Estimation of Air Velocity in Aeration Lines and Through Respiration Calorimeter Main Flask

In order to predict the diffusion of heat in the flask aeration line, it was necessary to determine the air velocity in the aeration line. The glass tube used as the air aeration entrance of the respiration calorimeter main flask was filled with water to a given length of tube. The volume of water placed in the line in cubic centimeters divided by the length of tube filled gives the tube mean cross sectional area. The mean diameter of the tubing used in the aeration line was verified to be 5 millimeters.

Since the aeration line was maintained at approximately 200 milliliters per 24 hours, the mean air velocity in the aeration line would then be approximately 6.94 centimeters per minute. With an estimated air void in the main flask of 770 milliliters, an average aeration rate of 2000 milliliters per 24 hours, the mean velocity of the air through the main flask would be approximately 0.3 centimeters per hour. This would mean that 2000 milliliters of air would pass through the main flask about 2.6 times per 24 hours.

CHAPTER V

PRESENTATION OF DATA AND RESULTS

Moisture Content

Bulk moisture content of the peanuts of the high moisture level ranged from 44.8 to 47.3 percent, wet basis. The range of the low moisture content level was between 29.2 and 35.6 percent. Measured bulk moisture content of each of the respiration test is presented in Table XVI of Appendix C. Considerable difficulty was encountered in drying the peanut samples to the designed moisture content of 30 percent, wet basis.

Temperature Rise

The bulk temperature rise in each of the ten respiration tests are presented in Figures 30 through 39. Results of each of the ten tests are given in Table XVI of Appendix C. In each test, a least squares best fit to a polynomial equation, expressing peanut bulk temperature as a function of time, was obtained. The general form of the polynomial equation was

$$T_\theta = \beta_0 + \beta_1\theta + \beta_2\theta^2 + \beta_3\theta^3 + \beta_4\theta^4 \quad \ldots\ldots\ldots\ldots [18]$$

Data for the entire test duration in each test were used to determine a least squares best fit curve for test results presented in Figures 30 through 39.

