# AN ENVIRONMENTAL STUDY
# ON THE USE OF INSULATING GLASS
# FOR THE HOUSING OF SWINE

By

Charles Nelson Hinkle

THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agricultural Engineering

1953

THESIS

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# ABSTRACT

The basis for this study was a comparison of environmental conditions between the two wings of the new Michigan State College swine barn. One wing is solar oriented with insulating glass windows along the entire south wall. The other wing, of conventional construction, is oriented on a north-south axis. Both wings are of similar construction to the top of the four foot concrete block lower wall and have the same number and location of pens, doors, heaters, and ventilating ducts. The difference in the two buildings lies in the insulating glass windows and shed roof construction of the solar wing and the gable roof and small ventilating windows of the regular wing.

A recording potentiometer was so wired that it was possible to take hourly readings automatically of temperatures and humidities. Twenty thermocouples were located in each wing for temperature measurement and a special unit was built to give wet bulb and dry bulb temperatures for determination of relative humidity.

The data was plotted onto weekly charts which also included values for solar radiation and outdoor temperatures. Charts were prepared for eight summer weeks and thirteen winter weeks. An analysis of the charts followed. General weather conditions for the winter weeks were obtained from the Lansing Weather Bureau to help explain the variations in the recorded data from the two wings.

A formula was constructed for converting solar radiation on a horizontal surface to solar radiation on a vertical south facing surface. This formula gave good results for the winter of 1953 when compared to calculations by other methods. These results indicated that it was possible to gain over four hundred BTU's per hour per pen by using solar oriented fixed sash insulating glass instead of conventionally located single glazed ventilating windows.

Data from the first year of the study, as a whole, were not conclusive because it was found to be practically impossible to control the conditions closely enough in the large piggery to make accurate comparisons between the solar and regular wing. Smaller buildings in which the variables can be more accurately controlled are necessary for future tests.

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# INTRODUCTION

## Description of Project

In June, 1952, work was started on the project which was to provide data for this thesis. This project was sponsored jointly by the Michigan Agricultural Experiment Station and Libbey-Owens-Ford Glass Company. The particular phase carried out in this work was a comparative study of the environmental conditions in the solar wing to the conditions in the regular wing of the new swine barn. Temperatures and humidities from both wings were recorded. Amounts of solar radiation and outdoor temperatures were obtained from the Michigan Hydrologic Research Station and the general weather conditions during the winter months were obtained from the Lansing Weather Bureau. These two sources of data were used in an attempt to help explain the variations in the recorded data from the two wings.

## Description of New Swine Barn

During the late summer of 1951 the new swine barn at Michigan State College was completed. As shown in Figure 1, not only was this a new building, but it was also a new design. The barn, commonly referred to as the piggery, is composed of three main parts. These are the two wings in which pens are located and the forty foot by eighty foot main barn which houses feed and bedding supplies, scale room, office, and living quarters for workers.

One wing of the piggery is of standard construction and is referred to as the regular wing (Fig. 2). This wing is oriented on a north-south axis and is ninety-six feet long and twenty-six feet wide. There are twelve pens on both sides of a six foot center alley each measuring eight feet wide and nine feet deep. (Sidewall construction consists of concrete block extending forty-four inches above the floor and two by four frame construction for the remaining three feet of wall heighth.) A gable roof over this wing gives a ceiling heighth in the center alley of about ten feet. Pen floor construction consists of a three inch concrete slab, one-half inch insulating board laid in a fifteen pound felt and hot pitch sandwich type construction, and a topping of three-quarter inch mastic.

The second wing of the piggery, commonly referred to as the solar wing, is oriented on an east-west axis. Layout and construction of this wing are similar to the regular wing to the top of the concrete block wall. From here on there is a radical change. Instead of the characteristic gable roof a shed roof opens to the south. Windows are found in the south wall only and consists of twenty-six pieces of three foot by five foot insulating glass. Each pane is composed of two pieces of three-sixteenth inch heavy sheet window glass with a one-half inch air space separating the two pieces, a total glass area of three hundred ninety square feet. To prevent the sun from entering during the summer months, an overhang was extended from the roof a distance of about five feet. Several views of this wing are shown in Figure 3 and Figure 4.

barn
hang
in

Fig. 2. Interior view of regular wing from connecting doorway to main barn.

Fig. 1. Michigan State College swine barn looking northwest towards College and Forest Roads on March 26, 1953; overhang in "back" position.

Fig. 2. Interior view of regular wing from connecting doorway to main barn.

There are other features which are common to both wings such as the heating system and the type and arrangement of the exhaust system. Both wings are heated by hot water unit heaters supplied by an oil furnace located in the main barn. There are two heaters in each wing, each having a rated capacity of 58,400 BTU's per hour. These are operated from one thermostat located in the center of each wing. The exhaust ventilation system is composed of three stacks in each wing starting three feet above the floor. The two outer stacks of each wing have wind driven fans at the top which will start to turn in a four mile an hour wind. The center stack of each wing is equipped with a manual switch motor driven fan which has an air output of fifteen hundred cubic feet per minute. All six of the stacks have dampers in them which are controlled by one humidistat for each damper. There are eight fresh air inlets in the regular wing, four along each of the long walls, and only four inlets in the solar wing, all located along the low north wall.

There are two main uses for this new piggery. One is to provide a place in which to conduct nutrition or feed studies and the other is to provide a place for farrowing. Since the feed studies are usually continuous and run for two to three month periods, this type of work is done in the regular wing. The main reason for this choice was that the regular wing is easier to clean daily since the manure can be carried directly out of the south door of the wing and placed in the manure spreader. Also this would leave the solar wing for the farrowing activities where the greater amount of light may be of more

Fig. 3. Exterior view of solar wing on September 22, 1952; overhang in "extended" position.

Fig. 4. Interior view of solar wing from connecting doorway to main barn.

benefit. Thus each wing is used for a different purpose and has a different type of animal in it.

## Environmental Requirements of Swine

The requirements of swine other than nutrient are not truly known and the design of buildings for swine involves a number of technical problems on which basic information is lacking. Only a small number of experiments dealing with environmental conditions on swine have been made and the majority of this information dealt more with extreme conditions in temperatures and humidities than with desired conditions. Much general information has come from observations which may not always be correct. Even so, proper housing is one of the first points in successful swine enterprises and the hog, more than any other farm animal, is sensitive to the extremes of heat and cold.

Effects of environment on the rate of gain. Heitman and Hughes (14)* made a study which was "concerned with the effect of changes in environmental temperature and humidity on the body temperature, respiration rate, pulse rate, and other factors in swine." They used a small air conditioned room which had a controllable air temperature and relative humidity. The results of these tests indicated that "hogs weighing 166 to 260 pounds gained most rapidly in the neighborhood of sixty degrees, while lighter weight animals weighing 70 to 144 pounds gained most rapidly at approximately seventy-five

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* Numbers in parenthesis refer to the appended bibliography.

degrees." The amount of feed required to produce one hundred pounds of gain was at a minimum when the rate of gain was at a maximum. This would indicate then that if it were just a matter of fattening pigs the best results would be had starting with a temperature of seventy-five degrees and gradually lowering it as the weight of the pigs increased. The necessary heating equipment to do this in the winter time would be prohibitive in cost.

Heat production of swine. Work was done by several investigators to determine the amount of heat produced by swine. The results of these separate investigations agree closely. The estimations which were made by Mitchell and Kelley (29) were from an "analytical study of the energy requirements of swine and the results were given for any particular age and weight." Their result for a two hundred pound fattening hog was 815 BTU's per hour. Since at seventy degrees, the temperature of the investigation, "twenty-five percent of the heat produced is latent heat," the actual amount of sensible heat would be about six hundred BTU's per hour.

The studies carried on by Kelly, Heitman and Morris (21) were measures on the heat loss from swine under various environmental conditions. This was done in the small air-conditioned room mentioned earlier. The heat loss from one two hundred pound fattening hog under conditions similar to the above example of Mitchell and Kelley was scaled from the graphical results for a value of 580 BTU's per hour which is almost the value obtained by Mitchell and Kelley. At forty degrees, this heat loss was about double the above value for seventy degrees. The study of heat loss from a pen of hogs becomes complicated for temperatures below sixty degrees because of their huddling together which reduces their exposed surface as much as sixty percent.

<u>The central farrowing house</u>. The use of a central spot for the swine enterprise, both farrowing and fattening, has had a lot of discussion both pro and con. The chief objection was the disease problem which can now be largely eliminated with proper management. For the convenience of the operator, a central farrowing house or system is almost a necessity for a large swine enterprise. The design conditions for a central farrowing house usually list a desirable temperature somewhere between fifty and sixty degrees and the use of electric pig brooders. The ventilation rate is given as six to ten cubic feet per minute for every one hundred pounds of pigs. Amounts of insulation recommended also varies, but there is common agreement that more insulation is desired in the ceiling than in the walls. Thus, if condensation takes place, it will occur on the walls and not on the ceilings where it would "rain" into the pens.

The amount of sunshine which should be admitted to the farrowing house is also debated. Large single glazed window areas are heat wasters. Even the generally accepted value of three to four square feet of window space per pen may waste too much heat. The use of insulating glass may provide a method of letting in more sunlight with a lower heat loss through the windows. For the fixed sash insulating glass installation at the piggery, heat loss due to infiltration is greatly reduced. According to the recommendations of Oregon State College (4), hog houses should be constructed "to provide maximum sunlight and good ventilation. This is an aid in the control of disease."

## Solar Energy

When one starts thinking about solar energy, it is hard to conceive the vastness of the subject. The sun was a source of wonder to the earliest cavemen and even today there is probably nobody who really knows just how this energy keeps coming. Some experimenters have come forth with interesting facts about the sun and the energy emitted from it.

General facts. The diameter of the sun is roughly one hundred times that of the earth or approximately 863,600 miles. Ackermann (1) said that each square foot of surface on the sun emits 12,500 horsepower which would be equivalent to $3.18 \times 10^7$ BTU's per hour. Thus, the energy emitted from four square feet of the sun's surface in one hour would be sufficient to heat an average six room Michigan house for one year. If all the energy from the entire surface of the sun for one hour were available, it would provide enough heat for heating three and one-half million average six room Michigan homes for one million-million years!

Ackermann (1) also states some of the conclusions made by Herschel from the results of his experiments conducted during the winter of 1836 to 1837.

From these experiments he deduced that a cylindrical rod of ice, 45.3 miles in diameter, and of indefinite length, continually darted into the sun with the velocity of light would barely suffice to employ the whole radiant heat for its fusion, without at all reducing the temperature of the sun.

A very minute amount of energy from the sun actually reaches the outer atmosphere of the earth and an even smaller amount will reach the ground. Of all the energy that leaves the sun, only 7,300 horsepower per acre, 1.93 gram-calories per square centimeter per minute, or 426 BTU's per square foot per hour reach the outer atmosphere. From this amount, about thirty percent more is lost before it reaches the earth's surface at noon on a bright sunny day.

Telluric adsorption. This adsorption by the atmosphere, referred to as telluric adsorption, is caused by many things. Chief among these would be water vapor, carbon dioxide, dust, smoke, and ozone. The season of the year also plays an important roll in the amount of telluric adsorption. Kimball (26) states that "the values of radiation intensity with an air mass equal to two is higher in winter than in summer partly due to the fact that the earth's 'radius vector' reaches its maximum value in early July and its minimum in early January, and partly to the fact that the atmosphere contains much less water vapor in winter than in summer." Ackermann (1) also states that "the adsorption of solar energy by the atmosphere is about twenty percent greater in summer than in winter."

About seven percent of this increase in winter transmission over summer transmission through the atmosphere is due to the earth's being closer to the sun in the winter than in the summer.

In some experiments conducted by Kimball (26), it was found that for an air mass of one (solar azimuth of zero degrees) and a perfectly dry atmosphere, ninety percent of the solar energy would pass through the atmosphere. For an air mass of two (solar azimuth of sixty degrees) this transmission was reduced to eighty-four percent and for an air mass of four (solar azimuth of seventy-five degrees) this was down to seventy-six percent.

The effect of the water vapor content of the atmosphere was even more pronounced. The amount of water vapor content was given as the depth of water that would be obtained if all the water vapor in the atmosphere were precipitated. With an air mass of one and one centimeter of water vapor, the transmission would be eighty percent. When the water vapor was increased to two centimeters, the transmission was seventy-six percent and for three centimeters of water vapor the transmission was reduced to seventy-three percent. The water vapor content of the air had the greatest reduction affect upon the transmission of the ultra-violet energy.

The depletion of energy by atmospheric dust amounted to about ten percent for most conditions. Dust had the greatest reduction affect again upon the ultra-violet energy and the least effect upon the infra-red energy.

<u>Studies for house heating</u>. During the past ten to fifteen years much interest has been taken in the heating powers of the sun. The majority of the work which has been done, however, was concerned more with the heat gain during the summer months as it would affect an air conditioning system. One such study (16) indicates from the results of many tests that "with minor variations the heat flows through the east, south and north walls were 83, 75 and 46 percent, respectively, of that for the west wall" during the summer months. It was impossible to use information such as this for winter studies when the sun is lower in the sky.

Cottony and Dill (8) found that "a surface capable of emitting long-wave radiation (radiant heat) will remain cooler when exposed to the sun than another surface which is similar with the exception that it emits less of such radiation." This means that a white gloss painted surface would be cooler than a green painted surface. Although these tests were made during the middle of the summer, the tests were made with the surfaces facing south and inclined at various positions to the horizon. Data such as this would then be applicable to winter months as well as summer months.

Only three investigators were found who had done a considerable amount of work on the possibilities of heating structures, namely houses, by the use of solar energy. Hutchinson (17) was directly connected with the solar heated house experiments at Purdue University. These experiments were conducted on two unoccupied houses which were architecturally, structurally and thermally similar. The glass area on the north and west sides were the same for both houses, but the solar house had an excess of sixteen square feet of glass on the east side and seventy-one square feet of glass on the south side. The glass in both houses was insulating glass. During a nine week test period in the winter of 1946-47, it took 2,924 kilowatt hours to heat the solar house and 2,514 kilowatt hours to heat the regular house.

Hutchinson also made up tables (18, 19, 20) to help in the calculation of solar energy impinging upon vertical walls facing east, southeast, south, southwest, or west. These tables provide a figure for various latitudes and represent the amount of solar energy on the wall for an average clear day during each of the winter months.

Hand (12) constructed tables to aid in the conversion of energy received on a normal surface to energy received on a vertical south facing surface for the winter months. With these tables it was possible to calculate instantaneous heat gains using data gathered locally. The formula which he recommended follows:

$$I_s = I_n (\cos a \cos D) + I_{sd}$$

where $I_s$ = energy normal to a south facing vertical wall

$I_n$ = direct solar radiation on a surface normal to the sun

$I_{sd}$ = diffuse energy on a south facing wall

$a$ = solar altitude angle

$D$ = solar azimuth angle

He further states that "owing to the insufficient data on values of $I_{sd}$, we used the formula $I_s = I_n$ (cos a cos D)." This further simplification makes the conversion more approximate and the results less accurate.

The majority of the work which was done by Telkes (38) was along the lines of possible methods of solar heat storage. Methods were developed for using the heat of fusion of a common chemical salt for the storage of solar heat. This work was done in the vicinity of Boston, Massachusetts and does show a solution to the heating of a house by the use of the sun's energy only.

## Instrumentation

Thermocouples. All of the instruments which were used in this project were thermocouples in basic construction, designed to record automatically in conjunction with a Brown Recording Potentiometer. The wires used for these thermocouples were twenty-six gauge copper and constantan. This size of wire was chosen because "small couples respond more promptly to changes in temperature and are less affected by radiation than large ones" (2-p. 1023). In the same reference a method was described for avoiding error due to radiation by using several thermocouples of different sizes, the true temperature being estimated by extrapolation of the readings to zero wire diameter.

There was the possibility in this study for the sun to be shining directly onto almost every one of the thermocouple junctions, especially during the winter when the sun was low in the sky. To prevent any increase in the recorded temperatures due to radiation, the junctions were placed inside of a paper cup from which the bottom had been removed. A close inspection of Figures 2 and 4 will show how these cups were used. This method had been used previously by other members of the Michigan State College Agricultural Engineering Department.

Since from all of the recorded temperatures in each wing an average value was to be used, two methods were investigated which would give average readings directly (31). One of these methods was composed of thermocouples connected in series in which every alternate junction was kept at a common temperature and the other junctions at various temperatures. This gave an electromotive force which, divided by the number of pairs of junctions, would give the true mean electromotive force. This large electromotive force would have been much too great from twenty thermocouples to be recorded on the recording potentiometer.

The second method was the connection of the thermocouple leads in parallel, the similar metals being connected together. The chief objection to this method was that for the recording of a true mean, for all temperatures, the electrical resistance of all the lines would have to be the same. In effect this would mean that all of the thermocouple leads would have to be the same length.

Neither of these two methods were considered usable and the final average temperatures were obtained by averaging the individually recorded results mathematically.

Relative humidity measurement. The measurement of relative humidities was accomplished with a wet bulb dry bulb thermocouple unit. The use of a hair element hygrothermograph was ruled out because of the large amount of dust in the air. According to Bruhn (7), "usually there is dust present which interferes with the accuracy of many instruments. The hair element hygrothermograph at best is not too accurate even when calibrated for a given range, and moving the instrument from the calibrating laboratory to a remote installation or changing the range of operation often causes inaccuracy."

Thermocouples are well suited for psychrometric use. When used as such, Wesler (40) states that they give low lag and are good for little or no ventilation. Bruhn (7) observed that dust accumulation seemed to have no effect on the wet bulb thermocouple unit.

The particular method employed was developed by Henderson (15). A picture of this unit as it was used for the project at the piggery is shown by Figure 16. The only changes in the plans presented by Henderson were the shortening of the wet bulb glass tube by about one-half inch and the omission of the paraffine which he used as a thermal fill in the glass tube. Tap water was used and the deposits left after evaporation and the dust accumulation on the wet bulb sock caused no discrepancies in the recorded data. The wet bulb socks were washed twice during the winter study.

# APPARATUS AND METHODOLOGY

## Use of Brown Recording Potentiometer

When this study was first started in the spring of 1952, it was decided to make the recording of data as automatic as possible. The eight point Brown Recording Potentiometer was available and was used throughout this first summer and winter of the project for recording the data (Fig. 5).

Fifty-two point switching box. Since it was going to be necessary to measure more than eight different temperatures with the recording potentiometer at the start of the study, it was decided to use the fifty-two point switching box which was developed by Hansen and Hall (13). This box, which permitted the use of up to fifty-two thermocouples is shown in Figure 6 as it was wired for the winter study. A total of forty-six wires were hooked into the box during the winter study and twenty-two during the end of the summer study. The leads from this box went to the potentiometer where they bypassed the eight point switching mechanism of the potentiometer. The location of the switching box with respect to the potentiometer is shown in Figures 5 and 7.

To keep the identity of the points straight on the strip chart, one thermocouple was taped against a continuously burning lightbulb (Figs. 5 and 7). This thermocouple was wired into the switching box twice to give a high temperature reading at the end of the temperature readings from each wing.

Fig. 5. Instrument location from door leading to solar wing. Shows respective location of potentiometer, switching box, time clock, transformer, and eight point plug. Sign on wall explains location of different thermocouples being recorded.

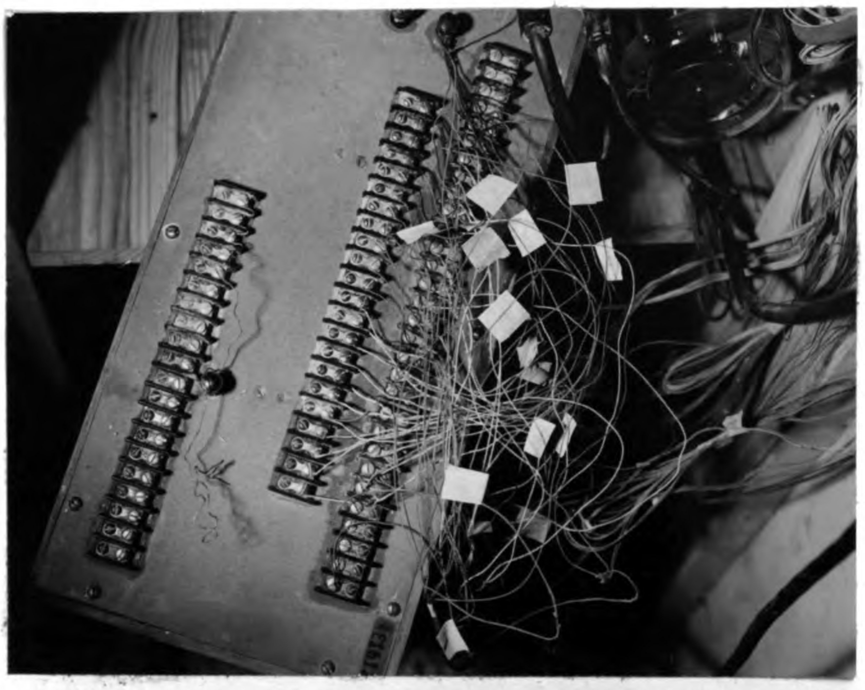


Fig. 6. Fifty-two point switching box slide off shelf for picture. Forty-six thermocouple leads were connected to box at this time.

Fig. 7. Location of switching box and time clock below potentiometer. Light-bulb to which thermocouple lead was attached appears in upper righthand corner.

This method helped greatly in the identification of the printed points on the strip chart record during the summer study.

Method for winter switching. During the winter study it was decided that it would be necessary to record only eight temperatures and thus the switching mechanism in the potentiometer was used. In order to make it easy to switch to all of the points from the switching box when desired, a special plug was used as shown in Figure 8. Eight of the sockets were used on this plug with the constantan wire coming to the potentiometer from the original position on the fifty-two point switching box. Jumper wires were used from the switching box to eight connections on the female plug which was fastened to the wall. The male plug carried these eight thermocouple leads to their connections on the potentiometer.

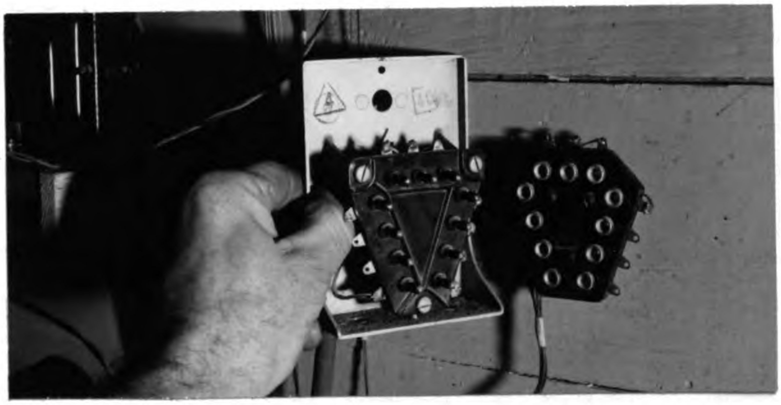


Fig. 8. This plug was used when it was desired to bypass 52 point switching box with eight thermocouples. Only eight of eleven sockets on plug were used.

The operation of this set up was as follows. When only eight points were to be recorded, the plug in Figure 8 was plugged in, the copper lead from the switching box was disconnected, and the wires from the potentiometer to the switching box which provided the electrical impulse for the switching action were disconnected. This would then result in the normal recording of only eight points. When it was desired to record more than eight points, the above procedure was reversed which then resulted in the use of the switching box.

This method worked satisfactorily until the high humidities and dust caused the switching box to give false readings during the winter study. From that point on the switching box was bypassed and only eight points were recorded.

