AN INVESTIGATION OF WEATHER DATA AS IT PERTAINS TO CROP DRYING

by

GERALD LEROY ZACHARIAH

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INTRODUCTION

The mechanical drying of grain has become an important phase of the harvesting operation. Controlled drying fits in with modern production, harvesting, and handling methods. It overcomes the problems presented by the use of grain combines and picker-shellers. These machines have the capacity to get the grain out of the field rapidly but often too wet for safe storage.

Drying of grain after harvest was at first almost entirely accomplished in storage by unheated air. During this initial stage in the evolution of the crop dryer it was used primarily as an emergency measure. When weather conditions were not conducive for natural drying in the field, the grain was harvested and dried in the bin. As farmers gained experience with natural air drying, they learned that drying could be beneficial nearly every year. Some of the benefits derived from drying are:

1. Grain can be harvested sooner in the season, earlier in the morning, later at night, and sooner after showers. Field losses from storms and natural shattering are reduced.

2. Machine losses are usually the least when grain is harvested at some moisture content above that allowable for safe storage.

3. The quality of grain is often better.

4. As an emergency measure, grain that will not dry naturally in the field may be harvested and safely stored.

The main disadvantage of natural air drying was the dependence on weather. When drying was most needed, the weather was often relatively poor for drying.

Small gas-fired heat units were added to the basic natural air-drying system to condition the air when poor drying weather existed. The supplemental heat-drying systems made it possible to dry under any weather condition. The elimination of weather as the controlling factor in drying made it possible to predict the drying time much more closely.

Although supplemental heat systems insured that drying could be accomplished, several problems were incurred. The initial cost of the heat unit, controls, and fuel storage were a considerable addition to the cost of the basic natural air system. The problem of a fire hazard from the direct fired heat unit was of concern to some individuals. When heat was added, over drying of the grain became a more prominent problem. The high demand for electric energy of the electrically-heated driers appeared to be a major disadvantage.

With natural air drying, the farmer had only three alternatives for handling his crop: (1) Leave the grain in the field until it dried; (2) sell the grain at a discount; (3) dry the grain with a natural air drier.

The addition of the supplemental heater made the choice of operating methods numerous. The expected weather conditions during the drying season became an important consideration in selecting as well as operating a drying system.

PURPOSE

This investigation was conducted to determine methods of utilizing recorded weather data as a basis for grain drier selection and operating procedures.

The objectives of the investigation can be defined under three main classifications:

1. To determine the essential weather data and their significance to the drying operation.
2. To compile the essential data in a usable form.
3. To develop methods for utilizing the data.

REVIEW OF LITERATURE

There were no reports on detailed weather analysis relative to crop drying prior to the initiation of this investigation. The research in the crop-drying area has been devoted to basic concepts of the drying process and requirements for safe storage.

Storage Requirements

Snow, et al. (18) found the main factors controlling mold growth in stored grain to be:

1. Relative humidity of the atmosphere surrounding the kernels.
2. Length of storage.

3. The balance and type of nutrients provided by the grain.

4. The temperature of storage.

5. Type of mold species present.

According to Barre and Sammett (3), the grain temperature and moisture content are important factors in the life process of insects. By controlling the temperature and moisture content, the two chief destructive agents, insect activity and mold growth, can be controlled.

Equilibrium Moisture Content

Coleman and Fellows (6) state that cereal grains are hygroscopic and their moisture content will vary with the conditions under which they are exposed.

Barre (2) reported that a hygroscopic material at a given moisture and temperature exerts a definite vapor pressure. He states that, "Although the vapor pressure of air is independent of temperature, the temperature effect in the case of a hygroscopic material is quite opposite to that of water vapor." Barre reported results of permeability tests on hygroscopic materials which show that the amount of water vapor transmitted varies directly with the vapor pressure difference when the relative humidity does not exceed 75 per cent. Above 75 per cent the amount transmitted per unit vapor pressure is usually greater.

Henderson (11) states that moisture content of hygroscopic materials which include all farm products is important because of its direct relationship to storage and drying problems. The moisture content of stored grain approaches a value controlled by the ambient relative humidity and temperature of the air available for drying. The moisture content of the grain when there is no net transfer of moisture to or from the air is known as equilibrium moisture content. Equilibrium relative humidity is the ratio of the vapor pressure of moisture in grain to the vapor pressure of pure water at the same temperature. Henderson (11) presents the following equation as the mathematical expression of the equilibrium moisture content curves for a number of materials.

$$1 - rh = \epsilon^{-cTM_e^n}$$

where rh = equilibrium relative humidity expressed as a decimal

M_e = equilibrium moisture content, per cent dry basis

T = temperature, degrees R

c and n = constants varying with the material.

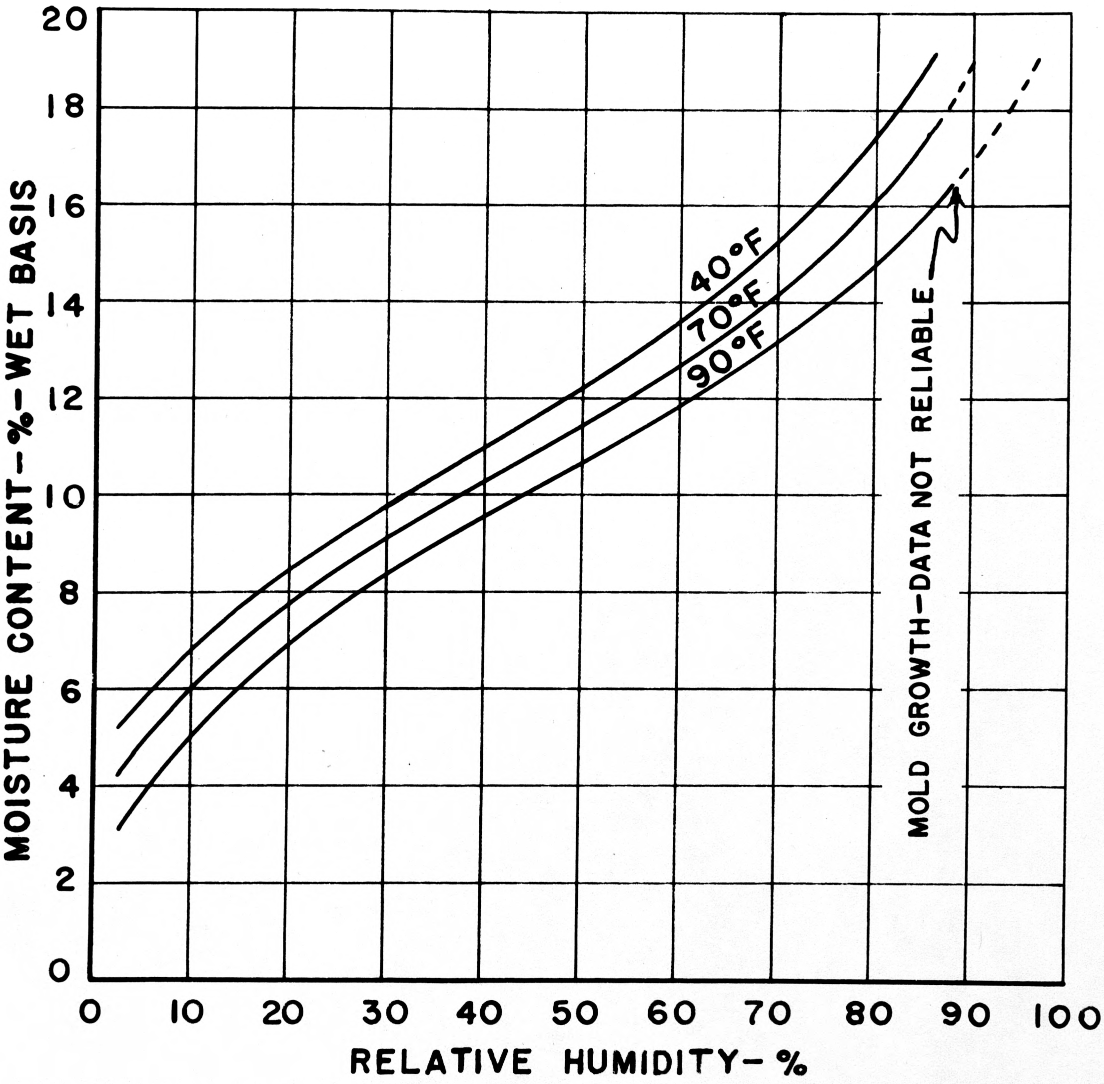
Fenton (8) determined the equilibrium moisture content of grains by exposing samples to a constant temperature and relative humidity maintained by sulphuric acid-water solutions. The equilibrium curves for Blackhull kafir, shown in Plate I, illustrate the effect of temperature.

The equilibrium moisture properties of grain are significant. If the relative humidity of the air forced through the grain for drying is higher than the equilibrium relative humidity of the grain, the grain will gain moisture. An air relative humidity lower than equilibrium will result in drying of the grain.

EXPLANATION OF PLATE I

Equilibrium moisture content curves for Blackhull kafir showing the effect of temperature. Data by Fenton (8).

PLATE I


MOISTURE CONTENT-%-WET BASIS
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100
RELATIVE HUMIDITY-%
40°F
70°F
90°F
MOLD GROWTH-DATA NOT RELIABLE

Heat Required to Vaporize Moisture

Hygroscopic materials such as grain contain moisture which is held within the material by physical and chemical forces. According to Henderson (11), the predominant fixing mechanism is adsorption, although solution, hydration, chemical combination, and capillarity are factors which may be present.

"Adsorption" refers to the phenomenon associated with the retention and concentration of molecules on solid surfaces. Johnson and Dale (15) cite data on the proportion of free and bound water for various moisture contents of wheat. At a moisture content of 15.6 per cent, over 90 per cent of the total water in the grain is reported as bound water. Free and bound water is present in about equal quantities as the moisture content approaches 30 per cent. Grain-drying processes, which usually lower the moisture content to 12 to 14 per cent, apparently involve the removal of both free and bound or adsorbed water.

The heat required for a phase change may be predicted from thermodynamic considerations. Several equations have been presented to predict the heat of vaporization based on equilibrium vapor pressure data. These equations are limited since the equilibrium conditions do not prevail during the drying process. It is the non-equilibrium condition, with respect to vapor pressures of moisture in the grain and that in the drying air, which provides the potential or driving force for the drying process.

In view of the difficulties encountered in calculating the amount of heat required to vaporize grain moisture, Johnson and Dale (15) developed a method for measuring directly the heat requirement during a drying process. This experimental procedure made possible the measurement of heat required at various moisture contents during drying processes at different temperatures and beginning from different initial grain moisture contents. Johnson and Dale (15) reported that moisture content during drying was found to have the greatest effect on heat requirements. The other factors, drying temperature and initial moisture, were of minor significance over the range of temperatures and moisture levels covered. Over the range of moisture encountered in most actual drying systems for wheat and shelled corn, above 12.3 per cent wet basis, the heat required for vaporization is between 1.00 and 1.06 times that for free water. If drying is carried below 12.3 per cent, the heat requirement is further increased. At a moisture content of 9 per cent, it is about 1.15 to 1.20 times that for free water. According to Johnson and Dale (15), the greater part of the water removed from the grain in most full-scale drying processes is evaporated at moisture levels such that the hygroscopic or moisture binding effect results in no marked increase in energy required for moisture vaporization.

The Drying Process

In the common deep bed drier, grain is placed in a bin and air is forced through it until the desired moisture content is reached. The grain at the air intake dries most rapidly and that where the air leaves takes the longest to dry. Hukill (13) reports that drying may take place in a narrow layer of grain on the intake side and this layer may be dried almost to completion before other layers have lost any moisture. The layer of grain where drying is taking place is referred to as the "zone of drying". The zone of drying progresses through the grain in the direction of air movement until it finally has passed through all the grain and drying is completed.

According to Hall (10), the depth of the drying zone varies with the temperature and humidity of entering air, the moisture content of the grain, and the velocity of air movement.

Heat is required for vaporization of moisture removed from the grain. The sensible heat in the grain and the sensible heat in the air are the only two possible sources of heat for evaporation. Grain does not normally contain enough heat to materially aid the drying process, so practically all of the heat must be furnished by the air. For this reason air will give up sensible heat as it passes through the grain if any drying has taken place. This temperature drop can be used to measure the amount of drying actually done. Dry air entering damp grain in a drying bin immediately starts to evaporate moisture from the grain. The air undergoes a reduction in temperature and an increase in absolute humidity. As the air continues through the grain, moisture will be evaporated more slowly in successive layers because of the lower temperature and higher humidity. Eventually the humidity will become high enough that no more drying will occur.

This process approximates a process of constant total heat. The wet bulb temperature is very nearly an expression of the total heat of the air, so the wet bulb temperature is approximately constant as it passes through the grain. Hukill (14) states that for all practical purposes the wet bulb temperature may be considered to be constant. The condition of the air as it passes through the grain may be assumed to follow a wet bulb line on a psychrometric chart.

In a bin grain drier, the drying rate obviously varies from layer to layer and from time to time. The change in moisture content of grain in a given time depends upon the characteristics of the grain and air used for drying. Heating the air used for drying increases the rate of moisture removal by increasing the vapor pressure of the grain while the vapor pressure of the air remains constant. Heating also increases the moisture-carrying capacity of the air.

Hukill (13) presents the following as important factors in determining drying progress:

1. The drying rate at full exposure for the kind of grain.
2. The initial air temperature (dry bulb).
3. The wet bulb temperature of the air.
4. Depth of grain.
5. Volume of air passed through grain.

Hall (10) states that two drying rate periods may be considered for deep layer drying. The "maximum rate drying" period occurs until the drying front reaches the top of the bed. When the drying front reaches the top of the bin, the rate of drying starts to decrease and is designated as the decreasing rate of layer drying.

Time Required for Drying

The work reported in the previous references on calculating drying time has assumed a constant temperature and relative humidity for the air entering. This condition does not exist in practice. There are quite marked fluctuations in both the temperature and relative humidity during the period required for drying a bin of grain. Foster (7) states that the drying capacity as well as the drying potential of natural air is changing continually. He reports that an arithmetic average of temperature and relative humidity was not sufficiently precise for calculating relative drying efficiencies of tests conducted in Indiana.

Saul and Lind (16) presented the following equation for calculating the time required for drying:

$$T\,t_{wd} = 3.04\,M\,\frac{W_{dm}}{W_a}$$

where T = computed time in days

t_{wd} = average wet bulb depression or part thereof available for drying weight of grain

M = pounds of water removed per pound of dry weight of grain

W_{dm} = pounds of dry weight being ventilated

W_a = pounds of air per minute.

This equation assumes that drying is an adiabatic process, that all the heat available for drying is used to evaporate water, that the specific heat of air equals 0.244 Btu per pound per degree F, and that the latent heat of water is 1070 Btu per pound. Saul and Lind (16) report that for an adiabatic process the degree-days ($T\ t_{wd}$) required for drying are a linear function of traverse time. Degree-days are a measure of the heat available for drying over the drying period. The degree-day term used in grain-drying work is not the same as that used in the heating and air-conditioning field. The degree-day term as used in the grain-drying field is the daily average wet bulb depression or per cent thereof available for vaporizing moisture from the grain. The heat available is determined by the condition of the air and the equilibrium relative humidity of the undried grain. The use of the equilibrium relative humidity of grain at the initial moisture content can be used only when the drying zone is completely within the grain. The traverse time is defined as the time required for a given mass of air to move from the entrance into the grain to any given point or level under consideration. They state that for the range of traverse times covered in the report, which would include most unheated air-drying systems, the error introduced by neglecting the final period as the zone moves out of the grain is small.

During the process of this investigation, Brooker and McQuigg (5) published a paper presenting a method of analyzing weather data applicable to grain drying. They calculated values of equilibrium temperature (T_x) for a number of values of wet bulb temperatures and equilibrium relative humidity. Equilibrium temperature is the temperature of the air after cooling by the drying process has occurred, and the vapor pressure of the air is in equilibrium with the vapor pressure of the grain. The average values of $T_d - T_x$ for a 24-hour period resulted in the degree-day drying measure of the drying potential of the air. This was done for equilibrium relative humidities of 50, 60, 70, 80, 90, and 100 per cent for the first 10 days of October for the years 1938-1958. The results were presented in the form of cumulative frequency curves for each of the equilibrium relative humidities plotting cumulative frequency versus day-degrees.

In the work which has been reported on grain drying, no complete study has been made to utilize weather data to predict the time required for drying with natural air. None of the studies have given consideration to utilizing a shorter period of the day during which the most favorable drying conditions normally exist. No analysis of weather data has been made which could be used to predict the requirement for supplemental heat. No report has been observed on the consideration of smaller amounts of heat practically available from resistance heaters for emergency use during short periods of bad weather.

PROCEDURE

Survey of Drying Installations

Following the fall harvest season of 1957, a questionnaire concerning grain drying was sent to each of the electrical power suppliers in Kansas. The questionnaires were sent to the power suppliers since they are normally notified when such a load is placed on their system, and therefore they are usually familiar with the drying installations in their service areas. The primary purpose of this survey was to determine the success or failure of natural air and supplemental heat drying for the extremely unfavorable weather conditions experienced during the 1957 season. The initial moisture content, final moisture content, and the difference in moisture content between the top and bottom of the bin were requested. The time required for drying and the time during the season in which drying was done were also requested.

A personal survey of a number of farmers in the North Central, South Central, Southwest, and Western areas of Kansas was conducted. The primary purpose of this survey was to determine the operating methods used for the supplemental heat driers and the effect of the different methods on the drying process. They were also questioned to determine weather information that would be useful in the operation of the driers.

These surveys indicated that natural air drying was not successful during the fall of 1957 with the exception of the extreme

Western area of Kansas. Supplemental heat drying was very successful in drying the grain to a safe moisture content. The average initial moisture content of the grain reported in this survey was 18.5 per cent. The final moisture content was 11.5 per cent. The moisture content in the bottom of the bin averaged 3.3 per cent lower than the top. This difference resulted in the average moisture content being 11.4 per cent when the top had dried to 13 per cent. In a 1,000-bushel bin, this overdrying resulted in an unnecessary loss of 1,000 pounds of salable weight plus added drying expense.

The time required for drying was available from a very small percentage of the individuals covered by this survey.

The surveys indicated that overdrying was a problem in most instances. This information substantiated the need for a weather data study because of the relationship between the weather and the overdrying problem. Two other factors brought out by the surveys were the desire for some method of estimating expected drying time and expected requirements for supplemental heat.

Drying Experiments

During the year 1958, two bins of shelled corn and one bin of sorghum grain were dried with supplemental heat driers. The characteristics of the supplemental heat driers were measured to provide an indication of weather data essential to the operation of the driers. The primary considerations in these experiments were:

1. To measure the overdrying resulting from various burner control methods and different levels of heat applied.

2. To determine the time required for drying.

3. To determine the burner operating time relative to the total operating time.

Analysis of Weather Data

The weather data used in this investigation were recorded by the U. S. Department of Commerce Weather Bureau at the class A station, Phillip Billard Municipal Airport, Topeka, Kansas. The months of July, October, and November were selected since they are the months in which grain is commonly dried in this area.