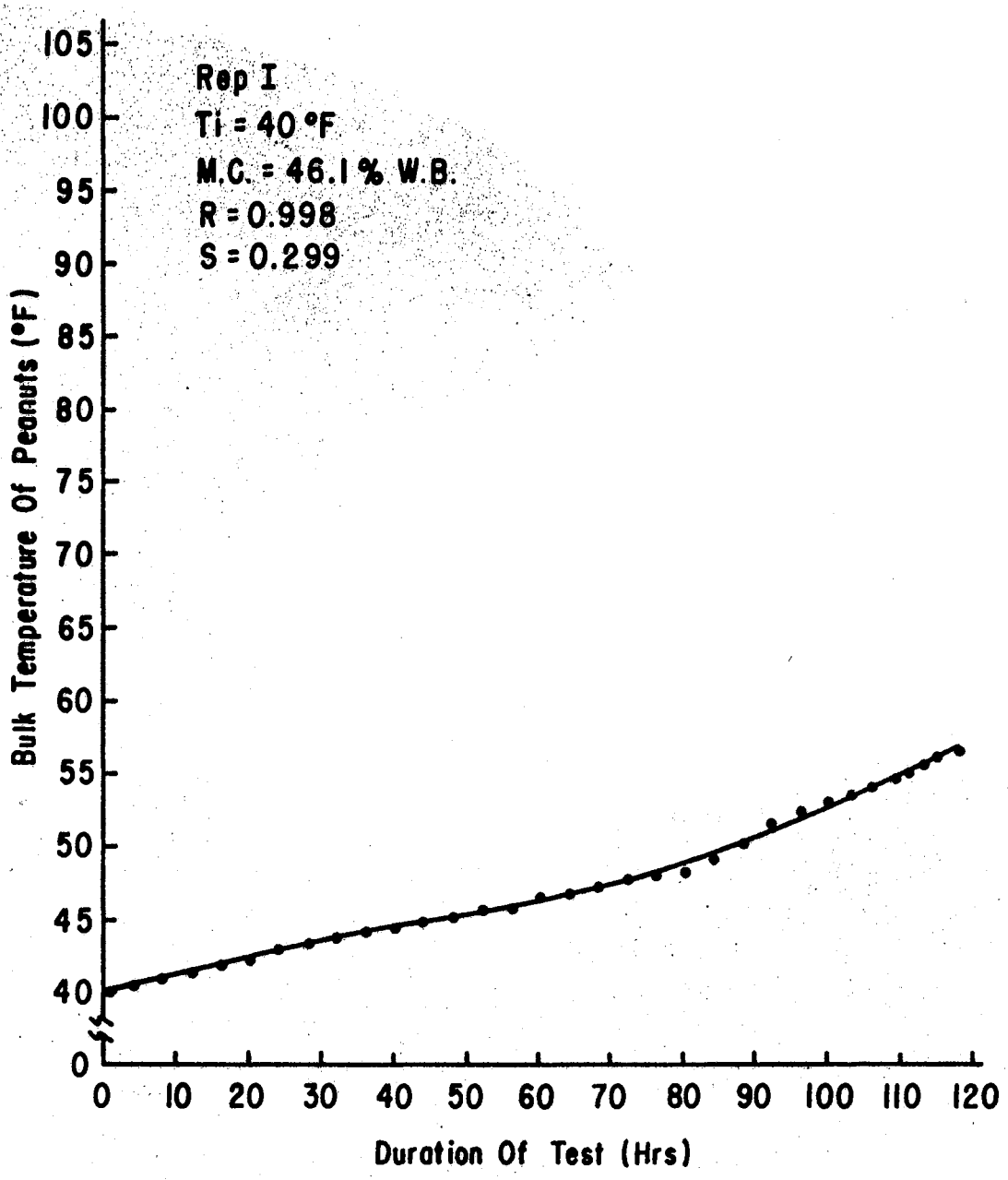


Figure 30. Bulk Temperature Versus Time of Test 1

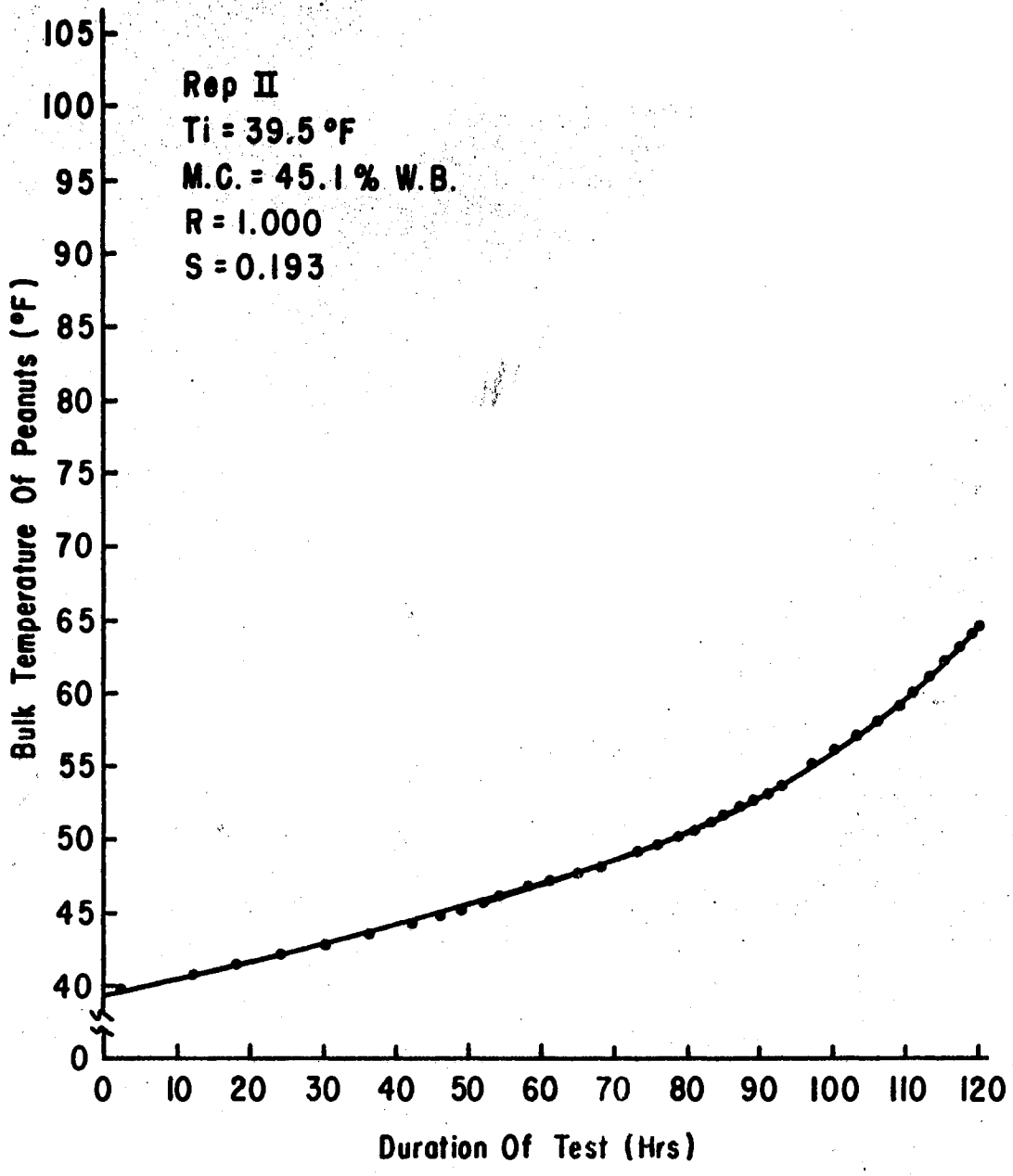


Figure 31. Bulk Temperature Versus Time of Test 2

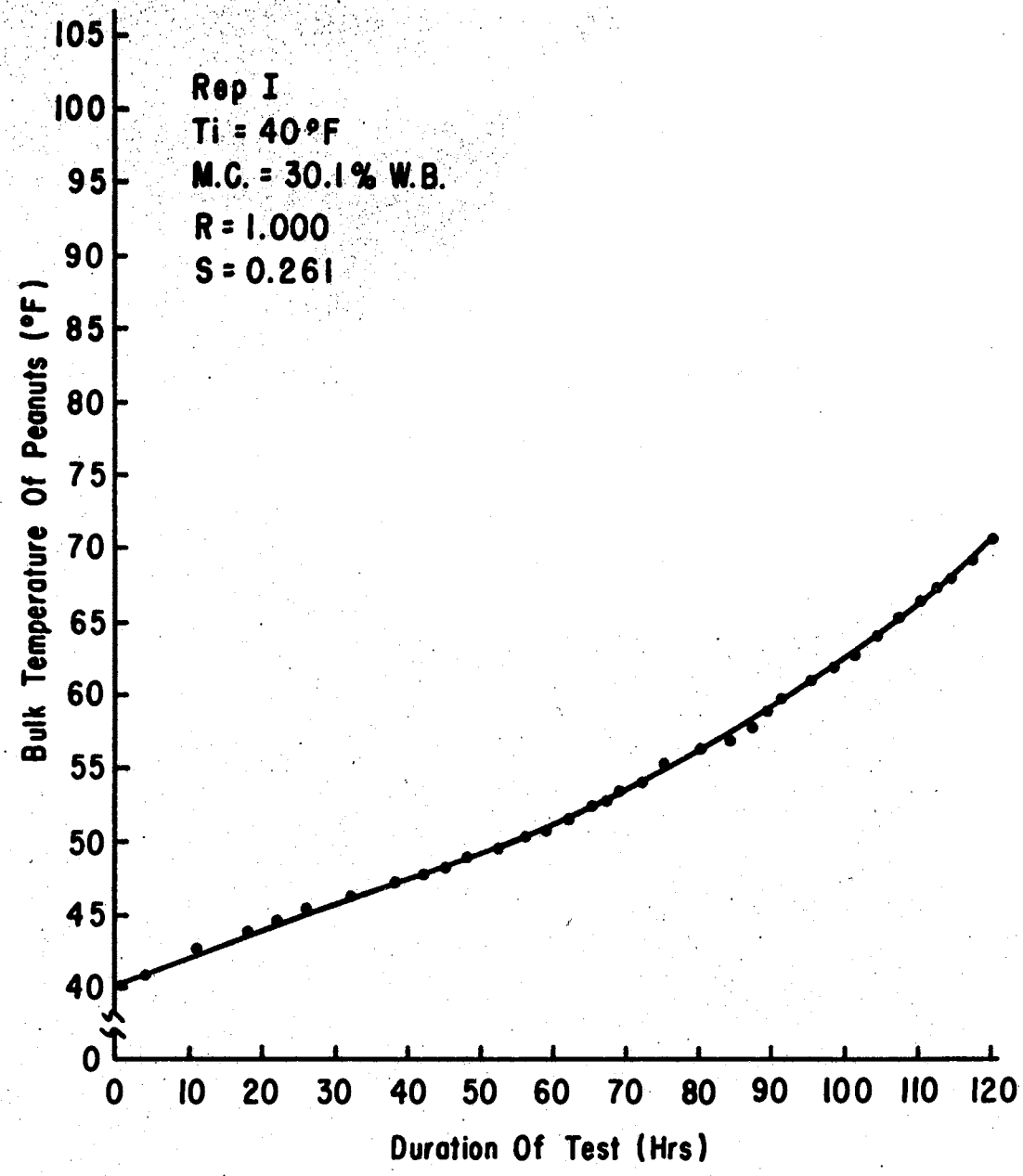


Figure 32. Bulk Temperature Versus Time of Test 3

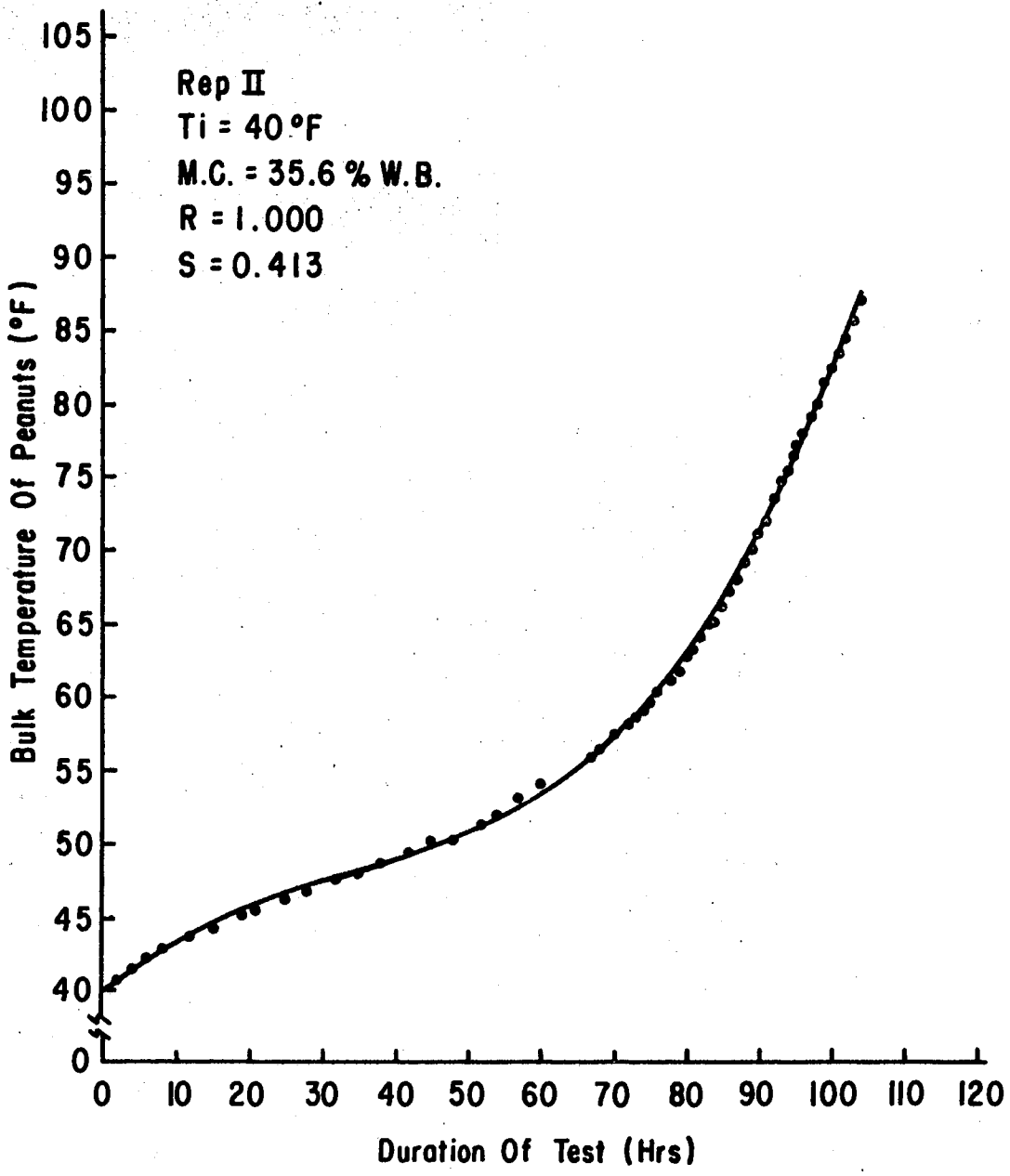


Figure 33. Bulk Temperature Versus Time of Test 4

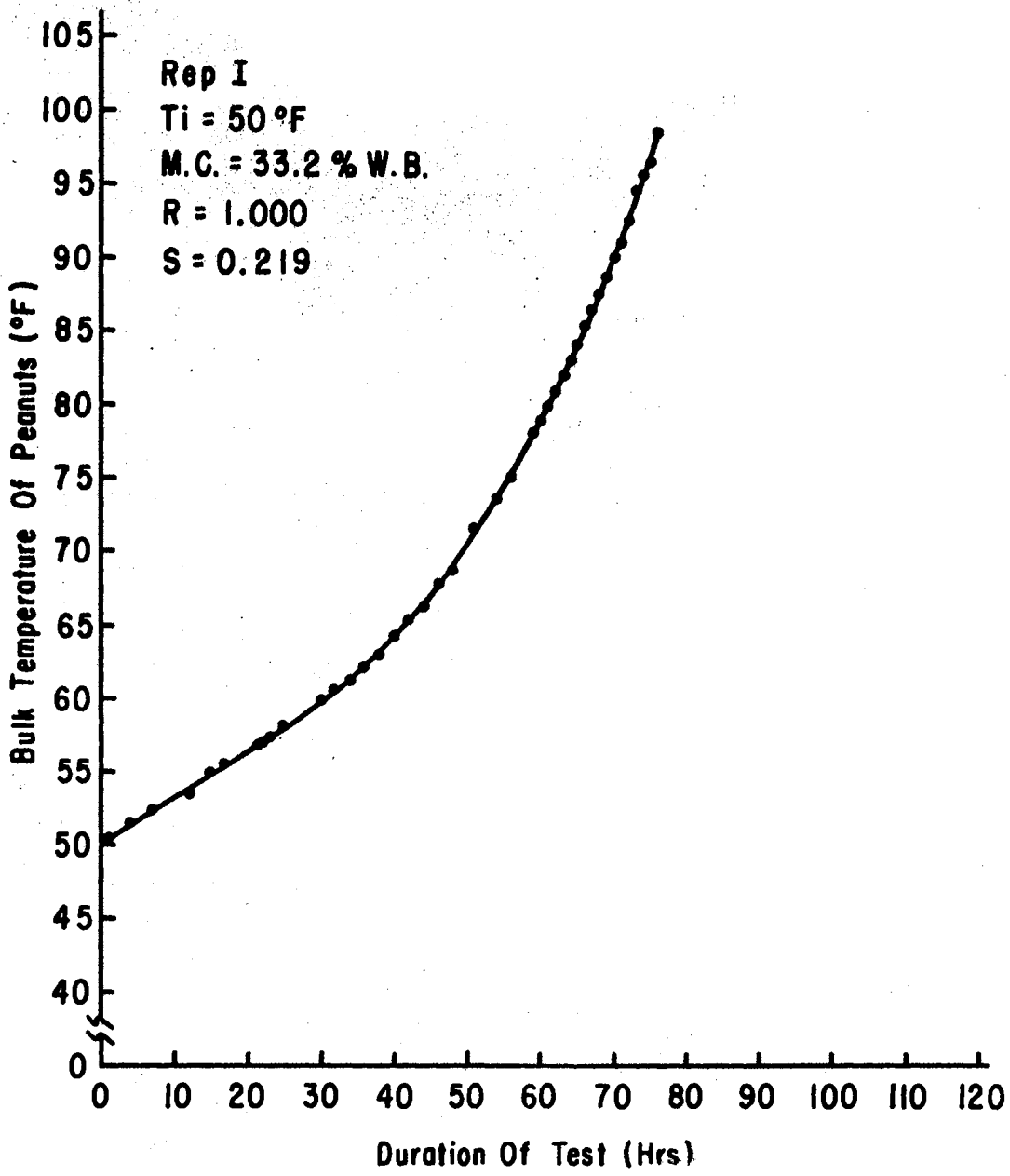


Figure 34. Bulk Temperature Versus Time of Test 5

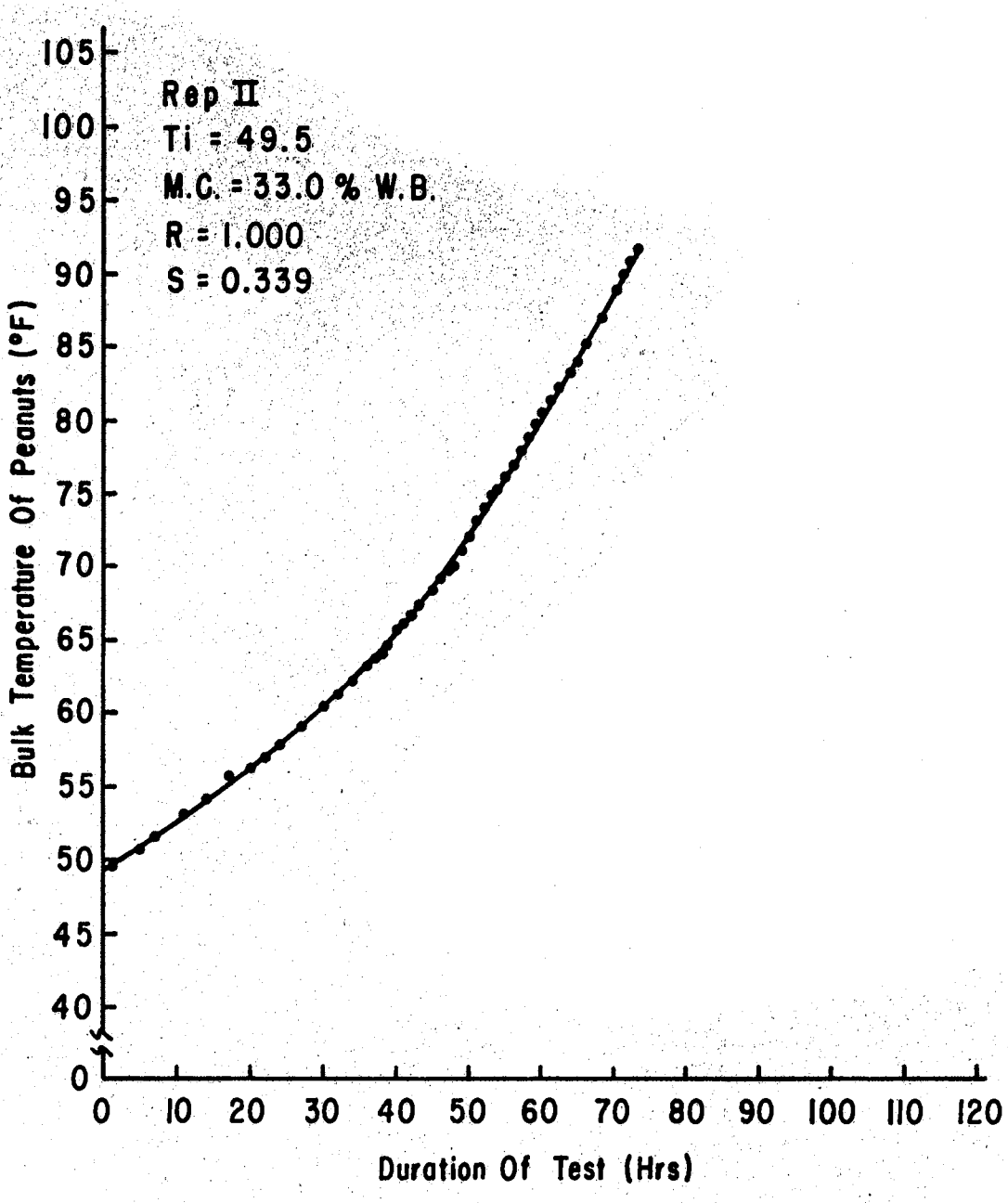


Figure 35. Bulk Temperature Versus Time of Test 6

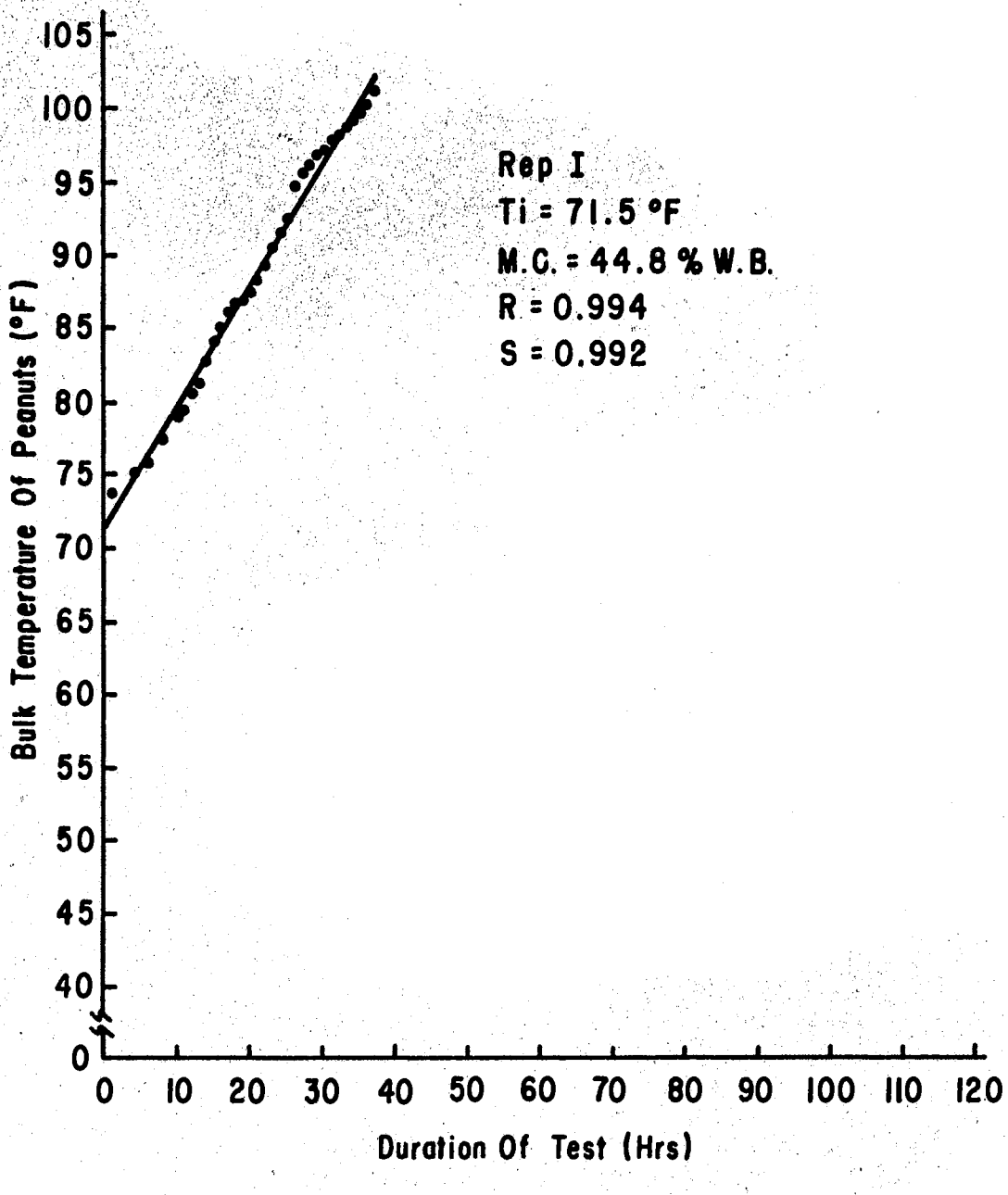


Figure 36. Bulk Temperature Versus Time of Test 7

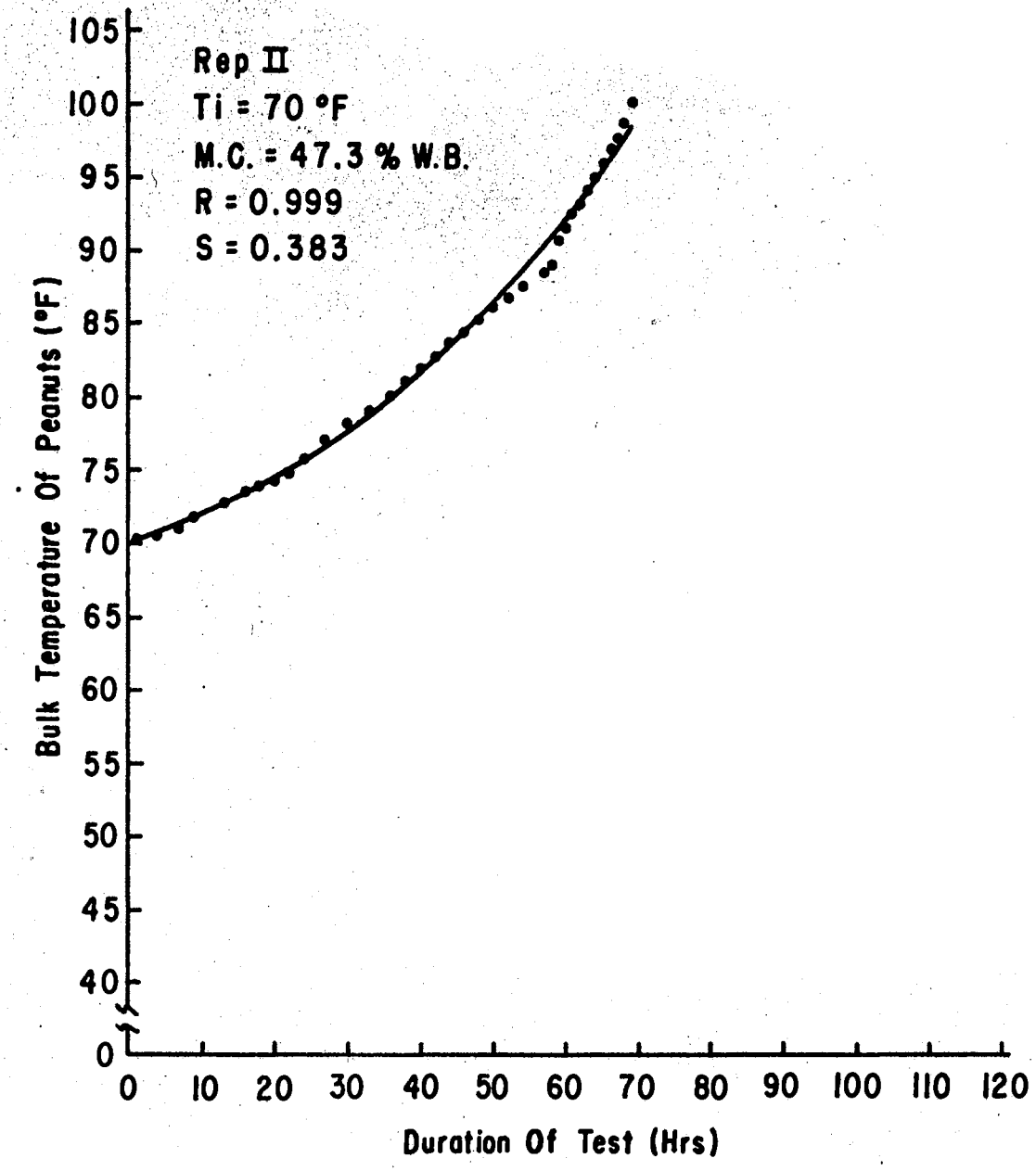


Figure 37. Bulk Temperature Versus Time of Test 8

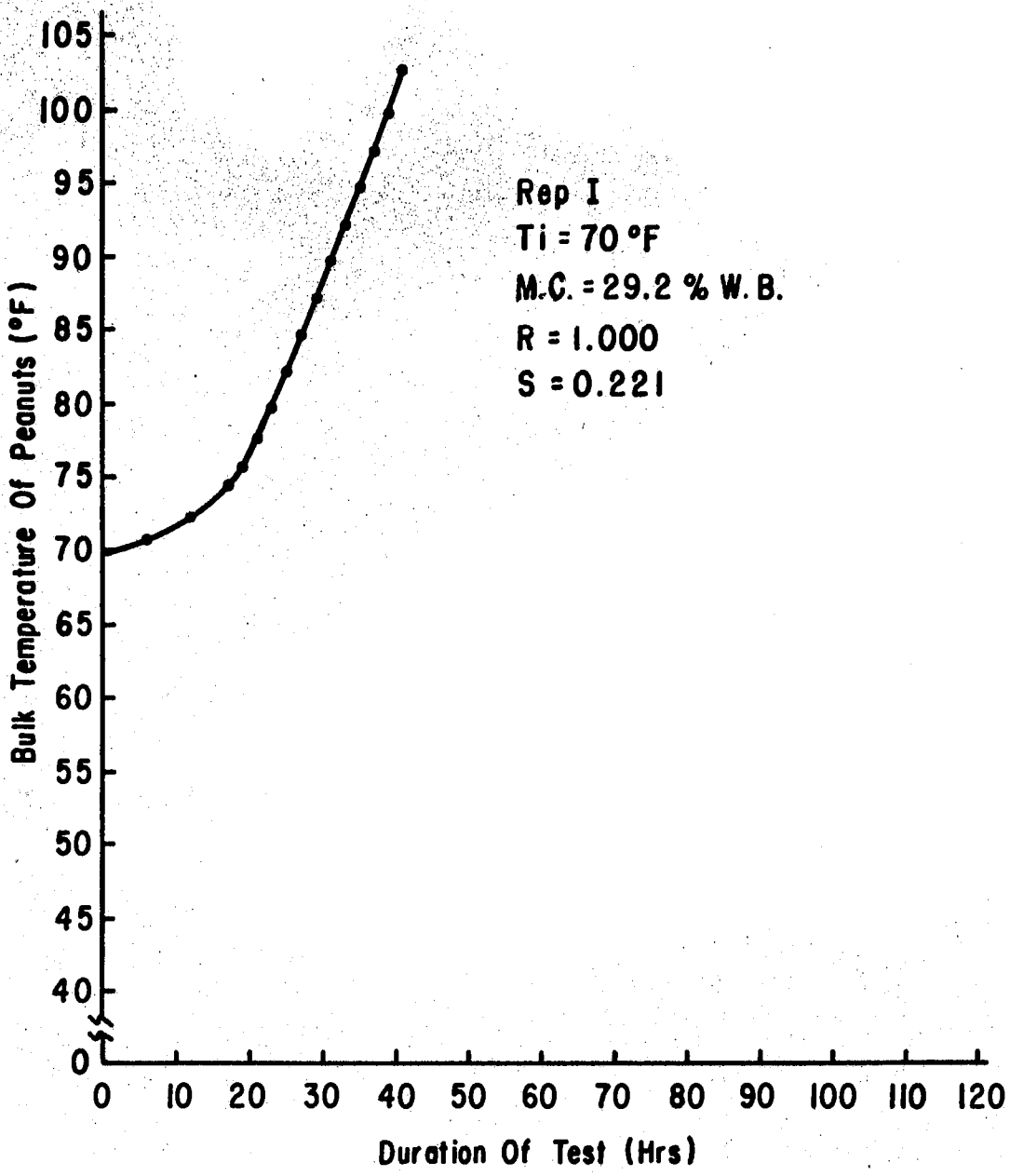


Figure 38. Bulk Temperature Versus Time of Test 9

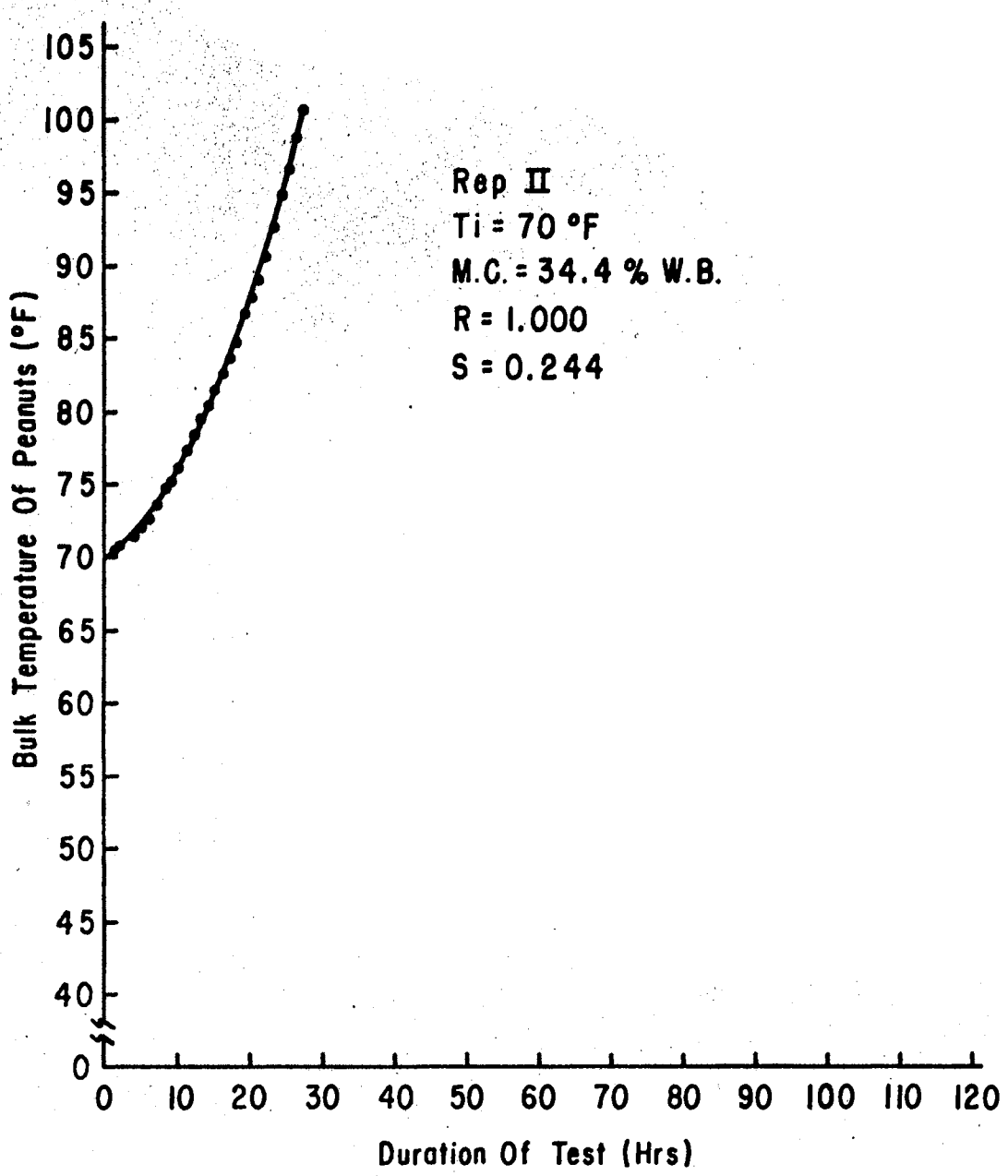


Figure 39. Bulk Temperature Versus Time of Test 10

It was observed that the difference between the bulk peanut temperature rise of the two replicates at the 40°F temperature level and of high moisture content appeared to become rather pronounced at about hour 72 of the tests. It was similarly observed for the tests run at 40°F initial bulk temperature and of low moisture content. It was, therefore, decided to obtain a polynomial best fit equation for each of the tests up to hour 72 only or until the end of the test, whichever was the shorter duration. Regression coefficients for the polynomial equation obtained for each of the ten tests are given in Table VI. The standard deviation and the applicable range for each equation is also presented in Table VI.