Time Control Circuit for Brown Recording Potentiometer

At the start of the study it was decided that a temperature record taken once every hour would be sufficient. These records were to be plotted onto weekly charts which would make anything more than an hourly record extremely hard and time consuming to plot. For this hourly record to be possible then, it was necessary to construct some type of time control mechanism for the chart drive. It was necessary to build this control so that the instrument power would be left on continously while turning the chart drive on and off once every hour to record the points.

A time clock alone was first tried for this control, but it did not work satisfactorily. The clock would turn the chart drive on accurately, but trouble was experienced on turning off the circuit. The clock used was a synchronous clock with a one hour switch period which shows up well under the right side of the potentiometer in Figure 7. The switch setting dial was marked in percent of an hour during which the switch would be closed and it was only possible to set the time duration of the switch to within about one-half of one percent of an hour. This time error could have amounted to about eighteen seconds which was always accumulating. After one hour there would be a maximum surplus of eighteen seconds and after two hours a maximum surplus of thirty-six seconds. Thus, since the recorder printed one point every thirty seconds, there would be an error possibility of one reading every other hour. This made it impossible to identify the proper points with their respective hours.

Control for summer study. A solution to this problem during the summer study was found by using a switch built into the switching box in conjunction with a relay switch and the time clock. The circuit diagram for this time control switch method is shown in Figure 9. The switch, which is labeled box switch, was built into the switching box and was set in the normally closed position. It was built to open momentarily when tripped by the prong on the rotating switching arrangement in the switching box as this prong passed the last thermocouple lead. The relay switch was set in the normally open position and made contact only when the coil was energized. The time clock switch completed the circuit and was also in the normally open position across the relay switch.

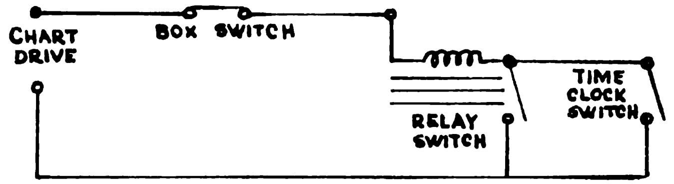



Fig. 9. Time control circuit used during summer months. Box switch and relay switch were located inside of 52 point switching box.

When it came time to record, the time clock switch would close, completing the circuit, and energizing the relay coil which in turn closed the relay switch. After several minutes, the time clock switch would open without disturbing the circuit. When the last reading was completed, the prong on the rotating switching arrangement would open the box switch momentarily, causing the relay coil to de-energize with the resulting opening of the relay switch. This permanently breaks the circuit until started again the following hour by the time clock switch.

This mechanism was positive in operation and would result in the chart drive being stopped in the exact spot every hour. Having the relay coil in series with the chart drive motor had no ill effects on it other than the fact that it ran at about seven-eighths normal speed.

During the last several days of the summer study, trouble was experienced with this circuit due to faulty action of the box switch which was a rather crude homemade switch. Thus, it was decided to find some other means to control the chart drive action during the winter phase of the study.

Control for winter study. Only eight points, the normal complement of the potentiometer, were to be recorded for the majority of the time during the winter study. Thus, it was decided that some type of internal switch was necessary so as to be an integral part of the potentiometer. It was also necessary to find a more permanent type of switch than that which was used during the summer study. The solution to these problems resulted in the construction of a new time control circuit.

The principle used was the same as before; that of turning the chart drive on and off while having the instrument power on all the time. The time clock switch used previously was retained to initiate the circuit. To turn the chart drive off after it had been started by the time clock, a Micro Switch was mounted on the potentiometer as in Figure 10. The switch had a flat follower which made contact with a cam mounted on the shaft pointed to by the arrow in Figure 11. On the eight point potentiometer two cam rises were necessary since this shaft revolved once every sixteen points. The Micro Switch was wired in the normally closed position and was opened at the end of a series of readings by the action of the cam against the follower. To prevent the stopping of the instrument during the standardization cycle, five seconds were allowed to elapse between the recording of the last point and the opening of the Micro Switch when used with the eight point potentiometer.

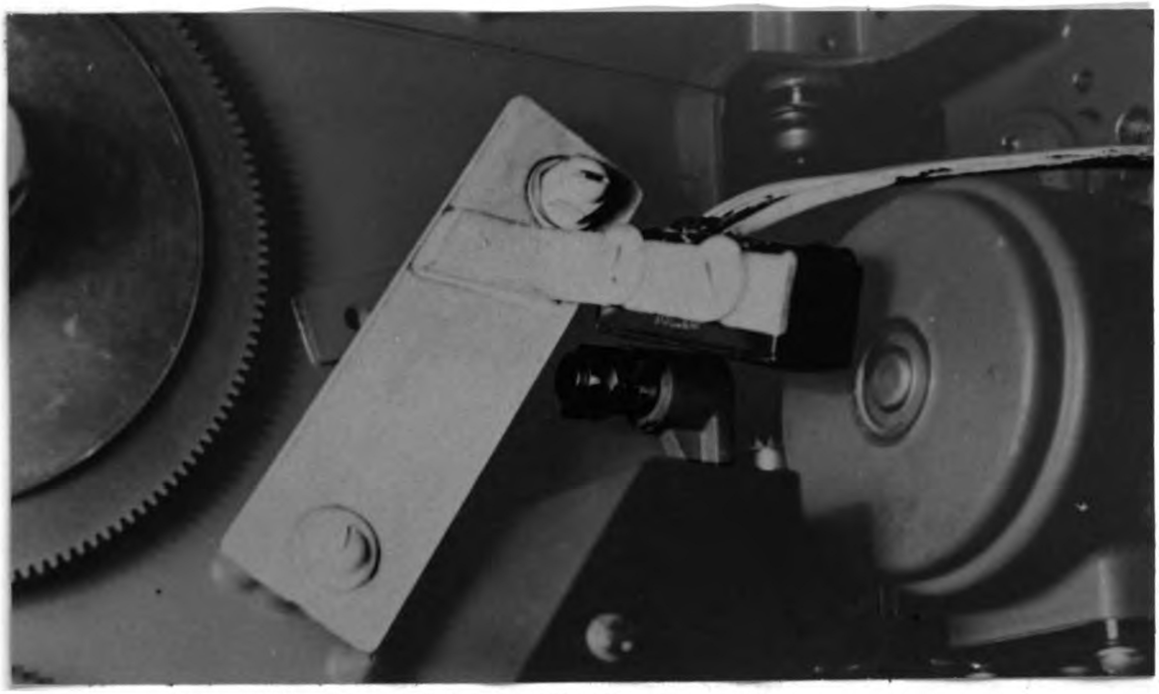


Fig. 10. Location of Micro Switch on chassis of potentiometer.

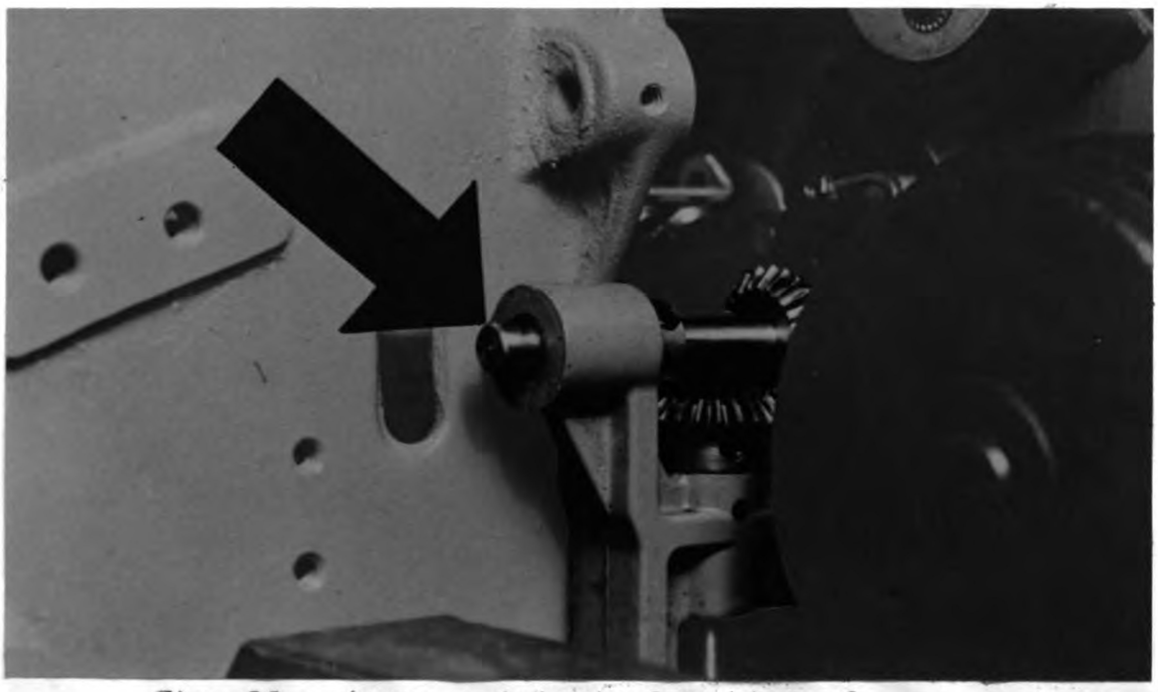


Fig. 11. Arrow points to location of shaft on which cam to operate Micro Switch was located.

Both the time clock switch and the Micro Switch were wired in parallel with the chart drive switch located on the front of the chassis. The closing of any of these three switches would thus start the chart drive action. A typical circuit sequence for the eight point potentiometer would then be as follows:

1. The chart drive switch would be set in the off position.
2. At the hour, the time clock switch would close starting the chart drive action.
3. After a short interval of time required for printing approximately two points, the cam for the Micro Switch would have turned enough to allow the follower to fall thus closing the Micro Switch.
4. Somewhere during the middle of the series the time clock switch would open, but the chart drive action would continue because the Micro Switch would be closed.
5. At the end of the eight point series the cam will raise the follower opening the Micro Switch and thus stop the chart drive action.

For every following hour, steps 2 to 5 would be repeated. When the fifty-two point switching box was used to increase the maximum possible number of temperatures recorded by the potentiometer, the set-up would be similar to that above. In this case, however, the time clock switch was left closed until the middle of the final set of eight points. When it was necessary to run the chart drive continuously, the chart drive switch on the front of the chassis was turned to the on position and the other two switches then had no effect on the circuit.

Because of the simplicity of both construction and operation of this circuit, a paper was prepared and submitted for publication in the "Journal of the American Society of Agricultural Engineers."

## Temperature Measurement

The measuring of temperatures was accomplished with thermocouples. The thermocouples used during the majority of the summer study consisted of two lines of ten thermocouples each, one line being placed in each wing. Since these lines were constructed for another project, they did not fit too well. It was possible to place eight thermocouples over the pens on the north side of the solar wing and only seven thermocouples over the pens on the east side of the regular wing. These were all located about one foot down from the ceiling. These thermocouples were considered as temporary and were replaced as soon as new lines were constructed.

Construction of thermocouples. A copy of the building plans for the piggery was obtained so that it would be possible to make the thermocouple strings fit as close as possible to the positions chosen. It was decided to place the thermocouples at pen height at the front and rear of every other pen. This took four strings of wire, one for each side of the alley of each wing. It was decided to make up each of these four strings with a common constantan wire. This would simplify construction and still give accurate results.

The method of construction used for these four strings was a unique one and greatly simplified the construction of the lines which were up to two hundred feet long. A picture of the apparatus used is shown by Figure 12. A two foot section of seven inch diameter stove pipe made up the main body of the apparatus. Wood blocks with a hole just large enough to pass a broomstick were nailed into the ends of the stovepipe and a broomstick placed through the holes in the block. Cardboard rings were cut with a seven inch inside diameter and an eight inch outside diameter. These were slipped over the stovepipe and fastened with masking tape about two inches apart to provide dividers to keep the different lengths of thermocouple wire separated. This provided the drum upon which the thermocouple wire was wound during construction. A crank handle provided a means for turning the drum.

To count the revolutions and thus measure out the wire, a counter was mounted where the crank handle would make contact with the counter arm once every revolution. Thus, it was possible to rapidly spool off onto the drum the correct amount of wire for each thermocouple in the string. The number of feet for each wire multiplied by 0.545 gave the number of turns.

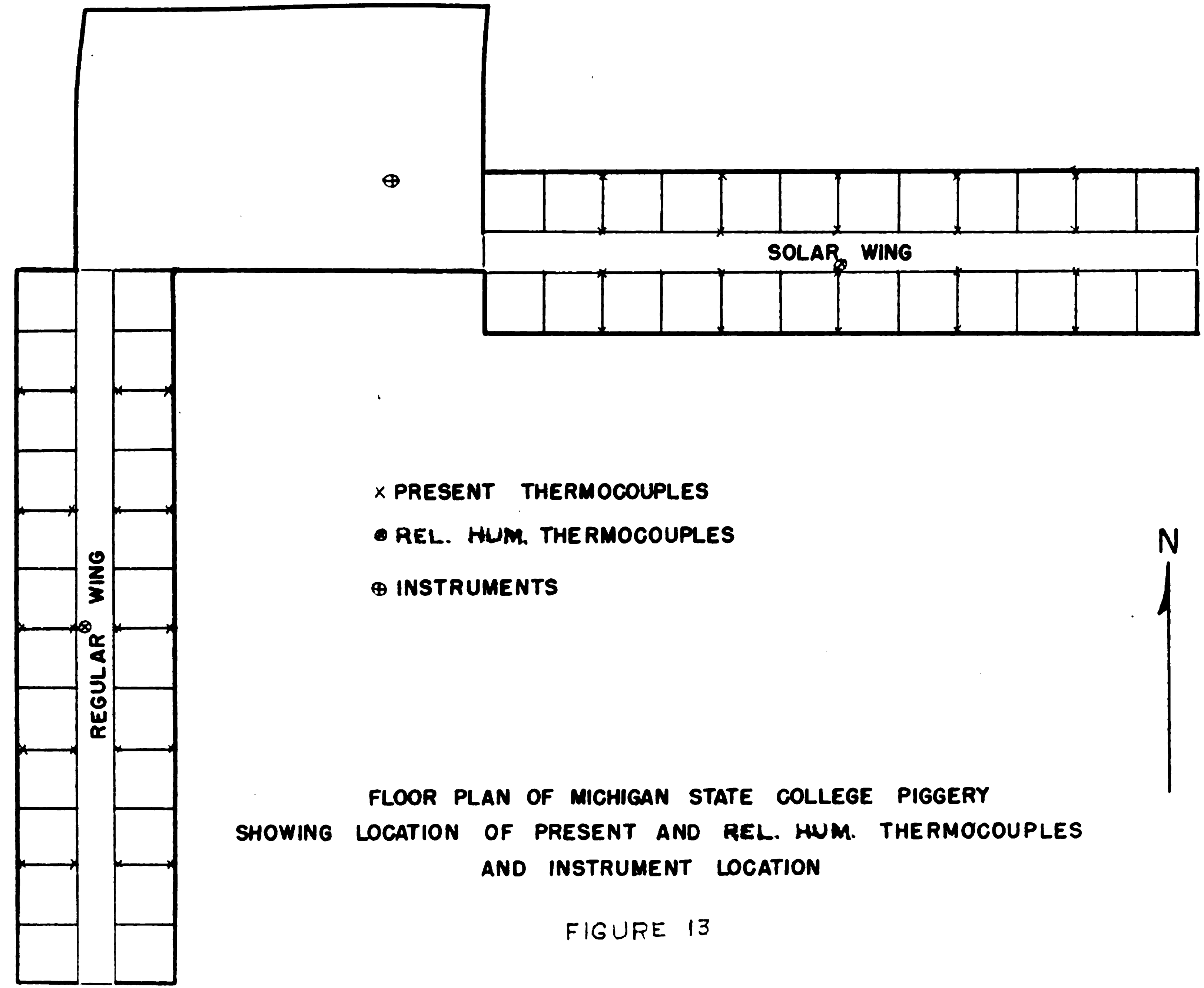
When the wires were wound back onto the smaller drum

Fig. 12. Drum with crank was used to wind up wires which made thermocouple strings. Drum revolution counter to meter out correct length of wire was located at front edge behind drum.

shown in the center background of Figure 12, they were combined into the thermocouple string. The junctions were made by scraping about three-eighths of an inch of insulation off the end of both the copper and constantan and twisting this length together. They were then dipped in hot solder to complete the junction (2-p. 1022).

Installation of thermocouples. The location of the thermocouples is shown by Figure 13. The string along the east wall of the solar wing and the string along the west wall of the regular wing were put into operation about the first of September. A shortage of wire did not allow the placing of the other two strings until November. Typical installations of the thermocouples are shown by Figures 14 and 15.

The use of a staple gun provided a fast method for stringing the thermocouple wires. For the leads which ran down the




FLOOR PLAN OF MICHIGAN STATE COLLEGE PIGGERY
SHOWING LOCATION OF PRESENT AND REL. HUM. THERMOCOUPLES
AND INSTRUMENT LOCATION

FIGURE 13

steel posts, masking tape was used to hold them in place. It was necessary to exercise some care with the use of metal staples since a break in the insulation of the wires would cause a faulty reading.

Checking of thermocouples. After the installation of all the thermocouple wires was completed they were checked in place by the use of an ice water solution in a thermos bottle. The potentiometer was set to record just one point continuously by bringing the thermocouple lead past both the switching mechanism of the potentiometer and the switching box with a jumper wire directly to the amplifying system. The thermocouple junction was then placed in the ice water solution for a period of about a minute and a half which was time enough for this thermocouple to be recorded on the strip chart two or three times. By checking this temperature recorded on the strip chart, it was possible to tell whether the thermocouple was operating correctly.

Each succeeding thermocouple lead was brought into the potentiometer one at a time by switching the jumper wire to the next lead. After moving the jumper wire each time, the proper thermocouple junction was placed in the ice water solution and the temperature recorded.

A check of the recorded data after the recording of the last point indicated that the last six thermocouples from the west side of the regular wing were giving false readings. This was corrected by loosening the staples along theline and a second check of this line showed that they had been put into good working order. Thus all forty of the thermocouples were in good working order during the winter study.

## Relative Humidity Measurement

Construction. The problem of relative humidity measurement was also solved by the use of thermocouples. A constant feed wet bulb unit was built according to plans by Henderson (15) and is shown in Figure 16. The bottle is a 250 ml Erlenmeyer flask and the glass tubing was 5 mm in diameter. This method maintained a constant level of water from which the wet bulb wick would draw. The thermocouple junction was enclosed in a glass tube which was surrounded by the wick. The upper set of thermocouple wires in Figure 16 measured the dry bulb temperature at a point about two inches to the side of the wet bulb unit. The thermocouple wires were constructed by the same method outlined earlier for the temperature recording lines.

Installation. Since it was decided to use a fan to supply air movement, it was necessary to mount the relative humidity unit where it would be out of the way. Thus, these units were hung from the girders on the righthand side of the alley of each wing. A location as close to the center of the wing as possible was chosen. In this location the instruments were undisturbed.

Controlling the wet bulb fan. An eight inch household fan (Fig. 16) was used to supply the air movement across the wet bulb units. The stands were removed and the fans hung in an up-side-down position. A system was set up whereby the fans

Fig. 14. Typical location of thermocouple junction on every other post along alley of both wings.

Fig. 15. Typical location of thermocouple junction along outside walls.

Fig. 16. Relative humidity measuring unit. Water level in large glass tube was always at same heighth because small tube in Erlenmeyer flask opens to atmosphere. Fan is eight inch household fan.

were turned on once every hour while the readings were being taken and then turned off again after the last thermocouple was recorded. This meant that the fan would not have to be run continuously.

When the time control chart drive circuit was set up for the potentiometer, it was found that whenever the chart drive switch was on, there was a 110 volt current source at terminals B and F of the chassis terminal block. Thus, it was possible to run wires from these terminals to a convenience outlet which was located on the top side of the potentiometer (Fig. 17). Whenever the chart drive mechanism was running, there was a 110 volt supply which would be turned off when the Micro Switch stopped the chart drive motor.

A six volt filament transformer (Fig. 17) was used to provide a control circuit for turning the fans on and off because of the distances involved. A relay switch (Fig. 18) was mounted near the fans and was energized by this six volt circuit. The operation of this relay switch would then turn the fans on and off with the chart drive motor. Since the potentiometer was a slow speed machine, printing one point every thirty seconds, by making the wet bulb thermocouples the last ones to record, at least three minutes of air movement would elapse before the points were recorded. This was sufficient time to give the desired results.

Checking. The thermocouples for the relative humidity measurement were checked by the same method which was described earlier for the temperature recording thermocouples.

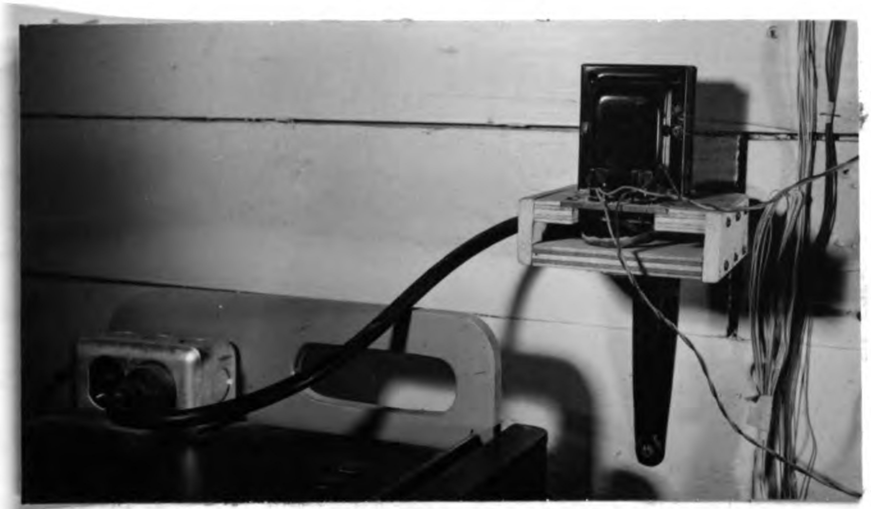


Fig. 17. Transformer connected to convenience outlet from potentiometer provides six volts to fan switch whenever chart drive operates.

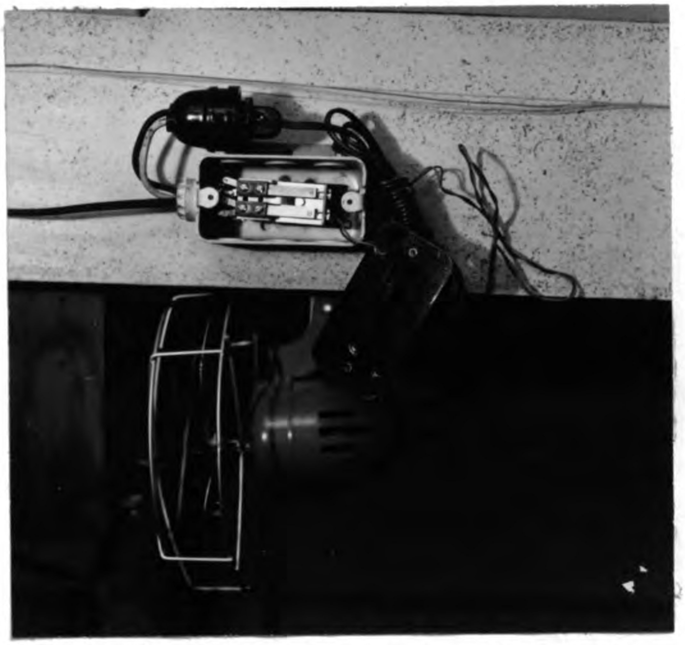


Fig. 18. Relay switch which turned fan on and off; wired as double pole switch.