The weather information shown by the previous references to be the most important for grain drying are the wet bulb temperature (T_w) and the dry bulb temperature (T_d). The drying potential of the air can be calculated from these two measurements and the moisture content of the grain. The hourly values of T_d and T_w for the years 1956-1958 were listed in the monthly supplement sheets published by the Weather Bureau. A copy of a supplement sheet is shown in the Appendix. The hourly data for the years 1949-1955 were copied from the weather records filed at the Topeka station.

It is commonly known from general observations of weather conditions that the relative humidity is normally considerably lower during the day than at night. In view of this, the hourly relative humidities for a five-year period (1950-1954) were calculated and plotted for each of the three months to indicate the period of the day in which the lowest relative humidities occurred. Based on this information, the 12-hour period from 0830 to 2030 was considered as a separate drying period for calculations. The information was then available for calculating the drying potential for the periods 0000-2400 hours and 0830 to 2030 hours.

The experiments conducted with the supplemental-heat driers showed that the occurrence of relative humidities would be valuable. This information would give an estimation of the expected operating time of the heat unit and would assist in determining practical amounts of heat necessary to provide satisfactory drying and yet limit overdrying to reasonable levels.

The occurrence of relative humidities was presented as the number of hours per month that the relative humidity was in given ranges.

From the recorded information on temperature and relative humidity, the following information was calculated:

1. The arithmetical averages of T_d, T_w, and $(T_d - T_w)$ for each day (0000-2400) of each year and the 10-year average.

2. The same information as in (1) for the period (0830-2030).

3. The averages of T_d, T_w, and $T_d - T_w$ for the first

and second 15-day periods of each month.

4. The occurrence of relative humidity based on the 10-year average.

From this information the average conditions for the 10-year period and for the poorest drying seasons were selected as the most important for estimating expected drying time. A method of calculating drying time required for these conditions was developed. By using the humidity occurrence data, a method of determining the performance of supplemental heat driers was developed. From a consideration of adding smaller values of heat, the merits of resistance heat for drying were evaluated.

The weather data utilized in this investigation are available on punch cards. The method used in this study is very laborious as compared to the use of electronic equipment. However, for this initial study, the personal contact with the data provided an opportunity to observe trends and unusual characteristics of the weather data that would have been overlooked if the other method had been used. The cost of using the equipment was also a major factor in the final decision against using IBM-650 equipment for this first station studied.

DRYING EXPERIMENTS

Drying Sorghum Grain

The first drying experiment was conducted on the University Agronomy Farm. A bin containing 860 bushels of sorghum grain harvested in 1957 was dried during March and April, 1958. The grain with an average moisture content of 14.45 per cent, had remained in good condition throughout the winter. This is a normal experience resulting from the relatively thorough natural cooling of a grain mass of this size. Storage difficulties with grain of a moderate moisture content normally result when warm weather arrives in early summer.

The apparatus used in this experiment was:

1. Round steel bin, 1350-bushel, 14-foot diameter, with perforated floor.

2. Black, Sivalls and Bryson 16-inch diameter, direct-connected vane axial fan with 3-horsepower motor.

3. Black, Sivalls and Bryson humidity controller.

   a. A.G. series heater (90,000 Btu per hour).

   b. Humidistat control.

4. Two hygrothermographs.

5. Running-time meter.

6. Thermocouples and potentiometer.

7. Deep grain probe.

8. Steinlite moisture tester.

The drying equipment used in this investigation is shown in Plate II.

The points investigated were:

1. Fuel consumption of the burner.

2. Hours of fan operation.

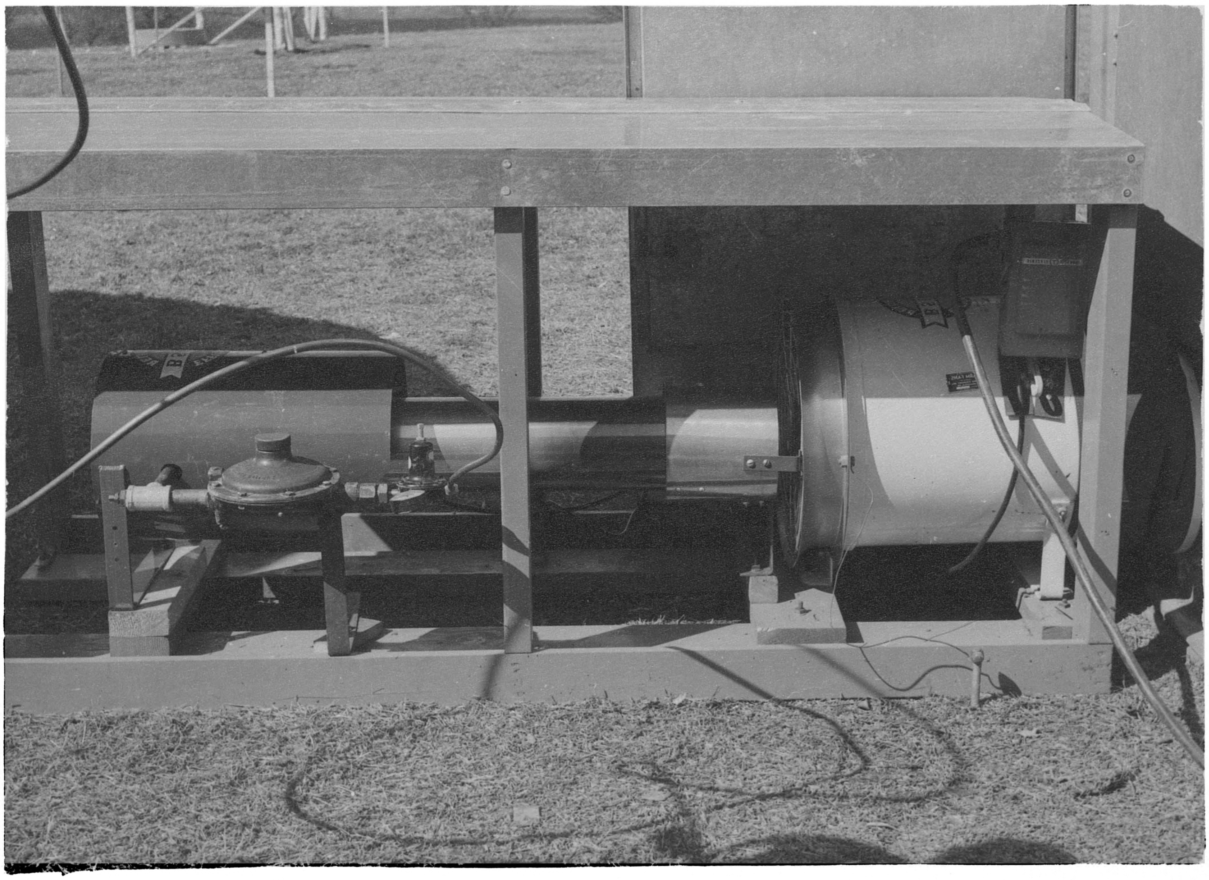
3. Hours of burner operation.

4. Temperature and relative humidity of air before

EXPLANATION OF PLATE II

The Black, Sivalls and Bryson supplemental heat grain drier used in the sorghum drying experiment. The 3-horsepower, 16-inch, direct-connected fan, supplemental heater, and weather shelter are shown.

PLATE II



and after passing through heat unit and fan.

5. Moisture content of the grain with particular regard to the difference between the top and bottom.

6. Temperature of grain.

7. Test weight of grain.

8. Cost of drying.

Drier Operation. The drier was operated only during the day. This was done so that drying could be observed over a wide range of weather conditions which was made possible by extending the drying period over a greater number of days. A grain temperature check was made to show the loss in sensible heat from the grain while the drier was off at night. A temperature check was made shortly after the drying began to show the temperature profile in the grain mass. Temperatures were read at one-foot intervals by thermocouples and a potentiometer. The temperature and humidity were recorded by hygrothermographs located outside the bin and in the plenum under the bin. The burner was controlled by a humidistat located in the plenum. The hygrothermograph and humidistat were located out of the direct blast from the fan. Thermocouple temperature checks were made to insure that the heated air was uniformly mixed, thereby eliminating hot areas. The airflow rate was determined by two methods. One method was to measure the fan discharge static pressure and use the fan characteristic curve to determine total air flow. The other method was to measure the pressure drop per foot of grain and use C. K. Shedd's (17) data for air-flow rate versus pressure drop. The drier was to operate until there was no grain with a moisture content above 13 per cent.

Results of Sorghum Drying Experiment. The laboratory fuel consumption test indicated a fuel consumption rate of 4.8 pounds of propane per hour. This gave a burner input of approximately 104,000 Btu per hour.

The reduction in average moisture from an initial of 14.45 per cent to a final of 12.36 per cent was accomplished in 163.15 hours of fan operation. The heat unit operated 30.65 hours, or 18.8 per cent of the actual drying time. The operating schedule, fuel consumption, and general weather observations are shown in Table 1.

The total fuel consumed was 183.7 pounds of propane. The average fuel consumption rate based on this data was 5.99 pounds per hour of burner operation. This variation from the 4.8 pounds per hour determined previously was attributed to the fuel consumed by the pilot light. The pilot light was on continuously for the 163.15 hours of operation.

The temperature data (Table 2) indicated that there was very little change in grain temperature after the initial warming of the grain. Temperature checks were made to determine the drop in temperature during the night when the drier was not running. This information is shown under the temperature data for March 12 and 13 in Table 2.

The temperature check showed a change only in the top and bottom readings and these were small.

The moisture content data showed that drying took place throughout the grain mass somewhat simultaneously. The expected drying layer was not evident to any extent. This can also be

Table 1. Operational data for the Black, Sivalls, and Bryson supplemental-heat grain drier experiment.

Date	Start time	Stop time	Operating time Hours		Fuel consumed-- pounds	Weather
			Fan	Burner		
Mar. 6	1330	1645	3.25	2.50		Cloudy
Mar. 8	0855	1200	3.08	2.15		Rain and snow
Mar. 10	0900	1615	7.25	5.10		
Mar. 11	0930	1645	7.25	4.30		P.c.*
Mar. 12	0945	1645	7.00	2.85		Lt.snow
Mar. 13	0945	1645	7.00	1.60	96.2	Clear
Mar. 15	0815	1645	8.50	0.75		Clear
Mar. 17	0845	1645	8.00	2.45		Cloudy
Mar. 18	0915	1655	7.67	1.10		Cloudy
Mar. 19	0915	1635	7.33	1.00		P.c.
Mar. 20	1030	1700	6.50	0.10		Clear
Mar. 21	0930	1700	7.50	0.20		Clear
Mar. 22	0830	1205	3.58	0.10		P.c.
Mar. 24	0840	1705	8.41	0.10		Clear
Mar. 25	0920	1650	7.50	0.15		Clear
Mar. 26	0915	1645	7.50	0.25		Clear
Mar. 27	0915	1400	4.75	0.30		P.c.
Mar. 31	1055**					P.c.
Apr. 1						Lt.rain
Apr. 2		1400	51.08	7.70	87.5	
Total			163.15	30.65	183.7	

*Partly cloudy.

**Begins a period of continuous operation extending over three days.

Table 2. Grain temperature data for the Black, Sivalls and Bryson drying experiment.

Grain depth (feet)	Temperature degrees F. March 6* 1330 hours	March 6 1645 hours	March 12 1645 hours	March 13 1945 hours
0	42	55	55	52
1		55	54	54
2	40	51	53	53
3		50	50	50
4	40	47	48	48
5		45	46	46
6	40	43	46	46
7	39	41	46	45

*Initial grain temperature.

observed from the temperature profile. The marked drying front was probably reduced by the relatively high rate of air flow (3.2 cfm per bushel), and the low initial moisture content of the grain.

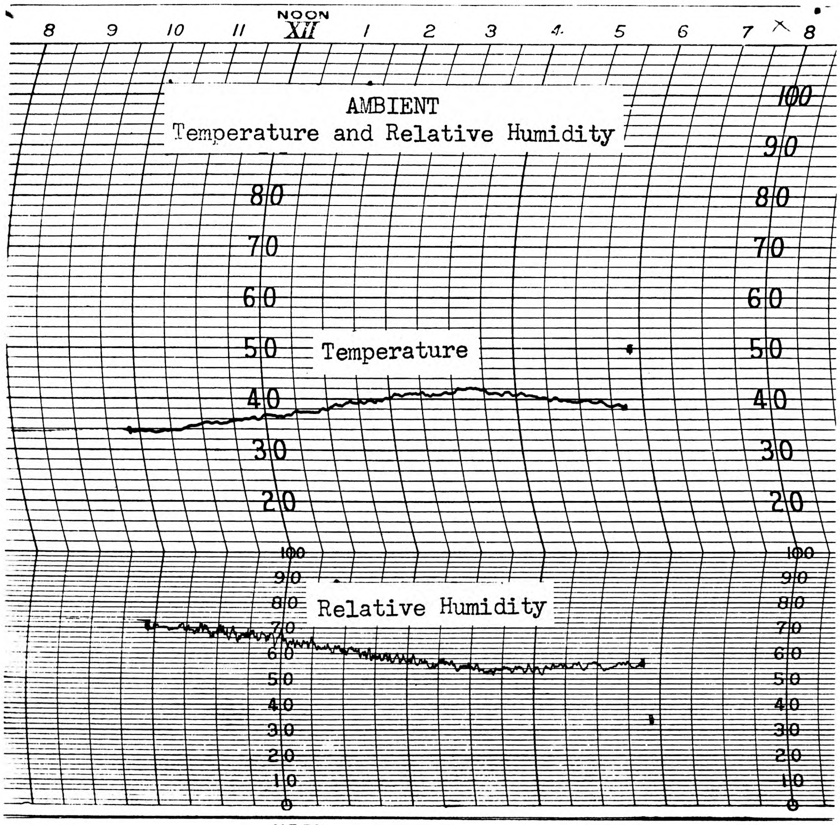
The overdrying in the bottom of the bin, while reducing the top grain to 13 per cent, was not serious. The maximum moisture content at the top was 13.17 per cent and the minimum at the bottom was 11.63 per cent. The final moisture content data are presented in Table 3.

The cycling effect of the burner resulting from the humidistat can be observed on the hygrothermograph records. A sample of the hygrothermograph records is shown in Plate III. The average temperature rise resulting from the cycling operation ranged from 15 degrees F to 28 degrees F. This variation was dependent on the humidity of the air entering the drier. The calculated maximum temperature rise of the air was 35 degrees F. The lag

EXPLANATION OF PLATE III

Hygrothermograph records showing ambient and plenum temperature and relative humidity. The cycling operation of the burner is shown by the plenum record.

PLATE III


NOON
8
9
10
11
XII
1
2
3
4
5
6
7
8
AMBIENT
Temperature and Relative Humidity
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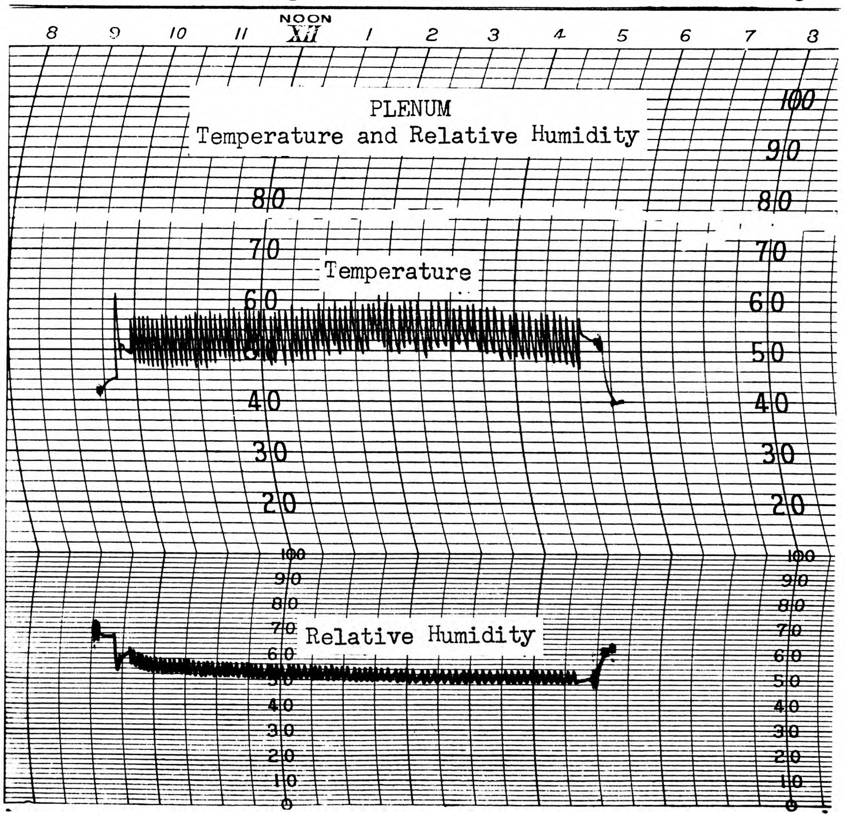
90
80
70
60
50
40
30
20
Temperature
Relative Humidity
10
0


NOON
8
9
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11
XII
1
2
3
4
5
6
7
8
PLENUM
Temperature and Relative Humidity
100
90
80
70
60
50
40
30
20
Temperature
Relative Humidity
10
0

Table 3. Moisture content data for the Black, Sivalls and Bryson drying experiment.

Grain depth (feet)	Moisture content; per cent wet basis		
	1*	2**	3***
0-1	11.63	11.78	12.02
1-2	11.79	11.92	12.27
2-3	11.99	12.31	12.33
3-4	12.02	12.35	12.51
4-5	12.28	12.50	12.87
5-6	12.23	12.82	13.15
6-7	12.73	12.85	13.17

*Sampling point No. 1 was four feet from north wall.
**Sampling point No. 2 was four feet from west wall.
***Sampling point No. 3 was two feet from south wall.

of the instruments would affect the maximum and minimum peaks on the recorded curves, but the average values are believed to be relatively accurate.

The determination of air flow rate from fan performance curves gave 3.4 cfm per bushel. The second method using pressure drop through the grain and Shedd's data, indicated an air flow rate of 3.2 cfm per bushel.

The humidistat, which is reportedly often a source of difficulty, performed very accurately. The system was operated with relative humidities up to 100 per cent, in light rain, and light snow, and under all of these conditions air capable of drying grain to below 13 per cent was delivered to the plenum.

The operating costs for drying the grain from 14.45 to 12.36 per cent was approximately 1.6 cents per bushel.