For each treatment combination of the 40°F and 50°F temperature levels, the data of both replications were combined to obtain a polynomial best fit equation. Results of the above equation are presented graphically in Figure 40 and summarized in Table VII.

Bulk temperature versus time for each replicate at both moisture content levels and initial bulk peanut temperatures of 70°F is presented in Figure 41. Data of the two replicates of each moisture content level were not combined due to the large variance between the two replicates.

In all the temperature-time curve fitting efforts, the degree of the equation selected was based on (a) the standard deviation and (b) the relative degree of good fit of the equation at the end points. For example, if the standard deviation of each of the two polynomial equations was approximately the same but one fitted the end points considerably better, the equation better fitting the end points would be selected.

TABLE VI

REGRESSION COEFFICIENTS OF TEMPERATURE-TIME POLYNOMIAL EQUATION*
OF RESPIRATION TESTS

Replicate	Moisture Content, Wet Basis (%)	Initial Peanut Temperature (^{o}F)	β_0	β_1** X 10	β_2** X 10^2	β_3** X 10^4	β_4** X 10^6	Range Applicable (Hours)	Std. Dev.
I	46.1	40.0	39.7	1.83	-0.297	0.352	-0.108	0-72	0.299
II	45.1	39.5	39.6	1.63	-0.182	0.182	--	0-72	0.142
I	30.1	40.0	40.2	2.66	-0.389	0.528	-0.177	0-72	0.261
II	35.6	40.0	39.6	4.42	-0.877	0.861	--	0-72	0.413
I	33.2	50.0	50.1	3.52	-0.448	1.16	0.106	0-72	0.219
II	33.0	49.5	48.6	4.77	-0.982	2.78	-1.69	0-72	0.339
I	44.8	71.5	71.2	8.31	--	--	--	0-37	0.977
II	47.3	70.0	70.3	-4.43	2.05	-4.57	3.77	0-69	0.383
I	29.2	70.0	70.6	-7.01	6.67	-9.22	4.21	0-41	0.221
II	34.4	70.0	70.3	-0.539	10.0	-44.5	88.1	0-27	0.244

*$T_\theta = \beta_0 + \beta_1\theta + \beta_2\theta^2 + \beta_3\theta^3 + \beta_4\theta^4$

**Divide each β coefficient by its respective multiplier to obtain its correct magnitude. Example: For β_2 values of β_2, divide by 100.

TABLE VII

REGRESSION COEFFICIENTS OF TEMPERATURE-TIME POLYNOMIAL EQUATION* DERIVED FROM COMBINED DATA OF TWO REPLICATES, RESPIRATION TESTS

Replicate	Moisture Content, Wet Basis (%)	Initial Peanut Temperature (^{o}F)	β_0	β_1** X 10	β_2** X 10^3	β_3** X 10^4	β_4** X 10^6	Range Applicable (Hours)	Std. Dev.
I	46.1	40.0	39.7	1.24	-0.460	0.0232	0.0443	0-72	0.359
II	45.1	39.5							
I	30.1	40.0	40.0	3.32	-4.81	0.344	0.176	0-72	1.029
II	35.6	40.0							
I	33.2	50.0	49.1	4.56	-9.45	2.54	1.36	0-72	0.649
II	33.0	49.5							

*$T_\theta = \beta_0 + \beta_1\theta + \beta_2\theta^2 + \beta_3\theta^3 + \beta_4\theta^4$

**Divide each β coefficient by its respective multiplier to obtain its correct magnitude. Example: For β_2 values of β_2, divide by 1000.

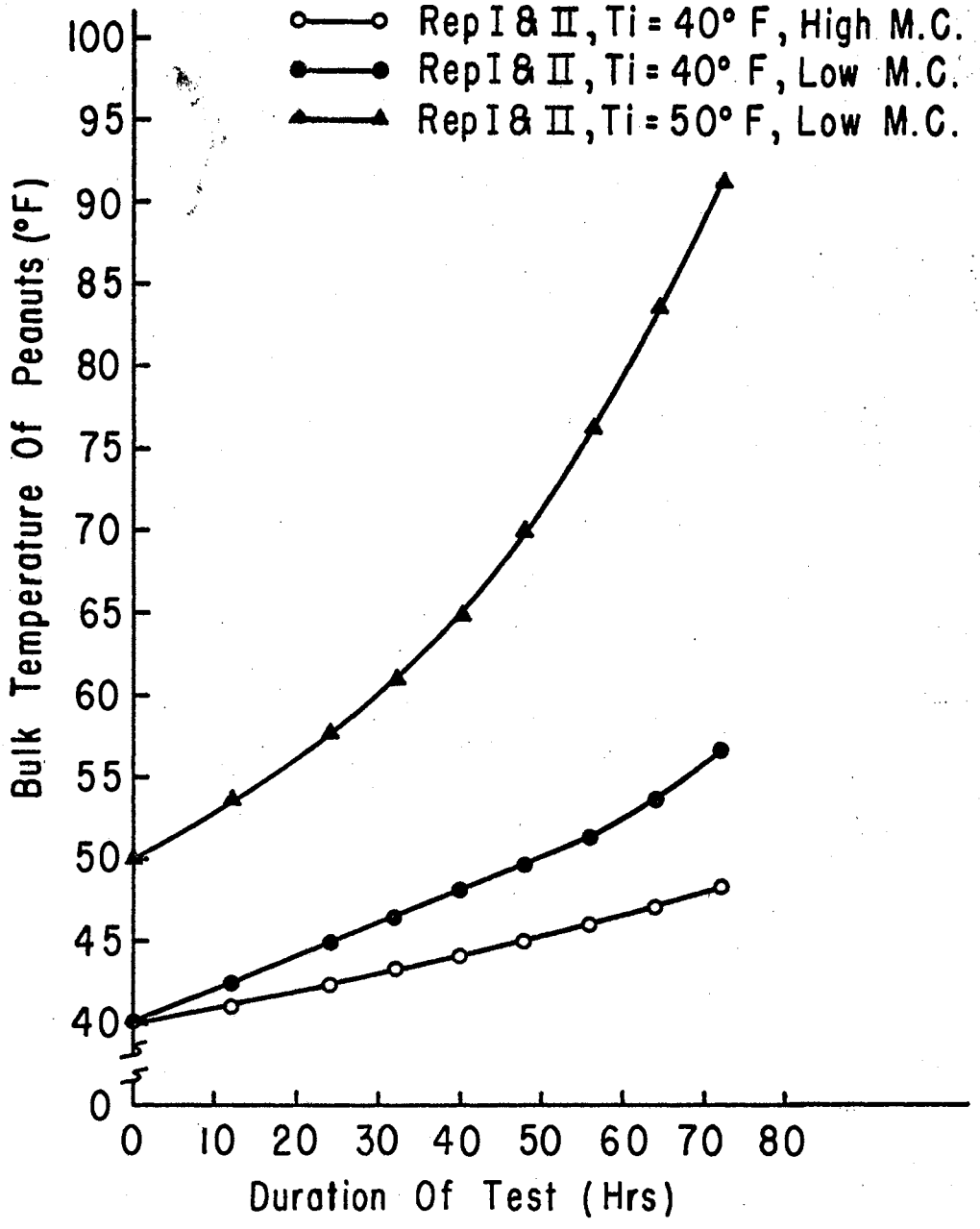


Figure 40. Bulk Temperature Versus Time from Combined Data of Two Replicates at Each Moisture Content Level for 40°F and 50°F.

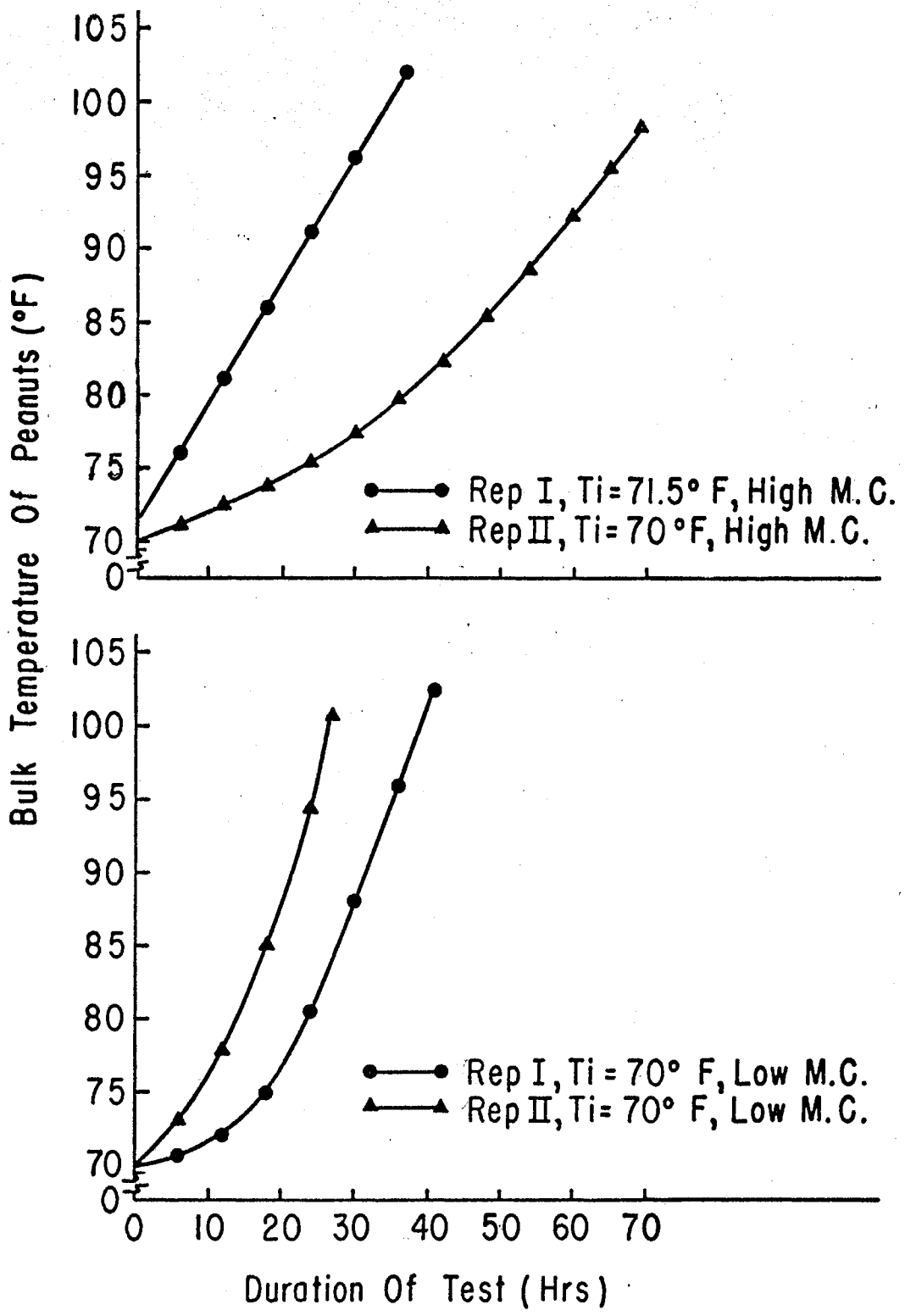


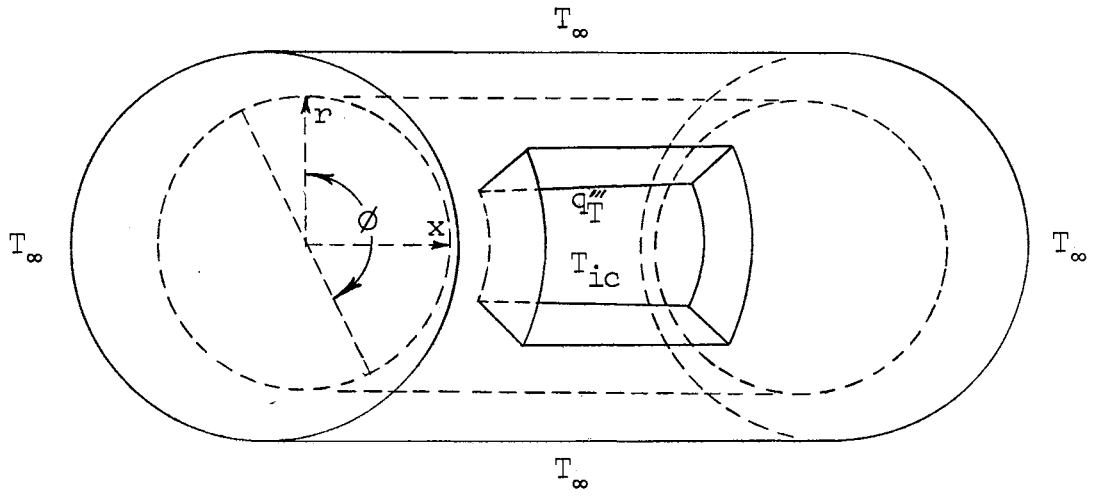
Figure 41. Bulk Temperature Versus Time for Each Replicate at Both Moisture Content Levels and Initial Bulk Peanut Temperature of Approximately $70^{\circ}F$.

Heat of Respiration

Recall the differential equation for adiabatic uniform heating, equation [13], as developed in Chapter II.

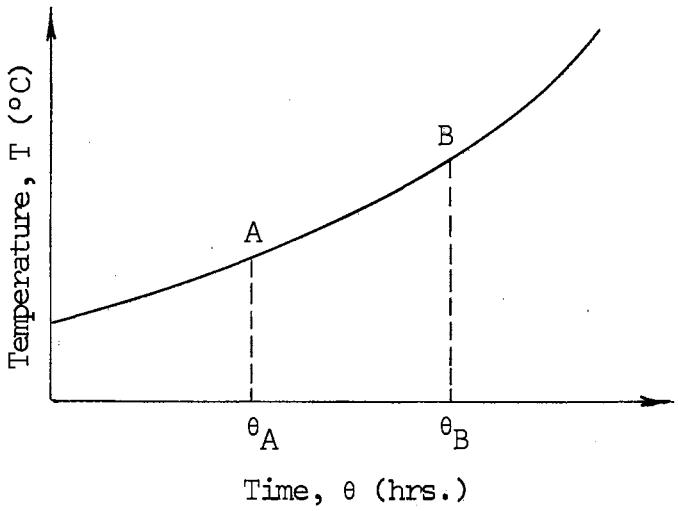
$$\frac{dq_T}{dT} = C\rho V$$

Consider a cylindrical porous volume composed of a non-uniform heat generating source, peanuts at some initial temperature, T_{ic}. If the porous material is composed of more than one component, then $\frac{dq_T}{dT}$ may be evaluated by examining each of the components separately since each may be considered as a heat sink.



Assume that the average temperature of the mass inside the volume, T_{ic}, is the same as that of the volume, T_∞. Also, assume that the temperature field inside the volume is uniform.

Consider transient heating due to respiration by a peanut mass in a Dewar flask with heat energy being stored also in the interseed air and flask walls. Assume a temperature curve as follows:



An energy balance equation of the control volume, Dewar flask, would be:

$$Q_{generated} = Q_{stored} \quad \text{or} \quad Q_g = Q_s \quad \ldots\ldots\ldots\ldots [19]$$

the heat stored in each heat sink, i.e., the peanuts (Q_p), the flask (Q_f), and the air (Q_a). Then neglecting the convected term,

$$Q_s = Q_p + Q_f + Q_a \quad \ldots\ldots\ldots\ldots\ldots\ldots [20]$$

If q_p = rate at which heat is stored in the peanuts in cal/sec,

$$\text{Then } Q_p = \int_{\theta_A}^{\theta_B} q_p d\theta = (C_p W)_{peanuts} \frac{g_c}{g} \int_{T_A}^{T_B} dT \quad \ldots\ldots\ldots [21]$$

Integrating both sides

$$q_p(\theta_B - \theta_A) = (C_p W)_p \frac{g_c}{g} (T_B - T_A)$$

$$\text{Then } q_p = \frac{C_p W g_c (T_B - T_A)}{g(\theta_B - \theta_A)} \quad \ldots\ldots\ldots\ldots\ldots\ldots [22]$$

$$\text{Similarly } Q_a = \int_{\theta_A}^{\theta_B} q_a d\theta = (c_p \rho V)_{air} \int_{T_A}^{T_B} dT \quad \ldots\ldots\ldots [23]$$

Integrating both sides

$$q_a(\theta_B - \theta_A) = (C_p \rho V)_a (T_B - T_A)$$

Then $$q_a = \frac{C_p \rho V (T_B - T_A)}{\theta_B - \theta_A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [24]$$

And $$Q_f = \int_{\theta_A}^{\theta_B} q_f \, d\theta = H_c \int_{T_A}^{T_B} dT \quad \ldots\ldots\ldots\ldots\ldots\ldots [25]$$

Integrating both sides

$$q_f(\theta_B - \theta_A) = H_c(T_B - T_A)$$

Then $$q_f = \frac{H_c(T_B - T_A)}{\theta_B - \theta_A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [26]$$

Hence $$q_g = q_s = \frac{(C_p W)_p g_c (T_B - T_A)}{g(\theta_B - \theta_A)} + \frac{(C_p \rho v)_a (T_B - T_A)}{\theta_B - \theta_A} + \frac{H_c(T_B - T_A)}{\theta_B - \theta_A}$$

Combining terms and solving for q_g, the heat generating term

$$q_g = \frac{[(C_p W)_p (g_c/g) + (C_p \rho v)_a + H_c] [T_B - T_A]}{\theta_B - \theta_A} \quad \ldots\ldots [27]$$

Temperature-time polynomial equations reported in Table VI were used in computing the heat of respiration, q_g, of each test. In each test, a least squares best fit to a polynomial equation, expressing heat of respiration as a function of time, was obtained. The general form of the polynomial equation was

$$q'_\theta = \beta_0 + \beta_1\theta + \beta_2\theta^2 + \beta_3\theta^3 + \beta_4\theta^4 \quad \ldots\ldots\ldots\ldots [28]$$

Respiration versus time curves of the tests run at the 40°F temperature level are presented in Figure 42. The 50°F temperature level respiration versus the time curves are shown in Figure 43. For the 70°F temperature level, the high and low moisture content respira-

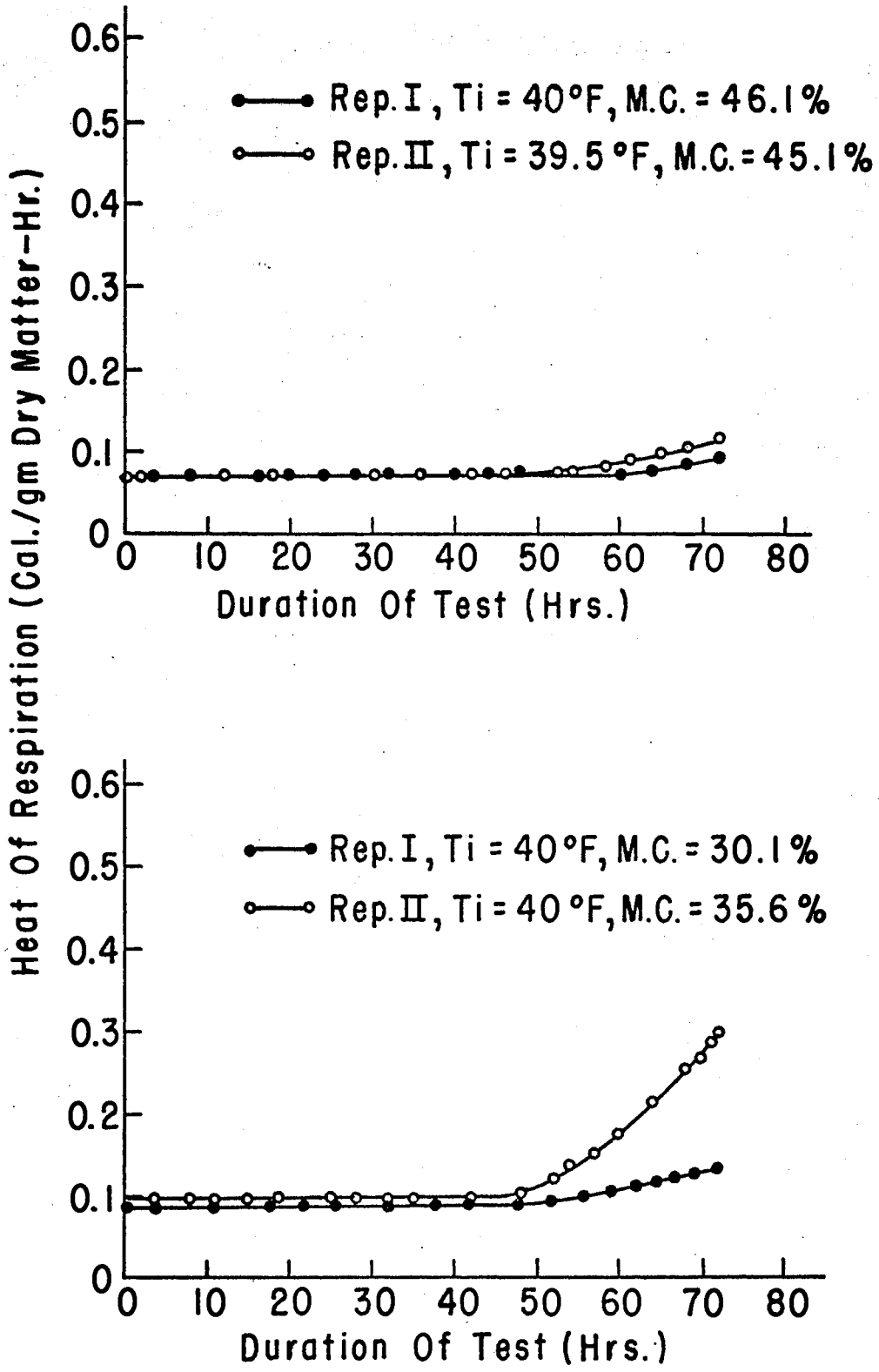


Figure 42. Respiration Versus Time of 40°F Temperature Level.