The operation of the fans was checked in the laboratory before being installed. It was found that the maximum air movement which occurred close to the fan about two inches in radius from the center was six hundred feet per minute. The entire unit was checked with a sling psychrometer while the unit was in operation. The results from the wet bulb dry bulb thermocouple unit were about five percent higher than the values obtained by the use of the psychrometer and were considered sufficiently accurate for the type of data being taken.

## Recording of Heater Fan Operation

During the last weeks of the winter study, an attempt was made to record the amount of time during which the fans on the unit heaters were operating. The method used was to connect a self starting clock in parallel with the wires running to the heater fans as shown in Figure 19. It was thought that by observing the time on every day, the difference in time between the readings of the present day and the previous day would give the total time of operation. This method failed because of the impossibility of getting to the study every day to record the clock time.

Fig. 19. Clock, connected in parallel with heater fan, was used to record total hours of heater fan operation.

# PRESENTATION OF DATA AND RESULTS

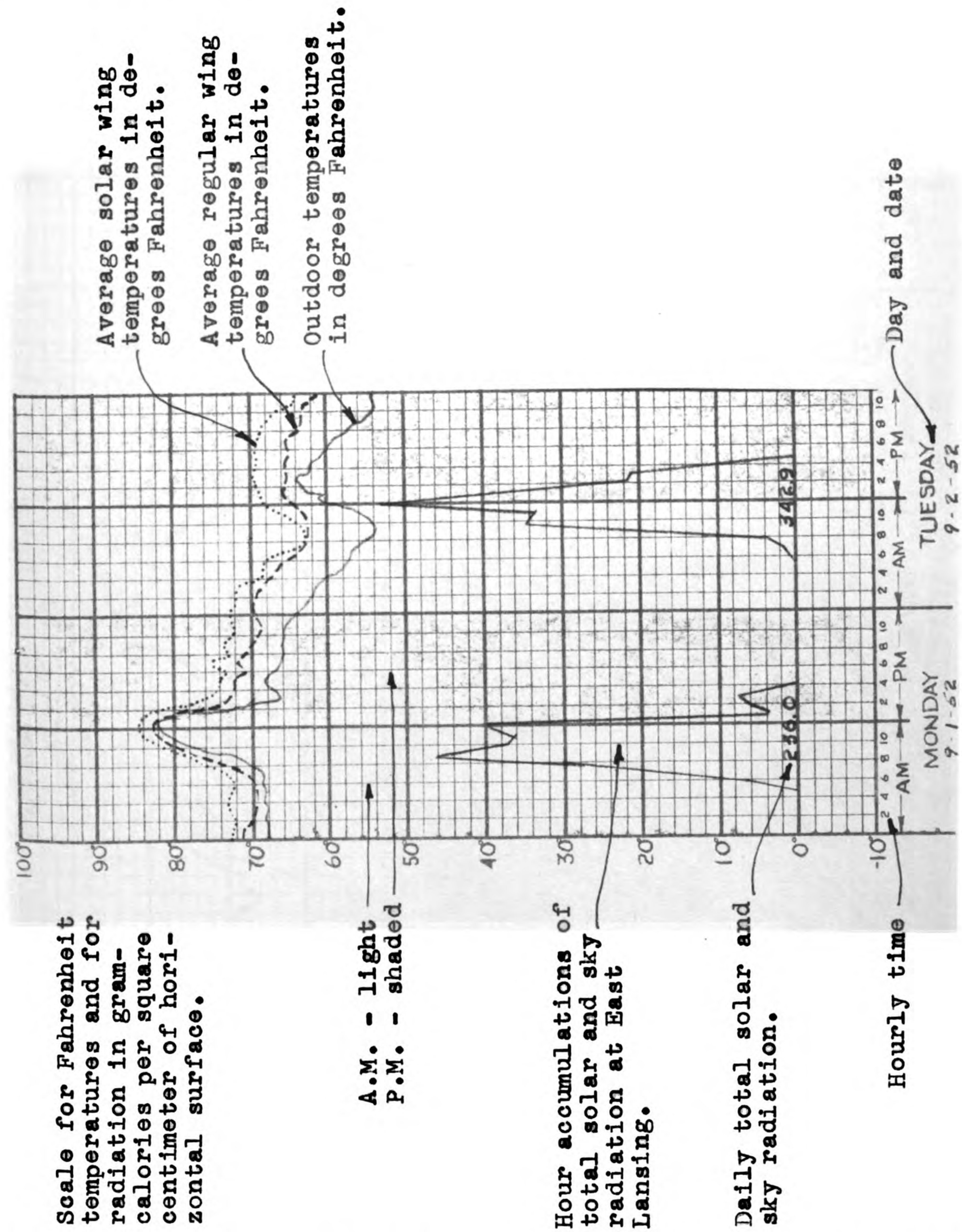
## Use of Weekly Charts

The data which were recorded on the strip chart during the summer and winter tests were transferred to charts for each week of the study. These charts (Figs. 20 and 21) were specially prepared for this study. The indoor temperatures plotted on these charts for both the summer and the winter months were average values for each wing obtained by a mathematical average of the recorded thermocouple temperatures. The outdoor temperatures for both sets of charts were transcribed from hygrothermograph data collected by the Michigan Hydrologic Research Project. A psychrometric chart was used to convert the wet bulb and dry bulb temperatures to relative humidity.

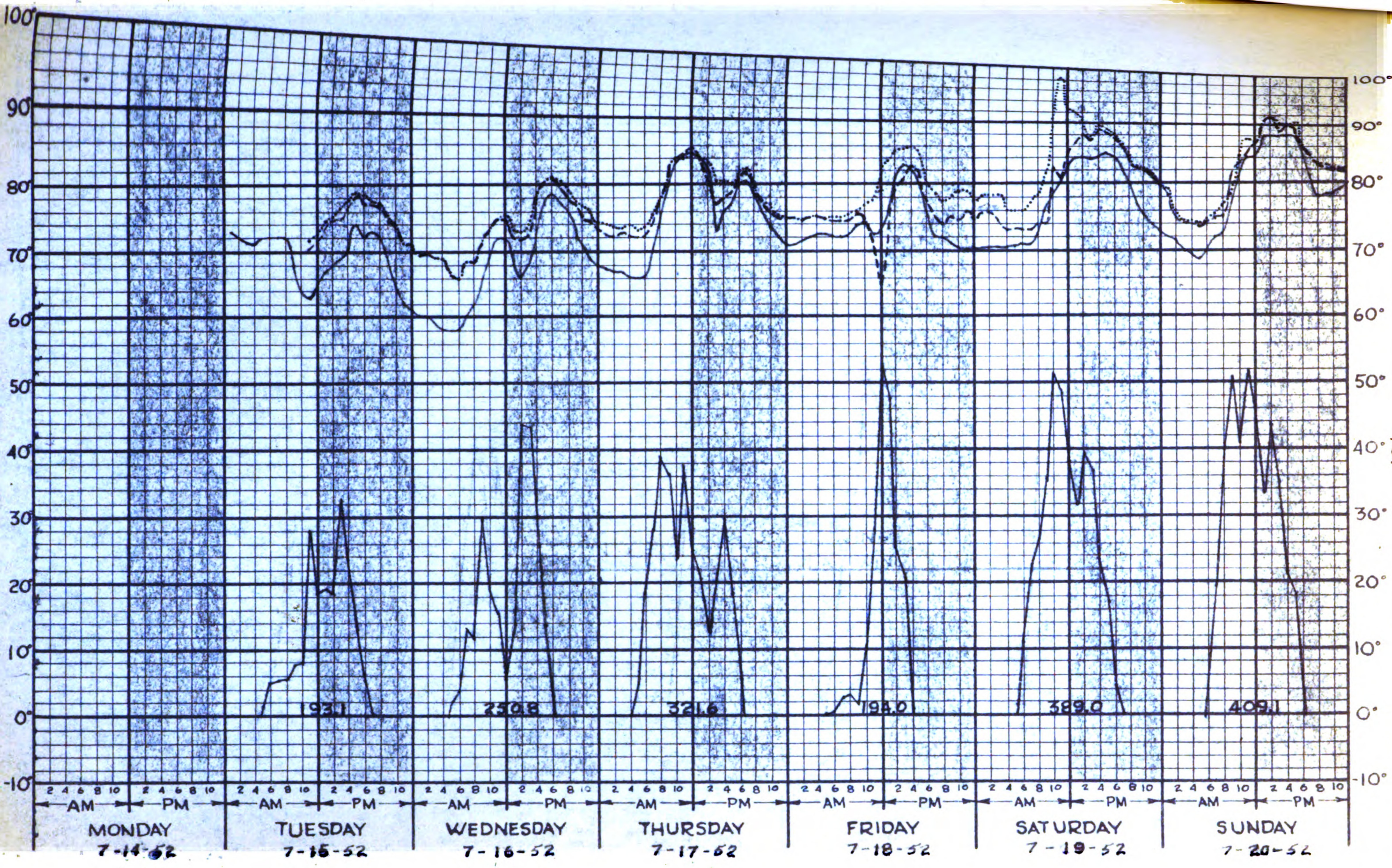
Total solar radiation was also included on these weekly charts. The values plotted were the total accumulations of solar radiation for each hour. Thus, the values for 12:00 noon would be those which were accumulated between 11:00 AM and 12:00 noon. These were plotted in units of gram-calories per square centimeter. To convert to BTU's per square foot, multiply by 3.68. The grand total for the day is shown below the curves for the day.

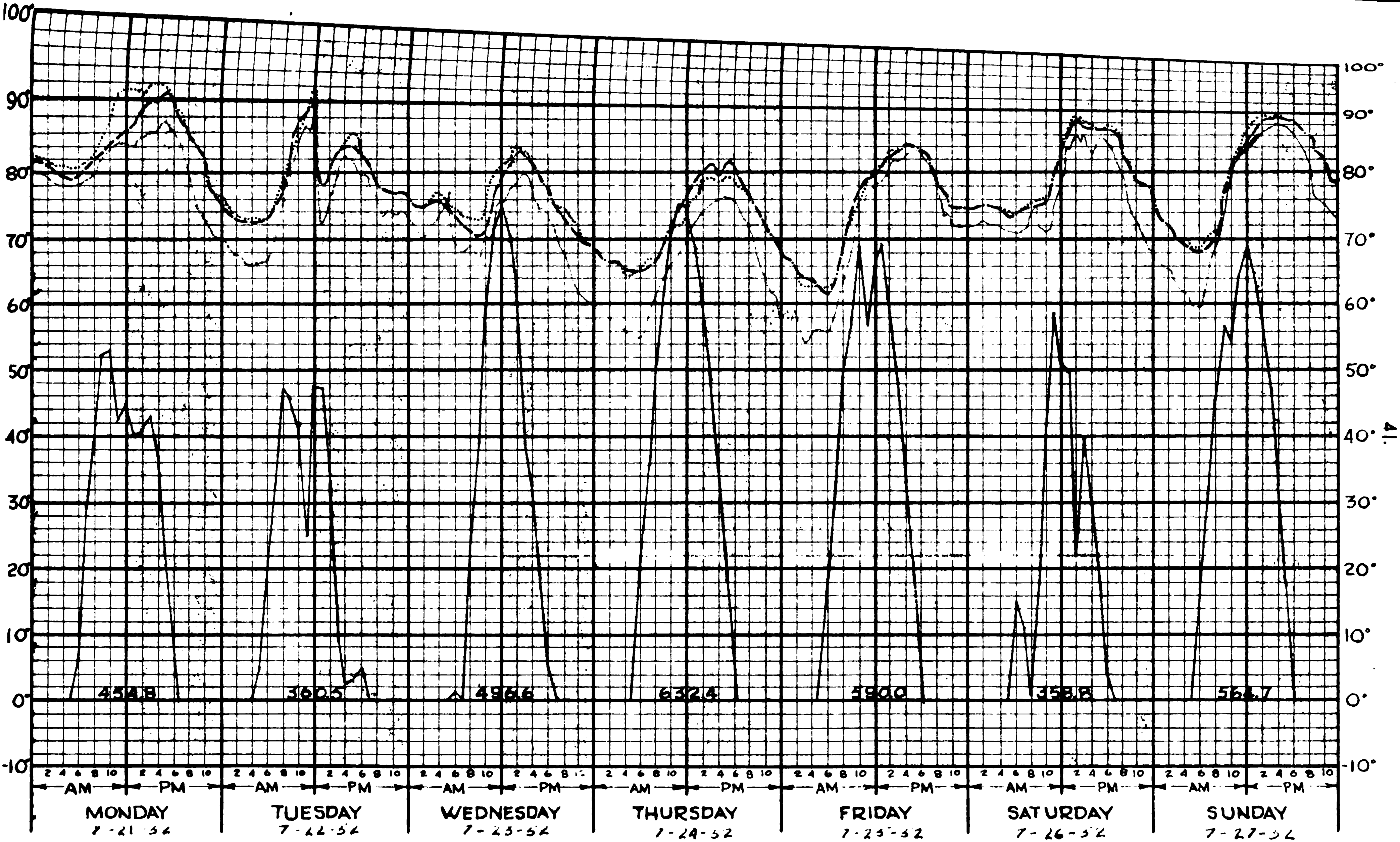
Figure 20

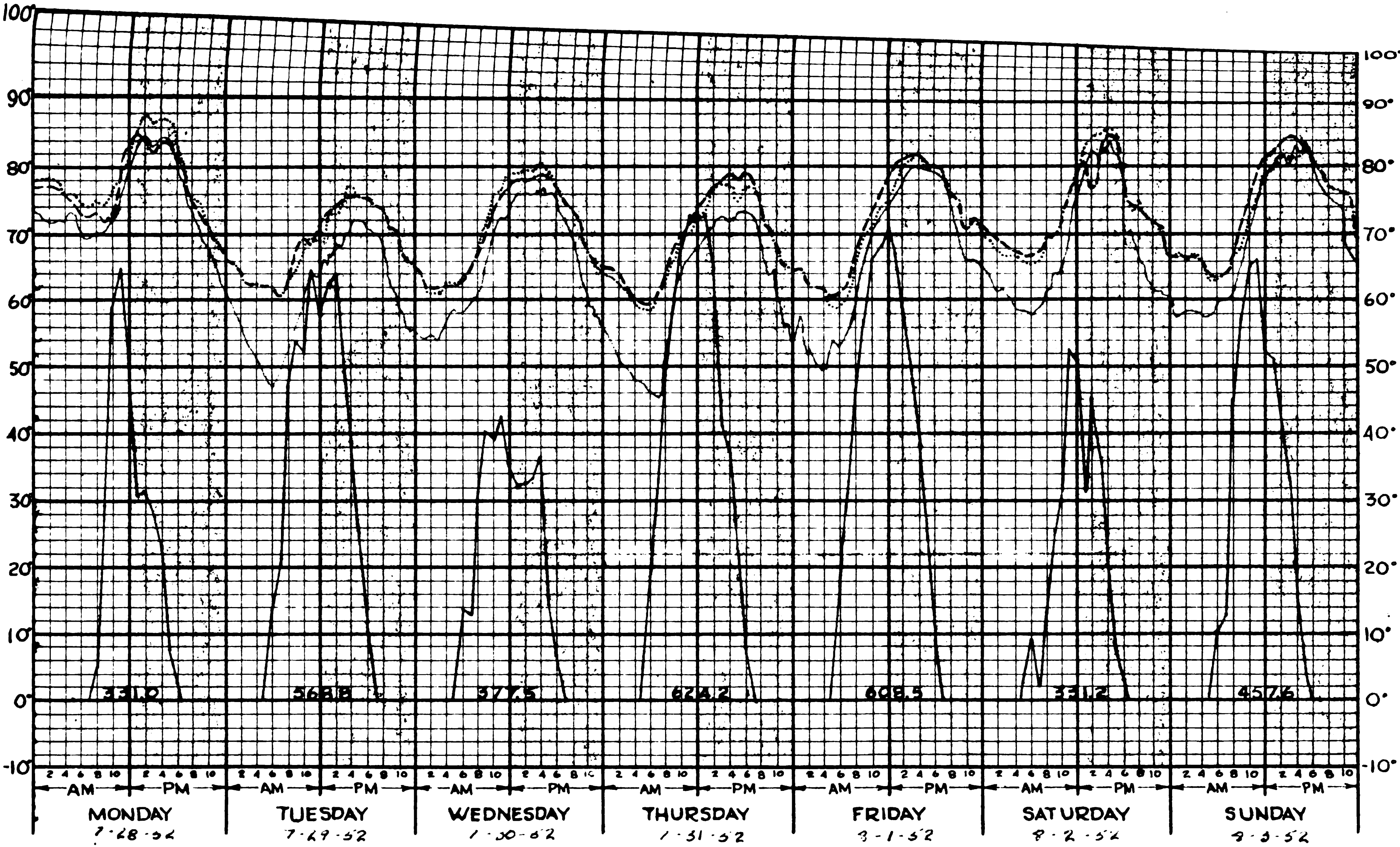
Results of summer hourly temperatures and solar radiation* plotted on weekly charts.

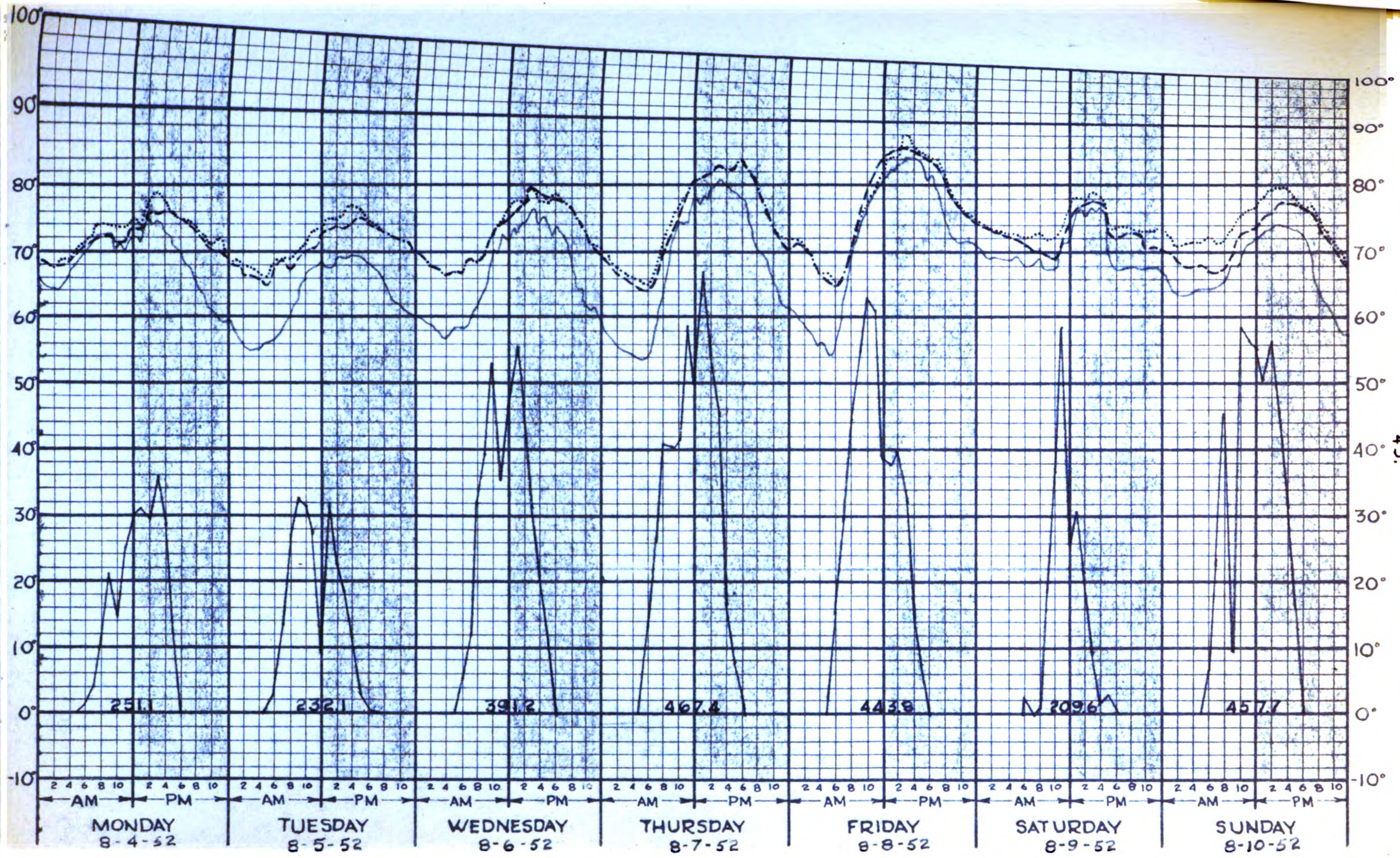



* The data necessary for the plotting of hourly and daily accumulations of solar radiation and for the plotting of outdoor temperatures came from data gathered by Michigan Hydrologic Research Project.