Drying Shelled Corn

The second drying experiment was conducted at the Irrigation Research Farm, Courtland, Kansas. Two bins of corn harvested by picker-sheller were dried during the period of October 31 to November 10, 1958.

One system was composed of a three-horsepower motor, direct-connected vane axial fan, 150,000-Btu-per-hour heat unit, and a 1,000-bushel bin with perforated floor. This equipment was provided by the Geis Irrigation Company, York, Nebraska.

The components of the second system supplied by the Butler Manufacturing Company, of Kansas City, Missouri, were: 1-1/2-horsepower motor, direct-connected fan, 61,000-Btu-per-hour heat unit, and a 1,000-bushel bin with perforated floor. The Butler system is shown in Plate IV.

The primary purposes of this experiment were to measure the overdrying resulting from the operation of the burners controlled by a humidistat located outside the bin and to determine the operating time of the burner relative to the operating time of the fan.

The controls and two of the recording instruments are shown in Plate V. There was no load other than the driers on this service; therefore the total power consumed was recorded on the standard kilowatthour meter. The power consumed by the Geis drier was recorded on the meter shown in the enclosure. The power consumed by the Butler system was recorded as the difference between the two meters. The running-time meter to record

EXPLANATION OF PLATE IV

The Butler drier used in the corn-drying experiment. The $1\frac{1}{2}$-horsepower fan unit and supplemental heater are shown connected to the 1,000-bushel bin.

PLATE IV

EXPLANATION OF PLATE V

The control panel used with the Geis and Butler driers in the corn-drying experiments. The service entrance switches, kilowatthour meter, motor starters, and power cable connections are located in the enclosure. The humidistat and running-time meters are attached below the enclosure.

PLATE V

the burner operating time is shown suspended from the enclosure. The one humidistat controlled the operation of both burners.

The overdrying of the grain in the bottom of the bin was a serious problem in this experiment. The overdrying occurring with the Geis system is shown by the moisture data in Table 4.

Table 4. Moisture content data for the Geis drying system.

Grain depth (feet)	Moisture content; per cent wet basis
0-1	6.9
1-2	8.0
2-3	8.6
3-4	9.5
4-5	10.4
5-6	11.3
6-7	15.0
7-8	16.8

The data in Table 4 clearly show the drying front in the zone around the six-foot level.

A record of relative humidity for the period indicates an average of 62 per cent. This would have been adequate for drying the corn to below 13 per cent without any supplemental heat. The humidistat was set at 60 per cent which allowed the burner to operate continuously when the humidity was above 60 per cent. The temperature rise of the air resulting from the heat applied was approximately 40 degrees. The heat was applied for 73 hours of the total 120 hours drying time. With the method of humidistat operation in this experiment, the burner operated continuously when the humidity was above 60 per cent. If the initial humidity was 62 per cent, the 40-degree temperature rise would lower the humidity to 16 per cent. This could dry the corn to approximately 6.4 per cent. The application of the unnecessary heat resulted in the serious overdrying shown in Table 4.

The Butler drying system was operated before the heat unit was installed; therefore the time of burner operation was not applicable. However, the significance of overdrying was not affected by this delay. The final moisture content data are shown in Table 5.

Table 5. Final moisture content data for the Butler drying system.

Grain depth (feet)	Moisture content; per cent wet basis
0-1	7.6
1-2	8.7
2-3	9.7
3-4	10.9
4-5	11.4

The burner on the Butler drier was controlled by the same method as used for the Geis drier. The temperature rise provided by the Butler burner was 28 degrees F, which accounts for the slightly less severe overdrying.

Summary of Drying Experiments

The information obtained from these drying experiments, particularly valuable in the study of weather data pertinent to crop drying, can be summed up by the following points:

1. The heat supplied by the burners used in these

investigations greatly exceeded that necessary for satisfactory drying even under the most adverse weather conditions.

2. For the weather conditions that existed during the drying experiments on shelled corn, drying without any heat would have provided more satisfactory results for in-storage drying.

3. The use of the humidistat located in the plenum under the bin gave much more even drying than when the humidistat was located outside the bin.

4. The natural drying conditions expected to be available should be considered more strongly as a source of drying potential and less emphasis should be placed on applying large amounts of heat for in-storage drying.

ANALYSIS OF WEATHER DATA

The review of literature and the crop-drying experiments showed the most useful weather data to be wet bulb temperatures, dry bulb temperatures, and humidity occurrences. The average relative humidities by hour of the day were also necessary in determining the 12-hour period with the lowest relative humidity.

The relative humidity records in the monthly supplement sheets were presented in the form shown in Table 6 for the years 1949-1955.

Table 6. Occurrence of relative humidity.

Hour of day	Hours per month in each range of relative humidity 0-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-100
00			1	4	3	4	6	10	2
01			1	5	3	4	4	10	3
02			1	4	4	4	5	8	4
03			1	4	1	4	9	8	3
04			1	2	3	4	9	6	5
05			1	2	3	4	10	5	5
06			1	2	2	8	6	7	4
07			1	2		8	8	6	6
08			1	1	5	5	8	4	6
09			1	6	3	5	8	4	3
10		1	3	4	8	7	2	2	3
11	1	2	3	6	6	5	4	1	2
12	1	3	5	5	6	3	4	1	2
13	1	6	4	5	6	3	2	1	2
14	1	7	5	4	5	2	2	1	3
15	1	7	4	6	3	3	1	2	3
16	1	7	5	5	2	3	3	2	2
17	1	3	5	5	5	2	2	5	2
18	1		6	5	6	1	5	4	2
19		1	3	5	4	6	4	5	2
20			4	2	5	5	8	4	2
21			2	4	2	5	7	8	2
22			3	3		5	8	8	3
23			3	2	2	5	7	9	2
Total	8	37	65	93	87	105	132	121	73

The humidity increments used in the 1956-1958 reports were: 0-29, 30-49, 50-69, 70-79, 80-89, 90-100. It was necessary to refer to the hourly recorded humidities for this period so that it could be presented in the same form as the 1949-1955 data.

An approximate method was used to calculate the average relative humidity from the data as presented. The following example illustrates the method of calculating the average relative humidity for the monthly values in Table 6.

$$\text{Average rh} = \frac{(8\text{x}10)+(37\text{x}25)+(64\text{x}35)+(93\text{x}45)+(87\text{x}55)+(105\text{x}65)+(132\text{x}75)+(121\text{x}85)+(73\text{x}95)}{8+37+64+93+87+105+132+121+73}$$

Although this method is not exact, it proved to be a very satisfactory approximation. In calculating the values used in plotting the diurnal changes in relative humidity, it was possible to check the approximated averages against the true averages at 0000, 0600, 1200, and 1800 hours. The largest error noted in these checks was 0.4 per cent relative humidity.

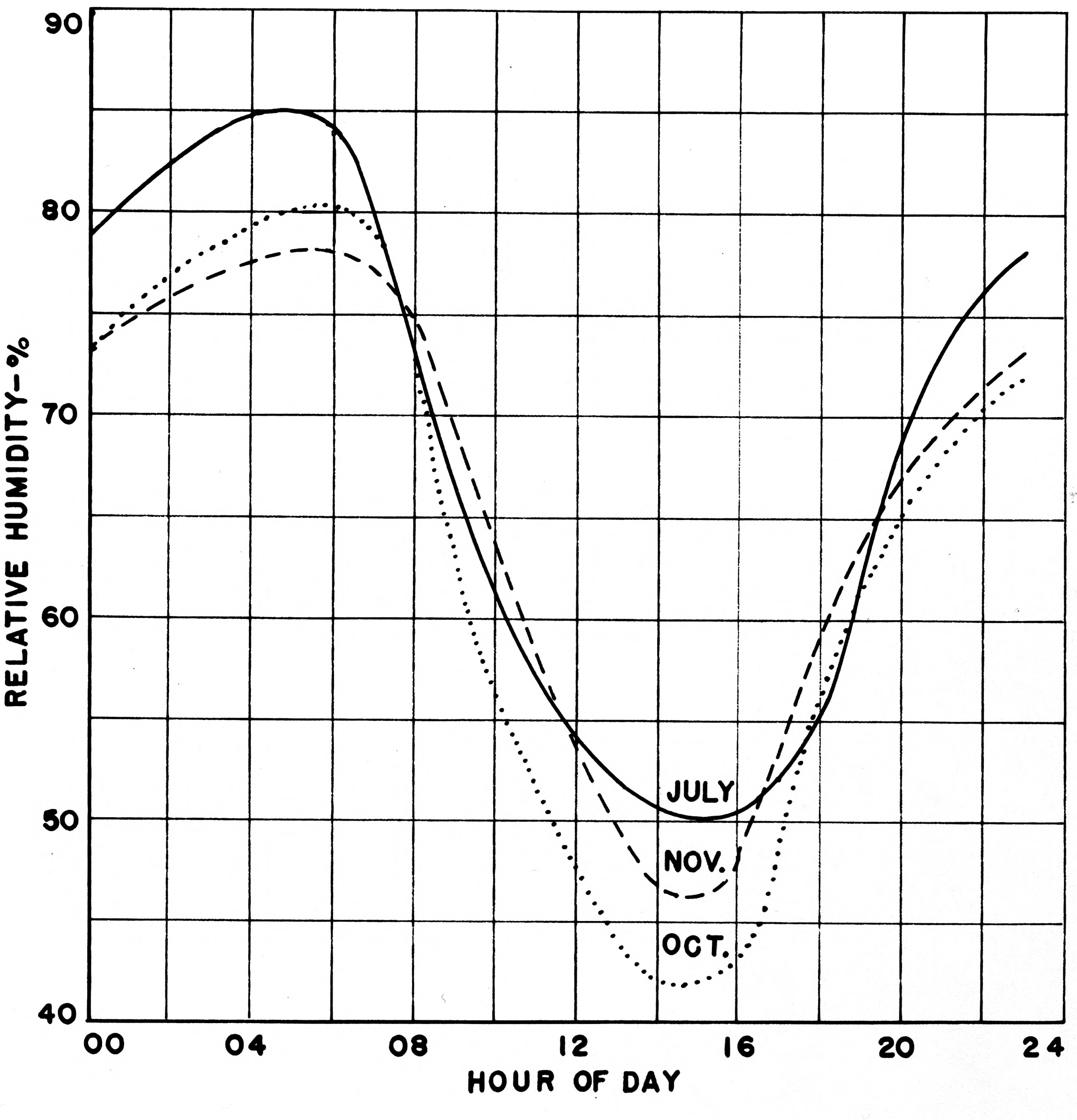
The average hourly relative humidities for the five-year period (1950-1954) were calculated for each month to determine the period of the day during which the lowest humidities occurred. These values are shown in graphical form in Plate VI. The 12-hour period from 0830 to 2030 was a period of comparatively lower humidities and still a long enough period to be of practical consideration for drying. An observation, which is contrary to common belief, is the occurrence of higher humidities over most of the day in July than in either October or November. This cannot be interpreted to mean that the drying potential is better in the average fall month. The higher temperature existing in July gives the air a much greater moisture-carrying capacity than air at the same relative humidity but lower temperatures. Also the equilibrium moisture content of the grain is higher at the lower temperatures.

The actual drying capacity of the air was determined by using the wet bulb and dry bulb temperatures of the air. If the grain moisture content is high enough for saturation of the air,

EXPLANATION OF PLATE VI

Diurnal humidity curves for average July, October, and November days based on the five-year period 1950-1954.

PLATE VI


90
80
70
60
50
40
RELATIVE HUMIDITY-%
JULY
NOV.
OCT.
00
04
08
12
16
20
24
HOUR OF DAY

and assuming that the drying process follows a constant wet bulb line, the wet bulb depression is an exact measurement of the drying capacity. The measurement of drying capacity is independent of the dry bulb temperature. This makes it possible to average the wet bulb depression over a period of time and a range of temperatures and derive the exact drying potential of the air.

The averaging of the relative humidities does not provide an exact measure of drying potential because the drying capacity resulting from a given change in relative humidity is dependent on the temperature.

When the grain condition is such that the drying air will not come off saturated, only a portion of the wet bulb depression is available for drying. This available portion is referred to as $(T_d - T_x)$. The value T_x is the temperature of the air at the condition in equilibrium with the grain. This temperature T_x may be determined by following the drying process along a wet bulb line on the psychrometric chart to the intersection with the relative humidity value in equilibrium with the grain. The method of determining the equilibrium moisture content based on the average temperatures is only approximate. It is approximate because such a method assumes that equilibrium relative humidity is a linear function of temperature. Equilibrium relative humidity has been shown to be an exponential function of temperature.

The 10-year (1949-1958) averages of wet bulb temperature, dry bulb temperature, and wet bulb depression by day of month are listed in Tables 7, 8, and 9 for the months of July, October, and November. The average daily values for the poorest drying seasons during the 10-year period are tabulated in Tables 10, 11, and 12. The value for both the 24-hour period and the 12-hour period per day are shown. The averages for the first 15 days of the month have been calculated separately. This provides a method of showing major changes in drying potential between the early and later stages of the month. The 15-day period is also within the range anticipated for drying to be accomplished.

The relative humidity data is necessary to predict the operation of humidistically-controlled driers. The relative humidity data was presented as a monthly summary. Based on the small average variation of the temperature data between the first and second periods of the month, it did not appear desirable to go to the hourly data to divide relative humidity data into 15-day periods. The occurrence of relative humidity within given ranges is shown in Plates VII, VIII, and IX. The average relative humidity calculated by the previously described approximation method is shown on these plates. The relative humidity information is essential for estimating the time required for drying when using humidistat-controlled, supplemental heaters. It is necessary for estimating the operating time of the heat unit and the equilibrium moisture content. The relative humidity occurrence data may also be utilized to determine the amount of heat desirable to accomplish drying without overdrying of the lower layers of grain.

The humidity records may also be used to predict the

Table 7. Average daily dry bulb temperature, wet bulb temperature, and wet bulb depression for July based on the 10-year period 1949-1958.

Day of month	Average 0000-2400 hours			Average 0830-2030 hours		
	T_d	T_w	$T_d - T_w$	T_d	T_w	$T_d - T_w$
1	80	71	9	86	73	13
2	80	72	8	85	75	10
3	80	72	8	85	74	11
4	78	70	8	84	72	12
5	78	69	9	83	71	12
6	78	70	8	84	72	12
7	78	71	7	84	73	11
8	77	69	8	82	70	12
9	75	67	8	80	69	11
10	75	67	8	80	69	11
11	78	70	8	83	72	11
12	78	70	8	82	71	11
13	77	70	7	83	72	11
14	78	70	8	84	72	12
15	78	70	8	83	72	11
Average 1-15	78	70	8	83	72	11
16	77	70	7	83	72	11
17	79	71	8	85	74	11
18	80	72	8	87	74	13
19	81	73	8	86	75	11
20	80	72	8	85	73	12
21	79	71	8	84	73	11
22	78	70	8	83	71	12
23	77	70	7	83	71	12
24	78	70	8	84	73	11
25	80	71	9	86	72	14
26	81	71	10	87	73	14
27	83	72	11	89	74	15
28	83	72	11	90	74	16
29	81	72	9	87	74	13
30	82	72	10	89	74	15
Average 16-30	80	71	9	86	73	13

Table 8. Average daily dry bulb temperature, wet bulb temperature, and wet bulb depression for October, based on the 10-year period 1949-1958.

Day of month	Average 0000-2400 hours			Average 0830-2030 hours		
	T_d	T_w	$T_d - T_w$	T_d	T_w	$T_d - T_w$
1	66	57	9	73	61	12
2	66	58	8	73	60	13
3	66	58	8	72	62	10
4	64	56	8	68	59	9
5	61	53	8	65	56	9
6	59	52	7	64	54	10
7	59	52	7	65	55	10
8	61	54	7	69	59	11
9	61	53	8	68	56	12
10	61	52	9	69	56	13
11	62	53	9	70	57	13
12	62	53	9	70	56	14
13	63	54	9	71	58	13
14	60	53	7	65	56	9
15	60	53	7	68	57	11
Average 1-15	62	54	8	69	57	11
16	62	54	8	69	57	12
17	58	50	8	64	53	11
18	57	49	8	64	53	11
19	59	51	7	67	55	12
20	59	53	6	64	56	8
21	57	50	7	62	53	9
22	55	49	6	62	53	9
23	54	47	7	59	49	10
24	52	45	7	59	49	10
25	52	46	6	58	48	10
26	52	45	7	57	47	10
27	50	43	7	56	46	10
28	49	43	6	56	47	9
29	51	45	6	59	49	10
30	51	45	6	57	47	10
Average 16-30	55	48	7	61	51	10

Table 9. Average daily dry bulb temperature, wet bulb temperature, and wet bulb depression for November, based on the 10-year period 1949-1958.

Day of month	Average 0000-2400 hours			Average 0830-2030 hours		
	T_d	T_w	$T_d - T_w$	T_d	T_w	$T_d - T_w$
1	50	44	6	56	47	9
2	45	39	6	49	41	8
3	42	36	6	48	39	9
4	45	38	7	50	41	9
5	45	38	7	50	41	9
6	43	37	6	49	40	9
7	43	38	5	48	41	7
8	42	37	5	47	40	7
9	44	38	6	49	41	8
10	46	39	7	54	44	10
11	49	43	6	56	47	9
12	49	43	6	54	46	8
13	51	45	6	57	48	9
14	52	46	6	56	49	7
15	49	44	5	54	45	9
Average 1-15	46	40	6	52	43	8
16	45	40	5	50	43	7
17	43	38	5	47	40	7
18	42	37	5	46	40	6
19	42	38	4	47	40	7
20	41	35	6	44	38	6
21	41	35	6	46	39	7
22	39	35	4	44	37	7
23	38	34	4	42	36	6
24	37	33	4	40	35	5
25	37	33	4	40	35	5
26	37	32	5	43	35	8
27	34	30	4	38	32	6
28	33	29	4	38	32	6
29	34	30	4	39	34	5
30	35	31	4	42	35	7
Average 16-30	39	34	5	43	37	6

Table 10. Average daily dry bulb temperature, wet bulb temperature, and wet bulb depression for the poorest drying summer season, July, 1950.

Day of month	Average 0000-2400 hours			Average 0830-2030 hours		
	T_d	T_w	$T_d - T_w$	T_d	T_w	$T_d - T_w$
1	75	68	7	80	71	9
2	74	69	5	80	72	8
3	73	70	3	78	73	5
4	75	67	8	83	68	15
5	69	64	5	71	65	6
6	71	64	7	79	66	13
7	72	64	8	80	67	13
8	74	69	5	78	72	6
9	68	67	1	67	66	1
10	68	67	1	70	69	1
11	73	70	3	76	72	4
12	71	70	1	74	71	3
13	65	58	7	69	59	10
14	67	60	7	76	63	13
15	76	71	5	81	74	7
Average 1-15	71	67	5	76	69	8
16	73	70	3	77	71	6
17	72	69	3	74	69	5
18	70	68	2	73	70	3
19	72	68	4	76	69	7
20	69	64	5	74	65	9
21	66	62	4	71	64	7
22	67	62	5	74	65	9
23	70	65	5	78	70	8
24	71	65	6	81	67	14
25	66	64	2	66	65	1
26	68	64	4	75	67	8
27	72	66	6	80	70	10
28	74	68	6	81	71	10
29	77	71	6	84	74	10
30	76	73	3	80	74	6
Average 16-30	71	67	4	76	69	8

Table 11. Average daily dry bulb temperature, wet bulb temperature, and wet bulb depression for the poorest fall drying season, October, 1951.