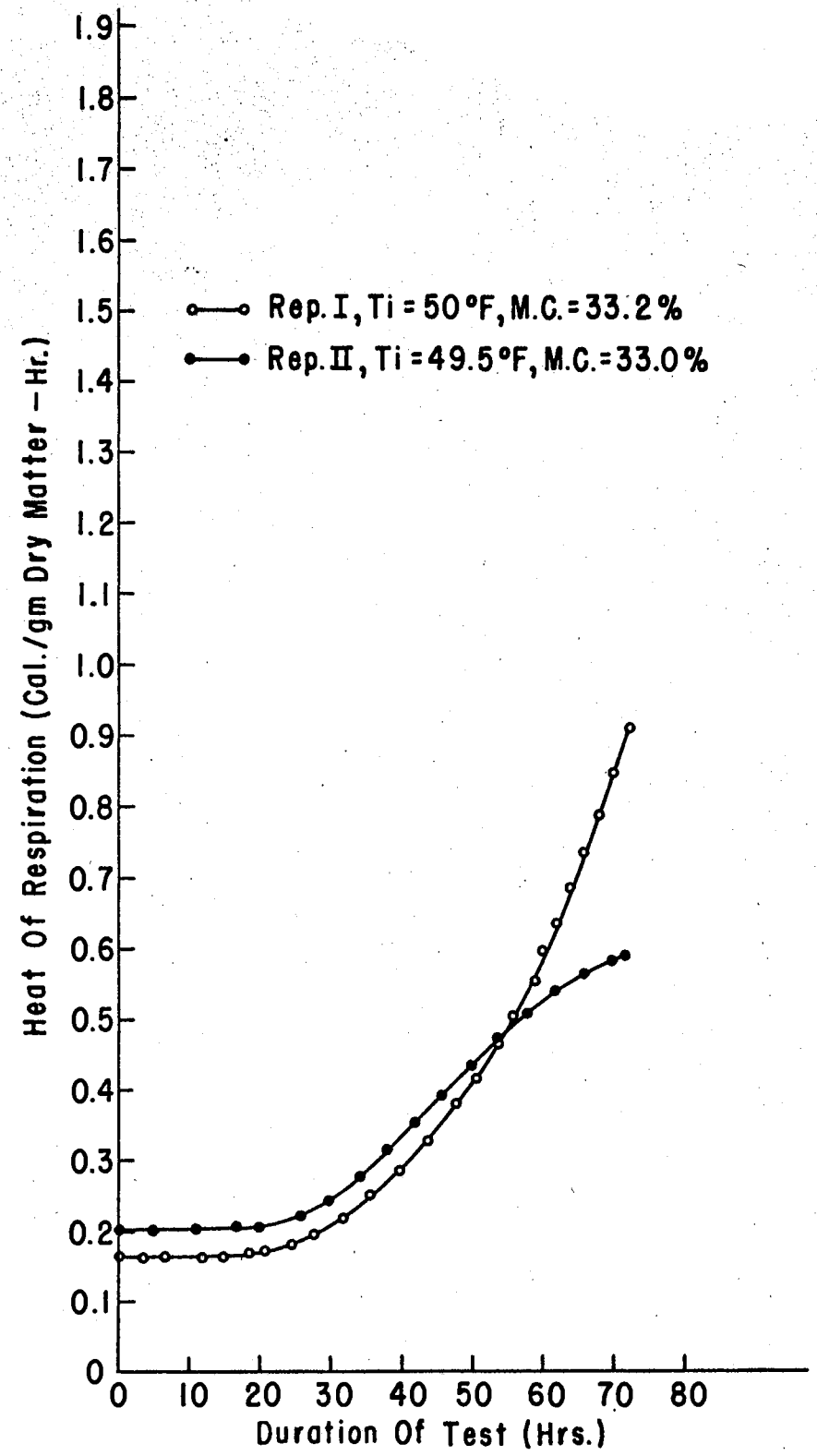


Figure 43. Respiration Versus Time of 50°F Temperature Level.

tion versus time curves are presented in Figures 44 and 45 respectively. The respiration data are given in Table XVII, Appendix D.

Data of the two replicates of each treatment combination were combined to obtain a respiration versus time equation for each case. Results of combining the data of both replicates are graphically presented in Figure 46, and summarized in Table VIII. A fourth degree polynomial equation was selected for the tests run at the $40^{\circ}F$ and $50^{\circ}F$ levels. However, due to the large variance between the results of the two replicates run at the $70^{\circ}F$ temperature level for both high and low moisture content, a first degree polynomial was selected in both cases.

One of the heat of respiration tests ran for only 27 hours before the bulk temperature of the peanuts reached $100^{\circ}F$. The respiration totals at hour 27 are presented in Table IX.

An analysis of variance run on the heat of respiration totals at hour 27 is presented in Table X. The temperature treatment was significant at the 10 percent level of significance. However, applying the variance ratio, F, as a criterion for testing the hypothesis that the treatment means are the same, the hypothesis is accepted for both the moisture content and temperature effects at the 5 per cent level of significance.

An analysis of variance run on the respiration totals at hour 27 and low moisture content level (43 per cent, dry basis) is presented in Table XI. Respiration totals used in the above analysis are given in Table XII. Orthogonal contrasts were computed for the treatment totals of (a) $40^{\circ}F$ versus $50^{\circ}F$ and (b) average of $40^{\circ}F$ and $50^{\circ}F$ versus $70^{\circ}F$. The latter contrast was significant at the 10 percent level of significance.

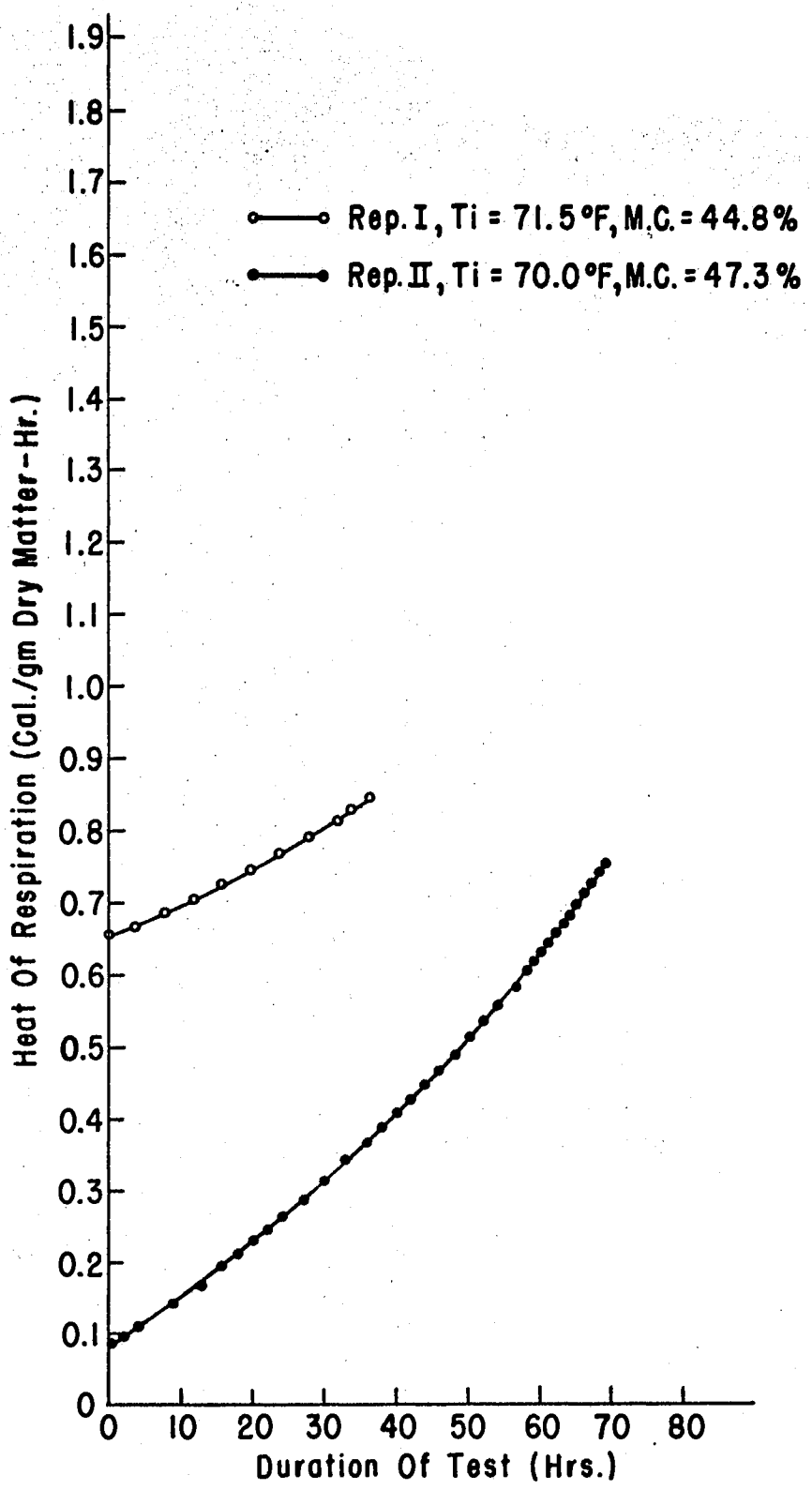


Figure 44. Respiration Versus Time of 70°F Temperature and High Moisture Content Level.

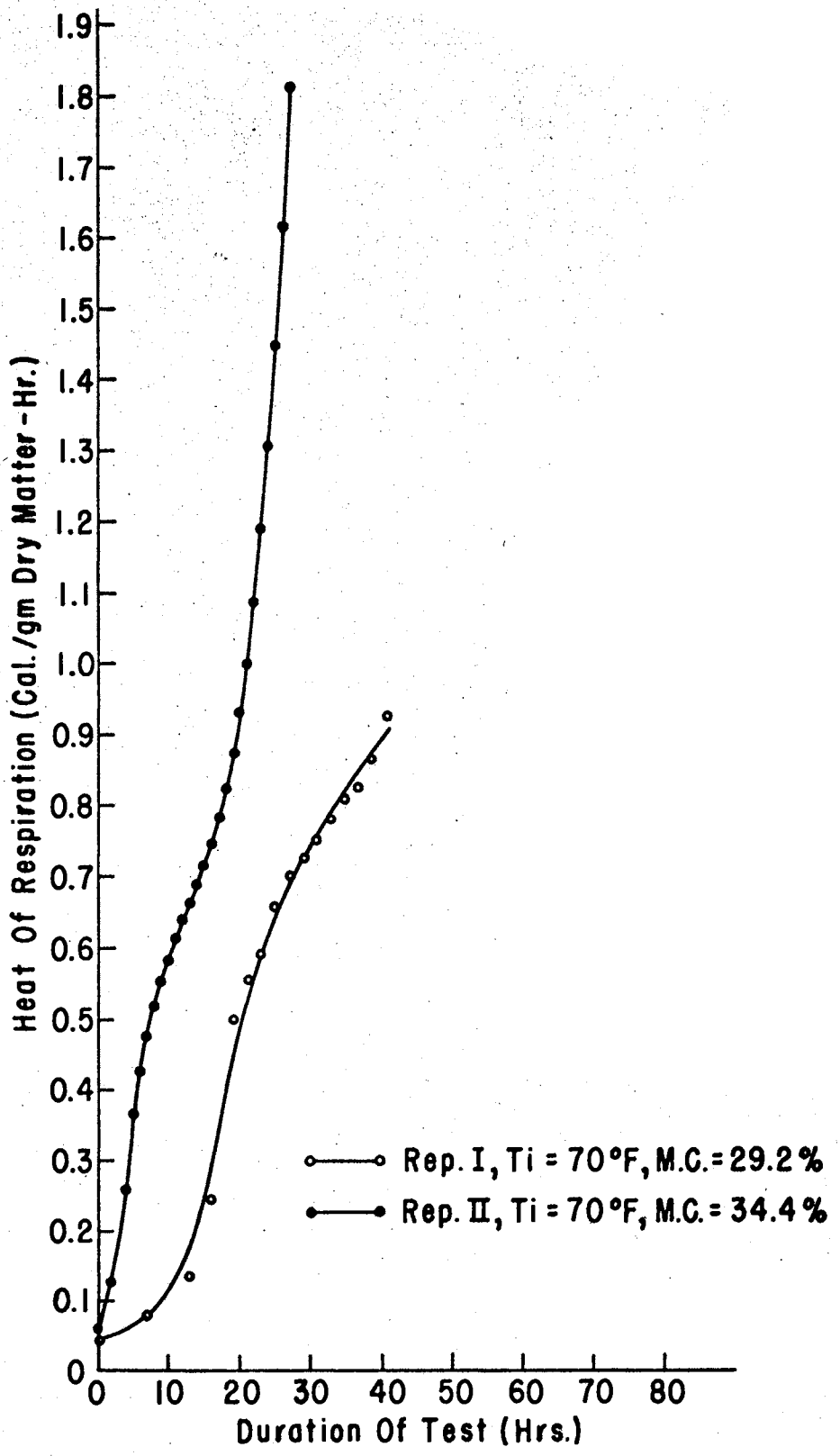


Figure 45. Respiration Versus Time of 70°F Temperature and Low Moisture Content Level.

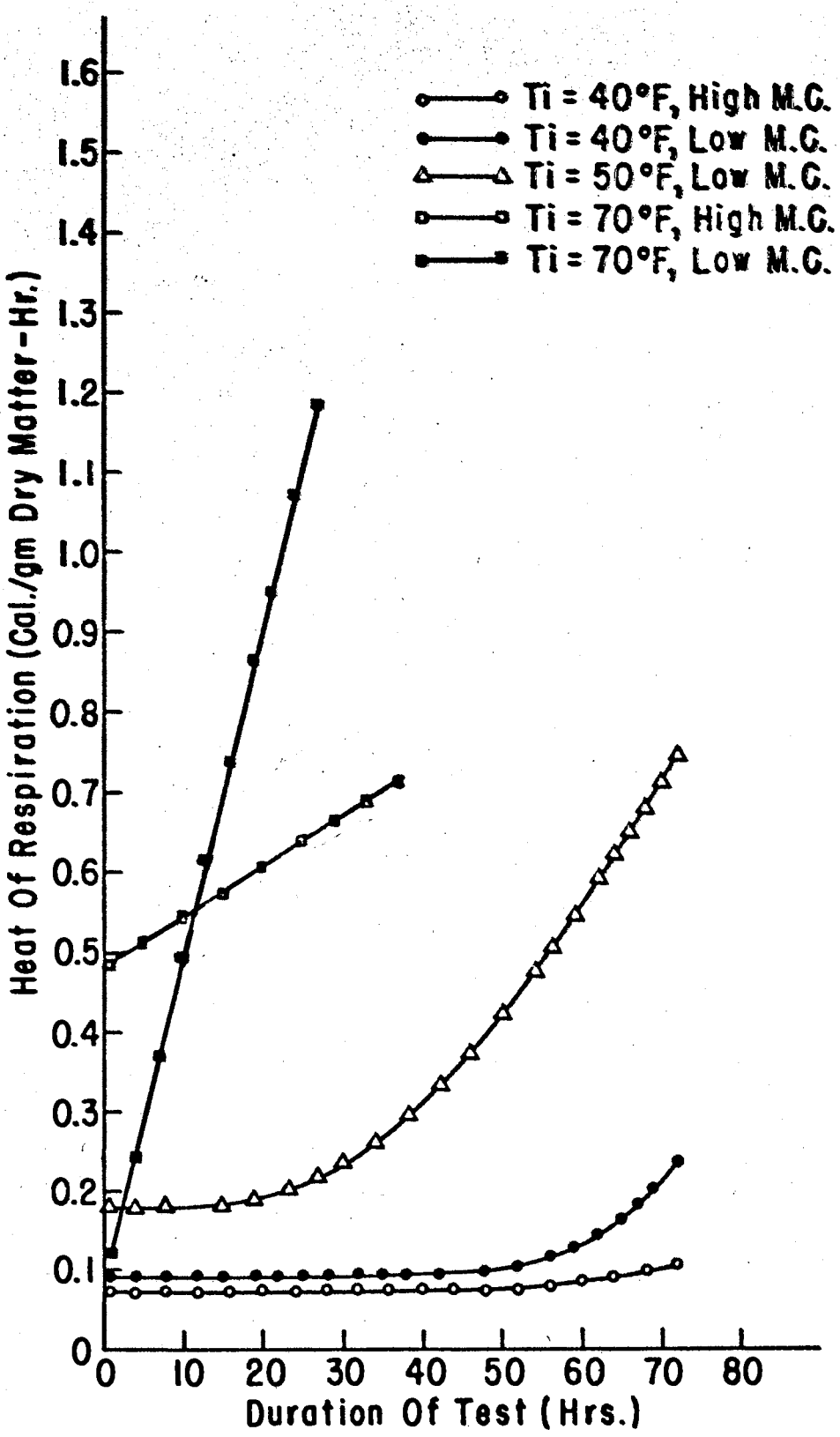


Figure 46. Treatment Combinations of Respiration Tests

TABLE VIII

REGRESSION COEFFICIENTS OF RESPIRATION-TIME POLYNOMIAL EQUATION*
DERIVED FROM COMBINED DATA OF TWO REPLICATES

Replicate	Moisture Content, Wet Basis (%)	Initial Peanut Temperature (^{o}F)	β_0** X 10	β_1** X 10^2	β_2** X 10^5	β_3** X 10^6	β_4** X 10^8	Range Applicable (Hours)	Std. Dev.
I	46.1	40.0	0.712	0.00711	0.243	-0.237	0.397	0-72	0.005
II	45.1	39.5							
I	30.1	40.0	0.927	-0.0642	6.92	-2.39	2.69	0-72	0.034
II	35.6	40.0							
I	33.2	50.0	1.98	-0.291	1.88	1.88	-1.64	0-72	0.057
II	33.0	49.5							
I	44.8	71.5	4.80	0.646	--	--	--	0-37	0.237
II	47.3	70.0							
I	29.2	70.0	0.426	4.23	--	--	--	0-27	0.270
II	34.4	70.0							

*$q_\theta' = \beta_o + \beta_1\theta + \beta_2\theta^2 + \beta_3\theta^3 + \beta_4\theta^4$

**Divide each β coefficient by its respective multiplier to obtain its correct magnitude. Example: For β_1 values of β_1, divide by 100.