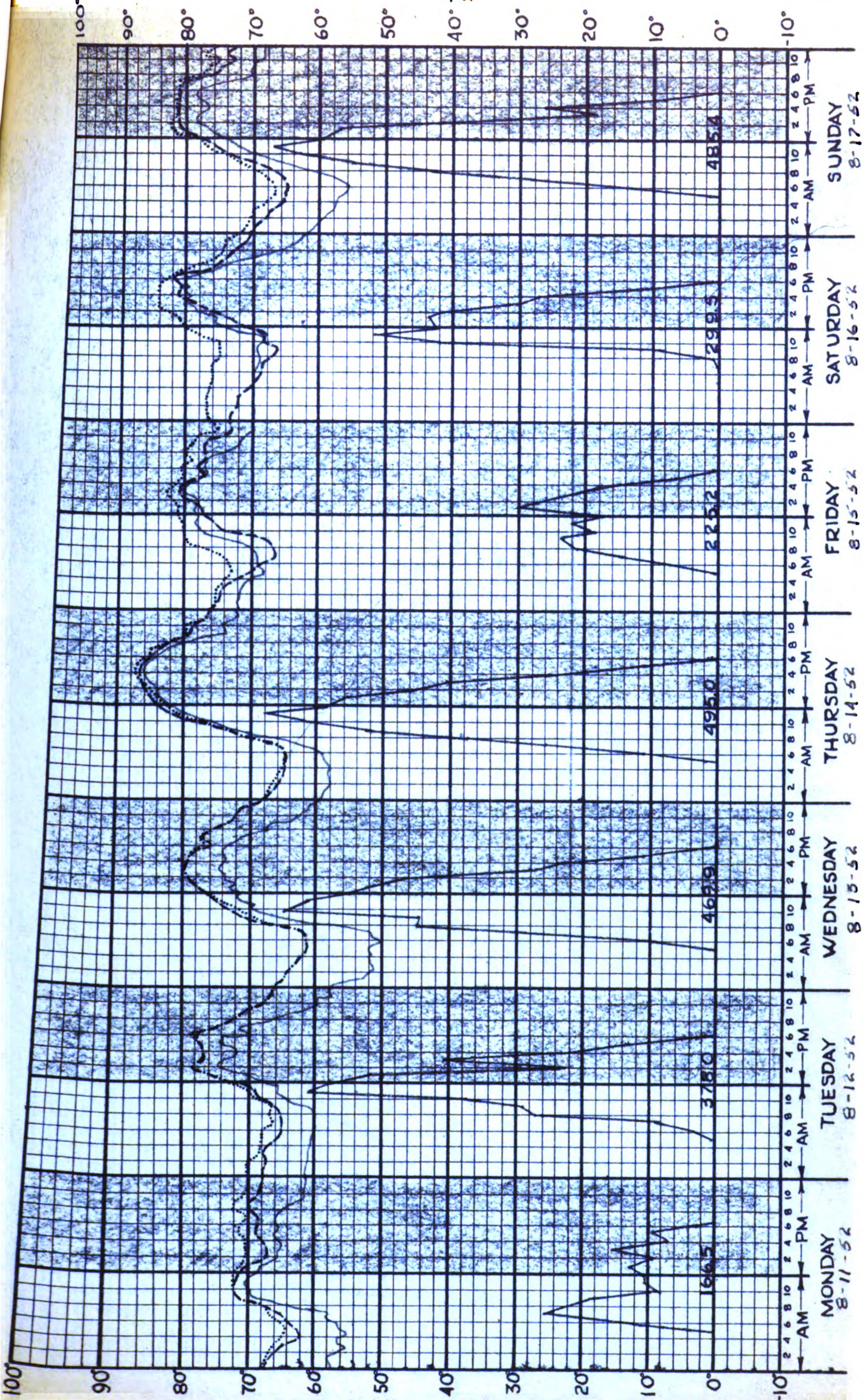

100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
193.1
250.8
321.6
194.0
389.0
409.1
AM
PM
MONDAY 7-14-52
TUESDAY 7-15-52
WEDNESDAY 7-16-52
THURSDAY 7-17-52
FRIDAY 7-18-52
SATURDAY 7-19-52
SUNDAY 7-20-52


100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
454.8
360.5
496.6
632.4
590.0
358.8
564.7
2 4 6 8 10 2 4 6 8 10
AM PM
MONDAY 7-21-52
TUESDAY 7-22-52
WEDNESDAY 7-23-52
THURSDAY 7-24-52
FRIDAY 7-25-52
SATURDAY 7-26-52
SUNDAY 7-27-52

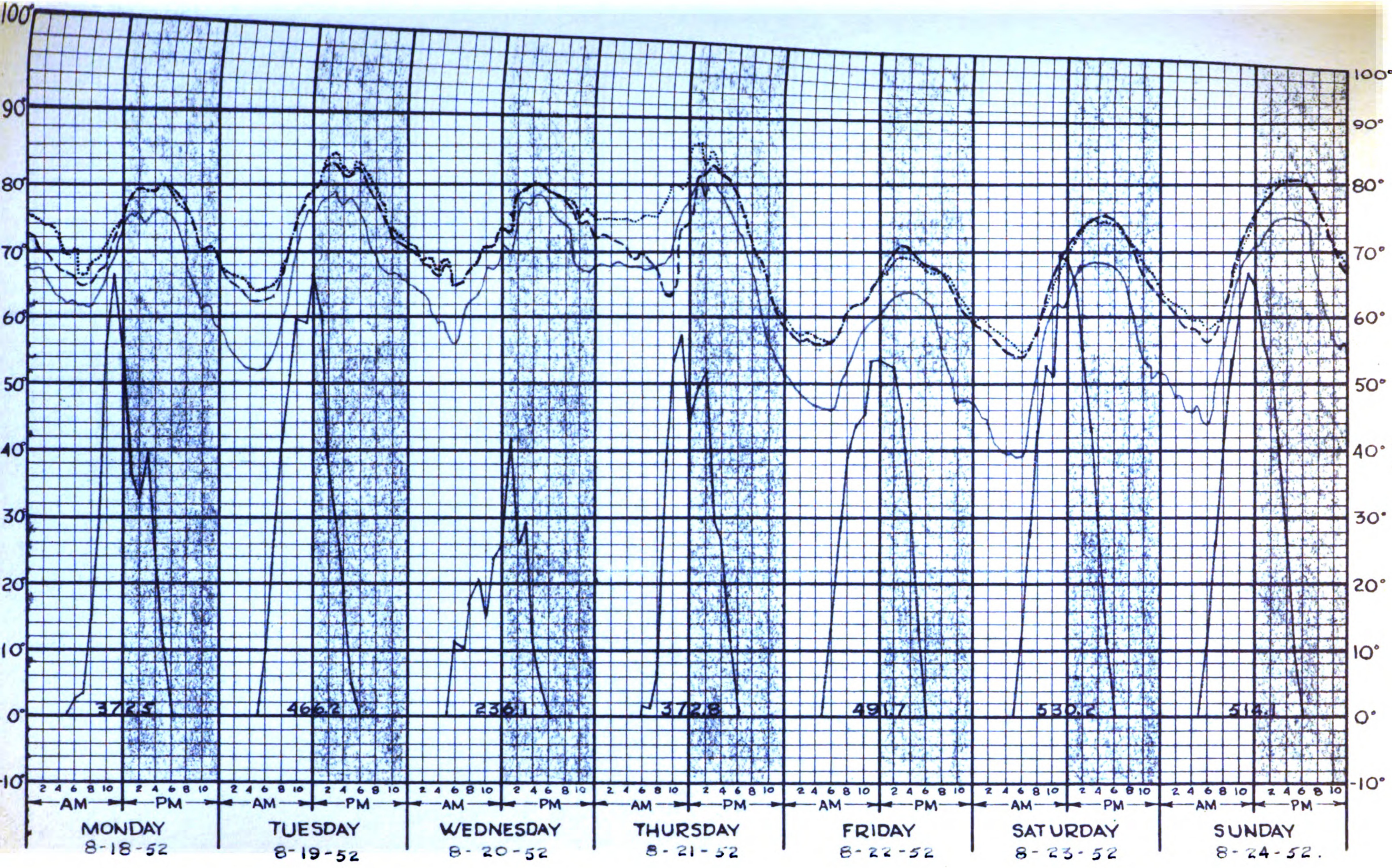

100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
331.0
568.8
377.5
624.2
608.5
331.2
457.6
2 4 6 8 10 2 4 6 8 10
AM PM
MONDAY
7-28-52
TUESDAY
7-29-52
WEDNESDAY
7-30-52
THURSDAY
7-31-52
FRIDAY
8-1-52
SATURDAY
8-2-52
SUNDAY
8-3-52

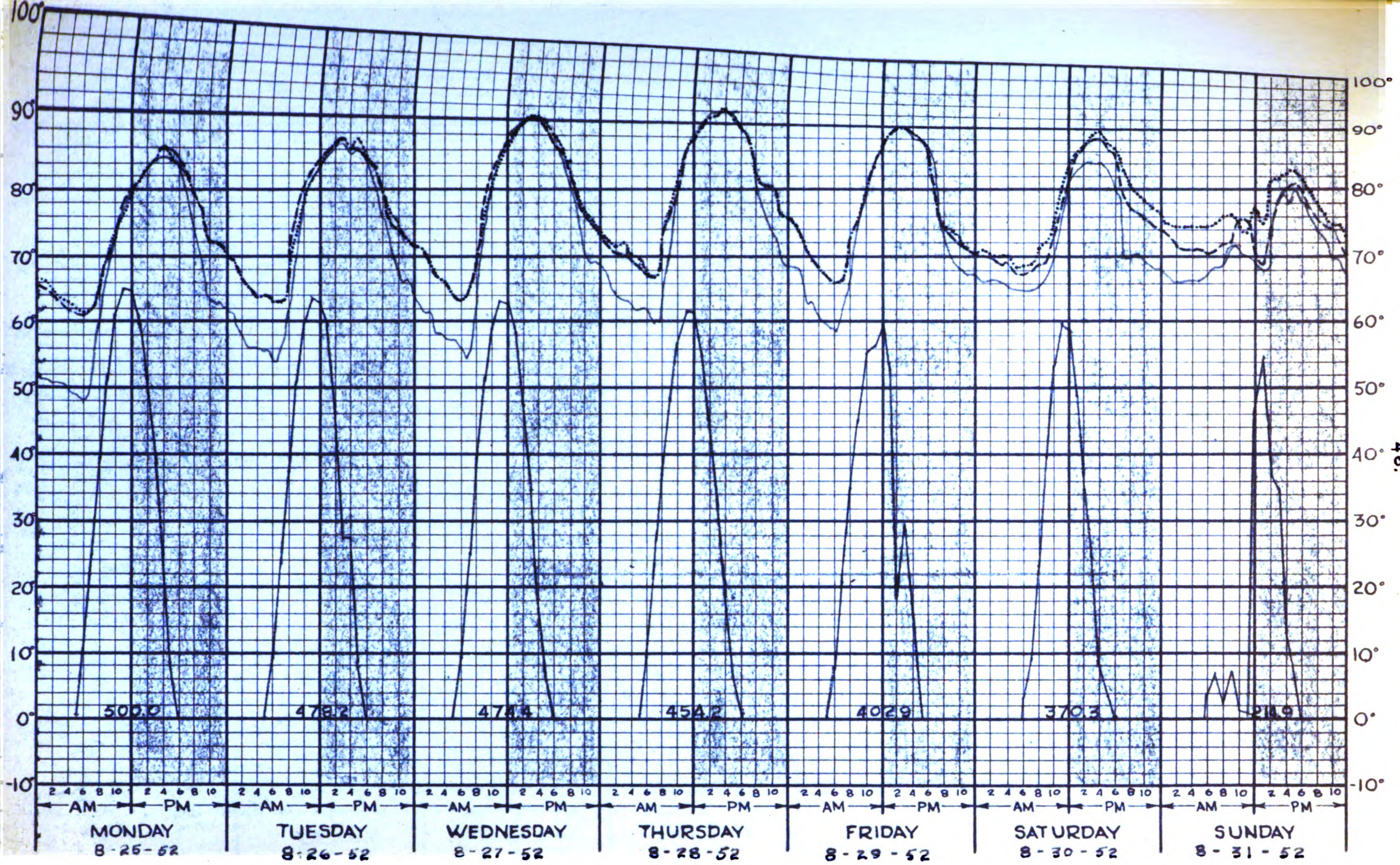


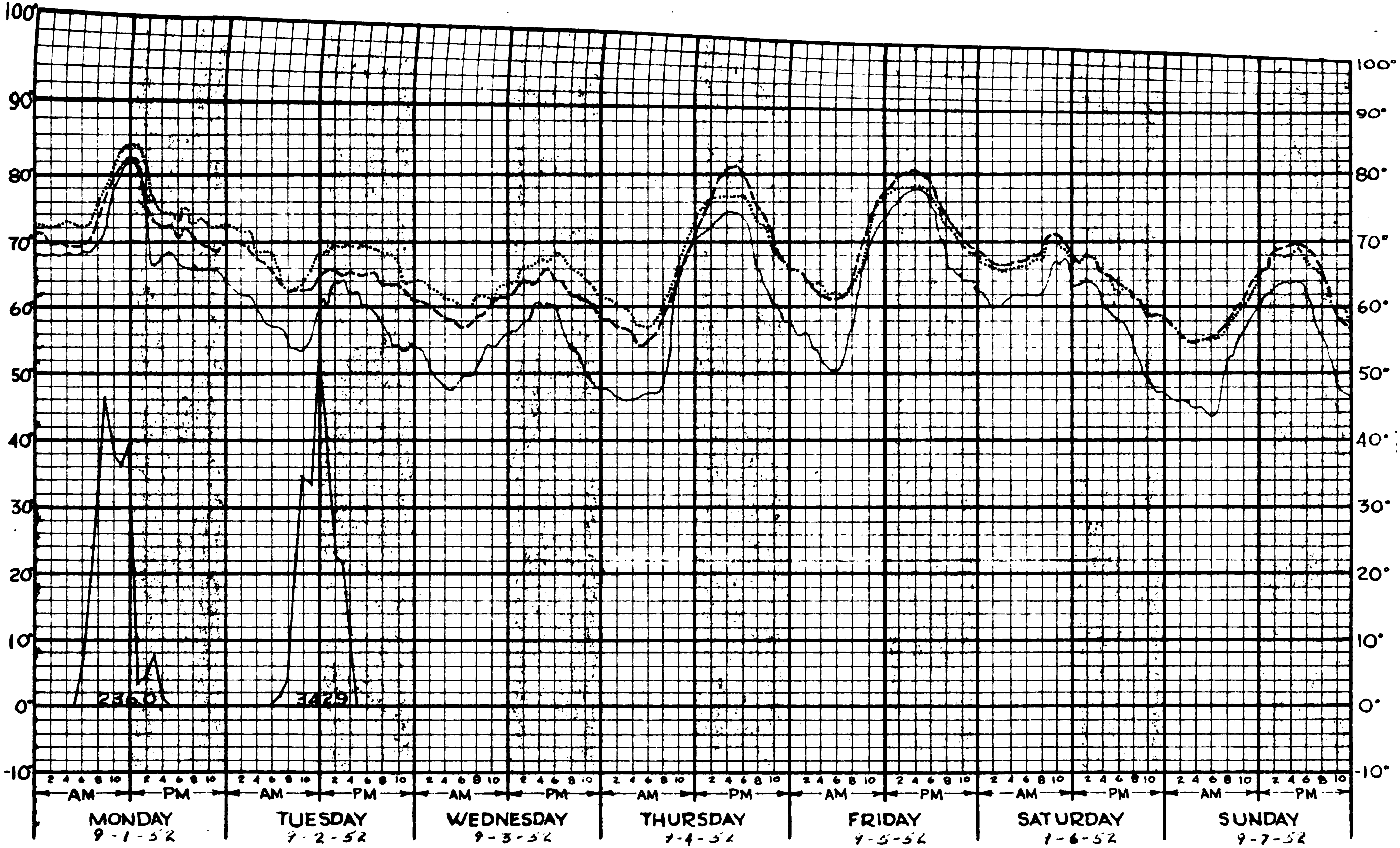
100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0° -10°
251.1
232.1
391.2
467.4
443.8
209.6
457.7
2 4 6 8 10 AM 2 4 6 8 10 PM
MONDAY 8-4-52
TUESDAY 8-5-52
WEDNESDAY 8-6-52
THURSDAY 8-7-52
FRIDAY 8-8-52
SATURDAY 8-9-52
SUNDAY 8-10-52



100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
2 4 6 8 10 AM 2 4 6 8 10 PM
MONDAY 8-11-52
1665
TUESDAY 8-12-52
3780
WEDNESDAY 8-13-52
4699
THURSDAY 8-14-52
4950
FRIDAY 8-15-52
2252
SATURDAY 8-16-52
2995
SUNDAY 8-17-52
4854


100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0° -10°
372.5
466.2
236.1
372.8
491.7
530.2
514.1
2 4 6 8 10 AM 2 4 6 8 10 PM
MONDAY 8-18-52
TUESDAY 8-19-52
WEDNESDAY 8-20-52
THURSDAY 8-21-52
FRIDAY 8-22-52
SATURDAY 8-23-52
SUNDAY 8-24-52.

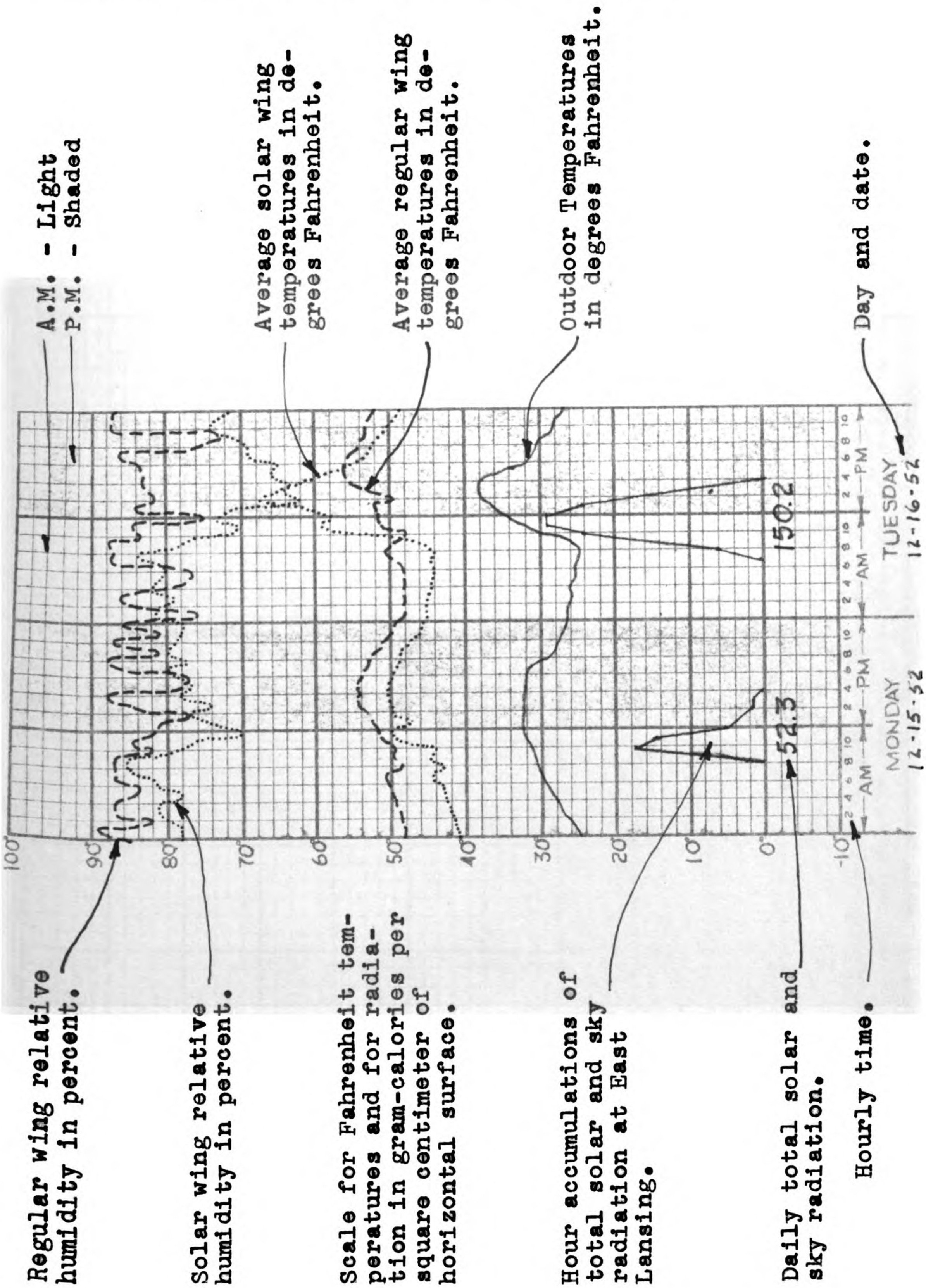

100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
500.0
478.2
474.4
454.2
402.9
370.3
218.9
2 4 6 8 10 AM 2 4 6 8 10 PM
MONDAY 8-25-52
TUESDAY 8-26-52
WEDNESDAY 8-27-52
THURSDAY 8-28-52
FRIDAY 8-29-52
SATURDAY 8-30-52
SUNDAY 8-31-52

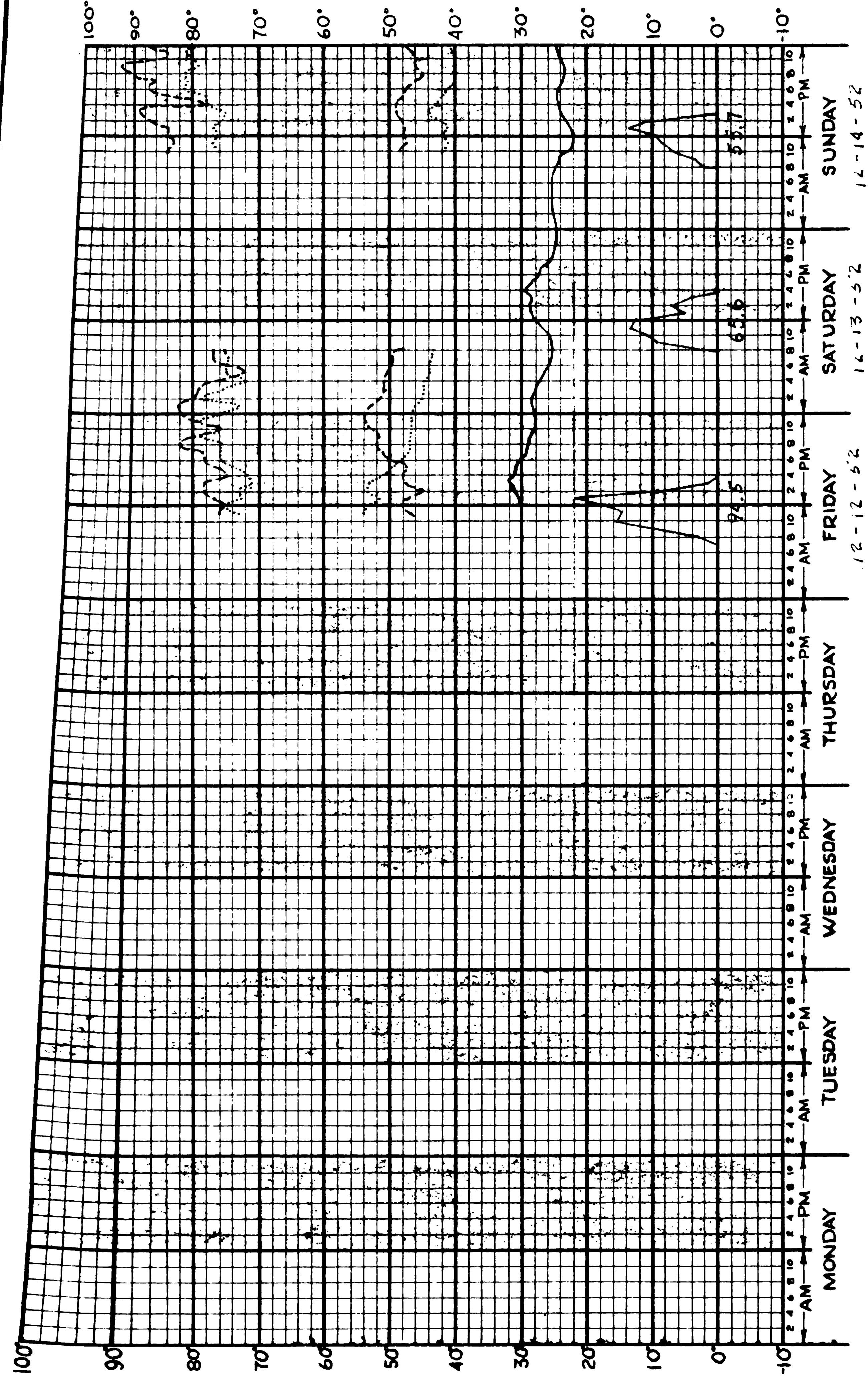

100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
2360
3429
AM
PM
MONDAY 9-1-52
TUESDAY 9-2-52
WEDNESDAY 9-3-52
THURSDAY 9-4-52
FRIDAY 9-5-52
SATURDAY 9-6-52
SUNDAY 9-7-52

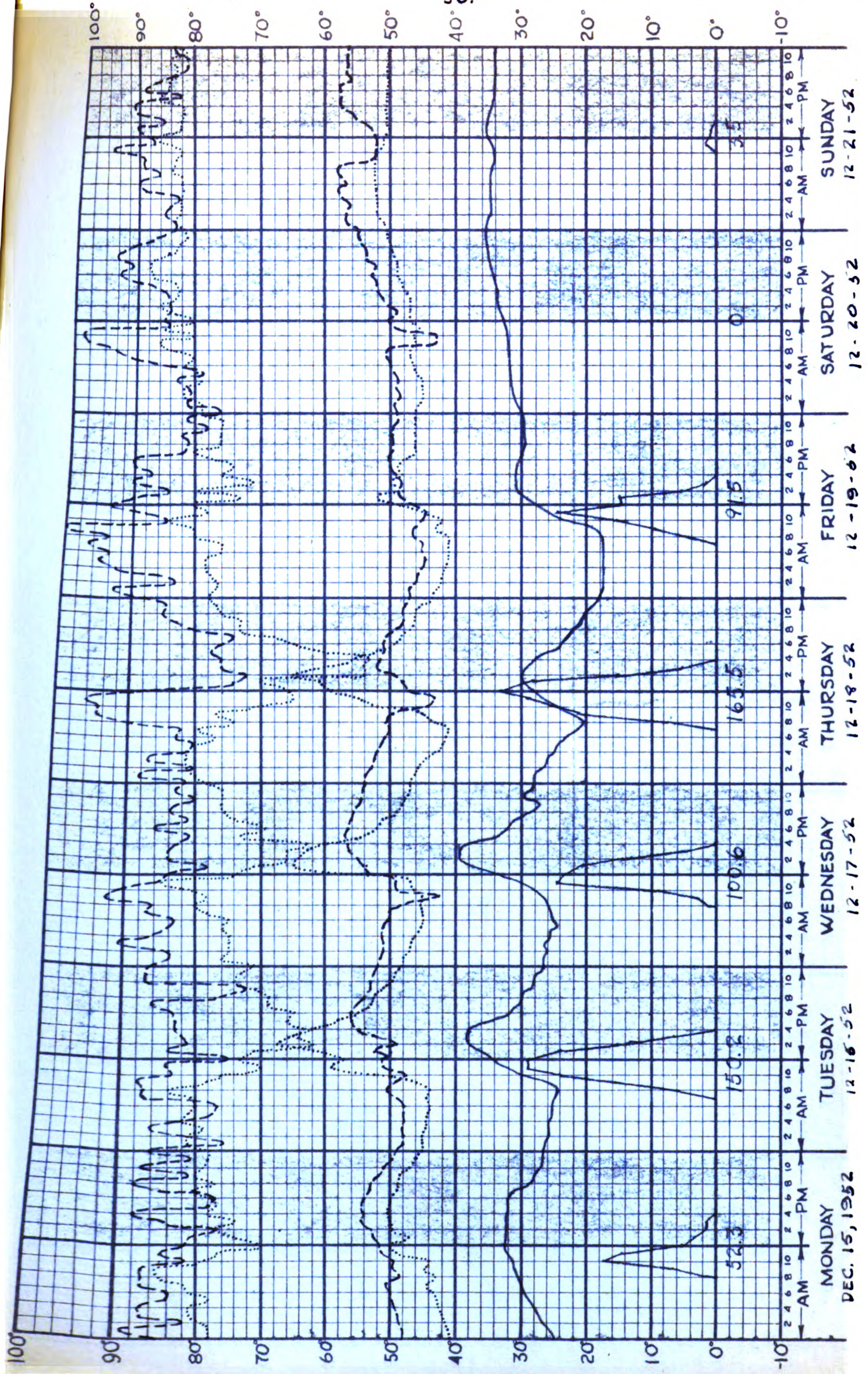
Regular wing relative humidity in percent.