Day of month	Average 0000-2400 hours			Average 0830-2030 hours		
	T_d	T_w	$T_d - T_w$	T_d	T_w	$T_d - T_w$
1	75	67	8	81	69	12
2	76	67	9	82	69	13
3	75	69	6	82	72	10
4	73	65	8	76	64	12
5	60	53	7	59	54	5
6	50	49	1	50	48	2
7	50	45	5	54	47	7
8	50	45	5	58	49	9
9	58	52	6	69	58	11
10	60	54	6	69	59	10
11	64	56	8	71	60	11
12	66	57	9	72	60	12
13	66	56	10	71	58	13
14	62	54	8	71	57	14
15	59	59	5	72	63	9
Average 1-15	63	57	7	69	59	10
16	61	54	7	60	53	7
17	47	44	3	46	44	2
18	46	44	2	47	45	2
19	45	42	3	45	42	3
20	60	54	6	68	60	8
21	65	58	7	70	61	9
22	46	42	4	49	44	5
23	43	42	1	45	43	2
24	48	44	4	57	50	7
25	50	45	5	53	47	6
26	54	52	2	54	52	2
27	39	38	1	39	38	1
28	48	45	3	56	50	6
29	50	49	1	53	52	1
30	49	46	3	50	45	5
Average 16-30	50	47	3	53	48	4

Table 12. Average daily dry bulb temperature, wet bulb temperature, and wet bulb depression for the poorest fall drying season, November, 1951.

Day of month	Average 0000-2400 hours			Average 0830-2030 hours		
	T_d	T_w	$T_d - T_w$	T_d	T_w	$T_d - T_w$
1	33	29	4	35	30	5
2	25	22	3	25	22	3
3	33	29	4	41	34	7
4	23	20	3	25	21	4
5	26	24	2	28	25	3
6	30	27	3	35	30	5
7	31	28	3	34	30	4
8	39	35	4	48	41	7
9	48	43	5	54	47	7
10	48	43	5	58	50	8
11	50	49	1	54	53	1
12	61	57	4	64	58	6
13	52	48	4	55	49	6
14	45	40	5	50	43	7
15	37	34	3	39	34	5
Average 1-15	39	35	4	43	38	5
16	30	28	2	32	29	3
17	23	21	2	24	22	2
18	26	24	2	33	29	4
19	35	31	4	43	36	7
20	41	35	6	46	38	8
21	51	45	6	58	51	7
22	33	31	2	30	29	1
23	27	26	1	31	28	3
24	29	27	2	31	28	3
25	37	35	2	39	37	2
26	34	33	1	37	34	3
27	41	36	5	48	40	8
28	45	41	4	52	45	7
29	47	44	3	54	48	6
30	48	44	4	56	48	8
Average 16-30	36	33	3	41	36	5

EXPLANATION OF PLATE VII

Fig. 1. The occurrence of relative humidity in per cent of the total month for the average July, based on the 10-year period 1949-1958.

Fig. 2. The occurrence of relative humidity in per cent of the total month for the poorest summer drying season (July, 1950) during the 10-year period 1949-1958.

Fig. 3. Occurrence of relative humidity in per cent of the monthly period occurring between the hours 0830 to 2030 for the average July.

Fig. 4. Occurrence of relative humidity in per cent of the monthly period occurring between the hours 0830 to 2030 during the poorest summer drying season.

PLATE VII

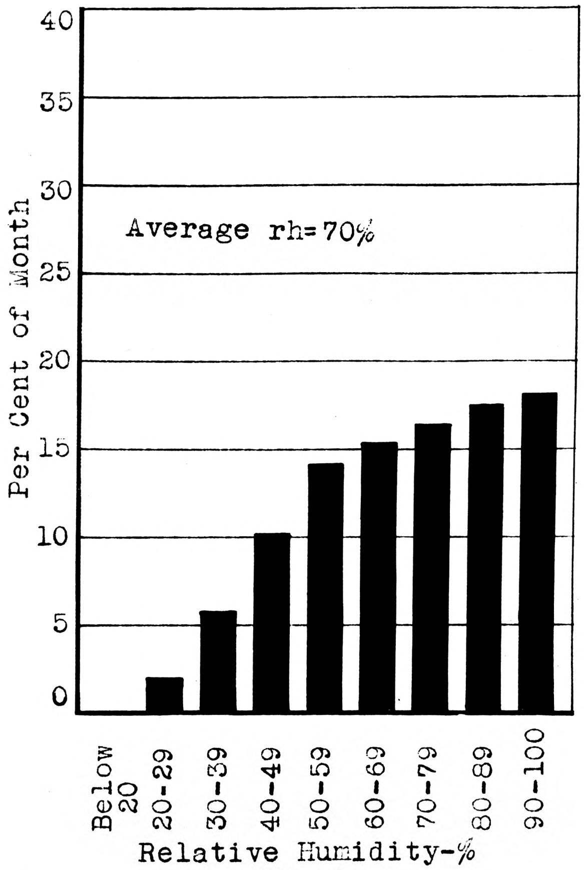


Fig.1

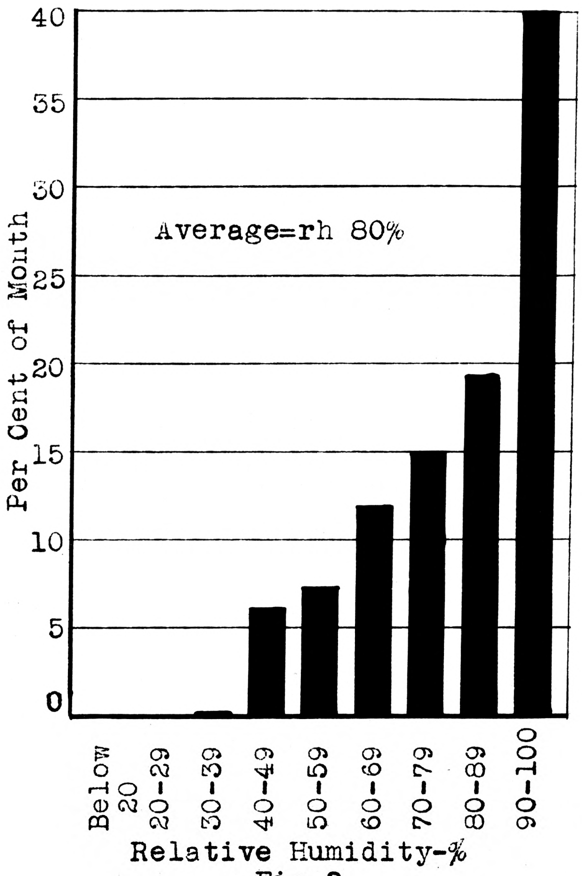


Fig.2

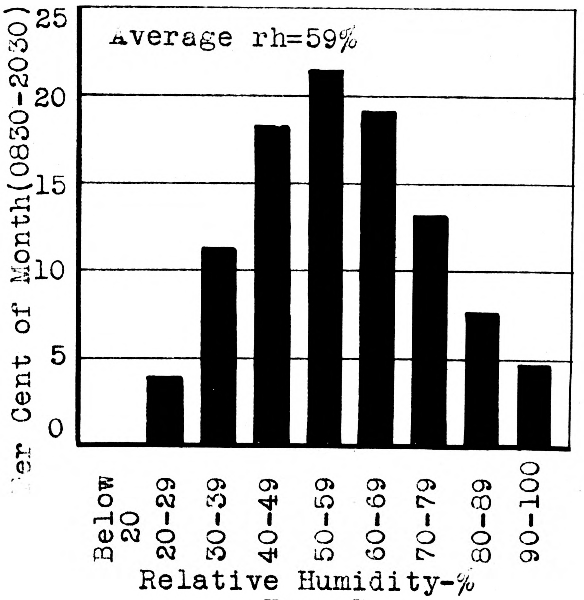


Fig. 3

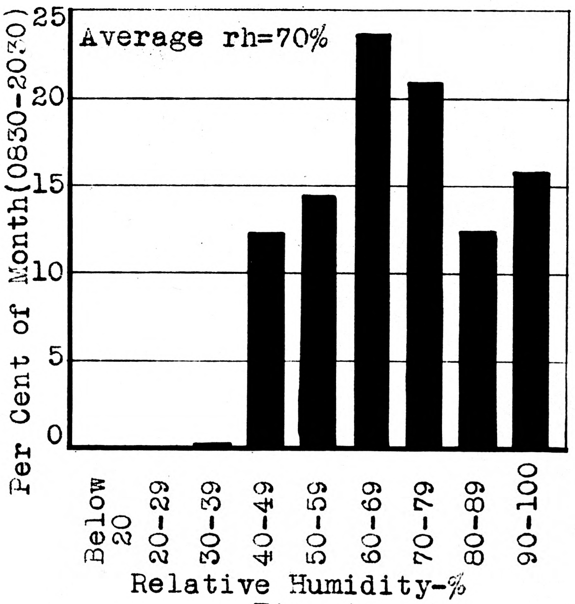


Fig. 4

EXPLANATION OF PLATE VIII

Fig. 1. The occurrence of relative humidity in per cent of the total month for the average October, based on the 10-year period 1949-1958.

Fig. 2. The occurrence of relative humidity in per cent of the total month for the poorest fall drying season (October, 1951) during the 10-year period 1949-1958.

Fig. 3. Occurrence of relative humidity in per cent of the monthly period occurring between the hours 0830 to 2030 for the average October.

Fig. 4. Occurrence of relative humidity in per cent of the monthly period occurring between the hours 0830 to 2030 during the poorest fall drying season.

PLATE VIII

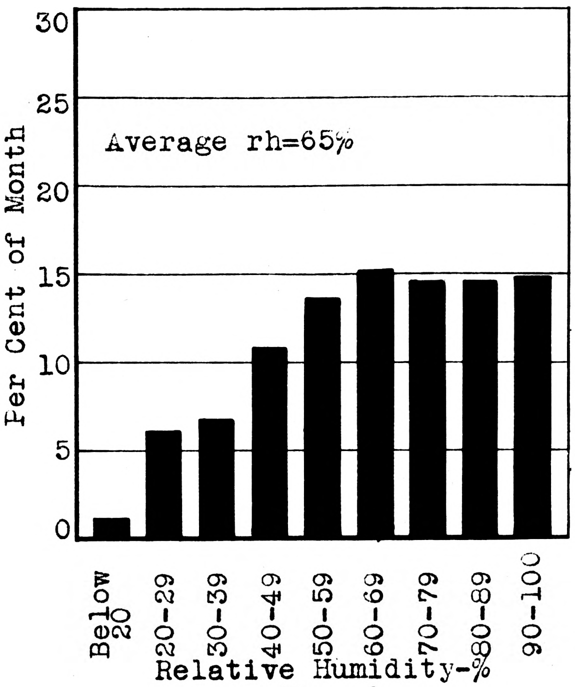


Fig. 1

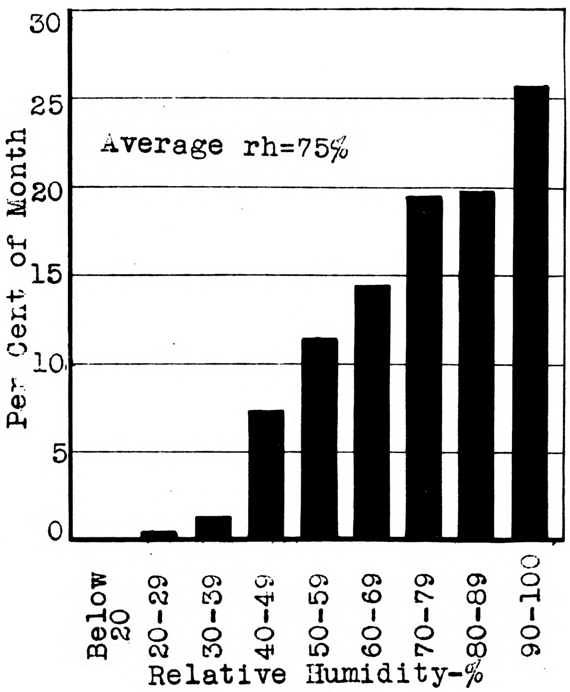


Fig. 2

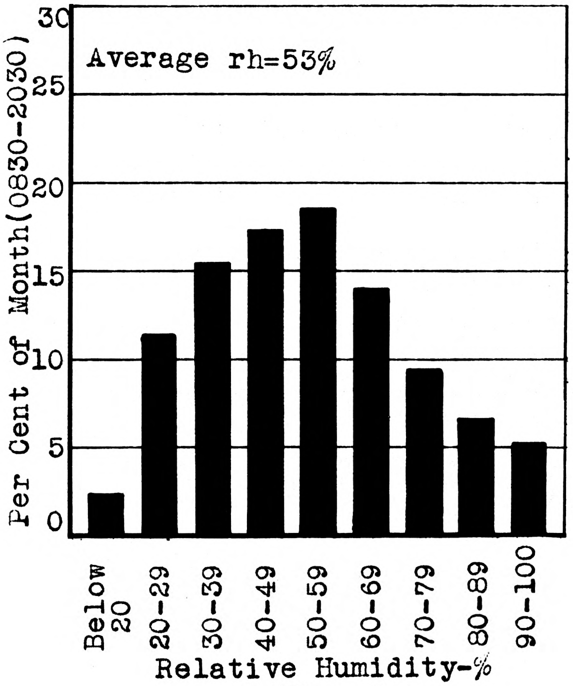


Fig. 3

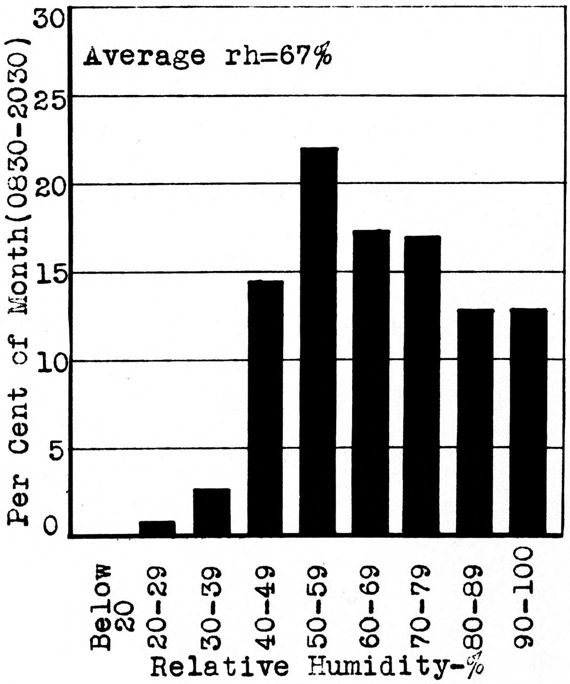


Fig. 4

EXPLANATION OF PLATE IX

Fig. 1. The occurrence of relative humidity in per cent of the total month for the average November, based on the 10-year period 1949-1958.

Fig. 2. The occurrence of relative humidity in per cent of the total month for the poorest fall drying season (November, 1951) during the 10-year period 1949-1958.

Fig. 3. Occurrence of relative humidity in per cent of the monthly period occurring between the hours 0830 to 2030 for the average November.

Fig. 4. Occurrence of relative humidity in per cent of the monthly period occurring between the hours 0830 to 2030 during the poorest fall drying season.

PLATE IX

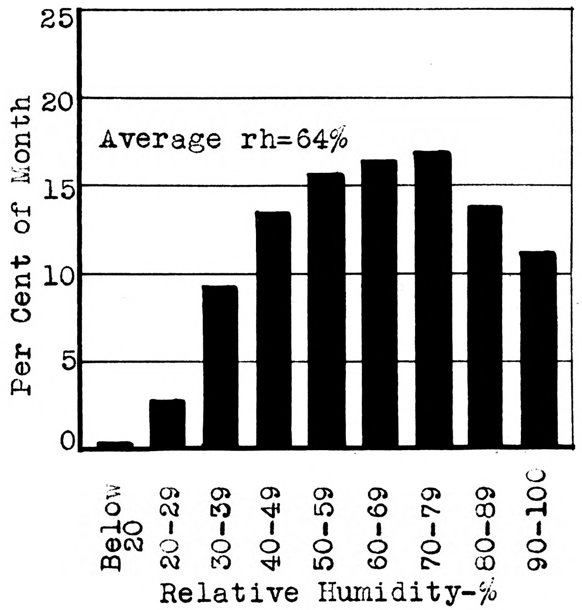


Fig. 1

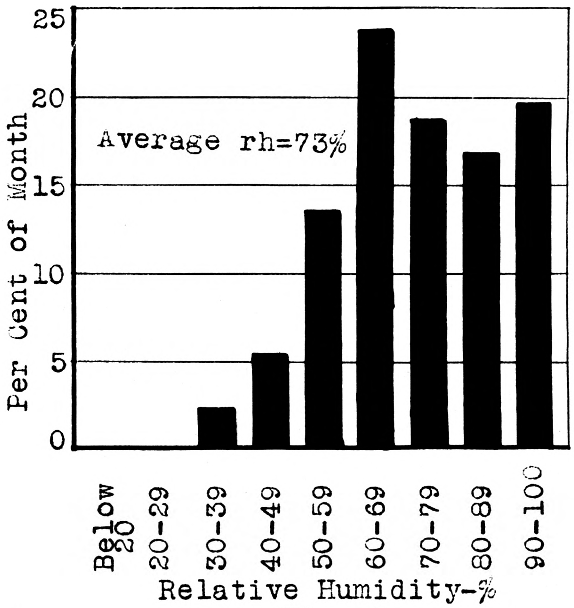


Fig. 2

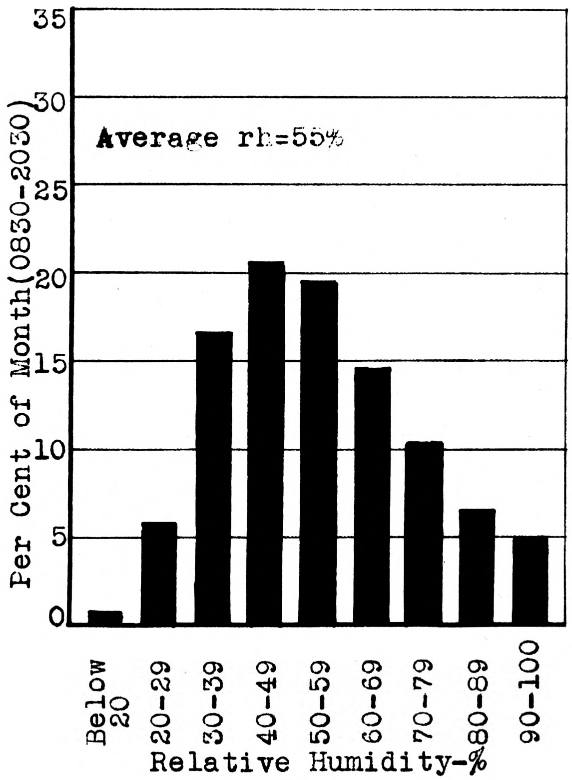


Fig. 3

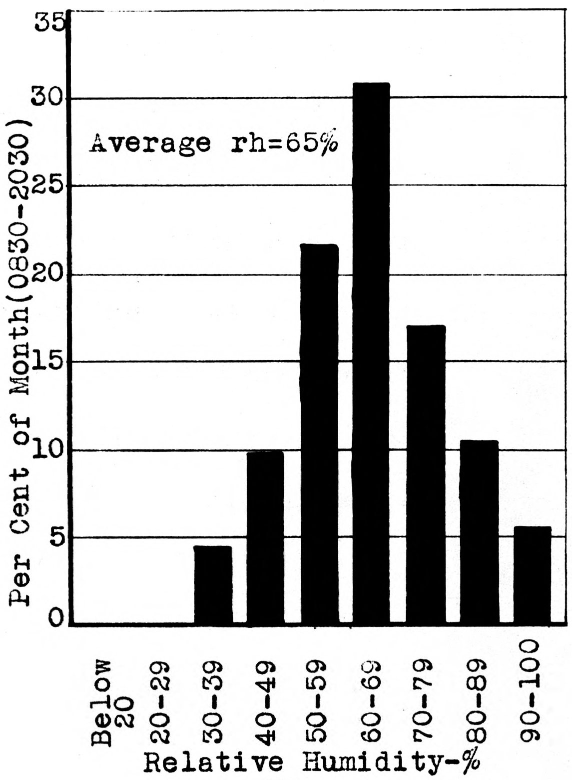


Fig. 4

operating time of natural air driers controlled by a humidistat. This method of control is desirable to stop fan operation when the humidity level exceeds that which will provide drying. The actual operating time available from the humidity occurrence data is necessary for calculating the time required for drying with this method of operation.