TABLE IX

HEAT OF RESPIRATION TOTALS AT HOUR 27

Factor		A = Moisture Content		
B = Temperature	Level	(a_1) = 30% wet basis (cal/(gm.dry matter-hr.))	(a_2) = 45% wet basis (cal/(gm.dry matter-hr.))	Totals
	$(b_1) = 40^{\circ}F$	0.183	0.145	0.328
	$(b_2) = 70^{\circ}F$	2.512	1.074	3.586
	Totals	2.695	1.219	3.914

TABLE X

ANALYSIS OF VARIANCE OF HEAT OF RESPIRATION RESULTS AT HOUR 27

Source	d. f.	SS	MS	F
Treatments	3	1.8442	0.6147	
A	1	0.2723	0.2723	1.46
B	1	1.3268	1.3268	7.11*
AB	1	0.2925	0.2925	1.57
Error	4	0.7455	0.1864	
Total	7	2.5897		

*Significant at the ten percent level of significance.

TABLE XI

ANALYSIS OF VARIANCE OF HEAT OF RESPIRATION DATA AT HOUR 27 AND LOW MOISTURE CONTENT LEVEL

Source	d. f.	SS	MS	F
Total	5	2.264		
Treatments	2	1.643	0.822	
40°F vs. 50°F	1	0.014	0.014	0.068
Avg. 40°F & 50°F vs. 70°F	1	1.629	1.629	7.870*
Within	3	0.621	0.207	

* Significant at the ten percent level of significance.

TABLE XII

HEAT OF RESPIRATION TOTALS AT HOUR 27 AND LOW MOISTURE CONTENT LEVEL

Replicate	a_0b_0 = 40°F (cal/(gm.dry matter-hr))	a_0b_1 = 50°F (cal/gm.dry matter-hr))	a_0b_2 = 70°F (cal/gm.dry matter-hr))	Totals
I	0.087	0.192	0.699	0.978
II	0.096	0.228	1.813	2.137
Totals	0.183	0.420	2.512	3.115

An analysis of variance was also run on the respiration totals at hour 72 and low moisture content level, Table XIII. The difference between the 40°F and 50°F respiration totals is significant at the 10 percent level of significance. Respiration totals used in the above analysis are listed in Table XIV.

During each of the heat of respiration tests, some of the peanut hulls became discolored. Discoloration of peanut hulls can be seen in Figures 47, 48, 49, 50, and 51. In order to represent the appearance of the peanut hulls at the beginning of the test, freshly harvested peanuts were utilized. Mold growth on the peanut hulls was observed at the end of all the tests.

Percent Sprouted Peanuts

At the end of each test, peanuts in the main flask were examined to determine the percent of peanuts which had sprouted. The only two tests in which sprouted peanuts were observed were the two replicates at the high temperature and high moisture content levels. The percent (by number) was 13.2 percent and 10.9 percent for replicates I and II respectively. Some of the sprouted peanuts can be seen in Figure 50.

Percent Immature Peanut Kernels

Samples were obtained from the main flask at the end of each test to estimate the percent of immature peanut kernels. Results of these maturity tests are summarized in Table XVIII in Appendix E.

Carbon Dioxide Measurement

It may be recalled that the inhibition effect of the concentration

TABLE XIII

ANALYSIS OF VARIANCE OF HEAT OF RESPIRATION DATA AT HOUR 72 AND LOW MOISTURE CONTENT LEVEL

Source	d. f.	SS	MS	F
Total	3	0.466		
$40^{\circ}F$ vs. $50^{\circ}F$	1	0.414	0.414	15.923*
Within	2	0.052	0.026	

* Significant at the ten percent level of significance

TABLE XIV

HEAT OF RESPIRATION TOTALS AT HOUR 72 AND LOW MOISTURE CONTENT LEVEL

Replicate	$a_0b_0 = 40^{\circ}F$ (cal/(gm.dry matter-hr))	$a_0b_1 = 50^{\circ}F$ (cal/gm.dry matter-hr))	Totals
I	0.095	0.911	1.006
II	0.118	0.589	0.707
Totals	0.213	1.500	1.713

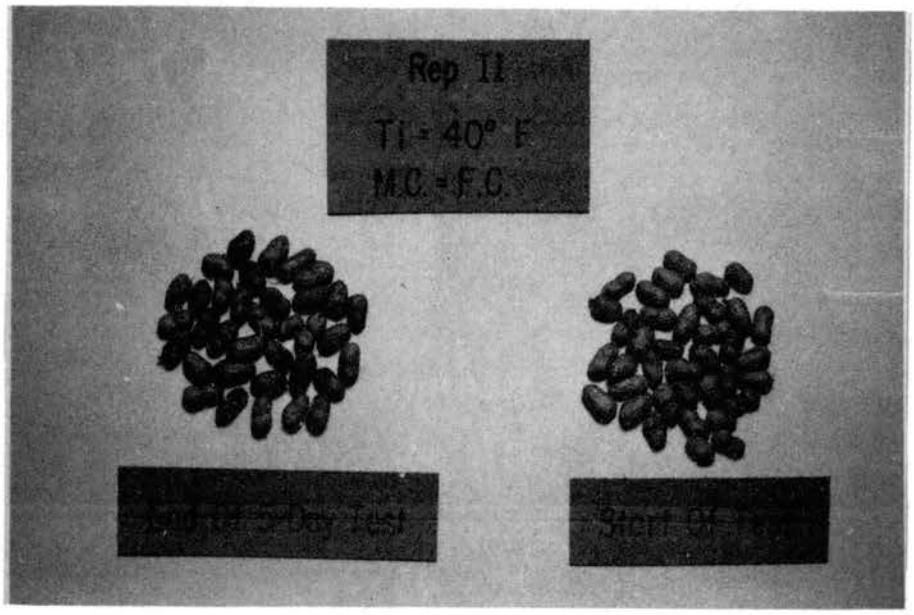


Figure 47. Appearance of Peanuts, Replicate II, T_i of $40^{\circ}F$ and MC of 45.1 Percent (F.C.)

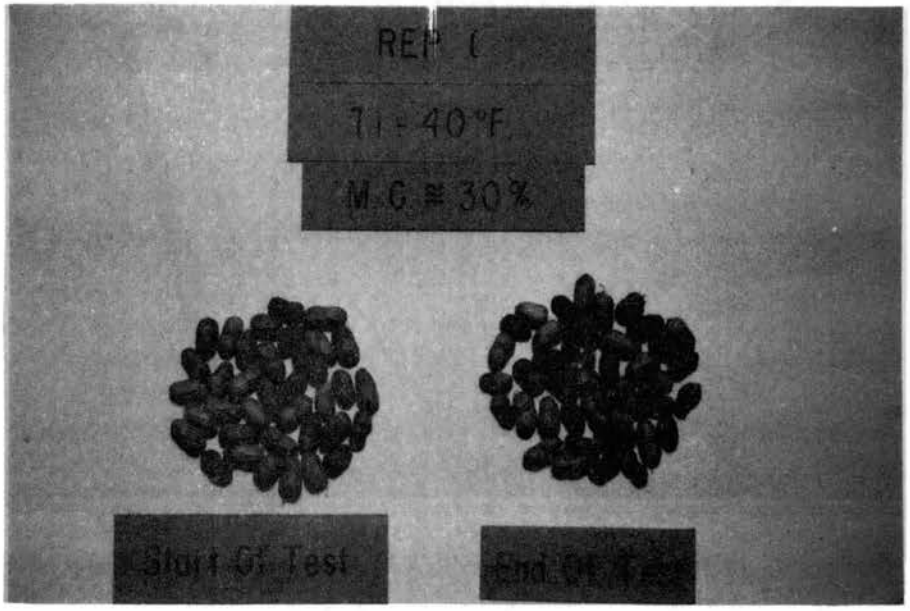


Figure 48. Appearance of Peanuts, Replicate I, T_i of 40°F and MC of 30.1 Percent

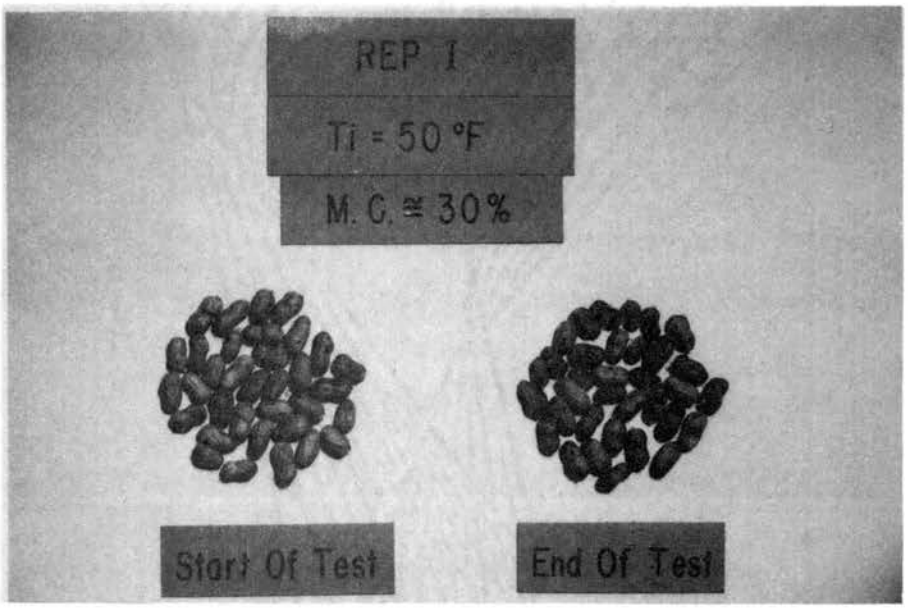


Figure 49. Appearance of Peanuts, Replicate I, T_i of 50°F and MC of 33.2 Percent

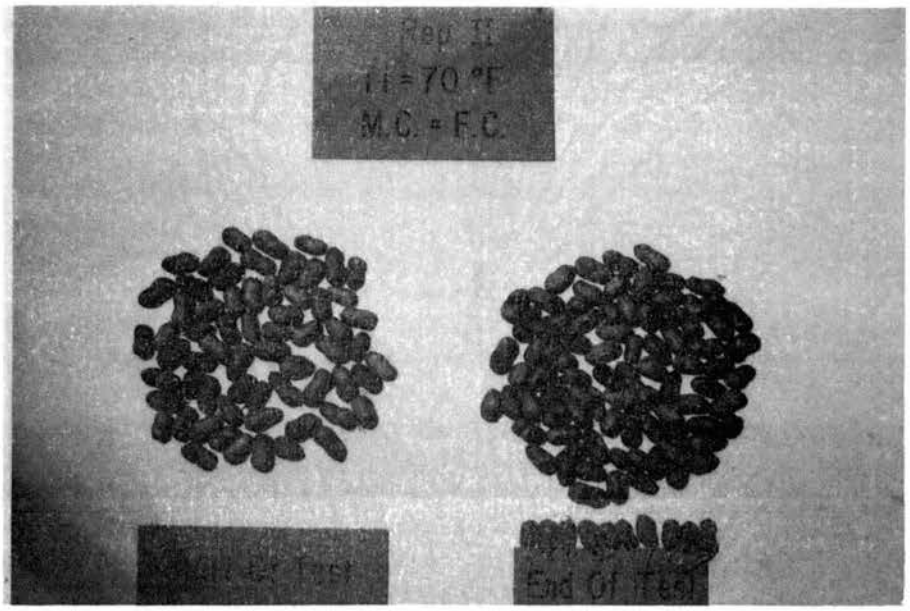


Figure 50. Appearance of Peanuts, Replicate II, T_i of 70°F and MC of 47.3 Percent (F.C.)

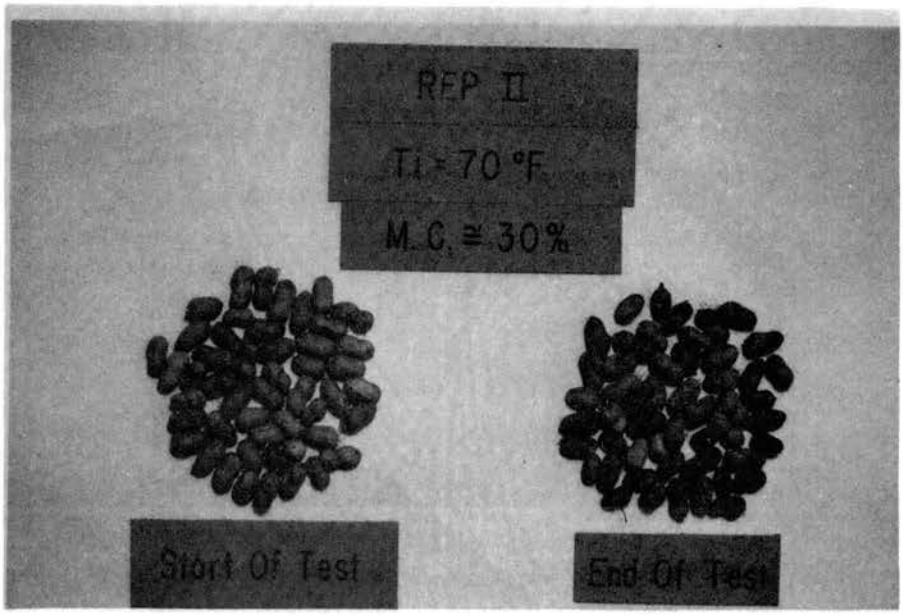


Figure 51. Appearance of Peanuts, Replicate II, T_i of 70°F and MC of 34.4 Percent

of carbon dioxide in the interseed air on the respiration rate was discussed in Chapter II. The procedure used in measuring the percent by volume of carbon dioxide in the effluent air removed from the main flask was discussed in Chapter IV. Results of carbon dioxide concentration is summarized in Table XV. Since the maximum duration of respiration tests considered was 72 hours, carbon dioxide concentration determinations were made at hour 72 or earlier.

TABLE XV

PERCENT BY VOLUME OF CARBON DIOXIDE IN EFFLUENT AIR REMOVED FROM MAIN FLASK

Replicate	Moisture Content, Wet Basis, (MC (%)	Initial Peanut Temperature (^{o}F)	Percent CO_2	Hour Calculated
1	46.1	40.0	6.4	72
2	45.1	39.5	7.3	72
1	30.1	40.0	2.4	72
2	35.6	40.0	6.1	72
1	33.2	50.0	19.8	72
2	33.0	49.5	*	72
1	44.8	71.5	6.9	37
2	47.3	70.0	3.4	69
1	29.2	70.0	**	41
2	34.4	70.0	5.3	27

* No data available at hour 72 due to breakdown of equipment.
** No data available due to experimental procedure error.

Specific Heat of Peanut Pods

Equation [29] was obtained by multiple regression analysis of all specific heat data obtained in this study, with a standard deviation of 0.047.

$$C_{pp} = 0.603 - 0.508(T_p) + 1.49(T_p)^2 - 0.180(M) + 0.131(M)^2 + 1.21\ (T_p)(M) \quad \ldots\ldots\ldots\ldots [29]$$

The response surface representing equation [29] is shown in Figure 52. The specific heat equation obtained by Wright (38), equation [2], and equation [29] are presented graphically in Figure 53. At about 0.60 moisture content, the 75°F curve presented by Wright nearly intersects the 75°F curve represented by equation [29]. However, Wright reported a decrease in the specific heat of the peanut pods with an increase in temperature. Results of this study indicate that, within the range of the variables studied, an increase in temperature effects an increase in the specific heat of peanut pods. This temperature effect on specific heat is in general agreement with the results presented in Chapter II reported by Chakrabarti and Johnson (9).

Specific heat results at the high and low moisture content levels are presented graphically in Figure numbers 54 and 55 respectively and given in Table XXIII, Appendix G.

All specific heat data of the high moisture content tests were lumped to obtain a second degree polynomial equation expressing specific heat as a function of temperature, °F, only. Regression analysis was utilized to obtain equation [30] with a standard deviation of 0.0460.

$$C_{pp} = 0.4502 + 0.00131(T_\theta) + 0.00003804(T_\theta)^2 \quad \ldots\ldots [30]$$