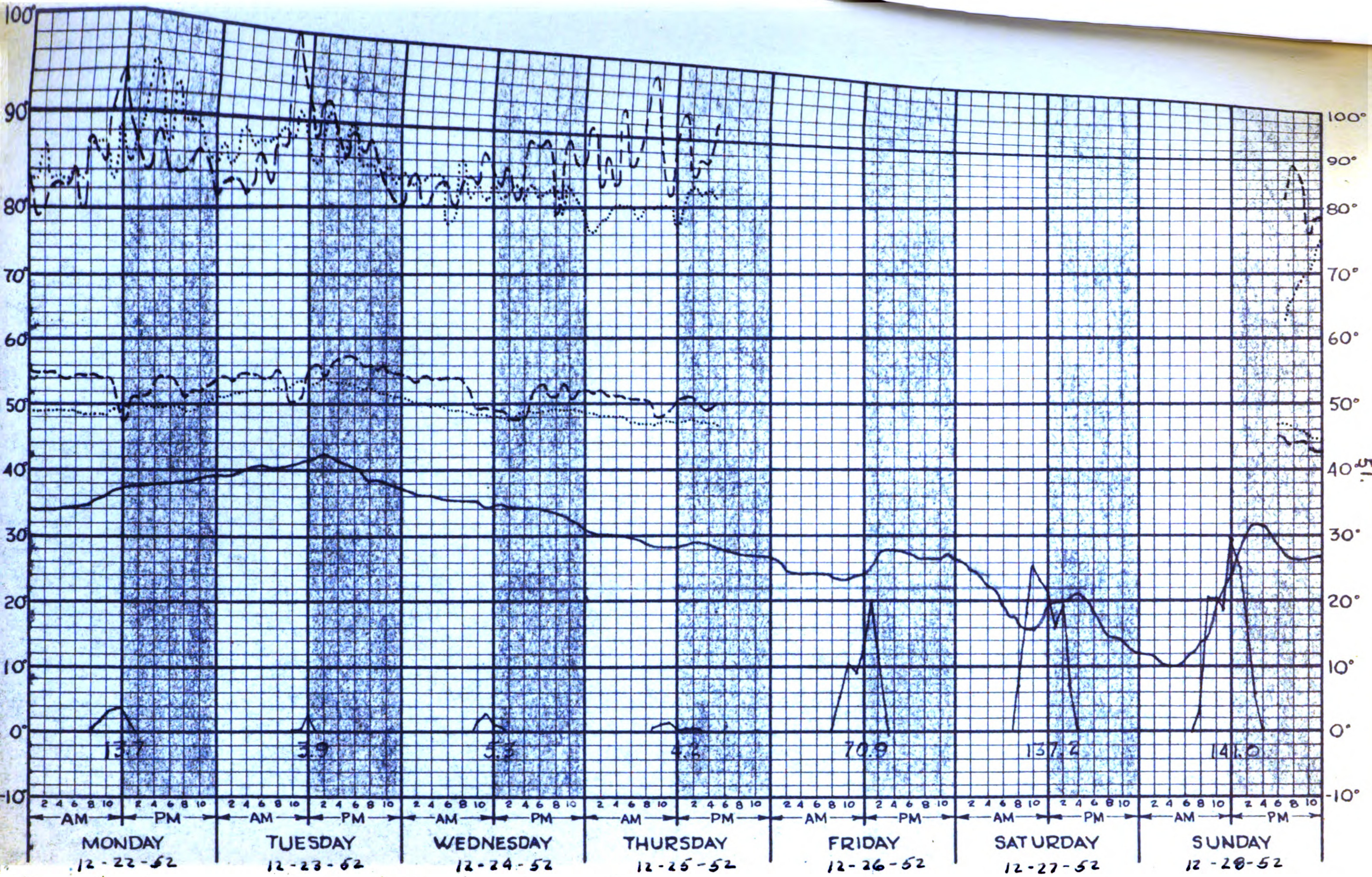
Figure 21

Results of winter hourly temperatures, relative humidities, and solar radiation plotted on weekly charts.

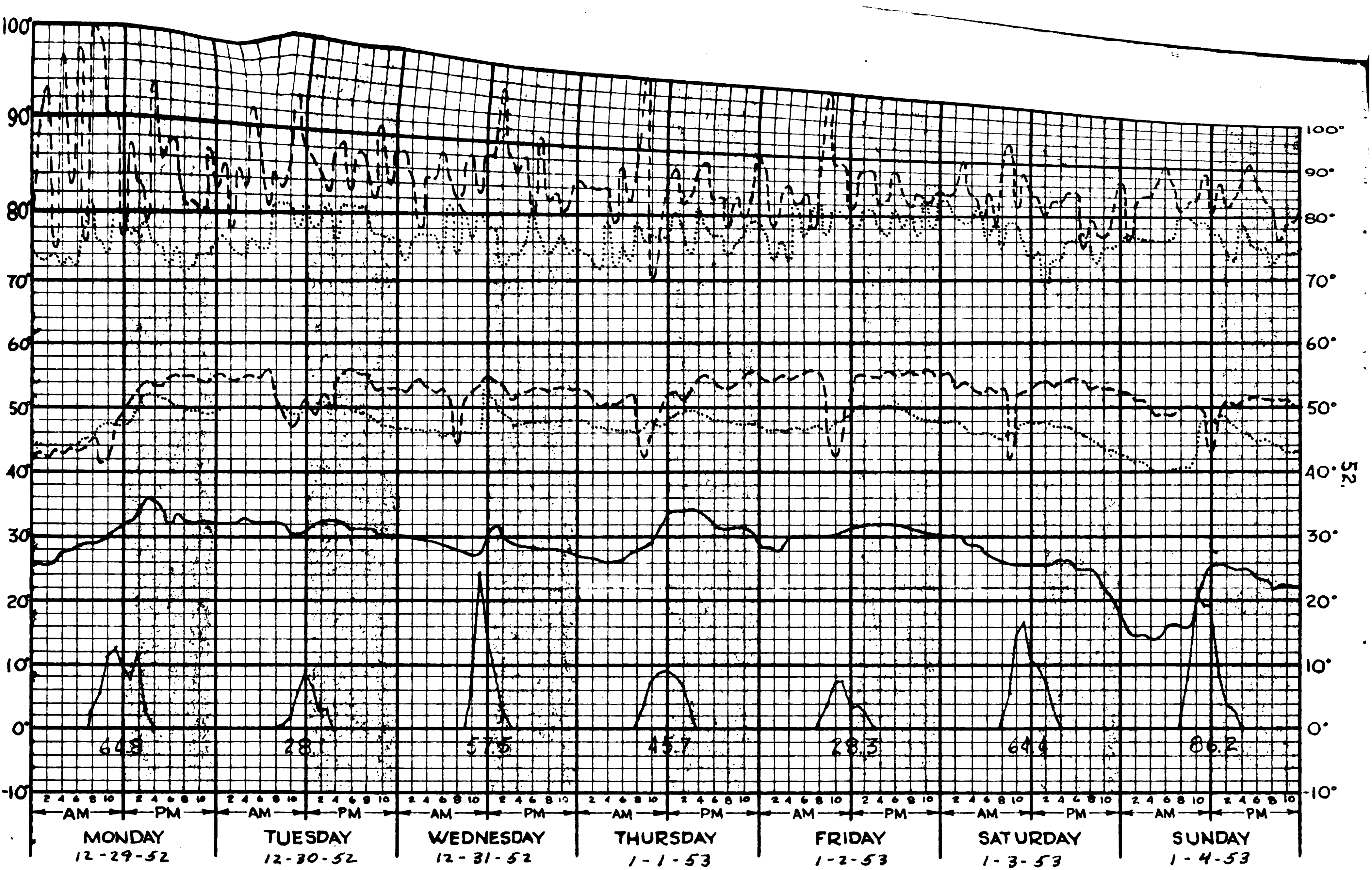


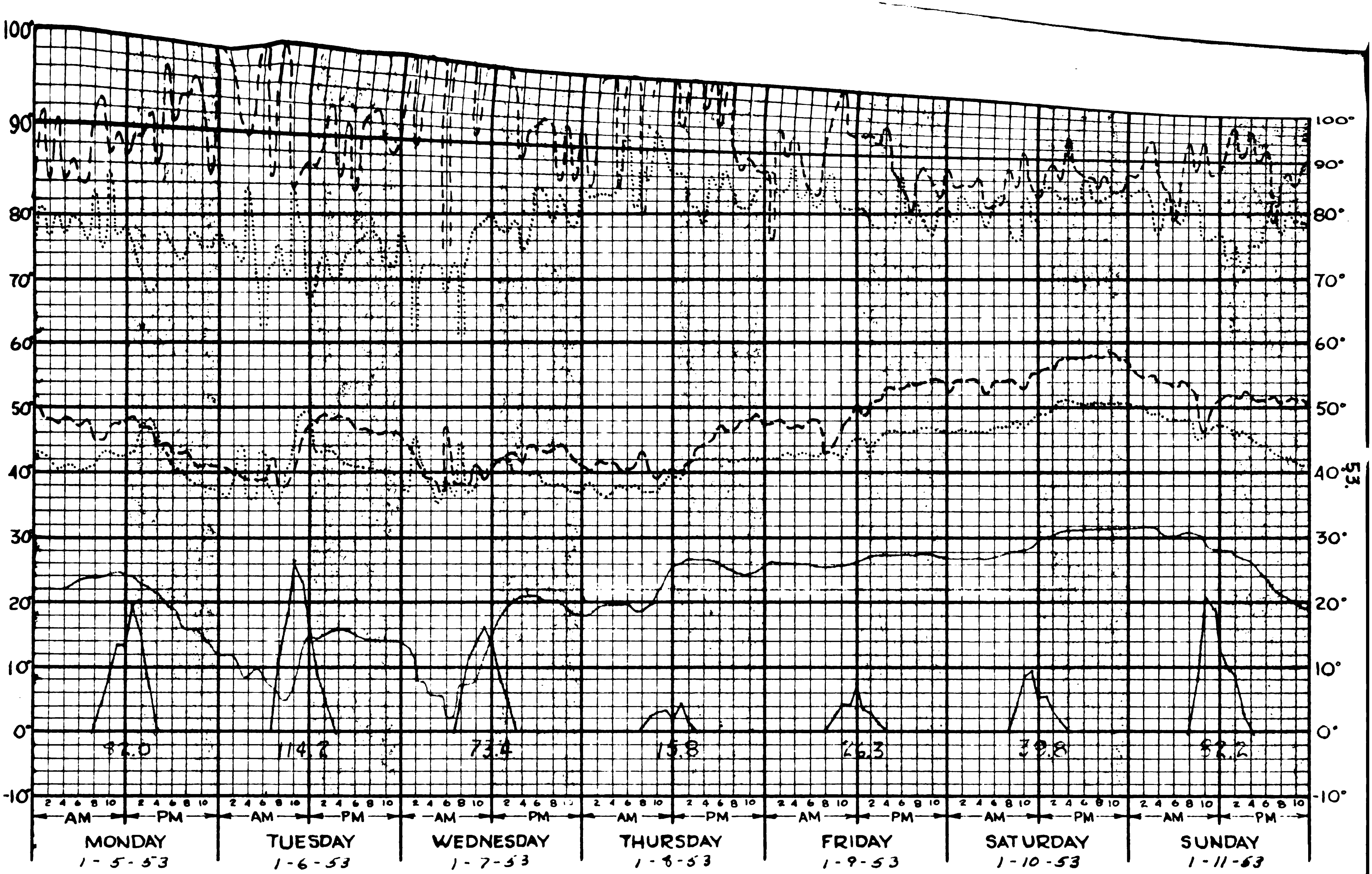

100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0° -10°
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
12-12-52
94.5
SATURDAY
12-13-52
65.6
SUNDAY
12-14-52
55.7
AM
PM
2 4 6 8 10


100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
AM
PM
MONDAY
DEC. 15, 1952
TUESDAY
12-16-52
WEDNESDAY
12-17-52
THURSDAY
12-18-52
FRIDAY
12-19-52
SATURDAY
12-20-52
SUNDAY
12-21-52
52.3
130.2
100.6
165.5
91.5
0
3.5



100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
13.7
3.9
5.5
4.2
70.9
137.2
141.0
2 4 6 8 10 AM 2 4 6 8 10 PM
MONDAY 12-22-52
TUESDAY 12-23-52
WEDNESDAY 12-24-52
THURSDAY 12-25-52
FRIDAY 12-26-52
SATURDAY 12-27-52
SUNDAY 12-28-52
51


100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
2 4 6 8 10 2 4 6 8 10
AM PM
MONDAY 12-29-52
64.8
TUESDAY 12-30-52
28.1
WEDNESDAY 12-31-52
57.5
THURSDAY 1-1-53
45.7
FRIDAY 1-2-53
28.3
SATURDAY 1-3-53
64.4
SUNDAY 1-4-53
86.2



53.
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
AM
PM
MONDAY
1-5-53
TUESDAY
1-6-53
WEDNESDAY
1-7-53
THURSDAY
1-8-53
FRIDAY
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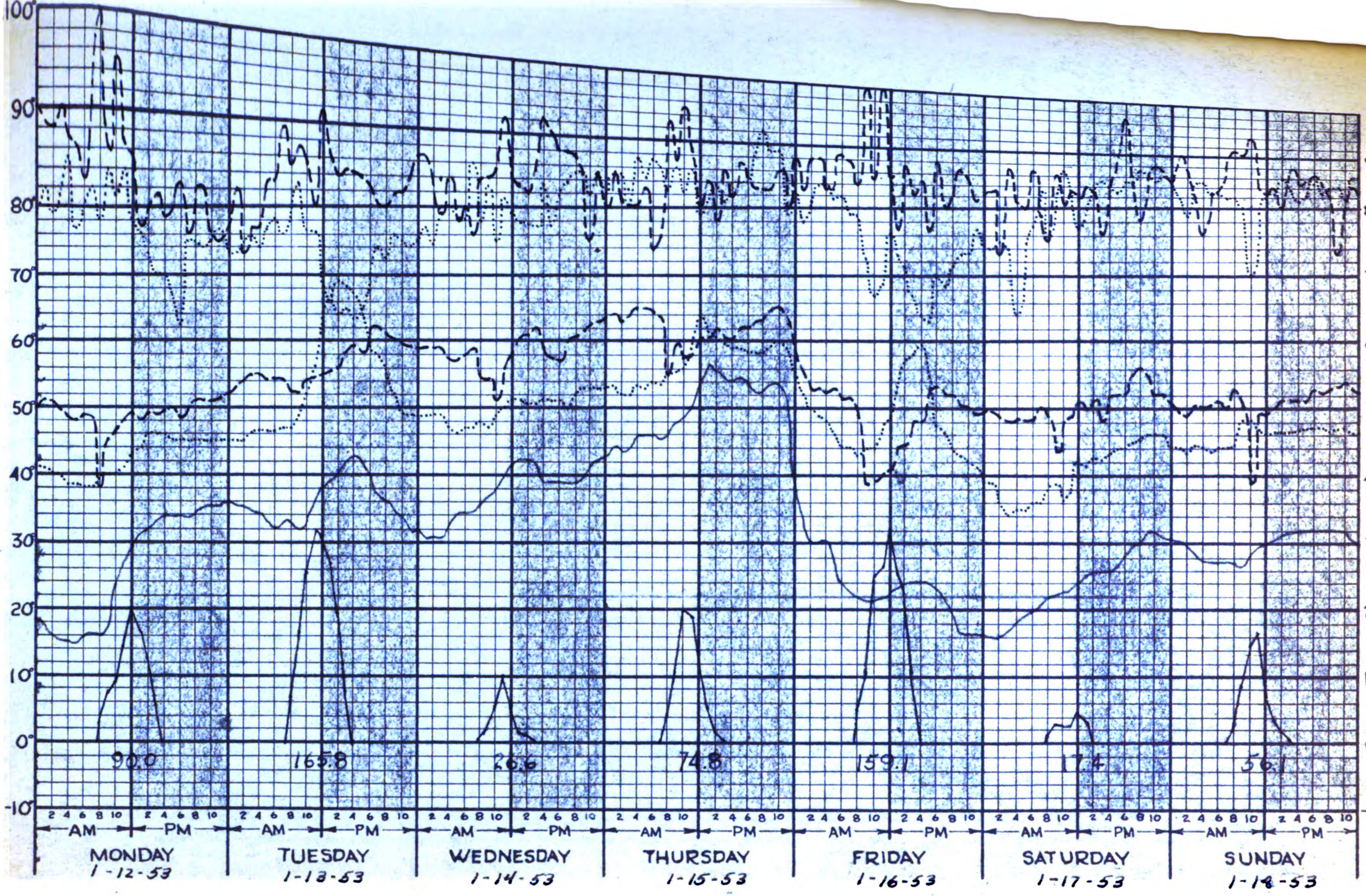
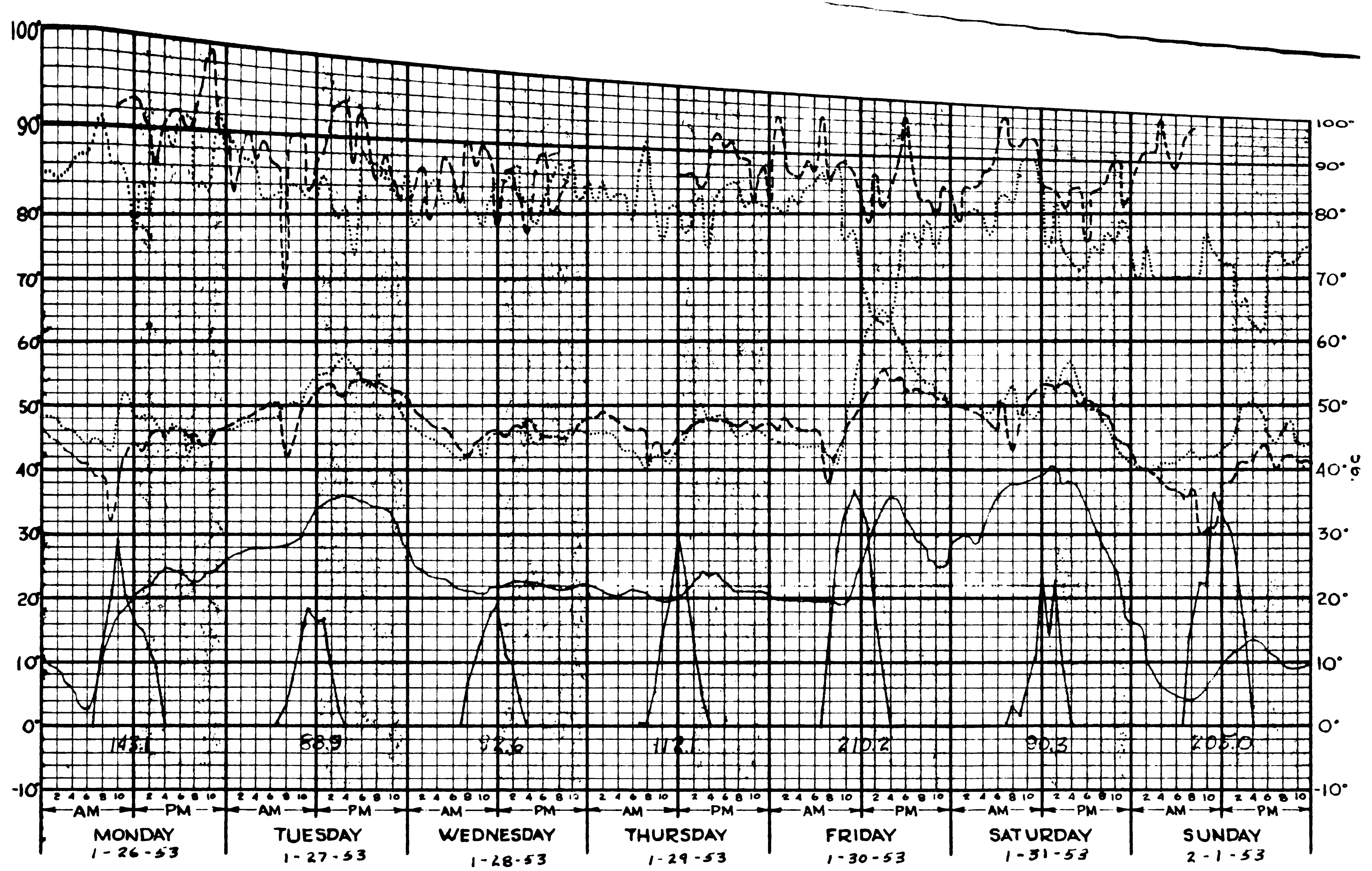
SATURDAY
1-10-53
SUNDAY
1-11-53
114.2
73.4
15.8
26.3