Estimating Drying Time

The drying times based on the average 10-year period and on the poorest drying seasons during the 10 years were assumed to be the most significant in estimating future drying rates. The estimations carried out in the following section were determined for grain with an initial moisture content of 18 per cent wet basis. The method demonstrated may be used for any initial grain moisture content or season for which the weather data is available.

Natural Air Drying

The method used for calculating the drying time for natural air drying was based on the method developed by Saul and Lind (16). Equilibrium relative humidities were determined from data presented by Hall (10), Fenton (8), and Henderson (11). The revised equation used in the calculations was:

$$T = \frac{W_w \times 1070}{0.24 \times (T_d - T_x) \times W_a}$$

where T = time in hours

W_w = pounds of water removed per original bushel of grain

1070 = latent heat of the water removed in Btu per pound

0.24 = specific heat of air Btu per pound-degree F

T_d = average dry bulb temperature

T_x = equilibrium temperature

W_a = pounds of air per hour per original bushel of grain.

Drying Wheat Using Average July Data. This example demonstrates the method of calculating the time required for drying 18 per cent wheat starting on July 1, using the data from Table 7. The calculation is independent of the quantity of grain being considered as long as the depth is adequate to provide sufficient exposure time of grain to air. The commonly recommended air flow rate of two cfm per bushel for grain of 18 per cent moisture content was used. The essential values taken from the weather data, equilibrium moisture data, and psychrometric chart are:

T_d = 78 degrees F

T_w = 70 degrees F

T_x = 73 degrees F

Grain moisture content at equilibrium with the air entering = 13.5 per cent

$$T = \frac{3.1 \times 1070}{0.24 \times 5 \times 8.7} = 318 \text{ hours}$$

The moisture content at the end of this period of drying is 13.5 per cent. To dry the grain below 13 per cent, it is necessary to utilize the 12-hour period 0830-2030 hours. This drying period would be starting on July 14 and would be primarily in the second 15-day period. The essential information for this period is:

T_d = 86 degrees F

T_w = 70 degrees F

T_x = 81.5 degrees F

Grain moisture content at equilibrium with the air entering = 11.9 per cent

$$T = \frac{1 \times 1070}{0.24 \times 3.5 \times 8.7} = 146 \text{ hours}$$

The total time required for drying was 464 hours extending over a period of approximately 25 days. A period of 13 days was required before the grain on the top of the bin was dried to 13.5 per cent. The recommended maximum time for drying grain to a moisture content of 15 per cent, at temperature levels occurring in July, is 10 days. To meet this requirement, the air flow rate should be increased slightly. The drying rate, as calculated by the equation used, is directly proportional to the rate of air flow.

By operating only during the 12-hour period, the total drying time would be reduced to 263 hours which would give a total lapsed time of 22 days. The cost of drying would be reduced considerably by this method of operation. The 10-day limit on lowering the moisture content to 15 per cent would be a major item to be considered.

Drying Wheat During the Poorest July. The following example illustrates the problem involved in drying 18 per cent wheat starting July 1 of the poorest July in the years 1949-1958.

The necessary information is:

T_d = 71 degrees F

T_w = 67 degrees F

T_x = 69.7 degrees F

Under these conditions the grain could not be dried below 16 per cent. Therefore the 12-hour per day operation was considered rather than the continuous operation.

The conditions for the 12-hour period are:

T_d = 76 degrees F

T_w = 69 degrees F

T_x = 72 degrees F

The lowest moisture content that could be reached by this method of operation was 14.1 per cent. The time required to dry to this level was 346 hours. By carefully selecting periods of the day shown by Plate VI to have the lowest humidities, the grain could have been dried to 13 per cent. Time limitations imposed by mold growth would definitely introduce a serious problem.

Drying Corn Using Average October Data. Calculations for determining the expected time required for drying 18 per cent corn starting October 1 are shown in the following example. The minimum recommended air flow rate of 3 cfm per bushel was used in the calculations for corn. The essential information is:

T_d = 62 degrees F

T_w = 54 degrees F

T_x = 56.5 degrees F

Grain moisture content at equilibrium with the air entering = 12.5 per cent

$$T = \frac{3.5 \times 1070}{0.24 \times 5.5 \times 13.5} = 210 \text{ hours}$$

If the drier was operated only during the 12-hour period, the final moisture content would be approximately 10 per cent.

$$T = \frac{5 \times 1070}{0.24 \times 9 \times 13.5} = 184 \text{ hours}$$

The reduction in drying cost resulting from the 12-hour per day operation would not be nearly as great as the loss due to unnecessary reduction in grain weight.

Drying Corn During the Poorest Harvest Season. The following calculations show the time required to dry 18 per cent corn during the poorest drying season in the years 1949-1958. The essential information is:

T_d = 63 degrees F

T_w = 57 degrees F

T_x = 59.5 degrees F

Moisture content of the grain in equilibrium with the average drying air = 13.7 per cent.

$$T = \frac{2.8 \times 1070}{0.24 \times 3.5 \times 13.5} = 265 \text{ hours}$$

By operating only during the 12-hour period, the grain would have been dried to 10.5 per cent.

The period of October 16-30 was a much poorer drying period than the first 15 days. The grain could have been dried to approximately 15.5 per cent by continuous operation and 13.6 per cent by the 12-hour per day operation. The time required for drying to 13.6 per cent was 265 hours.

T_d = 53 degrees F

T_w = 48 degrees F

T_x = 59.5 degrees F

$$T = \frac{2.8 \times 1070}{0.24 \times 3.5 \times 13.5} = 265 \text{ hours}$$

Utilization of Supplemental Heat

The sample calculation selected for the use of supplemental heat is for the period of the poorest drying conditions occurring during November, 1951. The assumed drying equipment includes a heat unit which heats the air 18 degrees F and is controlled by a humidistat placed in the plenum. The drying experiments showed that the average relative humidity of the heated air was approximately equal to the value set on the humidistat. The equilibrium relative humidity of corn at 13 per cent and at 40 degrees F is approximately 54 per cent. The relative humidity was above this level 87 per cent of the time. The average humidity for the relative humidities in the range above 54 per cent was 77 per cent. A temperature rise of approximately 8.5 degrees F is required to condition the heated air to an average relative humidity of 54 per cent. To achieve this, the heat unit would operate $(\frac{8.5}{18} \times 87)$, or 41 per cent of the total drying time. The average relative humidity of the heated and unheated air during the drying period is 53 per cent. The final moisture content would be approximately 13 per cent. The time required for drying would be:

$$T = \frac{3.2 \times 1070}{0.24 \times 5 \times 13.5} = 212 \text{ hours}$$

RESISTANCE SUPPLEMENTAL HEATERS

The use of resistance heaters to provide supplemental heat has been an application of considerable interest. Units are available with capacity to heat the air as much as 18 degrees F under normal operating conditions. A typical unit of this type has an 18-kilowatt heater plus the 3-horsepower motor. A load of this magnitude is too large to be considered practical on most farms at this time. Smaller heat units in the range of six kilowatts are more likely to be accepted.

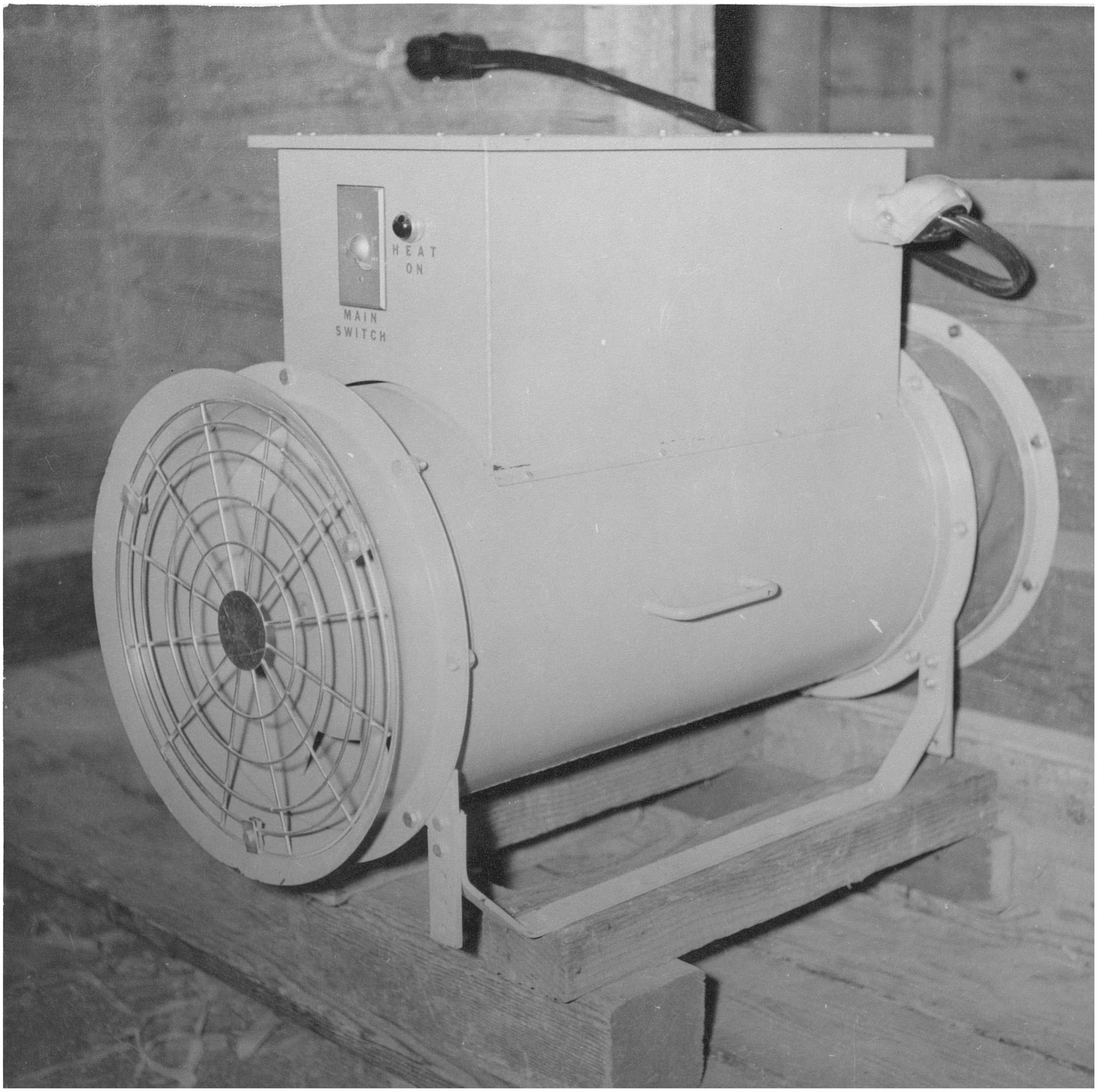
An electric heated drier is being tested during the 1959 wheat harvest season. This drier is shown in Plate X. Only one of the two six-kilowatt heat units is being used. This one unit will heat 2,150 cfm approximately 9 degrees F. This would be adequate for drying 1,000 bushels of wheat, or 700 bushels of corn with the recommended air flow rates.

The average temperature rise required during the poorest drying season was 8.5 degrees F, as shown in the application of supplemental heat. The application of heat was required for 174 hours in the example used. The cost of power consumed for heat during the poorest season would have been $20.90, or approximately three cents per bushel. This cost could be reduced considerably by operating the unit only during the day. For the less severe years the cost of heating would be much less.

EXPLANATION OF PLATE X

The supplemental heat grain drier using resistance heat. The drier uses a $1\frac{1}{2}$-horsepower, direct-connected fan unit with two 6-kilowatt heat units. The controls for the system are located in the enclosure above the fan tube. The heat units are in the fan tube between the fan and the discharge end of the tube.

PLATE X



The information provided by this investigation indicates that resistance heat has a practical application in providing the added drying potential sometimes necessary to supplement the natural air-drying system.

SUMMARY AND CONCLUSIONS

The survey and drying experiments conducted in this investigation indicated a severe overdrying problem existing in the common operation of supplemental heat driers. This overdrying results from the use of oversized heat units and controls which do not function to take the best advantage of natural drying conditions. Heat units with capacity to heat the air 18 degrees F are adequate for in-storage-drying systems. Humidistats placed in the plenum or duct system provide the best control of the heat unit. This method reduces overdrying and fuel consumption.

The one question most often encountered while working with farm operators considering the use of a grain drier was, "How long will it take to dry the grain?". The only answer available has been to recall the time required for some previous operation regardless of the relative weather conditions. This was usually based on very limited data. The drying conditions vary over the state and if there has been no experience on drying in a given area, no estimates could be presented for that area.

Due to the large variability of weather, there is no exact way to predict the time required for drying grain with natural air. The continually changing drying conditions during a given season make it impossible to calculate the exact time to dry for that season. For practical reasons the time required for drying must be based on average conditions over a period of time. This method has been shown to be a reasonably accurate method. The average conditions and the poorest drying conditions for the 10-year period appeared to provide the best insight into the expected weather conditions.

The method used to predict drying times is approximate and requires a number of assumptions. Although approximate, these methods provide the only available means to give an answer to the drying time question.

The analysis of weather data indicated that drying with unheated air is practical during most seasons. The operation of the drier between the hours of 0830 to 2030 provided a period of much better drying conditions.

The operation of humidistically-controlled heat units can be predicted from the occurrence of relative humidity. During the poorest drying season the heat unit operated only 41 per cent of the total operating time.

The use of small amounts of resistance heat appears to be a practical method of supplementing natural air drying. The major question appears to be justifying the initial cost of equipment and electrical service, considering the limited use normally expected.

Due to the variation in weather conditions over the state, data from several weather stations would be required to predict drying rates for the state. The use of punch cards would be the most practical method for evaluating the data for other stations.