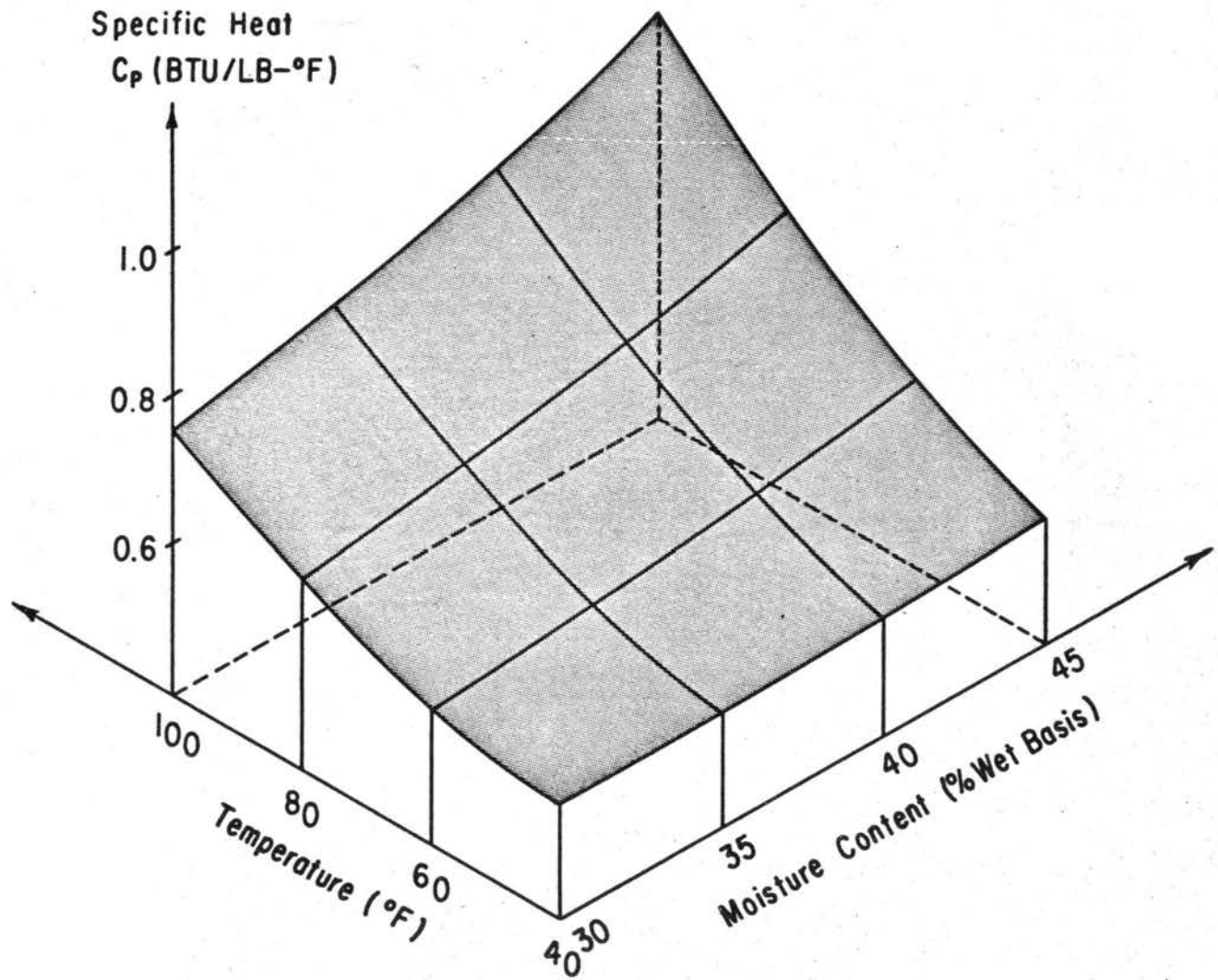


Figure 52. Specific Heat Response Surface of Peanut Pods

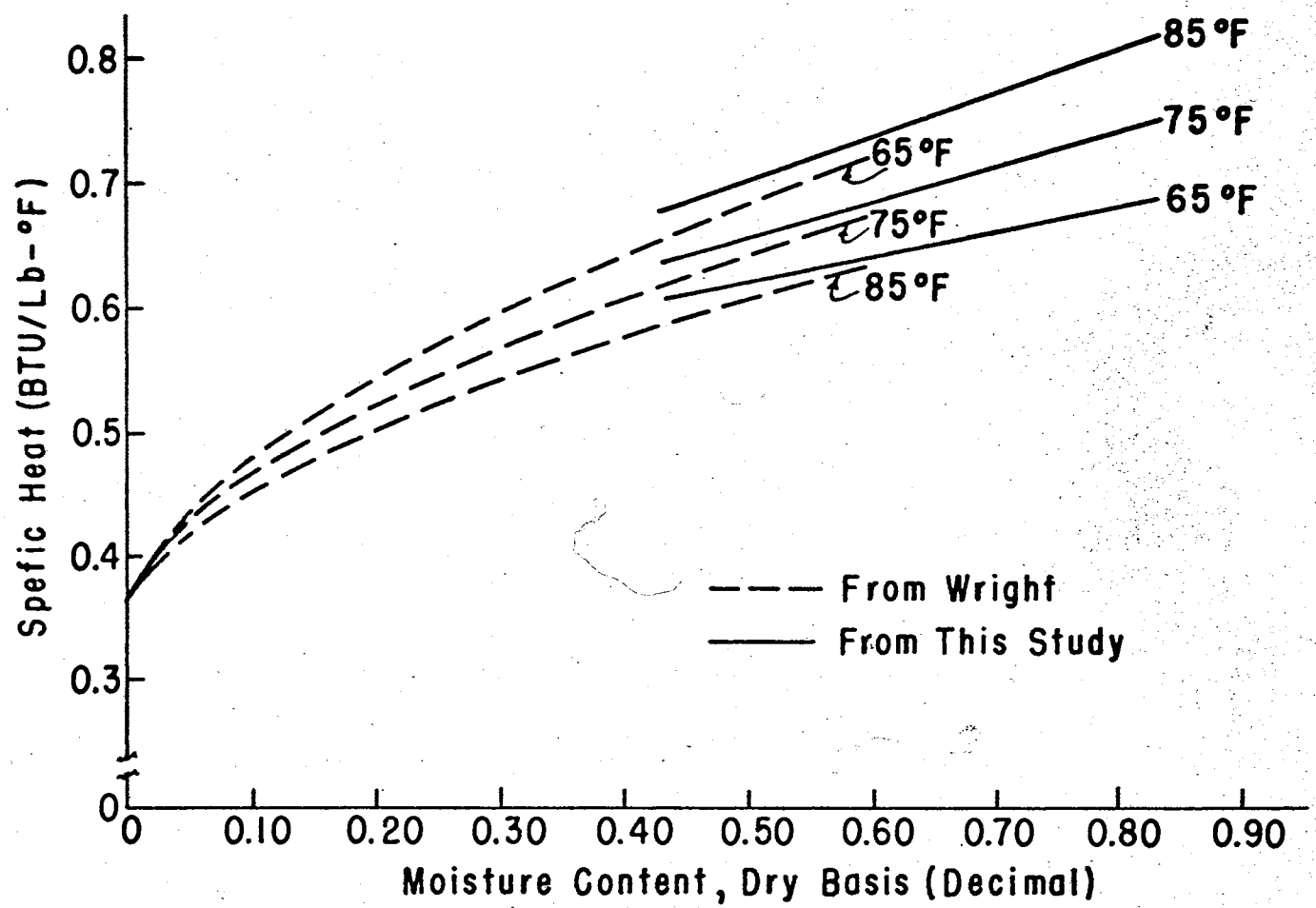


Figure 53. Wright's (42) Specific Heat Curves and Similar Curves Obtained in This Study.

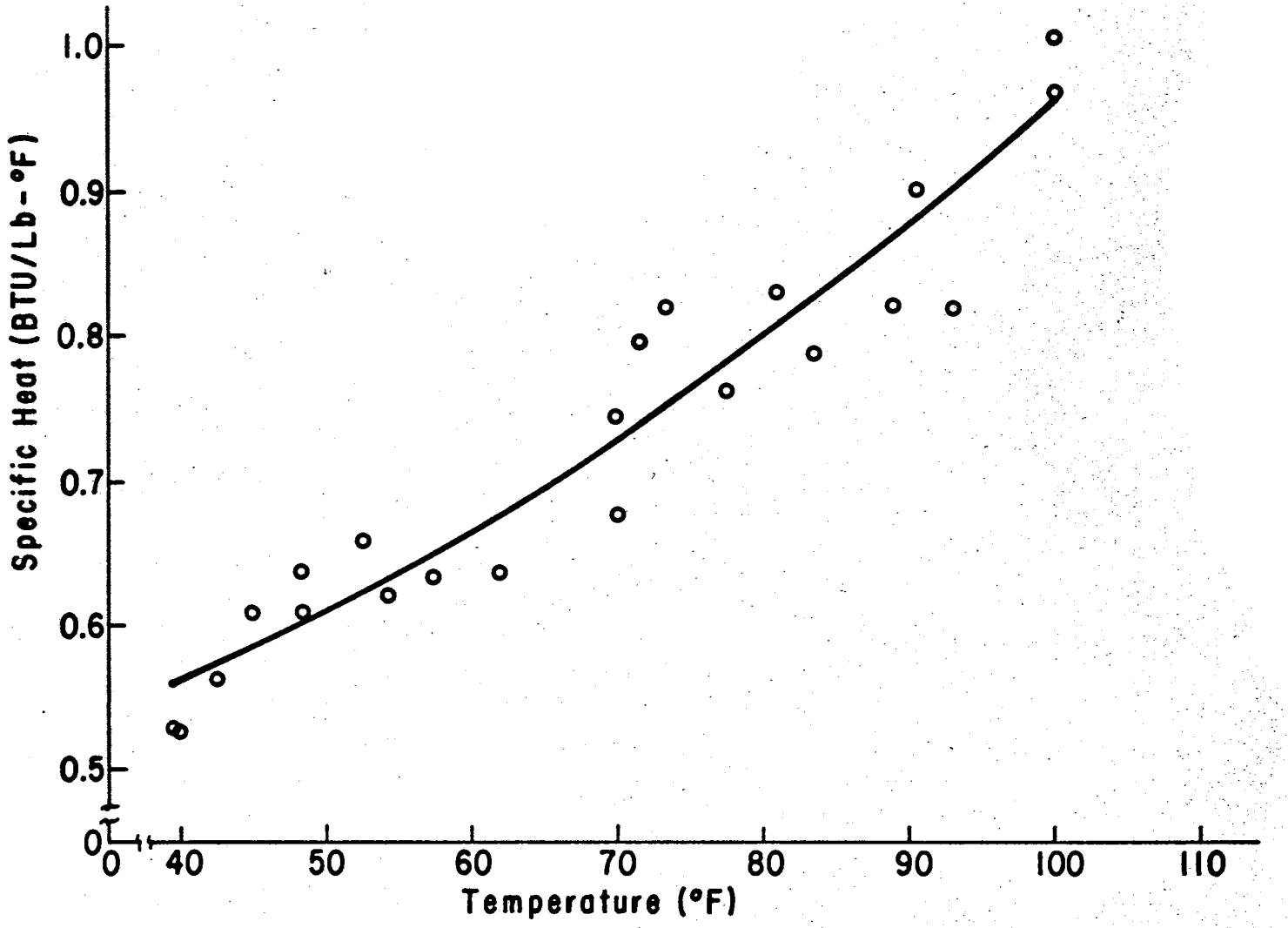


Figure 54. Specific Heat of Peanut Pods at High Moisture Content Level.

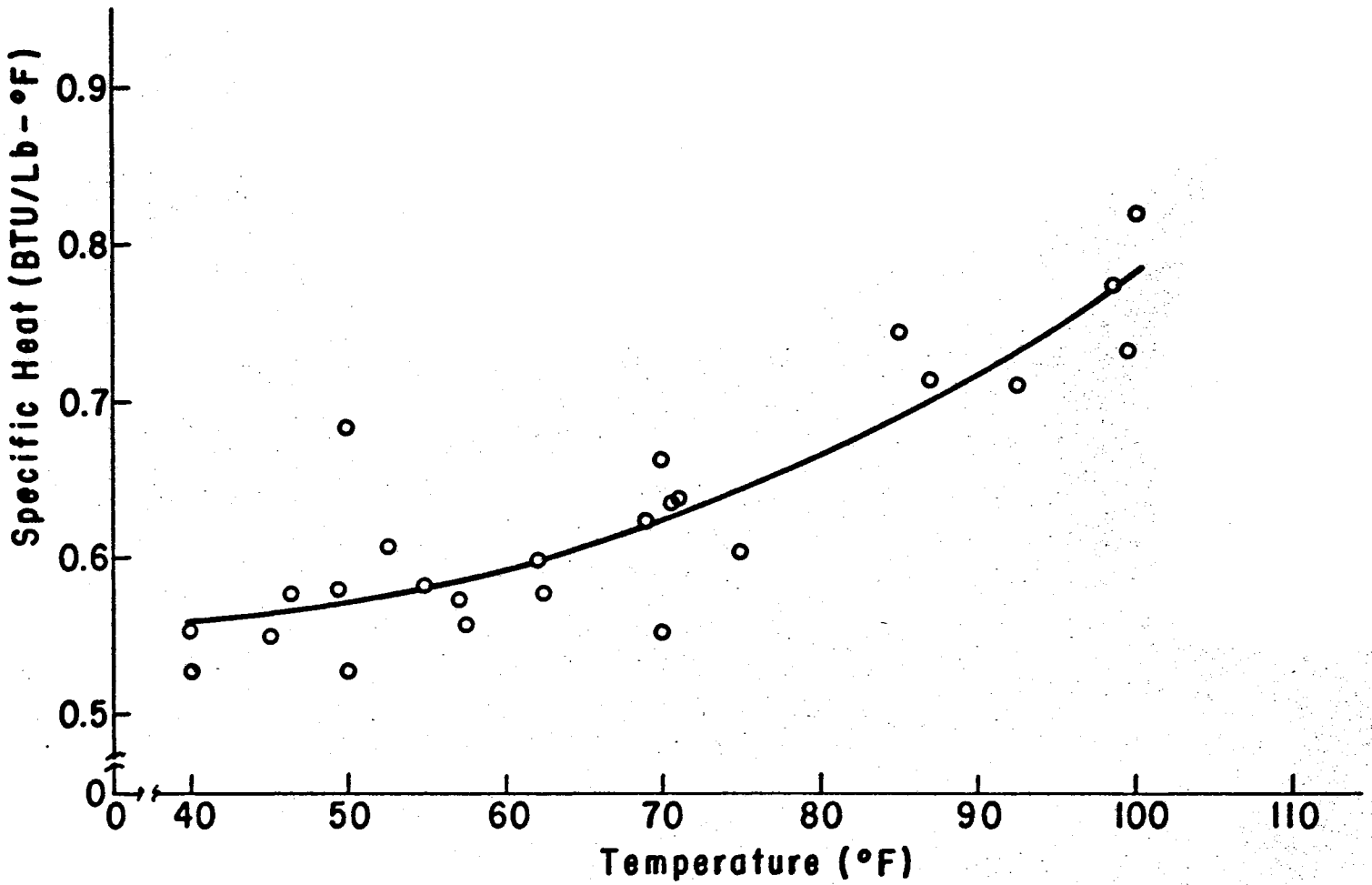


Figure 55. Specific Heat of Peanut Pods at Low Moisture Content Level.

Equation [30] is presented graphically in Figure 54.

Similarly, a second degree polynomial equation was obtained for the low moisture content data; equation [31] with a standard deviation of 0.395.

$$C_{pp} = 0.618\text{-}0.00350(T_\theta) + 0.0000512(T_\theta)^2 \quad \ldots\ldots\ldots [31]$$

Equation [31] is presented graphically in Figure 55.

Specific Heat of Peanut Hulls and Kernels

Specific heat of peanut hulls and kernels was measured individually in order to compare the specific heat of each with the peanuts of the respiration tests. Regression analysis of the data obtained on the hulls resulted in equation [32], with a standard deviation of 0.050.

$$C_{pp} = 0.916 - 0.0157(T_\theta) + 0.000164(T_\theta)^2 \quad \ldots\ldots\ldots [32]$$

The mean moisture content of the hulls was 29.8 percent, wet basis.

The specific heat equation of the kernels obtained is equation [33], with a standard deviation of 0.04027.

$$C_{pp} = 1.104 = 0.0152(T_\theta) + 0.000119(T_\theta)^2 \quad \ldots\ldots\ldots [33]$$

The mean moisture content of the kernels was 26.0 percent, wet basis.

The results of the specific heat of peanut hulls and kernels are presented graphically in Figure 56 and listed in Table XXIV of Appendix H. The specific heat curve of the low moisture content peanut pods is also shown in Figure 56.

Schedule of Tests

The date of harvesting the peanuts and starting the tests are listed in Table XXV, Appendix I. The scheduling of the 40°F and 70°F

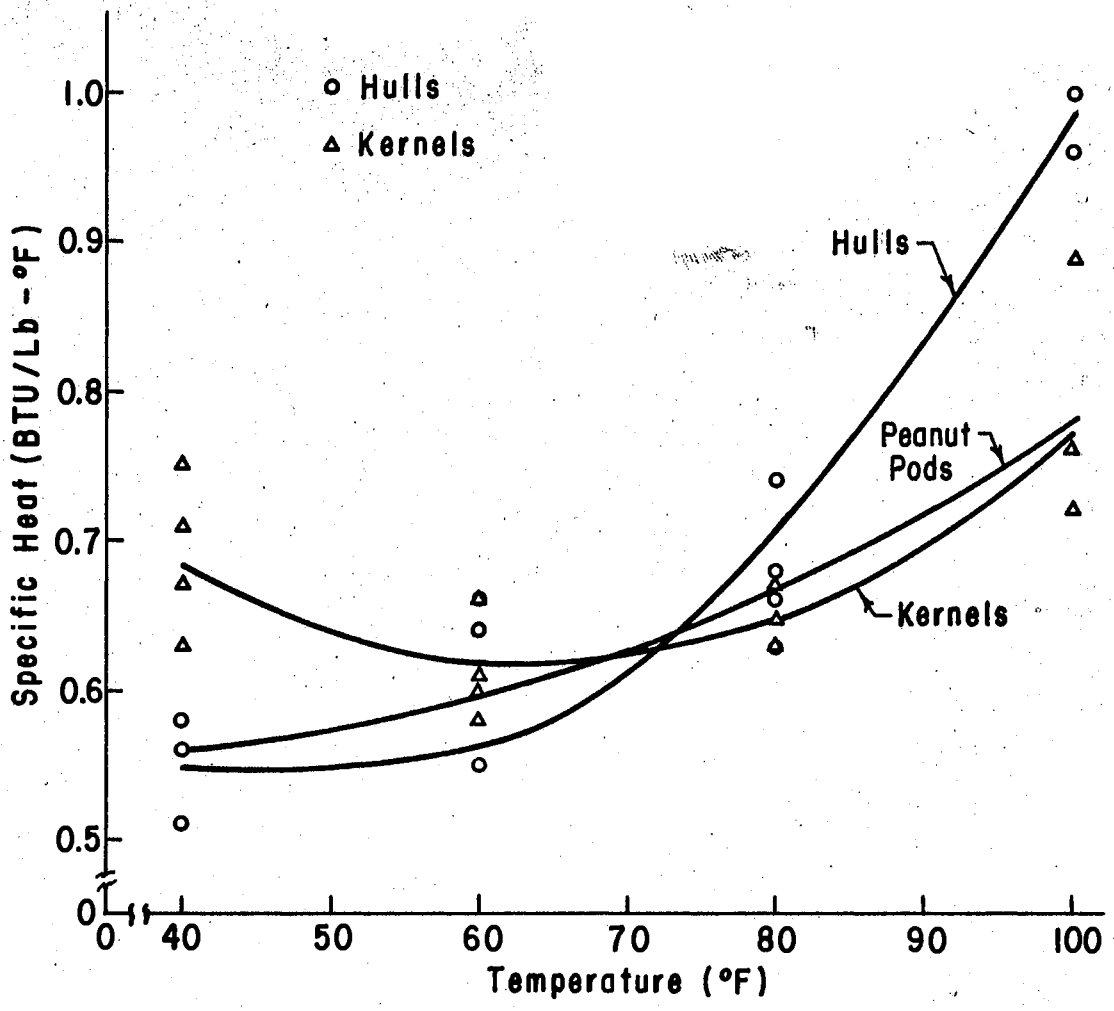


Figure 56. Specific Heat of Peanut Pods, Hulls, and Kernels (Moisture Content of Approximately 30 Percent, Wet Basis.)

temperature tests was based on the random drawing of previously assigned numbers. Since it was not known if the crop season could be extended to include the $50^{\circ}F$ level, these tests were scheduled last.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The primary objective of this study was to measure the effect of storage temperature, initial moisture content, and time in storage on the rate of heat production by the peanuts and any micro-organisms present during the test. A 1900 milliliter respiration calorimeter was designed and constructed for the study.

Temperature of the environment surrounding the calorimeter flask was controlled to insure adiabatic heating conditions. Aeration rate was maintained at approximately 2000 milliliters per 24 hours. The calorimeter should be satisfactory for measuring the heat of respiration of other biological materials.

A series of ten tests were conducted with Spanish peanuts in the respiration calorimeter. Both the moisture content and the temperature were varied. The three levels of peanut initial temperature were $40^{\circ}F$ ($4.4^{\circ}C$), $50^{\circ}F$ ($10.0^{\circ}C$) and $70^{\circ}F$ ($21.1^{\circ}C$). Two levels of moisture content included were approximately 45 per cent and 30 per cent, wet basis (82 per cent and 43 per cent, dry basis).

Tests were conducted to validate the accuracy with which peanut respiration could be measured by the calorimeter. The per cent difference between calculated and measured values ranged from 3.2 to 5.2 per cent.

In each heat of respiration test, a polynomial equation expressing peanut bulk temperature as a function of time was obtained. The general form of the polynomial equation is

$$T_\theta = \beta_o + \beta_1\theta + \beta_2\theta^2 + \beta_3\theta^3 + \beta_4\theta^4 \quad \ldots\ldots\ldots\ldots [34]$$

The difference between the bulk temperature rise of the two replicates at 40^oF and 70^oF temperature levels becomes pronounced at about hour 72 of the test. Therefore, the maximum period of each test considered for analysis was 72 hours.

A polynomial equation expressing respiration as a function of time was calculated for each test. The general form of the polynomial equation is:

$$q'_\theta = \beta_o + \beta_1\theta + \beta_2\theta^2 + \beta_3\theta^3 + \beta_4\theta^4 \quad \ldots\ldots\ldots\ldots [35]$$

Data of two replicates of each test were combined to obtain a polynomial equation for each treatment combination. The maximum heat of respiration in cal./(gm.dry matter - hour) and hour measured was

T_i of 40^oF, 45% MC: 0.107 at hour 72

T_i of 40^oF, 30% MC: 0.236 at hour 72

T_i of 50^oF, 30% MC: 0.746 at hour 72

T_i of 70^oF, 45% MC: 0.719 at hour 37

T_i of 70^oF, 30% MC: 1.186 at hour 27

A factorial statistical analysis of variance of the test results at the 40^oF and 70^oF temperature level indicated that the temperature main effect was significant at the ten per cent level of significance.

The only replicates in which sprouted peanuts were observed were the two replicates at the 45 per cent moisture content and 70^oF temperature levels. Mold growth was observed on peanuts at the end of all tests.

The percent immature peanut kernels in each test sampled did not vary widely and ranged from 0.96 to 4.12 per cent.

The per cent by volume of carbon dioxide in the effluent air removed from the main flask during last 12 hour test period considered in this report was usually less than eight percent, except one treatment combination at $50^{o}F$. Probably the high concentration of carbon dioxide measured was due to the combination of high respiration and duration of test.

In order to determine the amount of energy stored in the peanuts at a given temperature for each test the specific heat of peanut pods of each test was measured at various temperatures. The resultant specific heat equation as a function of temperature and moisture content was

$$C_{pp} = 0.603 - 0.508(T_p) + 1.49(T_p)^2 - 0.180(M) + 0.131(M)^2 + 1.21(T_p)(M) \quad [36]$$

The specific heat equation for peanuts at the high moisture content level was

$$C_{pp} = 0.4502 + 0.00131(T_\theta) + 0.00003804(T_\theta)^2 \quad [37]$$

and for the low moisture content level

$$C_{pp} = 0.618 - 0.00350(T_\theta) + 0.0000512(T_\theta)^2 \quad [38]$$

The specific heat equation obtained for the peanut hulls at 28.9 percent, wet basis, was

$$C_{pp} = 0.916 - 0.0157(T_\theta) + 0.000164(T_\theta)^2 \quad [39]$$

and for the peanut kernels at 26.0 percent, wet basis, was

$$C_{pp} = 1.104 - 0.0152(T_\theta) + 0.000119(T_\theta)^2 \quad [40]$$

Conclusions

The following conclusions are based on an interpretation of the experimental results.