100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0° -10°
90.0
165.8
26.6
74.8
159.1
17.4
56.1
MONDAY 1-12-53
TUESDAY 1-13-53
WEDNESDAY 1-14-53
THURSDAY 1-15-53
FRIDAY 1-16-53
SATURDAY 1-17-53
SUNDAY 1-18-53
AM
PM

100
90
80
70
60
50
40
30
20
10
0
-10
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
28.4
125.4
164.1
34.6
16.2
56.6
128.7
AM
PM
MONDAY 1-19-53
TUESDAY 1-20-53
WEDNESDAY 1-21-53
THURSDAY 1-22-53
FRIDAY 1-23-53
SATURDAY 1-24-53
SUNDAY 1-25-53


100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
143.1
88.9
92.6
112.1
210.2
90.3
205.0
AM
PM
MONDAY
1-26-53
TUESDAY
1-27-53
WEDNESDAY
1-28-53
THURSDAY
1-29-53
FRIDAY
1-30-53
SATURDAY
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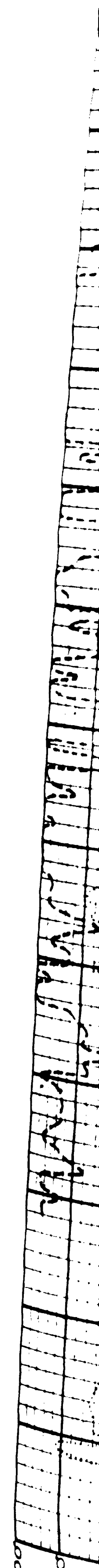
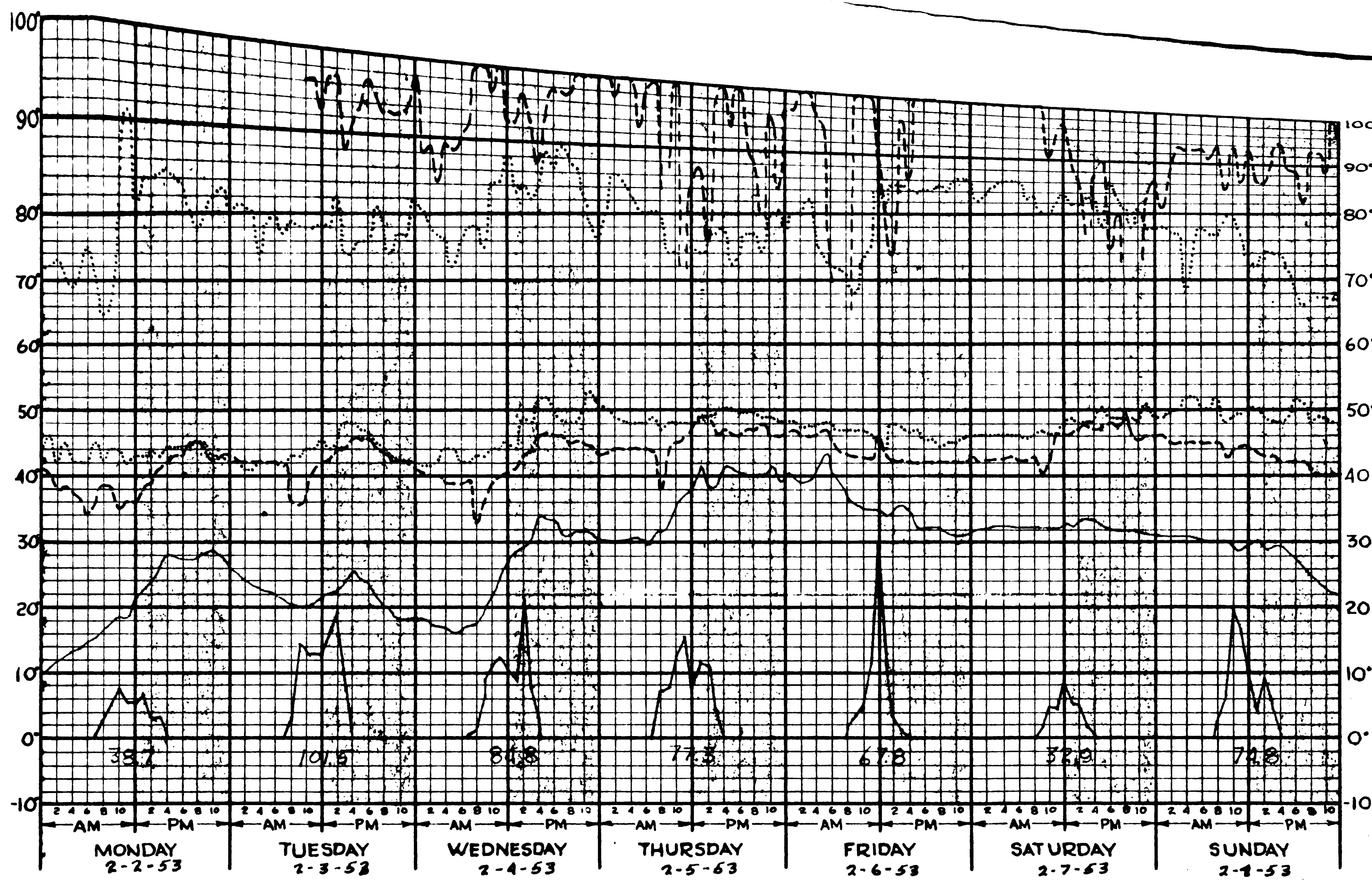
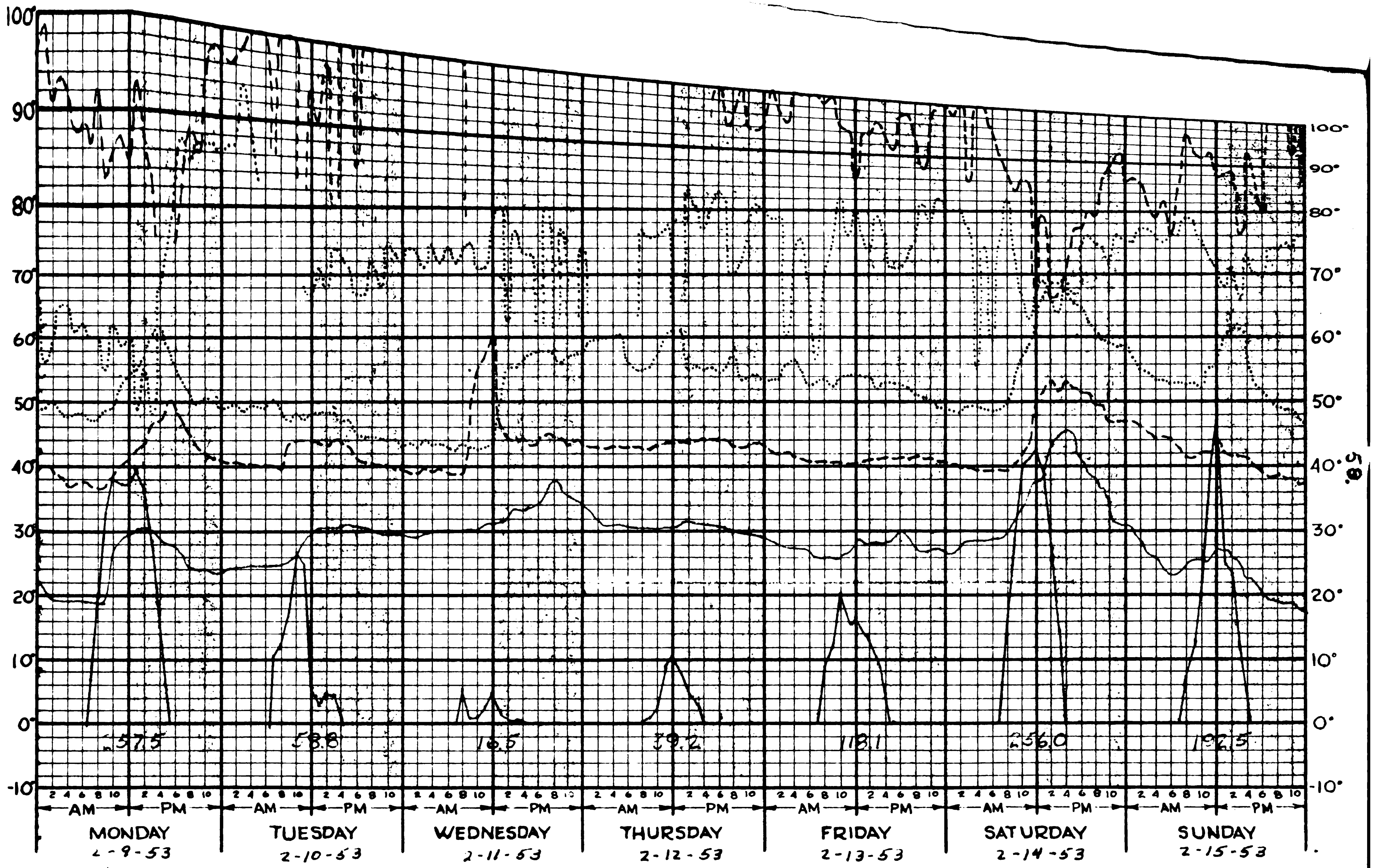
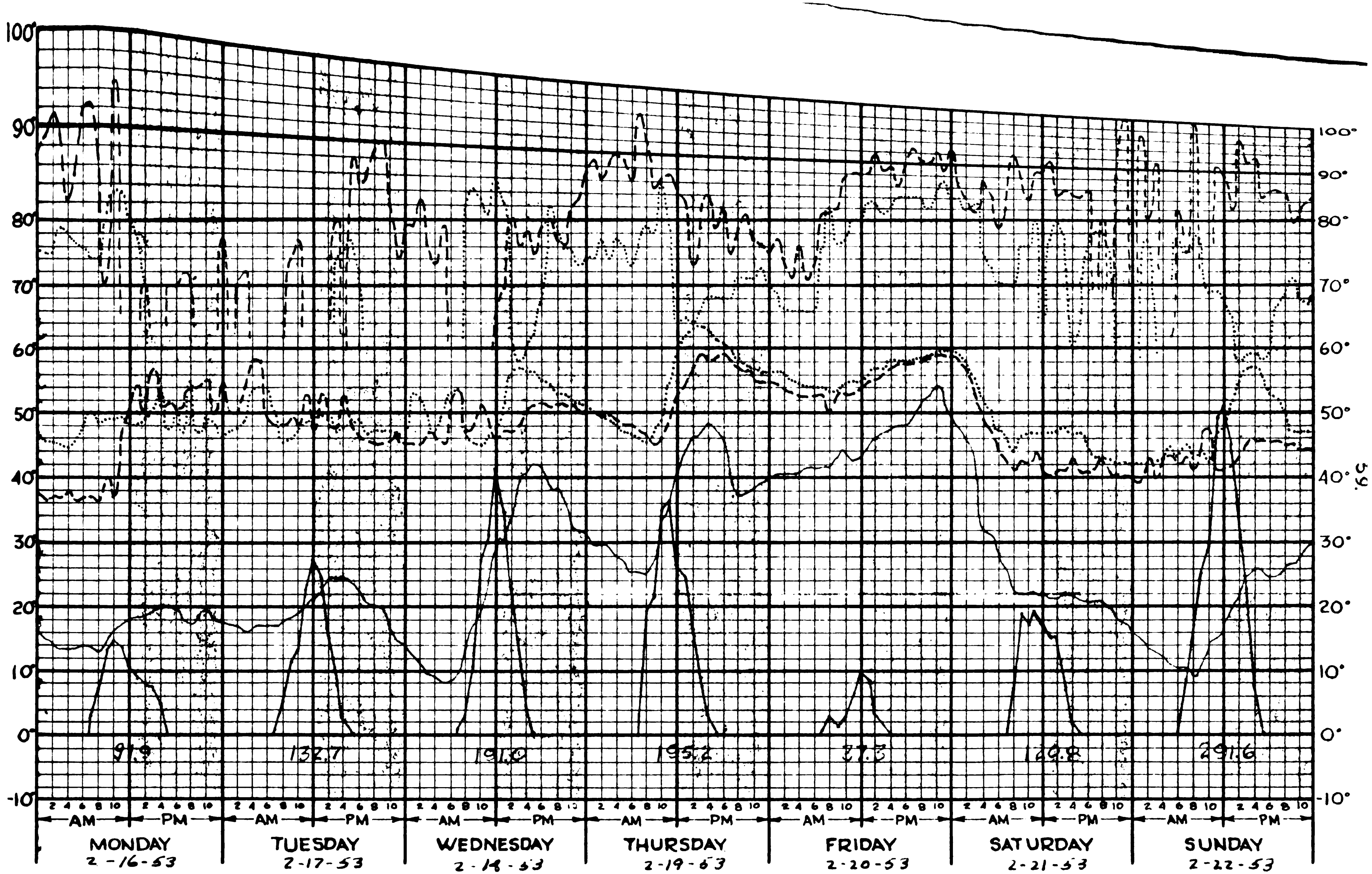
SUNDAY
2-1-53

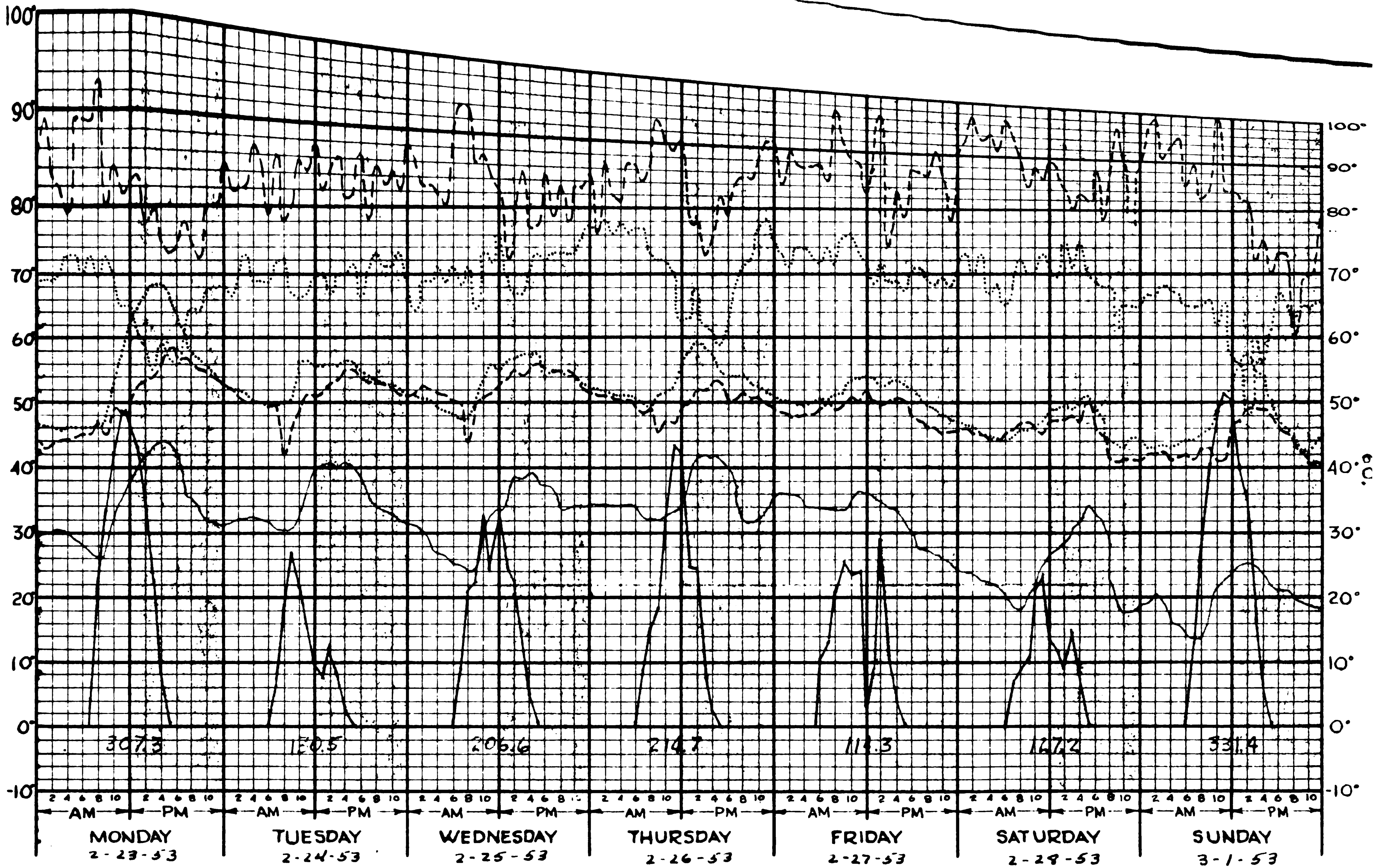


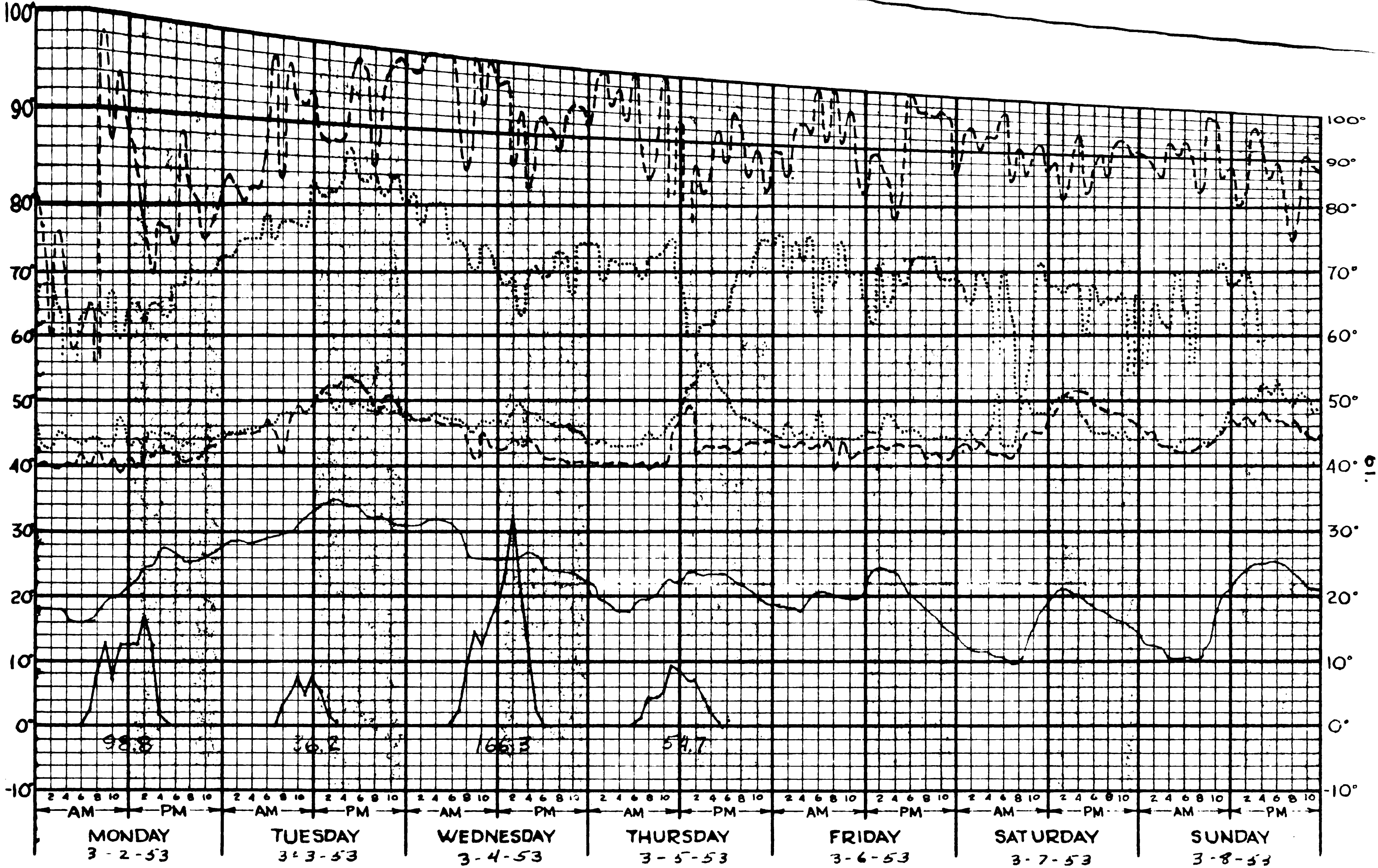

100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
2 4 6 8 10 AM 2 4 6 8 10 PM
387
101.5
84.8
77.3
67.8
32.9
74.8
MONDAY 2-2-53
TUESDAY 2-3-53
WEDNESDAY 2-4-53
THURSDAY 2-5-53
FRIDAY 2-6-53
SATURDAY 2-7-53
SUNDAY 2-8-53



MONDAY 2-9-53
TUESDAY 2-10-53
WEDNESDAY 2-11-53
THURSDAY 2-12-53
FRIDAY 2-13-53
SATURDAY 2-14-53
SUNDAY 2-15-53
AM
PM
57.5
58.8
16.5
39.2
118.1
256.0
192.5
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°


100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
2 4 6 8 10 2 4 6 8 10
AM
PM
91.9
132.7
191.0
195.2
27.3
169.8
291.6
MONDAY 2-16-53
TUESDAY 2-17-53
WEDNESDAY 2-18-53
THURSDAY 2-19-53
FRIDAY 2-20-53
SATURDAY 2-21-53
SUNDAY 2-22-53


100° 90° 80° 70° 60° 50° 40° 30° 20° 10° 0° -10°
100° 90° 80° 70° 60° 50° 40° °C. 30° 20° 10° 0° -10°
307.3
120.5
206.6
214.7
113.3
147.2
331.4
2 4 6 8 10 AM 2 4 6 8 10 PM
MONDAY 2-23-53
TUESDAY 2-24-53
WEDNESDAY 2-25-53
THURSDAY 2-26-53
FRIDAY 2-27-53
SATURDAY 2-28-53
SUNDAY 3-1-53


100°
90°
80°
70°
60°
50°
40°
30°
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10°
0°
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98.8
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166.3
54.7
2 4 6 8 10 2 4 6 8 10
AM PM
MONDAY 3-2-53
TUESDAY 3-3-53
WEDNESDAY 3-4-53
THURSDAY 3-5-53
FRIDAY 3-6-53
SATURDAY 3-7-53
SUNDAY 3-8-53

## Analysis of Summer Charts

The recording of the data started at 11:00 AM, Tuesday, July 15, 1952. Some unusual happenings had already occurred in this first week. For instance, at 12:00 noon on July 18, the temperature record in the regular wing showed an average value of sixty-six degrees which was about five degrees below outdoor air temperature. Also at 11:00 AM on July 19, the temperature in the solar wing rose to an average value above ninety-eight degrees. It is not possible to explain what happened to cause these wide fluctuations to occur. The temperature drop in the regular wing may have been caused by the evaporation of water from the termocouple junctions which may have become wet during the cleaning of the wing.

Aside from the above mentioned variations the temperatures in both wings ran close together and fluctuated with the changes in the outdoor temperature. It was also possible to pick out some correlation between the variation of the amount of solar radiation and the fluctuation of the outdoor temperature. The results also indicated that there was no apparent build up of heat in the walls of the structure to cause a time lag on the fluctuations of the temperatures.

At about 5:00 PM each night the outside doors were closed to the separate wings and to the main barn. This caused indoor temperatures to stay above outdoor night time temperatures and as will be brought out later in some cases it caused indoor temperatures to rise while outdoor temperatures were falling. With the closing of the doors, ventilation of the

solar wing was less than that of the regular wing. This was because of the fixed glazing in the solar wing and the open windows in the regular wing. Ventilation may have been further restricted because of a sheltering effect produced by the regular wing and the main barn over the solar wing.