ACKNOWLEDGMENTS

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APPENDIX

Supplement
(Based on one month's record)

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

LOCAL CLIMATOLOGICAL DATA

CENTRAL STANDARD TIME

TOPEKA, KANSAS
PHILLIP BILLARD MUNICIPAL AIRPORT
JULY 1958

A TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES (HOURLY OBSERVATIONS):

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
REL. HUMID. / TEMP. (°F)	UNDER 30	30-49%	50-69%	70-79%	80-89%	90-100%	UNDER 30	30-49%	50-69%	70-79%	80-89%	90-100%	UNDER 30	30-49%	50-69%	70-79%	80-89%	90-100%	UNDER 30	30-49%	50-69%	70-79%	80-89%	90-100%	
94/90			3						15						5										23
89/85		1	3	1				3	19	8					15	10									60
84/80		1	11	1	1			11	31	22	14			2	11	18	6								129
79/75			10	10	4	2			23	36	31	7			3	15	11	1			1	1	1		156
74/70			2	9	21	23			1	18	48	32				2	6	3				1	1	1	168
69/65				3	15	36					45	60					6	8						1	174
64/60						27						3												2	32
59/55						2																			2

B WIND DIRECTION AND SPEED OCCURRENCES:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR) 0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 OVER	TOTAL	AV. SPEED
N	3	9	30	14	1		2	1		60	11.7
NNE	3	5	17	4		1				30	9.9
NE	4	7	16	8	1					36	9.6
ENE	4	18	21	13						56	9.3
E	6	15	18	10						49	8.4
ESE	9	17	25	4	1					56	8.1
SE	6	20	23	17	2					68	9.4
SSE	6	7	15	29	9	1		1		68	13.6
S	3	22	33	39	17	2				116	13.0
SSW	3	10	11	13	1					38	10.4
SW	1	5	7		1					14	8.6
WSW	1	4	7	1						13	8.7
W	1	13	9	3						26	7.7
WNW	2	3	5	1	1		1			13	11.3
NW	4	4	6	2						16	7.8
NNW	2	9	5	1						17	7.2
CALM	68									68	0.0
TOTAL	126	168	248	159	34	4	3	2		744	9.4

C HOURLY AND DAILY OCCURRENCES OF PRECIPITATION AMOUNTS:

FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY

INTENSITIES	A.M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	NOON	P.M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	MID.	NO. OF DAYS WITH	INTENSITIES
TRACE		4	3	3	2	4	2	4	5	4	4	6	3	3	4	1	2		1	1	2	4	6	1	4	TRACE
.01 IN.	1				1				2	1	1		1						1				1	1	1	.01 IN.
.02 TO .09 IN.	1		1	1	3	1	1	1	1	1	1					1		1			1		1		3	.02 TO .09 IN.
.10 TO .24 IN.						2	2	4		1										1		1		1	2	.10 TO .24 IN.
.25 TO .49 IN.						2	3	1																	2	.25 TO .49 IN.
.50 TO .99 IN.							1		1												1			1	6	.50 TO .99 IN.
1.00 TO 1.99 IN.		1																							2	1.00 TO 1.99 IN.
2.00 IN AND OVER																										2.00 IN AND OVER
TOTAL	2	5	4	4	6	9	9	10	9	7	6	6	4	3	4	2	2	1	2	2	4	5	8	4	20	TOTAL

D CEILING–VISIBILITY OCCURRENCES (HOURLY OBSERVATIONS):

VISIBILITY (MILES)	CEILING (FEET) 0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9500	OVER 9500	TOT.
0 TO 1/8									2	2
3/16 TO 3/8		3							2	5
1/2 TO 3/4										0
1 TO 21/2				4	2	1	1		6	14
3 TO 6				10	8	4	1		8	31
7 TO 15			1	14	39	42	69	88	439	692
20 TO 30										0
35 OR MORE										0
TOTAL		3	1	28	49	47	71	88	457	744

E OCCURRENCES OF WEATHER BY HOUR OF DAY:

HOUR OF DAY	CLOUDS SCALE 0-10: 0-3	4-7	8-10	WIND SPEED (M. P. H.): 0-3	4-12	13-24	25- & OVER	RELATIVE HUMIDITY (%): 0-29	30-49	50-69	70-79	80-89	90-100	WEATHER TYPES: RAIN	FREEZING RAIN	DRIZZLE	SNOW, SLEET	HAIL	FOG	FOG WITH SMOKE	SMOKE OR HAZE	THUNDERSTORM
00	14	5	12	6	17	8					3	15	13	2					2			2
01	12	5	14	6	17	8					4	11	16	2					2			2
02	14	3	14	8	14	8	1				5	10	16	3					2			3
03	14	2	15	11	14	5	1				4	10	17	2					4			1
04	10	4	17	8	18	4	1			1	3	8	19	2		1			2			2
05	5	5	21	9	18	4			1		1	9	20	5		1			4			5
06	6	4	21	10	14	4	3					6	25	5		1			5			4
07	7	3	21	8	18	3	2				3	11	17	7		1			7			6
08	8		23	6	18	7				1	4	15	11	7					6			1
09	7	4	20	4	20	7				2	13	8	8	5					4			1
10	7	2	22	1	17	13				11	8	7	5	5					2			1
11	7	5	19	1	17	13			1	13	8	6	3	4					2			
12	5	6	20	2	20	9			2	13	11	5		3					1			
13	5	7	19		20	11			2	15	10	4										
14	7	8	16	3	18	10			3	15	10	3		2					1			1
15	6	9	16	1	22	8			3	16	10	1	1	1		1			1			2
16	6	11	14	2	18	11			2	21	6	1	1	1								1
17	7	12	12	3	16	12			2	20	7	2										
18	10	10	11	4	17	10			2	15	9	5		1								1
19	12	8	11	3	21	7				9	13	9										1
20	12	7	12	7	16	8				1	10	18	2	2								3
21	14	5	12	5	17	8	1				7	16	8	3								3
22	15	4	12	10	11	10					4	16	11	3		1						2
23	14	3	14	8	18	5					2	14	15	4					1			2
	224	132	388	126	416	193	9		18	153	155	210	208	69		6			46			44

F OCCURRENCES OF WEATHER BY WIND DIRECTION:

WIND DIR.	CEILING (FT.): 0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9500	OVER 9500	VISIBILITY (MI.): 0-1/8	3/16-3/8	1/2-3/4	1-2½	3-6	7 AND OVER	WEATHER TYPES: RAIN	FREEZING RAIN	DRIZZLE	SNOW, SLEET	HAIL	FOG	FOG WITH SMOKE	SMOKE OR HAZE	THUNDER-STORM
N			1	5	12	7	3	7	25				4		56	4		2			3			5
NNE				3	2	4	3	4	14					2	28	1		2			2			2
NE				2	8	7		3	16				1	6	29	8					5			5
ENE				3	3	8	7	4	31					3	53	5					3			3
E				1	6	5	6	6	25					2	47	7		2			2			3
ESE		1		6			1	4	44		1			3	52	6					4			5
SE				2	2	1	8	4	51					1	67	6					1			2
SSE				1	1		5	10	51				1		67	2								3
S				1	5	4	20	13	73					3	113	10					3			5
SSW							3	9	26						38	1								1
SW					1	1	3	3	6					1	13	2					1			
WSW				1	1		4	3	4					1	12	3					1			1
W					2	2	3	6	13						26	3								2
WNW				1	2	1	2	3	4				2	1	10	5					2			5
NW				1	2	1	1	2	9		1			2	13	3					2			2
NNW				1		2	2	3	9					1	16	2					1			
C		2			2	4		4	56	2	3		6	5	52	1					16			
		3	1	28	49	47	71	88	457	2	5		14	31	692	69		6			46			44

G MEANS FOR SYNOPTIC HOURS:

HOUR (LOCAL TIME)	SKY COVER (IN TENTHS)	STATION PRESS. (IN.)	DRY BULB (°F)	WET BULB (°F)	REL. HUM. %	DEW PT. (°F)	WIND DIR.	WIND SPEED	HOUR (LOCAL TIME)	SKY COVER (IN TENTHS)	STATION PRESS. (IN.)	DRY BULB (°F)	WET BULB (°F)	REL. HUM. %	DEW PT. (°F)	WIND DIR.	WIND SPEED
00	5	29.01	72	69	87	68	SSE	9	06	8	29.02	68	67	92	66	S	9
12	7	29.03	79	71	69	68	S	10	18	6	28.97	81	73	68	69	SSE	11

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USCOMM-WB-ASHEVILLE -- 8-19-58 -- 200

TOPEKA, KANSAS
PHILLIP BILLARD MUNICIPAL AIRPORT
JULY 1958

HOURLY OBSERVATIONS:

0000

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.94	78	72	75	69	S	18
2	4	15		UNL	28.98	80	73	72	70	SSE	15
3	8	15		CIR	29.05	73	70	87	69	NNE	9
4	10	15		17	28.88	73	71	90	70	SSE	5
5	4	8		UNL	28.96	71	70	96	70	C	
6	2	15		UNL	29.10	66	63	87	62	NNW	6
7	10	15		120	29.14	69	67	91	66	SE	4
8	0	12		UNL	29.17	64	63	95	62	NE	3
9	2	15		UNL	29.15	65	63	92	62	S	6
10	1	15		UNL	29.08	72	69	87	68	SE	7
11	10	12		33	28.94	70	67	85	65	SE	15
12	0	3		UNL	29.03	66	66	99	66	C	
13	0	10		UNL	28.94	69	67	90	66	E	7
14	0	15		UNL	28.77	82	75	73	72	SSE	15
15	6	15		65	28.91	81	76	82	74	S	9
16	6	15		75	29.17	72	69	88	68	N	4
17	10	15		25	29.18	66	63	85	61	ENE	7
18	2	12		UNL	29.05	75	74	94	73	ENE	6
19	9	12		CIR	28.95	82	78	84	77	SSE	12
20	10	6		6	28.97	69	68	95	68	NE	8
21	10	15		17	29.04	67	64	84	62	E	4
22	2	5		UNL	29.06	64	63	95	63	NW	3
23	2	10		UNL	29.03	67	65	90	64	C	
24	0	15		UNL	28.96	73	70	86	69	ESE	8
25	10	15		41	28.98	74	72	90	71	NW	3
26	6	15		UNL	29.02	66	64	89	63	SE	4
27	10	15		CIR	28.90	76	72	84	71	SSE	12
28	10	15		CIR	29.05	75	71	82	69	W	9
29	0	15		UNL	29.10	71	67	81	65	S	6
30	0	15		UNL	28.89	81	77	83	76	S	14
31	10	7		50	28.86	69	68	96	68	E	16

0100

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	1	15		UNL	28.93	77	71	75	68	S	18
2	3	15		UNL	28.97	79	72	70	68	SSE	13
3	8	15		CIR	29.04	72	70	91	69	ENE	6
4	10	15		12	28.87	73	71	91	70	S	3
5	6	7		UNL	28.97	70	69	96	69	SW	6
6	0	15		UNL	29.09	63	62	95	61	C	
7	10	15		100	29.13	69	67	89	66	N	5
8	0	15		UNL	29.17	62	62	97	61	C	
9	7	15		CIR	29.12	66	64	90	63	ESE	9
10	8	15		CIR	29.05	73	70	85	68	SSE	7
11	10	12		80	28.89	75	71	83	69	SSE	18
12	5	0	4	UNL	29.04	66	66	97	65	C	
13	1	10		UNL	28.92	68	67	93	66	ENE	8
14	1	15		UNL	28.79	81	75	76	73	S	20
15	10	15		41	28.91	80	76	83	74	SSW	14
16	8	15		70	29.15	70	68	90	67	N	5
17	10	15		27	29.15	65	63	89	62	ENE	8
18	1	7		UNL	29.05	74	73	97	73	ENE	3
19	10	12		CIR	28.93	81	76	80	74	S	12
20	10	7		6	28.91	68	68	98	68	ENE	10
21	10	12		18	29.05	66	65	92	64	W	4
22	2	4		UNL	29.07	63	63	97	62	WNW	5
23	1	10		UNL	29.02	66	64	92	63	C	
24	0	15		UNL	28.97	72	70	90	69	ESE	8
25	5	15		UNL	28.96	74	71	88	70	NNW	6
26	2	15		UNL	28.99	66	64	88	62	SSE	5
27	10	15		80	28.90	77	73	83	71	SSE	11
28	10	15		80	29.04	72	69	87	68	WSW	6
29	0	15		UNL	29.09	70	66	81	64	S	5
30	4	15		UNL	28.87	81	75	78	73	S	12
31	10	12		60	28.89	69	68	96	68	ESE	8

0200

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	1	15		UNL	28.92	76	71	78	69	S	16
2	3	15		UNL	28.96	78	72	75	69	S	18
3	9	15		70	29.03	72	70	92	69	ENE	8
4	10	15		80	28.86	72	68	84	66	WSW	4
5	7	7		UNL	28.97	69	69	96	68	C	
6	0	15		UNL	29.10	62	61	95	60	C	
7	10	15		120	29.12	67	66	94	65	C	
8	0	15		UNL	29.17	63	62	97	62	ENE	5
9	9	15		40	29.20	69	66	85	64	NNW	15
10	10	15		CIR	29.06	73	70	85	69	SE	5
11	10	10		50	29.00	64	63	95	62	N	35
12	4	0	4	UNL	29.02	65	65	99	65	NW	3
13	1	10		UNL	28.91	67	66	95	66	E	8
14	1	15		UNL	28.78	80	74	77	72	S	21
15	7	15		40	28.92	80	76	83	74	WSW	7
16	10	15		70	29.15	70	67	86	65	N	8
17	10	15		33	29.18	65	63	89	62	SE	9
18	1	7		UNL	29.04	73	72	96	72	E	4
19	10	12		CIR	28.92	80	75	79	73	SSW	13
20	10	7		4	28.95	69	67	92	66	N	10
21	10	12		18	29.03	66	64	90	63	C	
22	0	4		UNL	29.04	62	62	97	61	C	
23	3	10		UNL	29.00	66	64	90	63	C	
24	0	15		UNL	28.96	71	69	91	68	ESE	6
25	0	15		UNL	28.95	72	70	89	69	NNW	4
26	0	15		UNL	29.00	65	63	89	62	C	
27	10	12		35	28.94	73	67	74	64	WNW	18
28	8	15		CIR	29.05	71	69	91	68	W	8
29	0	15		UNL	29.08	69	65	81	63	S	5
30	3	15		UNL	28.87	79	74	80	72	S	14
31	10	12		60	28.87	69	69	97	68	SSE	12

0300

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.91	75	71	79	68	SSE	17
2	8	15		80	28.96	78	72	76	69	S	19
3	10	15		70	29.02	71	69	92	68	SSE	3
4	10	15		13	28.88	71	68	86	67	SW	9
5	9	8		80	28.98	70	69	95	69	WNW	9
6	1	12		UNL	29.10	61	60	97	60	C	
7	10	15		120	29.12	66	65	95	65	N	5
8	0	12		UNL	29.15	62	62	97	61	ENE	3
9	2	15		UNL	29.16	67	65	90	64	C	
10	10	15		CIR	29.06	71	69	92	68	SE	5
11	10	12		70	28.93	68	67	93	66	NE	10
12	10	0	4	1	29.01	65	64	99	64	C	
13	3	10		UNL	28.89	68	67	93	66	E	7
14	10	15		90	28.78	79	74	79	72	SSE	25
15	5	15		UNL	28.91	79	76	87	75	W	3
16	6	15		70	29.14	69	67	89	66	ENE	8
17	10	15		30	29.12	65	63	89	62	E	9
18	0	2		UNL	29.03	72	72	98	72	C	
19	10	12		CIR	28.91	79	74	79	72	S	10
20	10	7		8	28.95	67	66	94	65	N	15
21	10	12		22	29.02	66	64	90	63	C	
22	0	3		UNL	29.04	61	60	96	60	C	
23	3	6		UNL	29.00	64	63	96	63	C	
24	0	15		UNL	28.95	71	69	91	68	ESE	4
25	2	15		UNL	28.98	72	69	84	67	NNW	9
26	0	15		UNL	28.99	65	62	87	61	E	4
27	10	15		100	28.92	71	68	87	67	C	
28	3	15		UNL	29.06	71	67	85	66	W	7
29	0	15		UNL	29.07	69	65	81	63	S	7
30	3	15		UNL	28.85	78	74	84	73	S	13
31	10	15		CIR	28.86	70	68	94	68	E	12

0400

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.91	75	70	78	68	S	17
2	8	15		80	28.98	77	72	78	70	SSW	15
3	8	15		70	29.02	70	69	95	69	SSE	4
4	10	10		80	28.90	69	67	89	66	W	7
5	9	8		80	28.98	70	69	94	68	NW	6
6	3	12		UNL	29.11	61	61	97	60	SSW	3
7	10	15		120	29.12	66	64	92	64	N	3
8	0	12		UNL	29.15	60	59	95	58	ESE	3
9	4	15		UNL	29.09	67	65	90	64	ESE	8
10	10	15		CIR	29.05	71	69	91	68	ENE	8
11	10	12		70	28.96	67	64	85	63	SSW	5
12	10	0	4	1	29.03	65	65	99	65	C	
13	3	12		UNL	28.89	67	66	95	65	E	4
14	10	15		100	28.73	78	68	60	63	S	25
15	7	15		40	28.92	77	75	91	74	N	15
16	9	15		40	29.14	69	66	85	64	ENE	8
17	10	12		9	29.12	65	64	94	63	ESE	6
18	0	12		UNL	29.02	72	71	98	71	ESE	5
19	10	12		CIR	28.92	78	73	78	71	SSW	9
20	10	7		7	28.95	66	65	95	64	NNE	8
21	10	10		25	29.02	66	64	91	63	C	
22	6	3		UNL	29.05	60	60	99	60	C	
23	3	8		UNL	29.01	65	64	93	63	SE	3
24	0	15		UNL	28.93	71	69	91	68	ESE	6
25	1	15		UNL	28.99	71	68	86	66	N	9
26	10	15		120	28.99	64	62	90	61	C	
27	10	15		41	28.95	71	67	82	65	SW	10
28	2	15		UNL	29.06	69	66	86	64	W	6
29	0	15		UNL	29.07	68	65	86	63	SSW	7
30	4	15		UNL	28.84	77	74	85	73	S	12
31	10	15		CIR	28.87	69	68	95	68	ESE	4

0500

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	2	15		UNL	28.92	74	70	80	68	S	16
2	10	15		CIR	28.99	76	71	79	69	S	13
3	10	10		CIR	29.00	69	68	95	68	E	3
4	10	8		40	28.87	68	67	95	67	WSW	7
5	9	8		80	28.99	68	68	98	67	W	4
6	5	12		UNL	29.11	61	60	97	60	C	
7	10	15		100	29.13	65	64	94	63	N	7
8	5	12		UNL	29.16	60	60	98	59	E	3
9	8	15		CIR	29.11	65	63	94	63	SE	5
10	10	15		70	29.11	74	70	84	68	NNE	10
11	10	15		70	28.97	67	64	87	63	S	10
12	8	0	2	UNL	29.04	64	64	98	64	C	
13	5	12		UNL	28.89	67	66	95	66	ENE	8
14	10	15		50	28.77	84	67	41	57	S	20
15	10	15		20	28.97	72	69	86	68	NNW	8
16	10	10		35	29.16	68	66	87	64	ENE	8
17	10	7		8	29.11	65	64	94	63	ESE	5
18	4	7		UNL	29.04	71	70	97	70	E	4
19	10	12		CIR	28.93	76	73	86	72	SSW	3
20	10	4		5	28.96	65	64	95	64	NNE	8
21	10	6		25	29.03	66	64	91	63	NE	5
22	6	1	8	UNL	29.05	59	59	97	58	C	
23	1	7		UNL	29.02	65	64	94	63	SE	3
24	8	15		30	28.95	72	70	93	69	ENE	5
25	1	15		UNL	29.01	69	67	90	66	N	10
26	10	15		120	28.99	64	62	92	62	ESE	3
27	10	12		25	28.92	70	68	90	67	W	5
28	3	12		UNL	29.07	67	65	89	64	W	5
29	0	15		UNL	29.07	68	65	87	64	S	5
30	8	15		40	28.84	77	74	85	72	S	15
31	10	15		10	28.89	70	68	92	67	WNW	3

0600

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	1	15		UNL	28.94	74	70	81	68	S	15
2	10	15		CIR	28.97	75	71	80	69	S	19
3	10	12		UNL	28.99	71	70	93	69	ESE	4
4	10	8		70	28.84	68	67	95	67	NNW	6
5	9	8		UNL	29.01	69	69	97	68	C	
6	8	12		80	29.14	62	62	97	61	C	
7	10	15		100	29.14	65	63	89	62	ENE	4
8	5	12		UNL	29.18	60	60	97	59	E	3
9	8	15		UNL	29.14	65	64	94	64	C	
10	10	2		20	29.17	68	68	97	67	N	28
11	10	15		70	28.97	66	64	90	63	SSW	5
12	9	0	2	UNL	29.04	64	64	100	64	C	
13	6	12		75	28.90	67	66	94	66	ENE	5
14	10	15		50	28.82	77	73	80	70	S	25
15	10	8		15	29.09	71	68	86	66	WNW	33
16	10	3		10	29.20	67	66	95	65	NE	10
17	10	10		7	29.07	67	66	95	66	ESE	13
18	3	7		UNL	29.04	72	71	97	71	E	4
19	10	12		CIR	28.93	75	73	90	72	S	7
20	10	2		5	28.98	66	65	95	64	N	7
21	10	6		25	29.03	66	64	90	63	NNE	8
22	6	1	8	UNL	29.07	59	58	97	58	C	
23	1	8		UNL	29.01	64	63	95	63	C	
24	10	15		80	28.94	71	70	96	70	E	8
25	2	15		UNL	29.03	68	66	90	65	N	9
26	10	15		100	29.02	64	63	91	62	S	4
27	10	3		8	28.94	69	68	95	68	WSW	8
28	0	12		UNL	29.09	66	64	91	63	C	
29	0	15		UNL	29.08	68	66	93	65	SW	3
30	7	12		40	28.83	77	74	86	72	S	11
31	10	15		10	28.93	70	69	94	68	N	3