1. The respiration calorimeter as designed served satisfactorily for measuring the heat of respiration of high moisture Spanish peanuts.
2. Good duplication of results was obtained of the rate of temperature rise in the peanuts for all tests run at an initial bulk temperature of $40^{\circ}F$ and $50^{\circ}F$. However, the experimental results at the $70^{\circ}F$ initial peanut bulk temperature varied considerably. Several replications at the high temperature level will be required to reliably define the range of expected heat of respiration as a function of moisture content and time in storage.
3. At the end of both the $40^{\circ}F$ and $70^{\circ}F$ initial temperature level tests, the lower moisture content peanuts indicated a higher heat production.
4. Statistical analysis of the $40^{\circ}F$ and $70^{\circ}F$ respiration totals at hour 27 indicated that the temperature treatment effect was significant at the 10 per cent level of significance.
5. Orthogonal contrasts of heat of respiration totals of (a) $40^{\circ}F$ versus $50^{\circ}F$ and (b) average of $40^{\circ}F$ and $50^{\circ}F$ versus $70^{\circ}F$ indicated that the latter contrast was significant at the 10 percent level of significance.
6. Orthogonal contrasts of the heat of respiration totals, at hour 72 and low moisture content, of the $40^{\circ}F$ versus

50°F levels was found to be significant at the 10 percent level of significance.

7. Although sprouted peanuts were observed only in tests conducted at the high temperature and moisture content levels, mold growth on the surface of peanuts was observed in all tests.
8. Specific heat of peanut pods increased with both moisture content and temperature.
9. Specific heat of peanut hulls at 28.9 per cent, wet basis, increased with temperature over entire temperature range of 40°F to 100°F. Specific heat of peanut kernels at 26.0 per cent, wet basis, increased with temperature between 60°F and 100°F.

Recommendations for Further Study

The results of this study have indicated the order of magnitude of expected differences between respiration heat production of treatment combinations studied. Since variances at 70°F treatment level were rather large, more than two replications should be considered.

Additional research on the heat of respiration of Spanish peanuts needs to be done at the following treatment levels:

1. Initial bulk peanut temperature of 50, 60, and 70°F and bulk moisture content of 20, 30, and 45 per cent, wet basis.
2. Initial bulk peanut temperature of 40°F and 20 per cent, wet basis.

Auto-claved sterile peanuts inoculated by various fungi spores might be studied to determine the respiration heat production of such

fungi.

The effect of carbon dioxide concentration on the heat production of Spanish peanuts should be considered. Equipment to dynamically measure the oxygen consumption and carbon dioxide evolution is needed for the respiration calorimeter.

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APPENDIX A

PROCEDURE AT END OF EACH EIGHT HOUR PERIOD

PROCEDURE AT END OF EACH EIGHT HOUR PERIOD

Time		Operation
Prior To 8:00	1.	Prepare for filtration. Place funnels in jars and place filters in funnels. Place jars with funnels and filters on counter near lavatory.
	2.	Pour about 500 ml of distilled water into a beaker for flushing CO_2 traps to the required level.
	3.	Place $Ba(OH)_2$ container on counter in position ready to fill the CO_2 traps to the required level.
8:00	4.	Turn off electric switch of lowering mechanism.
	5.	Mark the level of the calcium chloride in both spirometers.
	6.	Note the temperature of the Currentronik vertical scale indicator and record it on the chart of the Electronik 16 recorder opposite the temperature recorded at 8:00.
8:01	7.	Turn valve nos. 1 and 3 to the down position.
	8.	Turn valve nos. 2 and 4 to the down position to allow the effluent to be transferred to the effluent reservoir.
	9.	Turn valve no. 5 to the down position to allow the transferring of the calcium chloride to the $CaCl_2$ reservoir.
	10.	Disengage the electric motor by sliding the frame away from the lowering mechanism pulley. Raise the leveling bulb to the maximum up position by turning the crank on the pulley shaft in a clockwise direction facing the crank. Hold the lowering mechanism pulley in place by inserting a piece of wood between the pulley metal radial rods as shown in Figure 19. The raising of the leveling mechanism will force the $CaCl_2$ of the leveling bulb to flow to the main spirometer; thus forcing effluent into the effluent reservoir.
8:03	11.	Turn valve no. 2 to the 225° position when the calcium chloride solution of spirometer no. 1 (main flask spirometer) is in the starting level.
	12.	Turn valve no. 3 to the 315° position to prevent any movement of the air either in or out of the main flask.
	13.	Turn valve no. 5 to the 225° position to hold the level of the calcium chloride in the effluent reservoir constant.

8:04 14. Fill the carbon dioxide traps to the required level with barium hydroxide. The tubes of trap nos. 1 and 2 are filled with 80 ml of barium hydroxide and the tubes of trap nos. 3, 4, and 5 are filled with 60 ml. Only 4 traps are used until the $BaCO_3$ precipatant is at least 1 gm; usually the last day of the test. All five traps are used the last day of the test. Tube no. 6 is also filled with 60 ml of barium bydroxide to provide a base estimate of the amount of carbon dioxide diffused into the barium hydroxide since there is carbon dioxide in the environment of the lab.

8:06 15. Place the tubes of the carbon dioxide traps in place.

16. Turn valve no. 4 to the 0^{o} position and valve no. 5 to the 180^{o} position.

8:08 17. Turn air pressure regular in a clockwise direction until the air bubbles from the effluent are just beginning to pass through the barium hydroxide in the CO_2 traps in a surging manner. The rate at which the effluent should be passed through the barium hydroxide should be at the rate of approximately 1000 ml in 30 minutes.

18. Turn valve no. 1 to the 90^{o} position to allow the calcium chloride solution of spirometer no. 2 (companion flask spirometer) to be raised to the starting level.

19. Pour the contents of tube no. 6 into the filter provided for it.

20. Slide the electric motor of the lowering mechanism into the operating position with the shaft of the lowering mechanism alligned properly to fit in the slot of the gear drive. The leveling bulb should be at a level whereby the level of the calcium chloride in the two spirometers is as close as possible to the zero ml level.

8:15 21. Turn on the electric switch on the lowering mechanism to begin the aeration of the flasks again.

22. Turn valve nos. 1, 2, and 3 to the 180^{o} position.

23. Mark the level of the calcium chloride solution in the two spirometers.

24. Record the following in the record book:
    A. The temperatures recorded on the chard of the Electronik 16 recorder.
    B. The temperature of the Currentronik cascade.
    C. The level of the calcium chloride in the spirometers at the end of the previous eight hour period (8:00)

and the level at the beginning of the next eight hour period (8:15).

8:45 25. The effluent should have passed through the CO_2 traps by this time. Turn valve no. 5 to the 225° position. Remove the three clamps on valve no. 4 to permit the easy removal of the CO_2 traps still attached to their mounting board.

26. Turn valve no. 4 to the 45° position. Turn air line pressure regulator counterclockwise to cut off air pressure.

27. Remove the wing nuts from the CO_2 traps' mounting board.

8:46 28. Remove the CO_2 traps and mounting board.

29. Place the mounting board on the holding rack.

30. Remove the filter from the funnel into which the contents of tube no. 6 was poured, fold the filter and place it in the oven to dry.

8:47 31. Remove tube no. 1 and pour its contents onto a filter.

32. " " " 2 " " " " " " "

33. " " " 3 " " " " " " "

34. " " " 4 " " " " " " "

35. " " " 5 " " " " " " "

8:48 36. Hold tube no. 1 in position and flush CO_2 trap no. 1.

37. " " " " " " " " " " " 2.

38. " " " " " " " " " " " 3.

39. " " " " " " " " " " " 4.

40. " " " " " " " " " " " 5.

8:50 41. Pour contents of tube no. 1 onto a filter.

42. Flush out all tubes with distilled water and pour onto the filters.

43. Use tap water and a bristle brush and scrub all the tubes thoroughly.

44. Rinse all the tubes with distilled water and place upside down on the drain rack.

8:52 45. Remove CO_2 traps' mounting board from holding rack and wash thoroughly with distilled water.

8:54 46. Return the CO_2 traps and mounting board back on the panel board and lock in place with wing nut.

47. Place the three clamps of valve no. 4.

48. Wash the pipette thoroughly with distilled water.

49. Turn off air line main valve at lab wall.

50. Turn the air line pressure regulator clockwise until the air begins to flow. When the pressure in the air line is removed, turn the air line pressure regulator counterclockwise several turns to prevent any damage to the aeration system in case the air line main pressure valve is accidentally turned on prematurely.

51. Turn valve no. 5 to the 90° position to allow the discharging into the atmosphere of the air in the main air line.

8:56 52. By now, all the contents of the CO_2 traps should have passed through the filters. Remove all the filters from the funnels and fold them to prevent accidental loss of any of the precipitant until dried and weighed. Place the folded filters into the electric oven and dry at 170° F for 24 hours.

9:00 53. Return all the equipment to the storage cabinet.

54. Fill the water heater with hot water.

55. Check the recording chart of the Electronik 16 unit and replace every two days.

56. Check the valve position of the process variable temperature indicator of the Cascade controller vertical scale. If the position is greater than the 75% time control, reset the butterfly valve position in the air bach chamber air circulation system by lowering the control lever 45°. The lowering of the control lever will change the percent of cold air entering the aeration system of the air bath chamber. The process variable temperature is indicated by the position of the red galvanometer pointer. The green band at the center of the bezel indicates the temperature of the interseed air in the main flask, the set point temperature. When the red galvanometer pointer is directly behind the green band, the temperatures outside the main flask is the same as that inside the flask. Changing the percent of cold air entering the air bath aeration system will change the temperature outside the flask.

Therefore, the percent of fultime control of the process must be readjusted to a lower percent until the red galvanometer pointer is directly behind the green band and remain there.

57. The percent time control must be decreased until the process variable dial (red) stays in alignment with the set point dial (green).

APPENDIX B

COMPUTATION OF CARBON DIOXIDE IN INTERSEED AIR

COMPUTATION OF CARBON DIOXIDE IN INTERSEED AIR

As the effluent is passed through the barium hydroxide, the carbon dioxide of the effluent will combine with the barium hydroxide as indicated by the following:

$$Ba(OH)_2 + CO_2 \longrightarrow BaCO_3 + H_2O$$

The molecular weight of $BaCO_3$ and CO_2 is 197.37 and 44 respectively. Since there are 22.4 liters per mole, the percent by volume of CO_2 in the effluent can be calculated by the equation (41).

$$Vc = \frac{44}{197.37} \times \frac{22.4 \text{ ltr/mol.}}{44 \text{ gm/mol.}} \times \frac{1000 \text{ ml.}}{1 \text{ ltr.}} \times \frac{Wb}{Va} \times 100$$

where Wb = Weight of $BaCO_3$ grams

Va = Volume of effluent in milliliters

or $$Vc = 1.135 \times 10^4 \frac{Wb}{Wa} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (41).$$

APPENDIX C

TEMPERATURE DATA OF RESPIRATION TESTS

TABLE XVI

TEMPERATURE DATA OF RESPIRATION TESTS

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Hour of Test	Peanut Bulk Temperature at Time θ (^{o}F)
1	46.1	40.0	0	40.0
		40.0	1	40.2
		40.0	4	40.4
		40.0	8	40.8
		40.0	12	41.2
		40.0	16	41.7
		40.0	20	42.2
		40.0	24	42.8
		40.0	28	43.3
		40.0	32	43.7
		40.0	36	44.0
		40.0	40	44.3
		40.0	44	44.7
		40.0	48	45.0
		40.0	52	45.5
		40.0	56	45.6
		40.0	60	46.4
		40.0	64	46.7
		40.0	68	47.1
		40.0	72	47.6
		40.0	76	47.8
		40.0	80	48.2
		40.0	84	49.0
		40.0	88	50.0
		40.0	92	51.5
		40.0	96	52.3
		40.0	100	53.0
		40.0	103	53.5
		40.0	106	54.0
		40.0	109	54.5
		40.0	111	55.0
		40.0	113	55.5
		40.0	115	56.0
		40.0	118	56.5
2	45.1	39.5	0	39.5
		39.5	1	39.5
		39.5	2	39.7
		39.5	12	40.7
		39.5	18	41.3
		39.5	24	42.0
		39.5	30	42.7
		39.5	36	43.4

TABLE XVI (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Hour of Test	Peanut Bulk Temperature at Time θ (^{o}F)
2	45.1	39.5	42	44.1
		39.5	46	44.6
		39.5	49	45.0
		39.5	52	45.6
		39.5	54	46.0
		39.5	58	46.6
		39.5	61	47.0
		39.5	65	47.6
		39.5	68	48.0
		39.5	73	49.0
		39.5	76	49.5
		39.5	79	50.0
		39.5	81	50.5
		39.5	83	51.0
		39.5	85	51.5
		39.5	87	52.0
		39.5	89	52.5
		39.5	91	53.0
		39.5	93	53.5
		39.5	97	55.0
		39.5	100	56.0
		39.5	103	57.0
		39.5	106	58.0
		39.5	109	59.0
		39.5	111	60.0
		39.5	113	61.0
		39.5	115	62.0
		39.5	117	63.0
		39.5	119	64.0
		39.5	120	64.5
1	30.1	40.0	0	40.0
		40.0	1	40.4
		40.0	4	40.8
		40.0	6	42.0
		40.0	11	43.1
		40.0	18	44.0
		40.0	22	44.9
		40.0	26	45.4
		40.0	32	46.3
		40.0	38	47.2
		40.0	42	47.7
		40.0	45	48.3
		40.0	48	48.9
		40.0	52	49.7

TABLE XVI (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Hour of Test	Peanut Bulk Temperature at Time θ (^{o}F)
1	30.1	40.0	56	50.3
		40.0	59	50.8
		40.0	62	51.6
		40.0	65	52.5
		40.0	67	52.9
		40.0	69	53.5
		40.0	72	54.2
		40.0	75	55.6
		40.0	80	56.6
		40.0	84	57.2
		40.0	87	58.1
		40.0	89	59.8
		40.0	91	60.1
		40.0	95	61.2
		40.0	98	62.2
		40.0	101	63.3
		40.0	104	64.3
		40.0	107	65.6
		40.0	110	66.6
		40.0	112	67.6
		40.0	114	68.3
		40.0	117	69.5
		40.0	119	70.1
		40.0	120	71.1
2	35.6	40.0	0	40.0
		40.0	1	40.0
		40.0	2	40.7
		40.0	4	41.4
		40.0	6	42.2
		40.0	8	42.9
		40.0	12	43.6
		40.0	15	44.2
		40.0	19	45.1
		40.0	21	45.4
		40.0	25	46.2
		40.0	28	46.6
		40.0	32	47.5
		40.0	35	47.9
		40.0	38	48.7
		40.0	42	49.4
		40.0	45	50.1
		40.0	48	50.2
		40.0	52	51.2
		40.0	54	51.8

TABLE XVI (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Hour of Test	Peanut Bulk Temperature at Time θ (^{o}F)
2	35.6	40.0	57	53.2
		40.0	60	54.0
		40.0	67	55.8
		40.0	68	56.3
		40.0	70	57.3
		40.0	71	57.4
		40.0	72	58.1
		40.0	73	58.7
		40.0	74	59.0
		40.0	75	59.5
		40.0	76	60.4
		40.0	78	61.1
		40.0	79	61.6
		40.0	80	62.6
		40.0	81	63.1
		40.0	82	64.1
		40.0	83	64.8
		40.0	84	65.5
		40.0	85	66.1
		40.0	86	67.1
		40.0	87	68.1
		40.0	88	69.1
		40.0	89	70.1
		40.0	90	71.1
		40.0	91	72.1
		40.0	92	73.5
		40.0	93	74.7
		40.0	94	75.8
		40.0	95	77.0
		40.0	96	78.0
		40.0	97	79.0
		40.0	98	80.0
		40.0	99	81.5
		40.0	101	83.5
		40.0	102	84.5
		40.0	103	85.7
		40.0	104	87.0
1	33.2	50.0	0	50.0
		50.0	1	50.5
		50.0	4	51.5
		50.0	7	52.4
		50.0	12	53.5
		50.0	15	55.0
		50.0	17	55.6

TABLE XVI (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Hour of Test	Peanut Bulk Temperature at Time θ (^{o}F)
1	33.2	50.0	19	56.0
		50.0	21	56.7
		50.0	22	56.9
		50.0	23	57.3
		50.0	25	58.2
		50.0	27	58.6
		50.0	28	58.7
		50.0	30	59.8
		50.0	32	60.6
		50.0	34	61.2
		50.0	36	62.2
		50.0	38	63.0
		50.0	40	64.2
		50.0	42	65.3
		50.0	44	66.2
		50.0	46	67.7
		50.0	48	68.7
		50.0	51	71.5
		50.0	54	73.5
		50.0	56	75.0
		50.0	59	78.0
		50.0	60	78.9
		50.0	61	79.8
		50.0	62	80.8
		50.0	63	81.8
		50.0	64	82.8
		50.0	65	84.0
		50.0	66	85.3
		50.0	67	86.4
		50.0	68	87.5
		50.0	69	88.7
		50.0	70	90.0
		50.0	71	91.0
		50.0	72	92.5
		50.0	73	94.5
		50.0	74	95.6
		50.0	75	96.5
		50.0	76	98.5
2	33.0	49.5	0	50.0
		49.5	3	49.7
		49.5	5	50.6
		49.5	7	51.5
		49.5	9	51.6
		49.5	11	53.0

TABLE XVI (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Hour of Test	Peanut Bulk Temperature at Time θ (^{o}F)
2	33.0	49.5	14	54.1
		49.5	17	55.6
		49.5	20	56.2
		49.5	22	57.1
		49.5	24	57.8
		49.5	27	59.1
		49.5	30	60.4
		49.5	32	61.2
		49.5	34	62.1
		49.5	36	63.1
		49.5	37	63.7
		49.5	38	63.9
		49.5	39	64.5
		49.5	40	65.7
		49.5	41	66.7
		49.5	42	66.9
		49.5	43	67.4
		49.5	44	67.7
		49.5	45	68.3
		49.5	46	69.2
		49.5	47	69.7
		49.5	48	70.0
		49.5	49	71.0
		49.5	50	72.0
		49.5	51	73.1
		49.5	52	74.0
		49.5	53	74.9
		49.5	54	75.2
		49.5	55	76.2
		49.5	56	76.8
		49.5	57	77.8
		49.5	58	78.8
		49.5	59	79.7
		49.5	60	80.5
		49.5	61	81.3
		49.5	62	82.2
		49.5	63	82.3
		49.5	64	83.2
		49.5	65	84.0
		49.5	66	85.1
		49.5	67	86.3
		49.5	68	86.8
		49.5	69	87.5
		49.5	70	88.8

TABLE XVI (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^oF)	Hour of Test	Peanut Bulk Temperature at Time θ (^oF)
2	33.0	49.5	71	89.8
		49.5	72	90.8
		49.5	73	91.7
1	44.8	71.5	0	71.5
		71.5	1	73.5
		71.5	2	74.5
		71.5	3	74.7
		71.5	4	74.8
		71.5	5	74.9
		71.5	6	75.6
		71.5	7	76.2
		71.5	8	77.1
		71.5	9	77.7
		71.5	10	78.2
		71.5	11	79.2
		71.5	12	80.3
		71.5	13	81.2
		71.5	14	82.6
		71.5	15	84.0
		71.5	16	85.0
		71.5	17	86.0
		71.5	18	86.5
		71.5	19	86.6
		71.5	20	87.2
		71.5	21	88.1
		71.5	22	89.2
		71.5	23	90.4
		71.5	24	91.4
		71.5	25	92.4
		71.5	26	94.5
		71.5	27	95.5
		71.5	28	96.0
		71.5	29	96.7
		71.5	30	97.0
		71.5	31	97.7
		71.5	32	98.0
		71.5	33	98.5
		71.5	34	99.0
		71.5	35	99.5
		71.5	36	100.0
		71.5	37	100.0
2	47.3	70.0	0	70.0
		70.0	1	70.1
		70.0	2	70.2