The sudden drop in temperatures at noon July 22 was caused by a violent and sudden wind and thunderstorm. This dropped all the temperatures about fourteen to twenty degrees. For the next three days, the total amount of solar radiation was high. The temperatures in the two wings stayed with the outdoor temperature, however, which was at a rather low value for that time of year. The great fluctuation of temperatures during those three days indicated the lack of any cloud covering. Had there been clouds, this fluctuation would have been greatly reduced.

On cloudy days during which rain fell, the afternoons and nights of August 11 and 15, the temperature fluctuations were markedly decreased. The least amount of fluctuation was noted in the solar wing, the amount of fluctuation being only about five degrees for each twenty-four hour period. August 13 shows a rising temperature inside the building from six to seven o'clock in the evening while the outdoor temperature was falling.

During the early morning hours of August 21 the regular wing cooled to quite a low temperature compared to the solar wing. This again was a condition which could not be explained.

The days of August 25, 26, 27, and 28, showed the build up of temperatures which takes place when there is an extended period of sunshine. The total each day added to the next to make the maximum indoor temperatures on the 28th of August about six degrees warmer than on August 25. Another cloudy period with rain is shown at the end of that week and the first three days of the following week.

## Analysis of Winter Charts

The recording of the winter data started on Friday, December 12, 1952. The following day the potentiometer started a twenty-four hour period of recording the same temperatures. It is not known why this happened, but whatever was wrong was corrected by itself. From this time on the potentiometer functioned properly. As can be seen on these first two days, the solar wing was about five degrees cooler than the regular wing and about eighteen degrees warmer than the outdoor temperatures. The relative humidity was greater in the regular wing by an average of about six percent. Solar radiation for this week was lower than average.

One of the reasons for higher temperatures and more humid conditions in the regular wing as compared to the solar wing was because of a greater number of pigs in the regular wing. This wing had about one hundred pigs weighing an estimated average of one hundred twenty-five pounds each. There were approximately thirty-five small size pigs in the solar wing.

The results from the second week of the winter study showed what was to be expected when days of high solar radiation occurred. The temperatures in the solar wing climbed to values over twenty degrees higher than the night time temperatures. A check of the relative humidity curves showed that as temperature increased, relative humidity would decrease by almost a like amount. These days of high solar radiation showed only a small increase in temperature for the regular wing and no effect upon the relative humidity.

The results during this second week also showed the effects of a small amount of solar radiation. This resulted in an almost constant temperature in both wings with about the same temperature differences as noted during the first two days of the winter study. It was also easy to see the results of the cleaning habits of the operator on the temperature in the regular wing. The cleanings from both wings passed out the south door of the regular wing. Cleaning of the pens was done during the first several hours of each morning and during that time the south door remained open. The effect on the relative humidity of the regular wing varied, but in most cases throughout the season, it caused a decided increase.

Due to electrical troubles the instruments were inoperative for a three-day period starting 5:00 PM, December 25, 1952.

The effects from operation of the heater fans can readily be seen during the early morning hours of January 6 and January 7. The outdoor temperature dropped to a low of $5^{\circ}$ F and

$2^{o}$ F respectively for those two days. The temperature fluctuations which were plotted on the graphs were toned down considerably. This was necessary since in each wing, one of the thermocouple wires was located at a distance of about ten feet from the heater. Fluctuations in the relative humidities also appeared. This made it necessary when plotting relative humidities to omit low points which were considered unreliable. It also made it possible to tell almost every night when the heaters in either or both wings operated. For the remainder of that week, cloudy conditions prevailed and the temperatures stayed at a high value.

During the week starting January 12, the south door of the regular wing was left open most of the day for three days. The days were Tuesday, Thursday, and Friday. On Thursday, the east door of the solar wing was open during the afternoon. The result was the lowering of the indoor temperature towards that of the outdoors. However, for the first two days, Tuesday and Thursday, the outdoor temperature was relatively high.

On 2:00 PM, Monday, January 19, the number of pigs in both wings were closely balanced. This was accomplished by bringing sixty-five head of pigs into the solar wing which gave a total of ninety-nine in the solar wing and one hundred one in the regular wing. The heavier weight was still in the regular wing, however. For the next two weeks, the number of pigs in each wing was kept almost equal. On Monday, January 26, twenty-five pigs were removed from each wing and on the following Monday, thirty more from each wing were removed.

The temperatures for both these two weeks remained close together and about twenty to twenty-five degrees above the outdoor temperature. The only days when the solar wing temperature raised any great amount above the regular wing were those several days which had a lot of sunshine. During both of these weeks the heater fans were not in operation. This was true for all days, including the early morning hours of Monday, January 26, when a low of three degrees was registered outside. The relative humidity, like the temperatures, also stayed about equal for both wings except for the days which had a lot of sunshine.

Difficulty was experienced with the operation of the relative humidity measuring device in the regular wing during the period of January 23, to February 12, 1953.

By the end of the week starting February 2, the majority of the pigs had been removed from each wing. During these last few days when the pig population was small, the added heat through the windows of the solar wing began to become important when total heat gain was considered. Thus until about Wednesday morning, February 11, the solar wing was several degrees warmer than the regular wing. The relative humidity of the solar wing was also markedly lower than that of the regular wing. The high humidities in the regular wing during Monday night, Tuesday, and Wednesday morning, February 9, 10, and 11, respectively, were caused by the use of the steam cleaner during Monday afternoon and Tuesday morning. Thus, the Monday afternoon temperature rise and the jump Tuesday morning in the regular wing can also be attributed to the same cause. This was the start of preparations for the new feed studies which began a week later.

During the afternoon of Wednesday, February 11, one hundred ten small pigs were placed into the solar wing and the thermostat was set to fifty-eight degrees. Earlier that morning the thermostat in the regular wing was mistakenly set to fifty-eight degrees and was set back to forty degrees at noon. From February 11, on, the operation of the heater fans was quite constant.

After 12:00 noon Thursday, February 12, the solar wing thermostat was set at fifty-five degrees and the following afternoon it was lowered to fifty degrees. Saturday, February 14, the thermostats in both wings were changed. The solar wing thermostat was lowered in the afternoon to forty-five degrees and the regular wing thermostat was set at sixty degrees for half an hour about 11:00 AM, back to fifty degrees until 5:00 PM, and then back to forty degrees, the lowest setting.

On Monday afternoon, February 16, approximately one hundred pigs from the solar wing were moved to the regular wing and started on a feed study. The thermostats in both wings were set at fifty degrees and remained at that setting until Wednesday afternoon when they were both set back to forty degrees for the remainder of the study. The temperatures for the remainder of the study remained fairly close with the solar wing being the higher in most cases even though there were only a few pigs in the solar wing. While there were about one hundred pigs in the regular wing, they were too small to put out as large an amount of heat as the earlier occupants of that wing.

The relative humidity in the solar wing was markedly less due to the absence of pigs when compared with the regular wing. The average for the last week of February was about seventy percent for the solar wing and eighty-five percent for the regular wing. For the last days of the study the spread was even greater: the relative humidity for the solar wing was down to about sixty-five percent and that of the regular wing up to about ninety percent.

## Results of Calculations of Appendix A

Heat gain through insulating glass windows facing south. The purpose of large areas of insulating glass windows facing south is to let in more of the sun's energy or heat and to trap this heat inside of the building during the winter months. In order to have some idea of how much heat can be expected through these insulating glass windows, calculations of the heat gain were made in Appendix A. These calculations were divided into three parts: use of the Sun Angle Calculator; results from Saia's (35) calculations; and calculations for the winter of 1953 using recorded energy values. The Sun Angle Calculator was used for both a clear and an industrial type atmosphere.

The results from column 1 of Table AV for a clear atmosphere indicate that a total heat gain of 44,265 BTU's per square foot of insulating glass could be available between December 10 and March 11. This would break down to a total of 481 BTU's per square foot per day or about twenty BTU's per square foot per hour if it were possible to spread the gain over a twenty-four hour period. This value being for a clear atmosphere would be good only as long as the sky was relatively free from clouds.

The results from the industrial atmosphere calculations (column 2, Table AV) would probably be closer to being correct for the Lansing area. These results gave a total heat gain for the same length winter season of 28,441 BTU's per square foot of insulating glass. For an average day, the value would be 309 BTU's per square foot and the heat gain per hour when spread over a twenty-four hour period would be thirteen BTU's per square foot per hour.

Saia's results (Table AVI) for the equivalent period gave a total heat gain of 64,336 BTU's per square foot of insulating glass. Again bringing this value to a daily average would give 699 BTU's per square foot and for a twenty-four hour period, the results would be twenty-nine BTU's per square foot per hour.

For the calculations made with the energy values recorded during the winter of 1953 (column 11, Table AIX), the total heat gain due to solar energy was 31,299 BTU's per square foot of insulating glass for the period between December 10 and March 11.

The average daily value would be 340 BTU's per square foot and the hourly heat gain when spread over a twenty-four hour period would equal about fourteen BTU's per square foot per hour.

When these four values were compared, it appeared that Saia's values were high. They were approximately fifty percent greater than the results which were obtained with the Sun Angle Calculator for a clear atmosphere and about one hundred twenty percent greater than the results for an industrial atmosphere. Since actual measurement of solar radiation on horizontal surfaces in East Lansing indicated values comparable to similarly recorded values of Chicago or Pittsburgh, it is hard to imagine that the solar energy through south facing insulating glass windows would be twice as great for East Lansing as for Chicago or Pittsburgh.

The results from the calculations made for the winter of 1953, compared favorably with the results from the Sun Angle Calculator for an industrial atmosphere and were thus considered to be more reliable. This value for the average heat gain during the winter of 1953 was used in the following analysis.

In the solar wing of the piggery there are twenty-six insulating glass windows, each having fifteen square feet of glass area. This makes a total glass area of three hundred ninety square feet and for the twenty-four pens, this number reduced to sixteen and one-quarter square feet of glass area per pen. Thus, the heat gain per pen during the winter of 1953 averaged about two hundred thirty BTU's per hour.

The heat loss through these windows would be due mostly to conduction since being a fixed window, heat loss due to infiltration or crack leakage would be negligible. The "U" value for insulating glass is equal to 0.58 and for an average temperature difference of twenty degrees during the winter of 1953, the average heat loss would be 11.6 BTU's per square foot of insulating glass per hour. This would represent a heat loss per pen of approximately one hundred ninety BTU's per hour.

The net heat gain due to solar radiation would then be the difference between the gain and the loss through the windows which would be equivalent to forty BTU's per hour per pen. In comparison, one two hundred pound fattening hog can supply fifteen pens with this same amount of heat, i.e. forty BTU's per hour per pen.

If the insulating glass windows were replaced with single glazed windows of the same area, the amount of heat intake would be increased a small amount while the heat loss would be about doubled. The actual value would be a solar radiation heat gain of about two hundred sixty BTU's per hour per pen and the heat loss through the glass would equal about three hundred seventy BTU's per hour per pen. This would result in a net heat loss of one hundred ten BTU's per hour per pen, or a difference of one hundred fifty BTU's per hour per pen between equivalent areas of single glazing and insulating glass windows facing south.

Heat gain through single glazed windows facing east. The results from the calculation of solar heat gain through the east facing single glazed windows of the regular wing by using the Sun Angle Calculator and a clear atmosphere indicated a gain of 19,638 BTU's per square foot for the total winter period under consideration. If this value were reduced to a figure suitable for the winter of 1953 by multiplying by the ratio of 31,299 (the value for insulating glass facing south during the winter of 1953) to 44,265 (the value from the Sun Angle Calculator for insulating glass windows facing south) the results would be about 13,900 BTU's per square foot. This value reduced to a daily basis would be 151 BTU's per square foot and for an hourly basis, 6.3 BTU's per square foot per hour.

Although the value of 6.3 BTU's per square foot per hour was obtained for single glazed windows facing east, the same value can be used for single glazed windows facing west. Each pen in the regular wing has one single glazed window with a total glass area of approximately three square feet. Thus, the total solar heat gain per pen would equal about twenty BTU's per hour.

When figuring the heat loss through this type of window, the heat loss due to air leakage will be the largest factor. Using the recommended value of one hundred eleven cubic feet of air per hour per foot of crack resulted in a heat loss of three hundred twenty BTU's per hour. The heat loss through the glass amounted to almost seventy BTU's per hour and the total net heat loss for each window was thus approximately three hundred seventy BTU's per hour.

When a pen in the solar wing was compared with a pen in the regular wing, the total hourly heat difference would be four hundred ten BTU's per hour per pen more in the solar wing than in the regular wing. This heat would be approximately equal to a one hundred pound fattening pig.

## CONCLUSIONS

### Use of Insulating Glass in Swine Buildings

The final answer to the use of insulating glass as a source of partial heat in swine buildings will probably be based upon economics and any improvement in environmental conditions for the swine or operator. Factors which must be considered are listed below:

1. The type and size of hogs in the housing.
2. The average solar radiation during the expected periods of use.
3. The desirable temperatures to be maintained.
4. The method of ventilation.
5. The amount of ventilation desired.

Data from the first year of the study were not conclusive because it was found to be practically impossible to control the conditions closely enough in the large piggery to make accurate comparisons between the solar and regular wings. Smaller buildings in which the variables can be more accurately controlled are necessary for proper tests.

The results, however, did suggest that:

1. During summer months, the fixed windows in the solar wing did not cause higher temperatures than the regular wing where ventilating windows were used.
2. Where proper ventilation is supplied by other means, ventilating windows should offer no advantage over fixed windows.

3. During winter months, fixed windows would have an advantage because of a negligible heat loss due to crack leakage.
4. When a small number or size of pigs were housed in both wings, solar energy gains became more important in determining the temperature of the solar wing.

Calculation of Solar Heat Gain

The formula used for the calculation of solar heat gain into the solar wing during the winter of 1953 gave results which were only slightly higher than a value computed for an industrial atmosphere with the sun angle calculator. Because of the close agreement with the results as given by the sun angle calculator the formula seems to be reliable. During a winter which had a large amount of snow, such as the winter of 1952, the last half of the equation would have to be increased by an appropriate factor to allow for the increase in diffuse energy reflected from the snow.

From the results of the theoretical solar heat gain calculations in Appendix A, it can be concluded that a pen in the solar wing compared to a pen in the regular wing would show a net increase of over four hundred BTU's per hour per pen. This resulted from a greater amount of solar heat gain and a lesser amount of heat loss through and around the windows.

In most cases a more accurate method for computing energy gained by solar radiation cannot be justified for animal housing, because of all the other approximations which are necessarily used. It is also safe to state that due to the large number of factors involved with solar heat gains, accurate mathematical calculations can never be made. To accurately determine solar heat gain, direct measurements will have to be made inside the building with appropriate instruments.

## Suggested Future Investigations

Instrumentation of this project still left several things to be desired. It would be desirable if some method could be devised for measurement of relative humidities without the use of a fan for air movement. The system used was good--but it was necessary to locate the instrument, because of the fan, near the ceiling of the building. If the fan could be eliminated, relative humidities could be recorded at pen height and the results would be more meaningful.

It would also be desirable if some method could be found for recording daylight intensities in each wing directly onto the potentiometer chart by means of photovoltaic cells. This would necessitate some method of accumulating the instantaneous variations and recording them at the end of every hour.

One important conclusion which can be drawn from this project to date is that trying to control the conditions in a building as large as the piggery so that accurate and reliable results can be obtained is practically impossible. Thus, for future studies of this type, smaller buildings are necessary in which more control can be maintained over the factors which affect environmental conditions.

# APPENDIX A

## CALCULATIONS OF SOLAR HEAT GAINS

### Statement of Problem

There has always been the problem of what to do with the solar radiation which falls upon the buildings of man. In the past, the answer has always been to neglect these radiation heat gains when calculating the total heat loss and gain on structures. During the past ten to fifteen years, however, more of an interest has been taken in this possible heat gain coming from the sun. The majority of the work which has been done has concerned itself with the additional heat gains during the summer months when it would apply to increasing the cooling loads for the air conditioning of a structure. Only a small amount of work has been done on the possibilities of heating a structure during the winter months by utilization of the sun's radiant energy. This is especially true when we narrow the field to include only farm buildings.

Before predictions of the heating value of the sun can be made, it is necessary to make some type of measurement of the energy received from it. In 1902, the United States Weather Bureau started inventigations on the amount of energy received from the sun upon a horizontal surface be setting up several pyrheliometric stations. During 1947 there were ten Weather Bureau stations and sixteen cooperative stations gathering this data. Data of this type has been recorded for about forty different locations in the United States at one time or another. Several of these stations have also collected data on the total radiation received on a surface normal to the sun and a few have made studies on the amount of total radiation received on a vertical surface. This then makes it necessary to convert the energy received on a horizontal surface to energy received on a vertical surface by mathematical methods. Calculations of this type are at best only good approximations because of the difficulty of dividing the total radiation on a horizontal surface into both direct and diffuse radiation and then recombining the two on a vertical surface.

## Calculations of Solar Heat Gain Through Insulating Glass Windows Facing South

Calculation by use of Sun Angle Calculator. In May, 1950, the Libbey-Owens-Ford Glass Company brought out a product which they developed and called a "Sun Angle Calculator." This calculator greatly simplifies the determination of such things as the profile angle of the sun, bearing of the sun, angle of incidence, and true altitude of the sun. It also helps with determining dimensions of overhead shading devices and lateral or vertical shading devices. Of most interest to the problem here were the included charts and tables which simplified the calculation of the total heat gain through insulating glass or regular glass windows.

Included with this calculator are eight plastic sun charts, one for each four degrees of latitude from 24° to 52° north

latitude. Curved lines on these charts indicated by days and months of the year represent the sun's paths on the earth's surface as seen from above at the latitude and on the dates shown.

The overlay which is applied to all sun charts is of clear plastic with red lines and printing. This is pivoted in the center to rotate when placed in position and includes the necessary lines for determining the angle of incidence and the profile angle.

The third part of the calculator is the wedge-shaped cursor which also pivots about the center point and is used to find the true altitude of the sun.

The calculation of the total solar heat gain by the use of this instrument is divided into two parts: calculation of direct solar energy, and calculation of diffuse solar energy. For both parts there is an alignment chart which gives the respective subtotals when the true altitude of the sun and the angle of incidence are known. These values, as stated above, are determined from the Sun Angle Calculator.

Values of transmittance for either insulating glass or regular glass are given by which the total heat gain on a vertical south wall is reduced to the correct value after passing through the glass. Another refirement includes the choice of either a clear or an industrial atmosphere.

The Sun Angle Calculator was used for both a clear and an industrial atmosphere for determining the total heat gain through south facing insulating glass windows. The industrial atmosphere was also selected since the total amount of solar radiation received in East Lansing is almost as low as that which is received through the industrial atmosphere of Chicago or Pittsburgh. The dates which were used were approximately that of the winter study; December 15, to March 8.

<u>Results from A.E. 500 special problem</u>. During Spring Quarter, 1950, Saia (35) worked on a special problem concerning the heat gain during the winter through insulating glass windows facing south using the average total radiation values on a horizontal surface for East Lansing. His calculations were simplified by dividing the winter season into weekly periods and using the mean for that period and by using a ratio developed from experiment by Hand (11) for converting total radiation on a horizontal surface to total radiation on a vertical surface.

<u>Calculation of heat gained during winter, 1953</u>. Since the total amount of solar energy received during the winter of 1953 was lower than the average for the past ten years, it was decided to make some special calculations of a more accurate nature to determine the actual amount of solar energy which was received inside of the insulating glass windows at the piggery. The following formula was developed which should give a closer approximation of the solar energy received on the south facing windows:

$$I_V = I_H \ (\cot a \cos D) \tfrac{1}{2}(2 - \frac{I_D}{I_H}) + \tfrac{1}{2} \ I_H \ (\frac{I_D}{I_H})$$

$I_V$ = total solar energy perpendicular to a south facing vertical wall

$I_H$ = total solar energy on a horizontal surface

a = altitude angle of the sun

D = solar azimuth angle

$\frac{I_D}{I_H}$ = ratio of diffuse energy on a horizontal surface to total energy on a horizontal surface

When using this formula, values of $I_H$ were taken from the weekly means for the period of December 15, 1952, to March 8, 1953. Values of angles "a" and "D" were taken from data prepared by Hand (12) for $42^\circ$ north latitude and were plotted in the combined form to simplify the calculations.

The last half of the equation was added from the fact that these south facing windows will be exposed to one-half of the sky and thus approximately one-half of the diffuse energy on a horizontal surface will pass through these windows. This approximation should hold fairly true unless there is a snow cover on the ground. The absence of normal snow cover this past winter will thus help in making this half of the equation more nearly correct.

The ratio of $I_D$ over $I_H$ will depend upon the amount of cloudiness. The greater the cloud covering, the greater will be the value of the ratio. This means that as the cloud covering increases more of the energy is diffuse and less is direct up to the maximum of one-half diffuse and one-half direct. Values for this ratio were determined from a table made up from Hand's (12) data and from the actual cloudiness of this area for the past winter as determined by the Lansing Weather Bureau.

The graphical and tabular results for these three methods of calculation appear later in this Appendix.

Radiation Gains Through Other Parts of a Structure

While it is true that the majority of the heat gained due to solar radiation will be through large south facing windows, other places of solar heat gain bear mentioning. This would include the other parts of the structure such as the walls, roofs and windows oriented in other directions.

Gains through walls. Saia (35) made some estimations of the heat which could be gained during the winter months through different types of south facing walls. For a cinder block wall facing south, about sixty BTU's per square foot will be gained for every thousand BTU's per square foot of heat gain through an insulating glass window. For a wall which faces east or west, the heat gain would probably be as low as twenty BTU's per square foot.

Gains through roofs. The winter solar heat gain through a roof is even harder to estimate because of the slope of the roof. It sounds logical, however, that the heat gain would be greater on a gable roof running north and south than on a shed type roof opening to the south. It has been proved (9) that during the summer months the color of the roof surface has much to do with the temperature of the roof and thus the space underneath. But these are only comparative studies and would not give accurate transmittance values for wintertime solar radiation. An estimation based on the estimations for solar heat through a south facing wall would probably locate the heat gain through a black surfaced gable roof running north and south at about twenty-five BTU's per square foot for each slope for every thousand BTU's per square foot of insulating glass windows facing south. A black surfaced shed roof opening to the south would probably transmit less than five BTU's per square foot for every thousand BTU's per square foot of insulating glass facing south. When all the other approximations of heating calculations are considered, this heat gain through a shed roof could be neglected.

Gains through single glazing on east and west facing walls. A calculation of the theoretical heat gain through east and west single glazed windows for a clear atmosphere only was made by using the Sun Angle Calculator. The calculations were made for the east windows and the results multiplied by two to obtain the final answer. This answer was then converted to one which would be closer to being correct for the past winter by multiplying by the ratio of the actual value for the south facing wall to the value obtained for the south facing wall with the Sun Angle Calculator. The results of these calculations appear later in this Appendix, included with the calculations for the south facing windows.

## Possible Radiation Losses at Night

While the gain of heat from radiation sources may be an important part of the heat source for a structure, radiation from the structure to the outer atmosphere should also be considered. This type of radiation would be classified as one of the ways in which heat is lost from a building. While this loss is thought to take place only during the hours of darkness, it has been conclusively proved that the loss can be just as great on a bright sunny day. Angstrom (3-p15) states the conclusions of some investigations made by Homen as follows:

1. If the sky is clear, there will always be a positive radiation from earth to sky, even in the middle of the day.
2. If the sky is cloudy, there will always, in the daytime, be a radiation from sky to earth.
3. In the nighttime the radiation for a clear as well as for a cloudy sky always has the direction from earth to sky.