0700

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	12		UNL	28.94	76	70	74	67	SSE	16
2	10	15		80	29.00	76	71	78	69	SSW	15
3	10	12		UNL	28.99	74	71	86	70	SSE	9
4	10	8		50	28.88	68	67	95	66	W	5
5	9	8		UNL	29.02	73	70	85	68	WNW	5
6	7	12		80	29.14	64	63	95	63	NNE	3
7	10	15		100	29.15	66	63	87	62	NNE	3
8	4	15		UNL	29.18	65	64	94	63	C	
9	3	15		UNL	29.14	69	67	91	66	SE	6
10	10	2		10	29.20	67	66	96	66	N	10
11	10	15		75	28.99	67	65	89	64	SSW	4
12	10	0	4	1	29.04	67	67	99	66	ESE	6
13	10	12		25	28.94	69	67	92	66	E	5
14	10	1	8	5	28.78	72	72	99	72	SSE	39
15	10	10		25	28.94	63	62	94	61	N	33
16	10	2		10	29.23	66	65	95	64	NE	10
17	10	2		6	29.15	66	66	99	66	WNW	8
18	2	8		UNL	29.06	76	74	91	73	ESE	4
19	10	12		CIR	28.93	77	74	87	73	SE	5
20	10	1	8	5	28.99	65	64	96	64	N	10
21	10	7		25	29.04	67	64	85	62	NE	10
22	8	1		CIR	29.07	61	61	98	61	C	
23	1	8		UNL	29.01	68	66	90	65	C	
24	10	15		70	28.96	74	71	88	70	C	
25	2	15		UNL	29.05	71	68	84	66	NNW	7
26	10	15		120	29.01	68	64	82	62	SSE	8
27	10	3		20	28.96	69	68	95	68	SW	5
28	0	12		UNL	29.11	70	66	83	64	C	
29	0	15		UNL	29.08	73	70	87	69	SSW	4
30	7	7		40	28.82	78	73	79	71	S	20
31	10	12		10	28.94	71	70	94	69	C	

0800

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.94	78	71	73	69	S	18
2	8	15		80	29.02	78	72	74	69	SSW	9
3	9	12		30	28.99	76	72	82	70	SSE	11
4	10	8		25	28.89	69	68	93	67	NW	7
5	9	12		CIR	29.05	74	69	78	67	N	10
6	8	15		UNL	29.14	70	67	85	65	ENE	5
7	10	12		100	29.17	68	64	80	62	NNE	8
8	1	15		UNL	29.19	70	67	85	66	S	4
9	1	15		UNL	29.14	73	69	83	67	S	10
10	10	7		20	29.15	66	65	96	65	ENE	15
11	8	15		75	29.01	69	66	87	65	SW	7
12	9	3		5	29.06	69	68	97	68	ESE	9
13	10	15		75	28.94	71	68	86	67	E	7
14	8	12		80	28.81	74	72	88	71	S	18
15	10	15		50	29.06	63	62	96	62	NE	11
16	10	3		15	29.22	65	64	95	63	NE	11
17	10	3		6	29.14	67	66	96	66	ESE	7
18	2	10		UNL	29.06	79	75	82	73	SSE	6
19	10	12		80	28.94	78	74	82	72	ENE	5
20	10	6		7	29.01	66	64	90	63	NNW	5
21	10	7		25	29.07	67	64	85	62	NNE	6
22	8	2		CIR	29.09	63	62	98	62	C	
23	0	12		UNL	29.02	72	68	82	66	SSE	3
24	10	15		70	28.99	75	73	90	72	C	
25	1	15		UNL	29.06	74	70	80	67	NE	3
26	10	12		120	29.00	69	65	82	63	SE	7
27	10	5		35	28.96	68	67	95	67	S	7
28	0	12		UNL	29.13	74	66	66	62	C	
29	0	15		UNL	29.07	78	73	79	71	SW	7
30	8	12		40	28.85	77	73	83	72	W	12
31	10	12		20	28.96	72	70	91	69	C	

0900

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.96	80	73	70	69	S	16
2	10	15		80	29.05	79	72	72	69	W	4
3	9	12		30	28.99	78	72	76	70	S	9
4	10	4		8	28.90	70	69	93	68	S	5
5	10	12		CIR	29.06	75	68	71	65	NW	8
6	6	15		CIR	29.13	74	69	78	67	ENE	9
7	10	12		100	29.17	71	65	72	61	NNE	10
8	3	15		UNL	29.19	74	67	70	64	SSE	9
9	7	15		UNL	29.14	76	70	76	68	S	10
10	10	12		70	29.12	68	66	90	65	E	10
11	8	15		75	29.03	71	67	82	65	SW	4
12	10	6		7	29.05	70	69	93	68	ESE	7
13	8	15		75	28.91	73	71	90	70	E	7
14	7	12		30	28.83	78	75	86	74	S	20
15	10	15		50	29.01	65	63	89	62	NE	17
16	10	5		8	29.19	65	64	93	63	ENE	13
17	10	7		30	29.11	69	68	96	68	SE	12
18	2	12		UNL	29.05	81	75	73	72	S	8
19	10	15		UNL	28.92	81	75	75	72	SE	7
20	10	7		8	29.00	67	65	91	64	N	11
21	10	8		25	29.07	68	64	80	62	N	8
22	8	3		CIR	29.09	67	64	86	62	NE	3
23	1	12		UNL	29.04	75	69	75	66	SE	3
24	10	4		15	29.04	68	67	97	67	NW	15
25	0	15		UNL	29.07	77	69	67	65	NE	3
26	10	10		120	28.99	71	67	81	65	SE	6
27	9	12		40	28.95	71	68	87	67	SSW	6
28	0	15		UNL	29.13	76	66	59	61	C	
29	0	15		UNL	29.07	83	76	72	73	SSW	10
30	5	15		UNL	28.87	80	75	79	72	E	4
31	10	12		25	28.97	72	69	84	67	S	5

1000

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.95	82	74	67	70	S	16
2	9	15		CIR	29.04	83	75	70	72	S	8
3	8	15		120	28.97	81	74	72	71	SSE	13
4	10	6		25	28.91	71	70	95	69	S	5
5	10	12		CIR	29.07	76	69	72	66	N	6
6	9	15		CIR	29.14	75	66	62	61	NE	8
7	8	12		CIR	29.17	74	66	66	62	N	10
8	3	15		UNL	29.18	77	69	67	65	SE	12
9	4	15		UNL	29.14	78	71	71	68	S	10
10	10	12		5	29.15	69	67	89	66	E	4
11	8	15		75	29.02	70	66	83	65	W	4
12	10	7		8	29.05	72	70	90	69	SE	8
13	8	15		80	28.86	80	72	71	69	SE	16
14	10	12		20	28.83	81	75	77	73	S	12
15	10	15		CIR	29.03	69	65	80	63	NE	13
16	10	5		8	29.17	66	64	90	63	ENE	14
17	10	8		30	29.10	71	70	92	69	SSE	11
18	1	15		UNL	29.05	83	75	68	71	S	5
19	10	15		UNL	28.89	84	75	65	71	SSE	10
20	10	8		10	29.00	68	65	85	64	N	12
21	10	8		30	29.07	68	64	81	62	NNE	12
22	9	8		CIR	29.09	70	66	78	63	SE	4
23	1	15		UNL	29.03	79	70	66	66	SSE	3
24	10	7		15	29.07	68	67	96	67	W	12
25	1	15		UNL	29.07	80	69	59	64	NNE	5
26	10	10		70	28.98	74	68	74	65	SE	7
27	9	10		40	28.96	72	69	86	68	S	5
28	0	15		UNL	29.14	79	67	52	60	N	5
29	1	15		UNL	29.05	85	76	67	73	SSW	11
30	4	15		UNL	28.86	84	76	69	73	SE	12
31	10	12		10	28.99	73	69	82	67	S	5

1100

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	1	15		UNL	28.95	85	75	64	71	S	15
2	7	15		35	29.03	85	76	66	73	S	9
3	7	15		UNL	28.94	83	76	72	73	SSE	14
4	10	8		13	28.90	74	70	82	68	S	5
5	9	15		CIR	29.07	77	69	67	65	N	10
6	7	15		CIR	29.13	77	67	58	61	SE	6
7	8	15		UNL	29.18	76	67	63	62	N	7
8	3	15		UNL	29.17	78	71	69	67	SE	13
9	6	15		25	29.15	81	72	65	68	S	8
10	8	12		40	29.12	69	67	91	66	SE	11
11	8	15		75	29.04	74	68	75	65	WSW	14
12	10	10		13	29.03	73	70	85	69	SE	9
13	8	15		30	28.84	80	73	72	70	SE	12
14	6	12		CIR	28.82	83	77	76	75	S	12
15	9	15		12	29.12	72	66	71	62	WSW	3
16	10	6		12	29.21	66	64	90	63	ENE	12
17	10	10		25	29.10	74	70	84	69	E	4
18	0	15		UNL	29.05	86	77	67	74	S	6
19	9	15		UNL	28.88	86	76	63	72	SSW	11
20	10	10		10	29.02	70	66	81	64	NW	12
21	10	10		30	29.07	68	64	81	62	ENE	12
22	8	10		CIR	29.09	73	65	66	61	ENE	4
23	2	15		UNL	29.02	81	71	64	67	SSE	4
24	10	5		15	28.97	68	67	96	67	SE	8
25	3	15		UNL	29.07	82	67	46	58	NNE	7
26	8	10		70	28.97	75	69	74	66	ESE	6
27	9	10		35	28.98	73	70	86	69	S	5
28	0	15		UNL	29.14	80	67	51	60	ESE	5
29	2	15		UNL	29.02	87	77	64	73	SSW	12
30	9	15		20	28.86	86	78	71	75	ENE	15
31	10	12		10	28.99	75	70	78	68	S	4

1200

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	1	15		UNL	28.94	87	77	65	73	S	18
2	9	15		35	29.04	86	75	61	71	SW	6
3	7	15		35	28.92	86	77	66	73	SSE	17
4	10	10		30	28.89	76	71	79	69	SE	4
5	9	15		CIR	29.08	78	70	67	66	N	10
6	7	15		CIR	29.13	79	68	56	62	E	9
7	5	15		UNL	29.17	78	67	56	61	NE	8
8	4	15		UNL	29.15	79	70	64	66	SE	16
9	3	15		UNL	29.14	82	74	68	71	S	10
10	8	12		40	29.10	76	72	86	71	S	10
11	10	15		40	29.05	76	69	70	66	WSW	10
12	10	15		20	29.09	77	70	70	66	W	6
13	8	15		30	28.84	81	75	75	72	SSE	16
14	5	12		UNL	28.82	86	78	70	75	SW	10
15	10	15		20	29.12	73	66	72	63	N	7
16	10	6		12	29.23	66	64	89	63	NE	8
17	10	10		25	29.10	74	71	86	70	E	5
18	0	15		UNL	29.05	88	79	68	76	N	6
19	8	15		UNL	28.87	89	76	56	71	SSW	15
20	10	12		12	29.01	72	67	77	64	N	12
21	10	10		30	29.07	68	64	78	61	ESE	4
22	8	10		CIR	29.08	76	66	59	61	C	
23	4	15		UNL	29.01	82	72	61	67	C	
24	10	15		CIR	28.92	73	70	87	69	E	11
25	8	15		UNL	29.06	82	65	40	55	NNE	6
26	8	12		90	28.97	77	71	74	68	ESE	9
27	10	10		45	28.98	74	70	82	69	S	5
28	0	15		UNL	29.13	83	68	45	59	W	4
29	2	15		UNL	29.01	89	77	60	73	SSW	14
30	9	15		25	28.85	85	78	72	75	ENE	14
31	10	12		10	28.99	76	71	78	69	E	4

1300

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	1	15		UNL	28.92	89	78	62	74	SSW	17
2	6	15		CIR	29.02	88	76	60	72	SSW	5
3	9	15		35	28.89	85	77	68	73	S	16
4	10	10		25	28.92	78	72	75	69	WNW	7
5	10	15		60	29.06	75	68	72	65	N	11
6	10	15		120	29.12	81	68	51	61	NE	10
7	4	15		UNL	29.15	80	69	60	65	NE	10
8	4	15		UNL	29.15	80	70	59	64	SE	10
9	2	15		UNL	29.12	84	74	62	70	S	9
10	7	12		100	29.02	78	73	79	71	SSE	18
11	10	15		40	29.05	76	69	72	66	W	8
12	10	15		CIR	29.07	79	70	64	66	WSW	5
13	8	15		30	28.81	82	77	81	75	SSE	12
14	5	15		UNL	28.82	89	77	58	72	SSW	11
15	8	15		120	29.11	75	68	70	65	NNW	8
16	10	7		12	29.20	67	64	86	63	ENE	12
17	10	15		25	29.08	78	74	82	72	SE	10
18	0	15		UNL	29.03	89	78	63	74	NE	4
19	5	15		UNL	28.86	90	76	53	71	SSW	12
20	10	12		12	29.02	71	66	77	64	N	11
21	10	10		25	29.07	69	64	76	61	NE	4
22	9	10		15	29.07	76	67	64	63	N	4
23	8	15		UNL	29.00	83	72	59	67	S	10
24	10	15		CIR	28.93	79	73	76	71	E	8
25	8	15		UNL	29.04	82	66	43	58	N	9
26	7	15		CIR	28.96	80	72	67	68	ESE	9
27	10	12		60	28.99	76	71	80	69	SW	7
28	1	15		UNL	29.11	83	68	45	59	NW	7
29	1	15		UNL	28.98	90	78	60	74	SSW	13
30	8	15		30	28.82	85	79	76	77	E	16
31	10	12		15	28.99	77	71	77	69	E	5

1400

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	3	15		UNL	28.91	90	77	56	72	SSE	17
2	6	15		120	29.00	89	76	56	71	SSW	9
3	8	15		35	28.86	82	74	71	71	S	16
4	9	12		100	28.91	81	72	65	68	W	4
5	10	15		70	29.07	75	69	74	66	NW	7
6	10	15		120	29.12	81	67	48	59	NE	8
7	6	15		CIR	29.15	81	68	52	62	N	8
8	1	15		UNL	29.12	81	69	56	63	SSE	11
9	5	15		UNL	29.12	84	74	63	70	S	8
10	8	12		50	29.01	79	75	81	73	S	13
11	10	15		40	29.05	78	70	69	67	WSW	9
12	10	15		65	29.03	81	71	62	67	S	4
13	6	15		80	28.78	82	75	72	72	SE	11
14	3	15		UNL	28.82	88	81	74	79	S	14
15	5	15		UNL	29.10	77	70	70	67	NW	10
16	10	6		10	29.17	67	65	89	64	E	11
17	9	15		30	29.06	81	75	77	73	S	9
18	1	15		UNL	29.02	90	78	60	74	ESE	3
19	2	15		UNL	28.87	92	79	57	74	WSW	10
20	10	12		12	29.01	72	65	70	61	N	10
21	10	10		25	29.07	70	64	75	61	NE	4
22	10	10		24	29.06	77	67	58	61	C	
23	8	15		UNL	28.99	85	73	56	67	SSE	6
24	10	15		UNL	28.90	83	75	69	72	ESE	8
25	7	15		UNL	29.02	83	65	38	55	N	8
26	6	15		CIR	28.94	82	73	65	69	ESE	15
27	10	10		60	28.99	76	71	80	69	SSW	5
28	1	15		UNL	29.11	84	68	44	60	WNW	10
29	1	15		UNL	28.98	92	78	54	73	S	12
30	5	15		UNL	28.81	88	80	71	77	ESE	14
31	10	15		15	28.99	79	73	75	70	S	3

1500

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	5	15		UNL	28.92	90	78	58	74	SSE	20
2	7	15		120	28.99	90	77	56	72	SSW	7
3	8	15		35	28.85	86	77	65	73	S	10
4	8	15		100	28.91	82	73	65	69	NW	10
5	10	15		70	29.08	75	69	74	66	WNW	4
6	10	15		140	29.10	81	67	49	60	ENE	13
7	6	15		CIR	29.14	82	70	54	64	NNE	10
8	1	15		UNL	29.09	82	72	63	68	SSE	15
9	5	15		UNL	29.12	85	75	63	71	SSE	10
10	7	12		50	29.00	84	77	73	74	S	7
11	10	15		40	29.04	77	70	72	67	SSW	9
12	10	15		65	28.96	77	70	70	67	E	10
13	8	15		50	28.77	84	76	70	73	SSE	15
14	0	15		UNL	28.81	89	81	71	78	S	12
15	3	15		UNL	29.10	80	69	59	64	N	8
16	10	3		10	29.19	66	64	90	63	E	10
17	9	15		30	29.05	85	78	73	75	SW	6
18	1	15		UNL	29.01	91	79	60	75	SE	4
19	5	15		UNL	28.87	94	79	53	74	W	10
20	10	12		12	28.99	72	68	80	66	N	8
21	10	10		25	29.07	70	65	77	63	NNW	6
22	10	10		CIR	29.05	79	67	54	61	C	
23	8	15		UNL	28.98	85	72	54	66	ESE	5
24	9	15		UNL	28.90	86	76	64	72	ESE	7
25	6	15		UNL	29.01	83	65	38	55	NNE	7
26	5	15		UNL	28.92	83	73	62	69	ESE	15
27	9	12		70	28.97	78	72	76	70	SSW	5
28	3	15		UNL	29.10	85	69	44	60	W	11
29	5	15		UNL	28.97	93	77	50	71	SSE	5
30	3	15		UNL	28.79	89	79	65	76	ESE	17
31	10	15		15	28.99	80	74	74	71	NE	5