TABLE XVI (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Hour of Test	Peanut Bulk Temperature at Time θ (^{o}F)
2	47.3	70.0	4	70.3
		70.0	7	70.9
		70.0	9	71.7
		70.0	13	72.6
		70.0	16	73.5
		70.0	18	73.8
		70.0	20	74.2
		70.0	22	74.7
		70.0	24	75.7
		70.0	27	77.0
		70.0	30	78.2
		70.0	33	78.9
		70.0	36	80.0
		70.0	38	81.0
		70.0	40	81.8
		70.0	42	82.7
		70.0	44	83.6
		70.0	46	84.3
		70.0	48	85.2
		70.0	50	86.2
		70.0	52	86.7
		70.0	54	87.5
		70.0	57	88.4
		70.0	58	89.0
		70.0	59	90.7
		70.0	60	91.5
		70.0	61	92.5
		70.0	62	93.1
		70.0	63	94.1
		70.0	64	94.9
		70.0	65	95.9
		70.0	66	96.9
		70.0	67	97.7
		70.0	68	98.7
		70.0	69	100.0
1	29.2	70.0	0	70.0
		70.0	1	70.0
		70.0	7	71.0
		70.0	13	72.5
		70.0	17	74.0
		70.0	19	75.5
		70.0	21	77.5
		70.0	23	79.5
		70.0	25	82.0

TABLE XVI (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Hour of Test	Peanut Bulk Temperature at Time θ (^{o}F)
1	29.2	70.0	27	84.5
		70.0	29	87.0
		70.0	31	89.5
		70.0	33	92.0
		70.0	35	94.5
		70.0	37	97.0
		70.0	39	99.5
		70.0	41	102.5
2	34.4	70.0	0	70.0
		70.0	1	70.5
		70.0	2	70.7
		70.0	4	71.4
		70.0	5	72.0
		70.0	6	72.6
		70.0	7	73.5
		70.0	8	74.7
		70.0	9	75.1
		70.0	10	76.2
		70.0	11	77.4
		70.0	12	78.3
		70.0	13	79.6
		70.0	14	80.4
		70.0	15	81.6
		70.0	16	82.7
		70.0	17	83.7
		70.0	18	84.7
		70.0	19	86.5
		70.0	20	87.8
		70.0	21	89.0
		70.0	22	90.6
		70.0	23	92.7
		70.0	24	94.8
		70.0	25	96.7
		70.0	26	98.8
		70.0	27	100.7

APPENDIX D

RESPIRATION DATA

TABLE XVII

RESPIRATION DATA

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Aeration Rate (m/hr)	Hour of Test, θ (hr)	Heat of Respiration, q'_θ (cal/(gm dry matter-hr))
1	46.1	40.0	81	1	0.071
			81	4	0.071
			81	8	0.071
			81	12	0.071
			81	16	0.072
			81	20	0.072
			81	24	0.072
			77	28	0.072
			77	32	0.072
			77	36	0.073
			77	40	0.073
			77	44	0.073
			85	48	0.073
			85	52	0.073
			85	56	0.074
			85	60	0.075
			85	64	0.081
			85	68	0.088
			86	72	0.095
2	45.1	39.5	76	1	0.072
			76	2	0.072
			76	12	0.072
			88	18	0.073
			88	24	0.073
			89	30	0.073
			89	36	0.073
			84	42	0.073
			84	46	0.074
			83	52	0.078
			83	54	0.081
			83	58	0.086
			83	61	0.093
			86	65	0.100
			86	68	0.109
			86	72	0.118
1	30.1	40.0	0	1	0.086
			0	4	0.086
			0	6	0.086
			0	11	0.086
			83	18	0.087
			83	22	0.087
			83	26	0.087

TABLE XVII (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Aeration Rate (m/hr)	Hour of Test, θ (hr)	Heat of Respiration, q'_θ (cal/(gm dry matter-hr))
1	30.1	40.0	85	32	0.087
			85	38	0.087
			82	42	0.087
			82	45	0.088
			82	48	0.089
			85	52	0.094
			85	56	0.100
			85	59	0.106
			85	62	0.112
			85	65	0.118
			85	67	0.123
			85	69	0.127
			85	72	0.132
2	35.6	40.0	44	1	0.095
			0	2	0.095
			0	4	0.095
			0	6	0.095
			0	8	0.095
			0	12	0.095
			0	15	0.096
			0	19	0.096
			80	21	0.096
			80	25	0.096
			80	28	0.096
			80	32	0.097
			80	35	0.097
			80	38	0.097
			80	42	0.097
			83	45	0.100
			83	48	0.104
			83	52	0.119
			83	54	0.135
			84	57	0.151
			84	60	0.172
			84	67	0.215
			84	68	0.252
			84	70	0.268
			84	71	0.284
			84	72	0.296
1	33.2	50.0	0	1	0.167
			0	4	0.168
			0	7	0.169
			82	12	0.170
			82	15	0.170

TABLE XVII (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Aeration Rate (m/hr)	Hour of Test, θ (hr)	Heat of Respiration, q'_θ (cal/(gm dry matter-hr))
1	33.2	50.0	82	17	0.171
			82	19	0.171
			82	21	0.172
			82	23	0.177
			82	25	0.183
			82	27	0.192
			82	28	0.200
			82	30	0.208
			82	32	0.221
			82	34	0.235
			82	36	0.251
			82	38	0.269
			82	40	0.288
			82	42	0.309
			82	44	0.332
			82	46	0.356
			82	48	0.382
			82	51	0.419
			82	54	0.467
			82	56	0.509
			82	59	0.558
			84	60	0.595
			84	61	0.617
			84	62	0.639
			84	63	0.662
			84	64	0.686
			84	65	0.710
			84	66	0.736
			84	67	0.763
			84	68	0.790
			84	69	0.819
			84	70	0.848
			84	71	0.879
			84	72	0.911
2	33.0	49.5	0	1	0.204
			0	3	0.204
			0	5	0.204
			0	7	0.204
			0	9	0.205
			82	11	0.206
			82	14	0.207
			82	17	0.207
			82	20	0.208
			82	22	0.209

TABLE XVII (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Aeration Rate (m/hr)	Hour of Test, θ (hr)	Heat of Respiration, q'_θ (cal/(gm dry matter-hr))
2	33.0	49.5	84	24	0.210
			84	27	0.228
			84	30	0.246
			84	32	0.264
			84	34	0.280
			91	36	0.297
			91	35	0.310
			91	38	0.319
			91	39	0.328
			91	40	0.338
			91	41	0.347
			91	42	0.357
			91	43	0.367
			91	44	0.377
			91	45	0.387
			91	46	0.397
			91	47	0.407
			85	48	0.417
			85	49	0.427
			85	50	0.436
			85	51	0.446
			85	52	0.456
			85	53	0.466
			85	54	0.475
			85	55	0.485
			85	56	0.494
			85	57	0.503
			85	58	0.511
			85	59	0.520
			86	60	0.528
			86	61	0.536
			86	62	0.543
			86	63	0.550
			86	64	0.556
			86	65	0.563
			86	66	0.568
			86	67	0.573
			86	68	0.578
			86	69	0.581
			86	70	0.585
			86	71	0.587
			82	72	0.589
1	44.8	71.5	92	1	0.658
			92	2	0.658

TABLE XVII (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^oF)	Aeration Rate (m/hr)	Hour of Test, θ (hr)	Heat of Respiration, q'_θ (cal/(gm dry matter-hr))
1	44.8	71.5	92	3	0.663
			92	4	0.667
			92	5	0.672
			92	6	0.677
			92	7	0.681
			92	8	0.686
			92	9	0.691
			92	10	0.696
			92	11	0.701
			92	12	0.706
			92	13	0.711
			82	15	0.721
			82	16	0.726
			82	17	0.732
			82	18	0.737
			82	19	0.742
			82	20	0.748
			82	21	0.753
			82	22	0.759
			82	23	0.764
			82	24	0.770
			82	25	0.776
			65	26	0.781
			65	27	0.787
			65	28	0.793
			65	29	0.799
			65	30	0.804
			65	31	0.810
			65	32	0.816
			65	33	0.823
			65	34	0.829
			65	35	0.835
			65	36	0.841
			65	37	0.847
2	47.3	70.0	82	1	0.095
			82	4	0.107
			82	7	0.126
			82	9	0.145
			78	13	0.168
			78	16	0.196
			78	18	0.216
			78	20	0.232
			82	22	0.249
			82	24	0.265

TABLE XVII (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^oF)	Aeration Rate (m/hr)	Hour of Test, θ (hr)	Heat of Respiration, q'_θ (cal/(gm dry matter-hr))
2	47.3	70.0	82	27	0.287
			82	30	0.313
			82	33	0.340
			84	36	0.368
			84	38	0.391
			84	40	0.410
			84	42	0.430
			84	44	0.450
			83	46	0.471
			83	48	0.492
			83	50	0.514
			83	52	0.536
			83	54	0.559
			83	57	0.590
			85	58	0.611
			85	59	0.624
			85	60	0.636
			85	61	0.649
			85	62	0.662
			85	63	0.675
			85	64	0.688
			85	65	0.702
			85	66	0.715
			85	67	0.729
			85	68	0.743
			85	69	0.758
1	29.2	70.0	44	1	0.045
			44	7	0.075
			44	13	0.135
			44	17	0.246
			44	19	0.497
			44	21	0.558
			44	22	0.576
			78	23	0.594
			78	25	0.660
			78	27	0.699
			78	29	0.740
			78	31	0.753
			78	33	0.766
			78	35	0.811
			78	37	0.827
			78	39	0.843
			78	41	0.927

TABLE XVII (Continued)

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^oF)	Aeration Rate (m/hr)	Hour of Test, θ (hr)	Heat of Respiration, q'_θ (cal/(gm dry matter-hr))
2	34.4	70.0	68	1	0.059
			68	2	0.130
			68	4	0.260
			68	5	0.367
			68	6	0.426
			68	7	0.475
			68	8	0.518
			68	9	0.555
			68	10	0.586
			68	11	0.615
			68	12	0.640
			68	13	0.665
			68	14	0.691
			68	15	0.718
			96	16	0.748
			96	17	0.783
			96	18	0.824
			96	19	0.873
			96	20	0.932
			96	21	1.003
			96	22	1.088
			96	23	1.189
			96	24	1.309
			96	25	1.450
			96	26	1.617

APPENDIX E

PERCENT IMMATURE PEANUT KERNELS

TABLE XVIII

PERCENT IMMATURE PEANUT KERNELS

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^oF)	Weight of Hulls (gms.)	Weight of Mature Kernels (gms)	Weight of Immature Kernels (gms.)	Total Weight (gms.)	Percent by Weight Immature Kernels
I	46.1	40.0	20.1393	53.7243	2.7019	76.5655	3.52
II	45.1	39.5	18.5436	41.7308	2.2506	62.5250	3.59
I	30.1	40.0	7.5428	18.9050	0.3500	26.7978	1.30
II	35.6	40.0	12.4005	32.6283	0.4387	45.4675	0.96
I	33.2	50.0	13.1330	33.0041	0.5294	46.6665	1.13
II	33.0	49.5	14.2406	34.3672	0.5316	49.1394	1.08
I	44.8	71.5	19.1960	42.8900	2.6745	64.7605	4.12
II	47.3	70.0	18.7332	41.4404	2.4410	62.6146	3.89
I	29.2	70.0	15.3218	32.4892	0.5287	50.3397	1.05
II	34.4	70.0	13.2679	33.1841	0.5534	47.0054	1.17

APPENDIX F

CALIBRATION DATA

TABLE XIX

DATA USED IN DETERMINING HEAT CAPACITY CONSTANT
OF SPECIFIC HEAT CALORIMETER FLASK

Test No.	Wt. Hot Water (gm.)	Wt. Cold Water (gm.)	Initial Temp. Cold Water (^{o}F)	Initial Temp. Hot Water (^{o}F)	Equilibrium Temperature (^{o}F)	ΔT_h [1] (^{o}F)	ΔT_c [2] (^{o}F)
1	198.7	118.4	45.6	95.7	78.2	17.5	32.6
2	197.1	117.1	46.4	94.1	77.45	16.6	31.05
3	1972.2	119.1	45.7	93.0	76.25	16.75	30.55
4	197.4	117.5	44.9	92.25	75.7	16.55	30.8
5	196.5	116.8	46.15	93.3	76.8	16.5	30.65
6	197.6	118.2	46.35	93.3	76.85	16.45	30.50
7	198.3	117.6	46.15	93.4	76.9	16.5	30.75
8	196.7	119.2	45.7	97.8	79.4	18.4	33.7

[1] Difference between initial hot water and equilibrium temperatures.

[2] Difference between initial cold water and equilibrium temperatures.

TABLE XX

SPECIFIC HEAT CALORIMETER VALIDATION TESTS' DATA

Test No.	Weight of Water (gm.)	Weight of Sulfur (gm.)	Sulfur Used	Specific Heat of Sulfur (calculated) (cal/gm-^{o}C)	ΔT_W[1] (^{o}F)	ΔT_S[2] (^{o}F)
1	199.6	271.5	Monoclinic	0.178	7.1	31.2
2	199.2	170.7	Monoclinic	0.178	5.0	35.2
3	198.1	264.1	Rhombic	0.173	7.6	36.6
4	196.5	274.0	Monoclinic	0.178	7.8	34.1
5	198.0	266.5	Rhombic	0.173	6.8	31.4
6	197.6	263.2	Rhombic	0.173	7.4	33.3

[1]Difference between initial water and equilibrium temperatures

[2]Difference between initial sulfur and equilibrium temperatures

TABLE XXI

DATA USED IN DETERMINING HEAT CAPACITY CONSTANT
OF RESPIRATION CALORIMETER MAIN FLASK

Test No.	Wt. Hot Water (gm.)	Wt. Cold Water (gm.)	Initial Temp. Cold Water (^{o}F)	Initial Temp. Hot Water (^{o}F)	Equilibrium Temperature (^{o}F)	ΔT_h [1] (^{o}F)	ΔT_c [2] (^{o}F)
1	502.7	404.2	37.25	95.2	70.7	24.4	33.45
2	502.9	400.1	33.5	96.35	70.0	26.35	36.5
3	502.3	401.1	33.8	95.9	69.8	26.1	36.0
4	503.1	406.1	35.2	95.5	70.0	25.5	34.8
5	504.0	401.8	35.25	96.8	70.95	25.85	35.7
6	505.1	391.6	34.9	96.4	71.0	25.4	36.1

[1] Difference between initial hot water and equilibrium temperatures

[2] Difference between initial cold water and equilibrium temperatures

TABLE XXII

RESPIRATION CALORIMETER VALIDATION TESTS' DATA

Test No.	Volts	Amperes	Duration of Test (sec.)	Temperature Rise in Calorimeter (^{o}F)	Thermal Energy[1] Measured (cal.)
1	8.1	0.3	3930	30.0	2213.7
2	8.2	0.3	3570	30.0	2213.7
3	8.2	0.3	3645	30.0	2213.7

[1]The energy stored in the calorimeter flask and heating apparatus was measured to be 132.82 cal./^{o}C.

APPENDIX G

SPECIFIC HEAT DATA

OF PEANUT PODS

TABLE XXIII

SPECIFIC HEAT DATA OF PEANUT PODS

Replicate	Peanut Bulk Moisture Content Wet Basis (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Peanut Bulk Temperature at Time 0 (^{o}F)	Specific Heat Observed (cal./(gm.-^{o}C)	Specific Heat Measured (cal./(gm.-^{o}C)
1	46.1	40.0	40.0	0.526	0.572
		40.0	48.5	0.657	0.606
		40.0	52.5	0.657	0.625
		40.0	57.5	0.633	0.649
2	45.1	39.5	39.5	0.528	0.567
		39.5	42.5	0.563	0.577
		39.5	45.0	0.609	0.587
		39.5	48.5	0.637	0.601
		39.5	54.5	0.620	0.628
		39.5	64.0	0.636	0.678
1	30.1	40.0	40.0	0.527	0.553
		40.0	45.0	0.550	0.559
		40.0	49.5	0.579	0.565
		40.0	55.0	0.581	0.576
		40.0	62.0	0.597	0.594
		40.0	71.0	0.637	0.623
2	35.6	40.0	40.0	0.554	0.554
		40.0	46.5	0.576	0.566
		40.0	52.5	0.607	0.581
		40.0	62.5	0.576	0.614
		40.0	87.0	0.710	0.733
1	33.2	50.0	50.0	0.684	0.570
		50.0	57.5	0.555	0.589
		50.0	69.0	0.622	0.628

TABLE XXIII (Continued)

Replicate	Peanut Bulk Moisture Content Wet Basis (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Peanut Bulk Temperature at Time 0 (^{o}F)	Specific Heat Observed (cal./(gm.-^{o}C)	Specific Heat Measured (cal./(gm.-^{o}C)
1	33.2	50.0	99.5	0.731	0.791
2	33.0	49.5	49.5	0.525	0.570
		49.5	57.0	0.573	0.587
		49.5	70.0	0.552	0.632
		49.5	92.5	0.710	0.745
1	44.8	71.5	71.5	0.795	0.720
		71.5	93.0	0.818	0.876
		71.5	100.0	1.038	0.937
2	47.3	70.0	70.0	0.676	0.737
		70.0	89.0	0.819	0.881
		70.0	100.0	0.965	0.980
3	46.6	70.0	70.0	0.743	0.729
		70.0	73.5	0.819	0.752
		70.0	77.5	0.761	0.781
		70.0	81.0	0.829	0.807
		70.0	83.5	0.786	0.826
		70.0	90.5	0.899	0.844
1	29.2	70.0	70.5	0.635	0.617
		70.0	75.0	0.602	0.634
		70.0	85.0	0.743	0.678
		70.0	100.0	0.818	0.761
2	34.4	70.0	70.0	0.662	0.638
		70.0	98.5	0.774	0.795

APPENDIX H

SPECIFIC HEAT DATA OF PEANUT HULLS AND KERNELS

TABLE XXIV

SPECIFIC HEAT DATA OF PEANUT HULLS AND KERNELS

Material	Test Number	Bulk Temperature (^{o}F)	Specific Heat (Btu/lb-^{o}F)
Hulls	1	40	0.505
	2		0.580
	3		0.504
	4		0.564
	Avg.		0.538
	1	60	0.546
	2		0.550
	3		0.635
	4		0.657
	Avg.		0.597
	1	80	0.675
	2		0.663
	3		0.737
	4		0.625
	Avg.		0.719
	1	100	1.008
	2		1.004
	3		1.012
	4		0.963
	Avg.		0.997
Kernels	1	40	0.750
	2		0.665
	3		0.711
	4		0.630
	Avg.		0.689
	1	60	0.659
	2		0.576
	3		0.614
	4		0.595
	Avg.		0.611
	1	80	0.672
	2		0.651
	3		0.632
	4		0.671
	Avg.		0.656

TABLE XXIV (Continued)

Material	Test Number	Bulk Temperature (^{o}F)	Specific Heat (Btu/lb-^{o}F)
	1	100	0.715
	2		0.885
	3		0.755
	4		0.719
	Avg.		0.768

APPENDIX I

DATES OF HARVESTING PEANUTS

AND STARTING TESTS

TABLE XXV

DATES OF HARVESTING PEANUTS AND STARTING TESTS

Replicate	Peanut Moisture Content, Wet Basis, MC (%)	Initial Peanut Bulk Temp., T_i (^{o}F)	Harvest Completed		Test Started	
			Date	Hour	Date	Hour
I	46.1	40.0	Oct. 6	2130	Oct. 7	1700
II	45.1	39.5	Oct. 24	1550	Oct. 25	1900
I	30.1	40.0	Nov. 20	1545	Nov. 21	1800
II	35.6	40.0	Nov. 25	1640	Nov. 26	2100
I	33.2	50.0	Dec. 1	1710	Dec. 3	800
II	33.0	49.5	Dec. 5	1600	Dec. 6	2100
I	44.8	71.5	Oct. 21	2330	Oct. 23	1930
II	47.3	70.0	Nov. 10	2110	Nov. 11	1100
I	29.2	70.0	Nov. 5	2355	Nov. 7	2000

VITA

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Doctor of Philosophy

Thesis: HEAT OF RESPIRATION OF HIGH MOISTURE SPANISH PEANUTS

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