1600

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	6	15		40	28.92	89	77	58	72	S	20
2	9	15		120	28.99	90	77	56	72	S	11
3	9	15		CIR	28.83	88	75	55	70	SSW	15
4	8	15		CIR	28.90	81	71	62	67	NW	4
5	10	15		70	29.07	75	69	76	67	NNW	4
6	10	15		150	29.10	79	67	56	61	ENE	9
7	6	15		CIR	29.13	82	69	53	63	NE	9
8	0	15		UNL	29.09	81	70	60	65	SSE	13
9	6	15		40	29.11	84	74	64	70	SE	8
10	2	12		UNL	29.01	88	77	61	73	SSW	6
11	5	15		UNL	29.02	81	73	70	70	S	10
12	10	15		CIR	28.93	78	70	69	67	ESE	10
13	8	15		50	28.75	85	77	71	74	SE	18
14	0	15		UNL	28.82	90	78	60	74	S	18
15	1	15		UNL	29.11	78	68	60	63	N	10
16	10	7		10	29.19	66	64	90	63	NE	12
17	8	15		120	29.04	87	78	69	75	S	3
18	1	15		UNL	29.00	92	78	56	73	ESE	6
19	6	15		120	28.87	91	79	60	75	W	10
20	10	15		14	28.99	73	68	78	65	NNE	10
21	10	8		70	29.05	69	66	85	64	N	11
22	6	10		CIR	29.04	80	69	58	64	C	
23	5	15		UNL	28.96	85	73	57	68	SE	10
24	5	15		UNL	28.92	89	76	57	71	SSW	8
25	7	15		UNL	29.00	83	65	37	54	NE	7
26	8	15		120	28.93	84	75	66	71	SSE	13
27	9	15		80	28.97	81	74	74	71	SSW	10
28	3	15		UNL	29.09	86	70	46	63	WSW	10
29	5	15		UNL	28.94	91	78	56	73	S	12
30	5	15		UNL	28.79	90	80	65	77	SE	18
31	10	15		15	28.99	80	73	74	70	N	7

1700

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	4	15		UNL	28.92	89	77	58	72	S	20
2	8	15		120	28.97	90	78	59	74	S	12
3	10	15		30	28.85	80	72	69	69	S	16
4	6	15		CIR	28.89	83	72	59	67	WNW	3
5	10	15		80	29.06	76	70	73	67	NNE	8
6	10	15		150	29.09	78	68	61	63	ENE	6
7	6	15		CIR	29.13	81	68	51	61	ENE	8
8	0	15		UNL	29.09	81	70	60	65	SE	16
9	5	15		UNL	29.11	83	73	62	69	ESE	9
10	4	12		UNL	29.00	85	78	73	76	NNE	10
11	3	15		UNL	29.01	78	72	76	70	S	11
12	8	15		UNL	28.92	78	70	68	66	E	10
13	8	15		50	28.74	85	77	69	74	SSE	15
14	0	15		UNL	28.82	89	79	65	76	S	15
15	2	15		UNL	29.11	79	69	61	64	N	10
16	10	12		20	29.18	67	63	82	61	ENE	12
17	6	15		120	29.02	85	80	77	78	ENE	4
18	1	15		UNL	28.98	92	80	60	76	SE	3
19	4	15		UNL	28.87	84	78	78	76	N	16
20	10	15		15	28.99	72	67	79	65	N	12
21	10	8		25	29.03	69	66	84	64	ENE	6
22	6	10		120	29.03	80	69	58	63	C	
23	5	15		UNL	28.95	84	74	63	70	SE	10
24	7	15		30	28.92	88	76	59	71	W	4
25	4	15		UNL	28.99	83	65	36	53	ENE	5
26	8	15		120	28.93	83	75	69	72	SE	13
27	9	15		100	28.96	83	74	66	70	S	8
28	2	15		UNL	29.08	86	70	46	63	W	4
29	3	15		UNL	28.93	91	80	63	77	SSE	10
30	7	15		150	28.79	90	80	66	77	SE	12
31	10	15		25	28.99	79	73	76	71	NE	8

1800

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	4	15		UNL	28.93	88	76	59	72	SSE	18
2	7	15		60	28.96	89	77	59	73	SSE	10
3	10	12		30	28.86	76	73	85	72	S	10
4	5	15		UNL	28.89	84	73	60	68	NW	3
5	10	15		80	29.06	74	69	78	67	N	7
6	10	15		150	29.09	78	68	61	63	C	
7	4	15		UNL	29.14	79	69	60	64	E	7
8	0	15		UNL	29.07	79	69	59	63	SSE	13
9	5	15		UNL	29.12	84	75	65	71	SSE	3
10	2	12		UNL	28.99	84	78	76	75	NE	11
11	3	15		UNL	29.01	78	73	78	70	S	10
12	6	15		UNL	28.93	78	69	62	64	E	7
13	8	15		50	28.74	86	78	70	75	S	16
14	1	15		UNL	28.82	88	80	72	77	SSE	16
15	7	15		100	29.11	76	68	66	64	N	10
16	10	15		25	29.17	68	64	83	62	NE	14
17	7	15		30	29.02	85	79	78	77	ENE	10
18	1	15		UNL	28.96	90	80	65	77	SE	6
19	10	15		20	28.86	80	76	83	74	N	16
20	10	15		18	28.98	70	66	80	64	N	12
21	10	8		25	29.02	69	66	83	64	E	7
22	8	10		CIR	29.02	77	67	60	62	C	
23	1	15		UNL	28.95	84	74	63	70	SE	8
24	10	15		35	28.92	81	75	76	73	N	18
25	2	15		UNL	28.98	82	66	43	57	ENE	7
26	6	15		140	28.92	83	75	68	71	SE	10
27	5	15		UNL	28.93	83	74	66	70	SSW	6
28	0	15		UNL	29.08	86	70	45	62	WSW	5
29	1	15		UNL	28.92	90	79	61	75	SSE	10
30	3	15		UNL	28.75	89	81	71	78	SSE	16
31	9	15		25	28.97	78	73	79	71	N	10

1900

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	1	15		UNL	28.93	86	76	62	71	SSE	16
2	8	15		50	28.99	77	70	70	66	ESE	9
3	10	15		CIR	28.87	77	73	83	71	S	10
4	4	15		UNL	28.90	80	72	69	69	E	4
5	10	15		100	29.06	73	69	82	67	N	5
6	10	15		CIR	29.09	75	70	78	68	C	
7	0	15		UNL	29.14	78	69	65	65	E	8
8	0	15		UNL	29.06	76	68	65	63	SE	11
9	0	15		UNL	29.10	80	72	68	69	SSE	13
10	2	12		UNL	28.98	81	77	82	75	ENE	9
11	2	15		UNL	29.01	77	72	79	70	SSW	8
12	6	15		UNL	28.94	77	71	74	68	E	8
13	9	15		50	28.74	84	78	76	76	SSE	8
14	3	15		UNL	28.83	86	79	74	77	S	12
15	7	15		100	29.11	76	68	67	64	N	8
16	10	15		25	29.17	67	63	82	61	NE	10
17	5	15		UNL	29.01	82	78	84	77	NNE	9
18	2	15		UNL	28.96	87	80	75	78	SSE	7
19	9	15		18	28.86	77	74	87	73	N	14
20	10	15		18	28.98	69	65	81	63	NNE	8
21	10	8		25	29.03	69	66	85	64	E	4
22	9	10		UNL	29.01	74	69	79	67	C	
23	0	15		UNL	28.95	81	74	72	71	ESE	8
24	10	15		35	28.90	79	72	72	69	NNE	12
25	0	15		UNL	28.99	79	68	57	63	ESE	3
26	5	15		UNL	28.92	80	72	69	69	SSE	8
27	6	15		CIR	28.96	81	74	73	72	S	9
28	0	15		UNL	29.08	82	73	65	69	S	5
29	0	15		UNL	28.92	87	79	73	77	SSE	8
30	5	15		UNL	28.72	87	80	74	78	S	13
31	5	15		UNL	28.98	77	73	85	72	ENE	6

2000

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.95	84	75	66	71	SSE	18
2	10	2		30	29.05	72	70	90	69	WNW	15
3	10	15		CIR	28.86	76	71	80	69	S	13
4	4	15		UNL	28.90	76	73	86	72	C	
5	9	15		CIR	29.07	71	67	83	65	NNE	7
6	10	15		140	29.09	73	68	79	66	NNE	6
7	0	15		UNL	29.14	73	68	76	65	E	3
8	0	15		UNL	29.05	73	66	70	62	SE	8
9	1	15		UNL	29.10	78	72	75	69	SSE	12
10	3	12		UNL	28.97	78	75	85	73	ENE	13
11	2	15		UNL	29.01	73	71	89	69	SSW	3
12	5	15		UNL	28.93	73	70	85	68	ESE	8
13	6	15		UNL	28.74	80	77	87	76	SE	4
14	7	15		UNL	28.84	83	78	80	76	S	16
15	6	15		100	29.11	74	68	76	66	C	
16	10	15		30	29.19	66	63	85	62	ENE	10
17	1	15		UNL	29.01	80	77	87	76	NE	10
18	5	15		UNL	28.96	84	80	84	79	SE	7
19	10	10		8	28.89	74	71	87	70	NNE	14
20	10	15		18	29.00	68	64	82	62	NE	13
21	9	8		25	29.04	68	66	89	65	N	3
22	8	10		UNL	29.01	72	68	84	67	C	
23	0	15		UNL	28.95	77	73	80	71	ESE	9
24	10	15		35	28.93	77	72	79	70	NNE	8
25	0	15		UNL	29.00	74	68	77	66	SE	3
26	5	15		UNL	28.91	76	72	83	71	ESE	8
27	9	15		30	28.99	77	73	82	71	S	9
28	0	15		UNL	29.08	77	71	75	68	S	4
29	0	15		UNL	28.91	84	78	77	76	SSE	10
30	9	15		CIR	28.75	84	79	79	77	SSE	7
31	2	15		UNL	28.99	74	72	91	71	ENE	5

2100

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.97	82	75	70	71	SSE	17
2	10	10		50	29.01	73	71	93	71	WNW	8
3	10	15		70	28.88	75	71	83	69	S	12
4	1	15		UNL	28.91	73	71	91	71	S	4
5	7	15		UNL	29.09	69	66	87	65	NNW	6
6	10	15		140	29.11	72	68	82	66	C	
7	0	15		UNL	29.15	70	66	81	64	ESE	3
8	0	15		UNL	29.07	69	65	79	62	SE	4
9	1	15		UNL	29.12	77	71	75	68	SE	5
10	10	10		15	29.00	76	73	87	72	E	13
11	0	15		UNL	29.02	71	69	92	68	SSE	3
12	4	15		UNL	28.95	71	69	88	67	ESE	4
13	0	15		UNL	28.74	78	76	90	75	SE	5
14	5	15		UNL	28.85	82	77	80	75	S	15
15	1	15		UNL	29.12	72	67	78	65	ENE	6
16	10	15		24	29.19	65	62	84	60	ENE	12
17	0	15		UNL	29.03	78	76	90	75	ENE	9
18	6	15		CIR	28.98	82	79	87	78	SE	7
19	10	10		9	28.93	72	70	91	70	NE	12
20	10	15		21	29.05	67	64	83	62	NNE	12
21	8	8		70	29.05	67	66	92	65	NNE	5
22	8	10		UNL	29.02	69	66	86	65	ESE	3
23	0	15		UNL	28.97	75	72	89	71	ESE	8
24	10	15		40	28.94	76	72	85	71	SE	6
25	0	15		UNL	29.01	70	65	77	63	E	3
26	5	15		UNL	28.91	76	73	86	72	ESE	10
27	9	15		35	29.00	76	72	83	70	S	10
28	0	15		UNL	29.09	74	70	81	68	S	8
29	0	15		UNL	28.92	83	77	78	75	SE	12
30	10	15		24	28.80	74	70	79	67	NNE	25
31	0	15		UNL	29.02	73	72	93	71	NE	4

2200

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	0	15		UNL	28.97	82	74	70	71	SSE	15
2	9	15		CIR	29.02	71	69	91	68	SW	17
3	10	15		80	28.89	74	71	86	69	S	12
4	2	15		UNL	28.94	73	71	89	70	C	
5	3	15		UNL	29.11	67	65	90	64	NNW	3
6	10	15		120	29.13	71	68	86	67	C	
7	0	15		UNL	29.16	67	64	85	62	ESE	3
8	0	15		UNL	29.13	68	64	84	62	SSE	3
9	0	15		UNL	29.12	73	70	84	68	SE	7
10	10	10		6	29.01	72	71	95	71	SE	7
11	0	15		UNL	29.03	69	68	95	68	SE	3
12	2	10		UNL	28.96	71	69	91	68	ENE	7
13	0	15		UNL	28.74	77	75	92	74	SE	7
14	7	15		65	28.90	82	77	80	75	S	12
15	6	15		100	29.15	72	67	78	65	E	3
16	10	15		30	29.20	66	62	82	60	E	13
17	0	15		UNL	29.04	76	75	94	74	ENE	6
18	9	15		CIR	28.99	82	79	87	78	ESE	7
19	10	10		9	28.95	71	69	92	68	N	12
20	10	15		16	29.06	67	64	84	62	ENE	12
21	8	8		70	29.05	66	65	93	64	NNW	7
22	7	10		UNL	29.04	68	66	90	65	C	
23	1	15		UNL	28.97	74	72	89	70	ESE	9
24	10	15		40	28.94	76	72	84	71	N	8
25	0	15		UNL	29.02	68	65	85	63	ESE	3
26	5	15		UNL	28.93	77	73	82	71	SE	11
27	9	15		CIR	29.02	75	72	84	70	SSW	10
28	0	15		UNL	29.10	73	68	79	66	S	8
29	0	15		UNL	28.92	83	77	76	74	SE	13
30	10	15		35	28.84	73	68	80	66	E	13
31	0	15		UNL	29.04	72	71	96	70	ENE	3

2300

Day of Mo.	Sky Cover (Tenths)	Visibility Whole Miles	Visibility 16th Mi.	Ceiling (Hnds. of Ft.)	Station Press. (In.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Hum. (%)	Dew Pt. (°F)	Wind Dir.	Wind Speed (Knots)
1	2	15		UNL	28.98	80	73	71	70	SSE	15
2	9	15		CIR	29.02	73	69	82	67	W	7
3	10	15		100	28.89	74	71	85	69	S	11
4	3	12		UNL	28.95	71	70	95	70	C	
5	2	15		UNL	29.11	65	64	93	63	NW	6
6	10	15		120	29.14	71	68	86	66	NNE	3
7	0	15		UNL	29.17	65	64	94	63	ESE	3
8	0	15		UNL	29.12	64	63	92	62	SE	4
9	0	15		UNL	29.11	72	69	86	68	ESE	9
10	10	10		31	29.02	69	68	93	67	E	13
11	0	1		UNL	29.03	67	67	99	67	C	
12	2	10		UNL	28.95	70	68	91	67	ENE	7
13	0	15		UNL	28.77	78	75	89	74	SE	6
14	6	15		65	28.93	82	77	80	75	W	10
15	6	15		75	29.17	71	69	91	68	C	
16	10	15		30	29.18	66	63	83	61	ENE	10
17	0	15		UNL	29.05	75	74	94	73	ENE	5
18	10	12		100	28.98	82	79	88	78	SE	7
19	10	10		7	28.98	70	69	91	68	NW	5
20	10	15		17	29.06	67	64	84	62	NE	5
21	10	7		CIR	29.06	65	64	95	63	NNW	4
22	4	10		UNL	29.02	67	65	90	64	C	
23	1	15		UNL	28.96	74	71	85	69	ESE	9
24	10	15		41	28.97	75	72	85	70	NNW	3
25	1	15		UNL	29.02	66	64	91	63	ESE	5
26	10	15		CIR	28.92	76	72	83	71	SE	10
27	10	15		100	29.03	75	72	87	71	SW	8
28	0	15		UNL	29.11	72	67	79	65	S	7
29	0	15		UNL	28.91	82	78	82	76	SSE	14
30	10	12		35	28.85	71	69	91	68	E	14
31	10	10		UNL	29.05	72	71	97	71	ENE	3

Station pressures in this table apply to the official elevation of 885 feet above mean sea level.
Wind speeds are in knots; multiply by 1.15 to convert to miles per hour.
UNL indicates ceiling unlimited.
CIR indicates a cirriform cloud ceiling with height unknown.

AN INVESTIGATION OF WEATHER DATA AS IT PERTAINS TO CROP DRYING

by

GERALD LEROY ZACHARIAH

B. S., Kansas State University
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AN ABSTRACT OF
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The drying of grain by mechanical means has become a part of the modern harvesting operation. The first widespread drying in Kansas was done with natural or unheated air. This drying process is very dependent on the weather. To make drying more dependable, small heat units were added to the driers to condition the air when bad weather existed. Observations indicated that considerable overdrying often resulted from the use of supplemental heat.

The time required for drying has always been the foremost question asked by farm operators regarding grain driers. The questions of drying rates and overdrying are closely associated with the weather conditions.

The objectives of this investigation were:

1. To determine the essential weather data and their significance to the drying operation.

2. Compile the essential data in a usable form.

3. To develop methods of utilizing the data.

A survey of electrical power suppliers was conducted to obtain information on the drying of sorghum grain under the very adverse weather conditions of 1957. A personal survey was made in several areas of the state. These surveys were to determine the success achieved by natural air and supplemental heat driers. This included not only the ability of the drier to reduce the grain moisture content of the grain to below 13 per cent, but also the quality of the drying.

Three bins of grain were dried with supplemental heat driers during 1958 to determine the operating characteristics of the driers relative to the weather. Two methods of using humidistat heat unit controls were tested to determine which would provide the better application of heat for conditioning the air.

The wet bulb temperatures, dry bulb temperatures, and occurrence of relative humidity were found to be the most essential weather data for the operation of grain driers. The hourly recorded wet bulb and dry bulb temperatures were averaged for the months of July, October, and November for the years 1949-1958. The occurrence of relative humidity in hours per month occurring in given humidity ranges was determined.

Based on the common reduction in relative humidity during the day as compared to night, a 12-hour period between 0830 and 2030 hours was found to have a much higher drying potential. The data for this period was averaged separately from the 24-hour per day data.

The surveys and drying experiments showed that overdrying was a serious problem in the use of supplemental heat. An average of 1,000 pounds was removed unnecessarily by overdrying for each 1,000 bushels dried as reported in the survey. The added cost of this overdrying is another unnecessary waste.

The use of smaller amounts of heat and humidistat controls located in the plenum or duct system was shown to be effective in reducing overdrying.

The time required for drying can be estimated by the use of recorded weather data. The average year and the poorest drying year for the 10-year period were selected and the two most useful guides for estimating drying rates.

This investigation showed that the average potential for natural air drying is adequate for summer and fall drying. For extreme years, supplemental heat will be required. The expected requirement for supplemental heat can be calculated from the weather data. For the poorest drying season, an 18-degree F temperature rise was required 41 per cent of the drying time.

The low expected heat requirement found by this investigation increases the practicality of resistance heat for grain drying. Driers with 6- to 12-kilowatt heating capacity would be adequate for supplying supplemental heat for most common in-storage-drying systems. The added safety and convenience of the electric heat must be compared with the lower energy costs of the gas-fired units.

Due to the variation in weather conditions over the state, weather data from several stations would be required to predict drying rates for the state. The use of punch cards would be the most practical method for evaluating the data for the other stations.