The majority of the studies which have been made on this type of radiation loss have been done at night when the diffuse or sky radiation causes no complications. That is why this radiation is often termed "nocturnal radiation." Recent investigations have shown that on a clear winter night, "radiation to the sky may take place at a rate sufficient to cool a building surface, particularly the roof, to a temperature $10^{\circ}$ to $15^{\circ}$ below the air temperature" (5-p145). In fact such cooling of exposed bodies to a temperature lower than the surrounding temperature was observed very early by the natives of India who made ice by exposing flat plates of water to the night sky.

So whether the problem is considered as an old one or a new one, only a small amount of scientific work has been done on it. Some of Angstrom's (3) results for radiation loss during the night indicate that for a clear sky, the average radiation is in the range of thirty to forty-five BTU's per square foot per hour. For a light cloud covering, these values would be reduced to approximately sixteen to thirty-two BTU's per square foot per hour. Medium to heavy clouds can reduce these values down to almost nothing. From this, it can be seen that the amount of cloud covering on radiation losses at night can be just as important as the amount of cloud covering on total radiation gains during the day.

## Charts and Tabular Results

Results from the use of the Sun Angle Calculator. The methods for three similar types of calculations are explained by this section. The first was the amount of solar radiation heat gain through insulating glass windows facing south under a clear atmosphere. The second was for the same type of window as the first except that the calculations were made for an industrial atmosphere. The third set of calculations was made for single glass windows facing east under a clear atmosphere. Since the method was the same for all three, it will be explained in terms of the first sets of calculations only, with all calculations included later.

The Sun Angle Calculator was used according to the instructions to determine the altitude angle and the angle of incidence of the sun at 44° north latitude. The 44° north latitude chart was selected as being the closest to the true latitude of this area which is 42°-42'. These values were read from the Sun Angle Calculator for the days and hours listed in Tables AI, AII and AIII. When the altitude angle and the angle of incidence were known, it was then possible to use the alignment charts to determine the direct and diffuse energy falling upon a south facing wall for the given days and hours. These energy values were then multiplied by the appropriate transmission values and recorded in the subtotal columns. The transmission values were taken from Table #1 in the instruction manual. Glass A was used for the single glass and glass B ≠ B was the most representative of farm type insulating glass windows. These subtotals were then added to give the total heat gain in BTU's per square foot per hour for the days and hours indicated.

The instantaneous total heat gains found in the last column of Tables AI, AII, and AIII were then plotted in graphical form for the various days in Figures A1, A2, and A3. The area under each of these curves was found by the use of a polar planimeter and was recorded in Table AIV. It was determined that each square inch was equal to 27.25 BTU's per square foot and the square inch areas were then multiplied by this factor to obtain the total heat gain through each square foot of glass area for the indicated days.

Average daily values for the different weeks (Table AV) were obtained by rough plotting the data from Table AIV on graph paper and taking the mid week average for each week. This method was considered accurate enough for the purpose of this study.

Table AV then, represents the final results. It shows the total heat gain through each square foot of glass for an average day during the weekly period. Totals were listed at the bottom of the columns so that an over-all comparison can be made for the three different methods of calculation in this Appendix.

# TABLE AI

## CALCULATIONS OF THEORETICAL INSTANTANEOUS HEAT GAIN THROUGH INSULATING GLASS WINDOWS FACING SOUTH - CLEAR ATMOSPHERE

| DATE | HOUR ANGLE | ALTITUDE ANGLE | INCIDENCE ANGLE | DIRECT ENERGY | DIFFUSE ENERGY | DIRECT TRANSMISSION | DIFFUSE TRANSMISSION | SUB-TOTAL DIRECT ENERGY | SUB-TOTAL DIFFUSE ENERGY | TOTAL ENERGY BTU/FT² HR |
|---|---|---|---|---|---|---|---|---|---|---|
| DEC. 21 | 4 | 3 | 52.5 | 25 | 4.2 | 0.64 | 0.64 | 16.0 | 2.7 | 18.7 |
| | 3 | 11 | 42.5 | 99 | 15.4 | 0.68 | 0.64 | 67.3 | 9.9 | 77.2 |
| | 2 | 17 | 32.5 | 153 | 23 | 0.68 | 0.64 | 104 | 14.7 | 118.7 |
| | 1 | 21 | 25.5 | 184 | 28 | 0.69 | 0.64 | 127 | 18.0 | 145.0 |
| | 0 | 22 | 22.0 | 191 | 30 | 0.69 | 0.64 | 132 | 19.2 | 151.2 |
| JAN. 11 | 4 | 4 | 53.5 | 33 | 5.4 | 0.64 | 0.64 | 21.5 | 3.5 | 25.0 |
| | 3 | 12 | 43.5 | 104 | 16.4 | 0.67 | 0.64 | 69.5 | 10.5 | 80.0 |
| | 2 | 18 | 34 | 155 | 24 | 0.68 | 0.64 | 105 | 15.3 | 120.3 |
| | 1 | 22.5 | 27 | 185 | 29 | 0.68 | 0.69 | 128 | 18.5 | 146.5 |
| | 0 | 24 | 24 | 197 | 31 | 0.69 | 0.69 | 136 | 19.8 | 155.8 |
| JAN. 21 | 4 | 6 | 55 | 46 | 8 | 0.63 | 0.64 | 29 | 5.1 | 34.1 |
| | 3 | 13.5 | 45 | 111 | 17.5 | 0.67 | 0.64 | 74.3 | 11.2 | 85.5 |
| | 2 | 20 | 36 | 160 | 25 | 0.68 | 0.64 | 109 | 16.0 | 125.0 |
| | 1 | 24.5 | 28 | 190 | 30 | 0.69 | 0.64 | 131 | 19.2 | 150.2 |
| | 0 | 26 | 26 | 200 | 31.5 | 0.69 | 0.64 | 137 | 20.2 | 157.2 |
| FEB. 1 | 4 | 7.5 | 57 | 53 | 9.4 | 0.62 | 0.64 | 32.9 | 6.0 | 38.9 |
| | 3 | 16 | 47 | 119 | 19.5 | 0.66 | 0.64 | 78.5 | 12.5 | 91.0 |
| | 2 | 22.5 | 37.5 | 165 | 26.5 | 0.68 | 0.64 | 112 | 17.0 | 129.0 |
| | 1 | 27 | 31 | 196 | 31 | 0.68 | 0.64 | 133 | 19.8 | 152.8 |
| | 0 | 28.5 | 28.5 | 203 | 32.5 | 0.68 | 0.64 | 140 | 20.8 | 160.8 |
| FEB. 11 | 5 | 1 | 69 | 5 | 1.2 | 0.53 | 0.64 | 2.6 | 0.7 | 3.3 |
| | 4 | 10 | 59 | 64 | 12 | 0.61 | 0.64 | 39 | 7.7 | 46.7 |
| | 3 | 19 | 49 | 127 | 21.5 | 0.65 | 0.64 | 82.5 | 13.7 | 96.2 |
| | 2 | 26 | 40 | 170 | 28 | 0.68 | 0.64 | 116 | 18.0 | 134.0 |
| | 1 | 30 | 34 | 197 | 32 | 0.68 | 0.64 | 134 | 20.5 | 154.5 |
| | 0 | 32 | 32 | 206 | 33.5 | 0.68 | 0.64 | 140 | 21.5 | 161.5 |
| FEB. 21 | 5 | 3 | 72 | 13 | 3.5 | 0.45 | 0.64 | 5.8 | 2.2 | 8.0 |
| | 4 | 13 | 62 | 71 | 14.5 | 0.59 | 0.64 | 41.8 | 9.3 | 51.1 |
| | 3 | 22 | 52 | 128 | 23 | 0.64 | 0.64 | 82 | 14.7 | 96.7 |
| | 2 | 28.5 | 43 | 170 | 29 | 0.67 | 0.64 | 114 | 18.5 | 132.5 |
| | 1 | 33.5 | 37.5 | 196 | 33 | 0.68 | 0.64 | 133 | 21.1 | 154.1 |
| | 0 | 35 | 35 | 205 | 34.5 | 0.68 | 0.64 | 140 | 22.0 | 162.0 |
| MAR. 1 | 5 | 6 | 74 | 22 | 6.7 | 0.40 | 0.64 | 8.8 | 4.3 | 13.1 |
| | 4 | 16 | 64 | 76 | 16.8 | 0.58 | 0.64 | 44 | 10.7 | 54.7 |
| | 3 | 24 | 54.5 | 125 | 24 | 0.63 | 0.64 | 78.6 | 15.4 | 94.0 |
| | 2 | 32 | 47 | 166 | 29 | 0.66 | 0.64 | 109 | 18.5 | 127.5 |
| | 1 | 37 | 41 | 193 | 33 | 0.68 | 0.64 | 131 | 21.1 | 152.1 |
| | 0 | 38.5 | 38.5 | 200 | 34.5 | 0.68 | 0.64 | 136 | 22.1 | 158.1 |

TABLE A II

THROUGH

# Table A II

## Calculations of Theoretical Instantaneous Heat Gain Through Insulating Glass Windows Facing South - Industrial Atmosphere

| Date | Hour Angle | Altitude Angle | Incidence Angle | Direct Energy | Diffuse Energy | Direct Transmission | Diffuse Transmission | Sub-Total Direct Energy | Sub-Total Diffuse Energy | Total Energy BTU/FT² HR |
|---|---|---|---|---|---|---|---|---|---|---|
| DEC. 21 | 4 | 3 | 52.5 | 14.5 | 5.6 | 0.64 | 0.64 | 9.3 | 3.6 | 12.9 |
| | 3 | 11 | 42.5 | 46 | 17.7 | 0.68 | 0.64 | 31.3 | 11.3 | 42.6 |
| | 2 | 17 | 32.5 | 76 | 29 | 0.68 | 0.64 | 51.6 | 18.5 | 70.1 |
| | 1 | 21 | 25.5 | 97 | 37.5 | 0.69 | 0.64 | 67.0 | 24.0 | 91.0 |
| | 0 | 22 | 22.0 | 102 | 40 | 0.69 | 0.64 | 70.5 | 25.6 | 96.1 |
| JAN. 11 | 4 | 4 | 53.5 | 17.5 | 7 | 0.64 | 0.64 | 11.2 | 4.5 | 15.7 |
| | 3 | 12 | 43.5 | 48 | 18.8 | 0.67 | 0.64 | 32.2 | 12.0 | 44.2 |
| | 2 | 18 | 34 | 78 | 30.0 | 0.68 | 0.64 | 53.0 | 19.2 | 72.2 |
| | 1 | 22.5 | 27 | 101 | 38.5 | 0.68 | 0.64 | 69.8 | 24.6 | 94.4 |
| | 0 | 24 | 24 | 109 | 41 | 0.69 | 0.64 | 75.2 | 26.2 | 101.4 |
| JAN. 21 | 4 | 6 | 55 | 22.5 | 9.4 | 0.63 | 0.64 | 14.2 | 6.0 | 20.2 |
| | 3 | 13.5 | 45 | 51 | 20.5 | 0.67 | 0.64 | 34.2 | 13.1 | 47.3 |
| | 2 | 20 | 36 | 84 | 32 | 0.68 | 0.64 | 57.1 | 20.5 | 77.6 |
| | 1 | 24.5 | 28 | 105 | 41 | 0.69 | 0.64 | 72.5 | 26.2 | 98.7 |
| | 0 | 26 | 26 | 112 | 44 | 0.69 | 0.64 | 77.3 | 28.2 | 105.5 |
| FEB. 1 | 4 | 7.5 | 57 | 25.5 | 10.7 | 0.62 | 0.64 | 15.8 | 6.7 | 22.5 |
| | 3 | 16 | 47 | 58 | 26 | 0.66 | 0.64 | 38.3 | 16.6 | 54.9 |
| | 2 | 22.5 | 37.5 | 89 | 35 | 0.68 | 0.64 | 60.5 | 22.4 | 82.9 |
| | 1 | 27 | 31 | 111 | 43 | 0.68 | 0.64 | 75.5 | 27.5 | 103.0 |
| | 0 | 28.5 | 28.5 | 118 | 46 | 0.68 | 0.64 | 81.5 | 29.4 | 110.9 |
| FEB. 11 | 5 | 1 | 69 | 3.5 | 1.8 | 0.53 | 0.64 | 1.8 | 1.1 | 2.9 |
| | 4 | 10 | 59 | 30 | 13 | 0.61 | 0.64 | 18.3 | 8.3 | 26.6 |
| | 3 | 19 | 49 | 62.5 | 26.5 | 0.65 | 0.64 | 40.6 | 17.0 | 57.6 |
| | 2 | 26 | 40 | 96 | 38 | 0.68 | 0.64 | 65.3 | 24.3 | 89.6 |
| | 1 | 30 | 34 | 114 | 45.5 | 0.68 | 0.64 | 77.5 | 29.0 | 106.5 |
| | 0 | 32 | 32 | 122 | 48 | 0.68 | 0.64 | 83.0 | 30.8 | 113.8 |
| FEB. 21 | 5 | 3 | 72 | 7.4 | 4.3 | 0.45 | 0.64 | 3.3 | 2.7 | 6.0 |
| | 4 | 13 | 62 | 33.5 | 15.6 | 0.59 | 0.64 | 19.7 | 10.0 | 29.7 |
| | 3 | 22 | 52 | 68 | 29 | 0.64 | 0.64 | 43.5 | 18.5 | 62.0 |
| | 2 | 28.5 | 43 | 97 | 39 | 0.67 | 0.64 | 65.0 | 25.0 | 90.0 |
| | 1 | 33.5 | 37.5 | 116 | 46.5 | 0.68 | 0.64 | 79.0 | 29.8 | 108.8 |
| | 0 | 35 | 35 | 122 | 49 | 0.68 | 0.64 | 83.0 | 31.4 | 114.4 |
| MAR. 1 | 5 | 6 | 74 | 11 | 7.2 | 0.40 | 0.64 | 4.4 | 4.6 | 9.0 |
| | 4 | 16 | 64 | 37.5 | 18.5 | 0.58 | 0.64 | 21.7 | 11.8 | 33.5 |
| | 3 | 24 | 54.5 | 69 | 30 | 0.63 | 0.64 | 43.5 | 19.2 | 62.7 |
| | 2 | 32 | 47 | 97 | 40 | 0.66 | 0.64 | 64.0 | 25.6 | 89.6 |
| | 1 | 37 | 41 | 117 | 48 | 0.68 | 0.64 | 79.5 | 30.7 | 110.2 |
| | 0 | 38.5 | 38.5 | 122 | 50 | 0.68 | 0.64 | 83.0 | 32.0 | 115.0 |

# TABLE A III

## CALCULATIONS OF THEORETICAL INSTANTANEOUS HEAT GAIN THROUGH SINGLE GLAZED WINDOWS FACING EAST – CLEAR ATMOSPHERE

| DATE | TIME | ALTITUDE ANGLE | INCIDENCE ANGLE | DIRECT ENERGY | DIFFUSE ENERGY | DIRECT TRANSMISSION | DIFFUSE TRANSMISSION | SUB-TOTAL DIRECT ENERGY | SUB-TOTAL DIFFUSE ENERGY | TOTAL ENERGY BTU/FT² HR |
|---|---|---|---|---|---|---|---|---|---|---|
| DEC. 21 | 8 | 3 | 38 | 32.5 | 4.7 | 0.90 | 0.83 | 29.3 | 3.9 | 33.2 |
| | 9 | 11 | 49 | 88 | 14.6 | 0.88 | 0.83 | 77.5 | 12.1 | 89.6 |
| | 10 | 17 | 62.5 | 84 | 17.7 | 0.82 | 0.83 | 68.9 | 14.7 | 83.6 |
| | 11 | 21 | 76 | 49 | 18.3 | 0.58 | 0.83 | 28.4 | 15.2 | 43.6 |
| | 12 | 22 | 90 | 0 | 17.3 | 0.0 | 0.83 | 0.0 | 14.4 | 14.4 |
| | 1 | 21 | 123 | | 15.2 | | 0.83 | | 12.6 | 12.6 |
| | 2 | 17 | 148 | | 12.3 | | 0.83 | | 10.2 | 10.2 |
| | 3 | 11 | 164 | | 8.4 | | 0.83 | | 7.0 | 7.0 |
| | 4 | 3 | 176 | | 2.4 | | 0.83 | | 2.0 | 2.0 |
| JAN. 11 | 8 | 4 | 36.5 | 45 | 6.3 | 0.90 | 0.83 | 40.5 | 5.2 | 45.7 |
| | 9 | 12 | 49 | 94 | 15.5 | 0.88 | 0.83 | 82.7 | 12.9 | 95.6 |
| | 10 | 18 | 62 | 88 | 18.6 | 0.82 | 0.83 | 72.1 | 15.4 | 87.5 |
| | 11 | 22.5 | 76 | 50 | 19.0 | 0.58 | 0.83 | 29.0 | 15.8 | 44.8 |
| | 12 | 24 | 90 | 0 | 18.0 | 0.0 | 0.83 | 0.0 | 15.0 | 15.0 |
| | 1 | 22.5 | 122 | | 15.7 | | 0.83 | | 13.0 | 13.0 |
| | 2 | 18 | 145 | | 13.0 | | 0.83 | | 10.8 | 10.8 |
| | 3 | 12 | 163 | | 9.0 | | 0.83 | | 7.5 | 7.5 |
| | 4 | 4 | 175 | | 3.1 | | 0.83 | | 2.6 | 2.6 |
| JAN. 21 | 8 | 6 | 35 | 66 | 9.5 | 0.90 | 0.83 | 59.4 | 7.9 | 67.3 |
| | 9 | 13.5 | 48 | 105 | 17.2 | 0.88 | 0.83 | 92.4 | 14.3 | 106.7 |
| | 10 | 20 | 62 | 93 | 20.0 | 0.82 | 0.83 | 76.2 | 16.6 | 92.8 |
| | 11 | 24.5 | 75.5 | 54 | 19.8 | 0.59 | 0.83 | 31.8 | 16.4 | 48.2 |
| | 12 | 26 | 90 | 0 | 19.0 | 0.0 | 0.83 | 0.0 | 15.8 | 15.8 |
| | 1 | 24.5 | 120 | | 16.5 | | 0.83 | | 13.7 | 13.7 |
| | 2 | 20 | 143 | | 14.0 | | 0.83 | | 11.6 | 11.6 |
| | 3 | 13.5 | 160 | | 10.0 | | 0.83 | | 8.3 | 8.3 |
| | 4 | 6 | 173 | | 4.7 | | 0.83 | | 3.9 | 3.9 |
| FEB. 1 | 8 | 7.5 | 34 | 82 | 11.7 | 0.90 | 0.83 | 73.8 | 9.8 | 83.6 |
| | 9 | 16 | 47.5 | 118 | 19.6 | 0.88 | 0.83 | 104.0 | 16.3 | 120.3 |
| | 10 | 22.5 | 61.5 | 99 | 21.3 | 0.82 | 0.83 | 81.1 | 17.7 | 98.8 |
| | 11 | 27 | 75.5 | 57 | 21.0 | 0.59 | 0.83 | 33.6 | 17.4 | 51.0 |
| | 12 | 28.5 | 90 | 0 | 19.8 | 0.0 | 0.83 | 0.0 | 16.4 | 16.4 |
| | 1 | 27 | 118 | | 17.8 | | 0.83 | | 14.8 | 14.8 |
| | 2 | 22.5 | 141 | | 15.0 | | 0.83 | | 12.4 | 12.4 |
| | 3 | 16 | 158 | | 11.5 | | 0.83 | | 9.6 | 9.6 |
| | 4 | 7.5 | 171 | | 5.8 | | 0.83 | | 4.8 | 4.8 |
| FEB. 11 | 7 | 1 | 21 | 13.4 | 1.9 | 0.91 | 0.83 | 12.2 | 1.6 | 13.8 |
| | 8 | 10 | 33 | 105 | 15.4 | 0.90 | 0.83 | 94.5 | 12.8 | 117.3 |
| | 9 | 19 | 46.5 | 133 | 22.0 | 0.89 | 0.83 | 118 | 18.3 | 136.3 |
| | 10 | 26 | 61 | 109 | 23.0 | 0.83 | 0.83 | 90.5 | 19.1 | 109.6 |
| | 11 | 30 | 75 | 61 | 22.4 | 0.61 | 0.83 | 37.2 | 18.6 | 55.8 |
| | 12 | 32 | 90 | 0 | 21.0 | 0.0 | 0.83 | 0.0 | 17.4 | 17.4 |
| | 1 | 30 | 117 | | 18.8 | | 0.83 | | 15.6 | 15.6 |
| | 2 | 26 | 138 | | 16.5 | | 0.83 | | 13.7 | 13.7 |
| | 3 | 19 | 155 | | 13.0 | | 0.83 | | 10.8 | 10.8 |
| | 4 | 10 | 168 | | 7.6 | | 0.83 | | 6.3 | 6.3 |
| | 5 | 1 | 178 | | 0.8 | | 0.83 | | 0.7 | 0.7 |
| FEB. 21 | 7 | 3 | 18 | 39 | 5.5 | 0.91 | 0.83 | 35.5 | 4.6 | 40.1 |
| | 8 | 13 | 32 | 130 | 19.0 | 0.90 | 0.83 | 117.0 | 15.8 | 132.8 |
| | 9 | 22 | 46 | 144 | 24.5 | 0.89 | 0.83 | 128.0 | 20.4 | 148.4 |
| | 10 | 28.5 | 60 | 117 | 24.8 | 0.83 | 0.83 | 97.0 | 20.6 | 117.6 |
| | 11 | 33.5 | 75 | 64 | 23.5 | 0.61 | 0.83 | 39.0 | 19.5 | 58.5 |
| | 12 | 35 | 90 | 0 | 22.0 | 0.0 | 0.83 | 0.0 | 18.3 | 18.3 |
| | 1 | 33.5 | 115 | | 20.0 | | 0.83 | | 16.6 | 16.6 |
| | 2 | 28.5 | 135 | | 17.5 | | 0.83 | | 14.5 | 14.5 |
| | 3 | 22 | 152 | | 14.4 | | 0.83 | | 12.0 | 12.0 |
| | 4 | 13 | 165 | | 9.5 | | 0.83 | | 7.9 | 7.9 |
| | 5 | 3 | 177 | | 2.4 | | 0.83 | | 2.0 | 2.0 |
| MAR. 1 | 7 | 6 | 17 | 76 | 10.9 | 0.91 | 0.83 | 69.2 | 9.1 | 78.3 |
| | 8 | 16 | 30.5 | 150 | 22.5 | 0.90 | 0.83 | 135.0 | 18.7 | 153.7 |
| | 9 | 24 | 45 | 152 | 26.0 | 0.89 | 0.83 | 135.0 | 21.6 | 156.6 |
| | 10 | 32 | 60 | 122 | 26.0 | 0.83 | 0.83 | 101.0 | 21.6 | 122.6 |
| | 11 | 37 | 75 | 66 | 24.8 | 0.61 | 0.83 | 40.2 | 20.6 | 60.8 |
| | 12 | 38.5 | 90 | 0 | 23.0 | 0.0 | 0.83 | 0.0 | 19.1 | 19.1 |
| | 1 | 37 | 113 | | 21.0 | | 0.83 | | 17.4 | 17.4 |
| | 2 | 32 | 133 | | 18.5 | | 0.83 | | 15.4 | 15.4 |
| | 3 | 24 | 149 | | 15.0 | | 0.83 | | 12.4 | 12.4 |
| | 4 | 16 | 162 | | 11.3 | | 0.83 | | 9.4 | 9.4 |
| | 5 | 6 | 174 | | 4.7 | | 0.83 | | 3.9 | 3.9 |

FIGURE A1

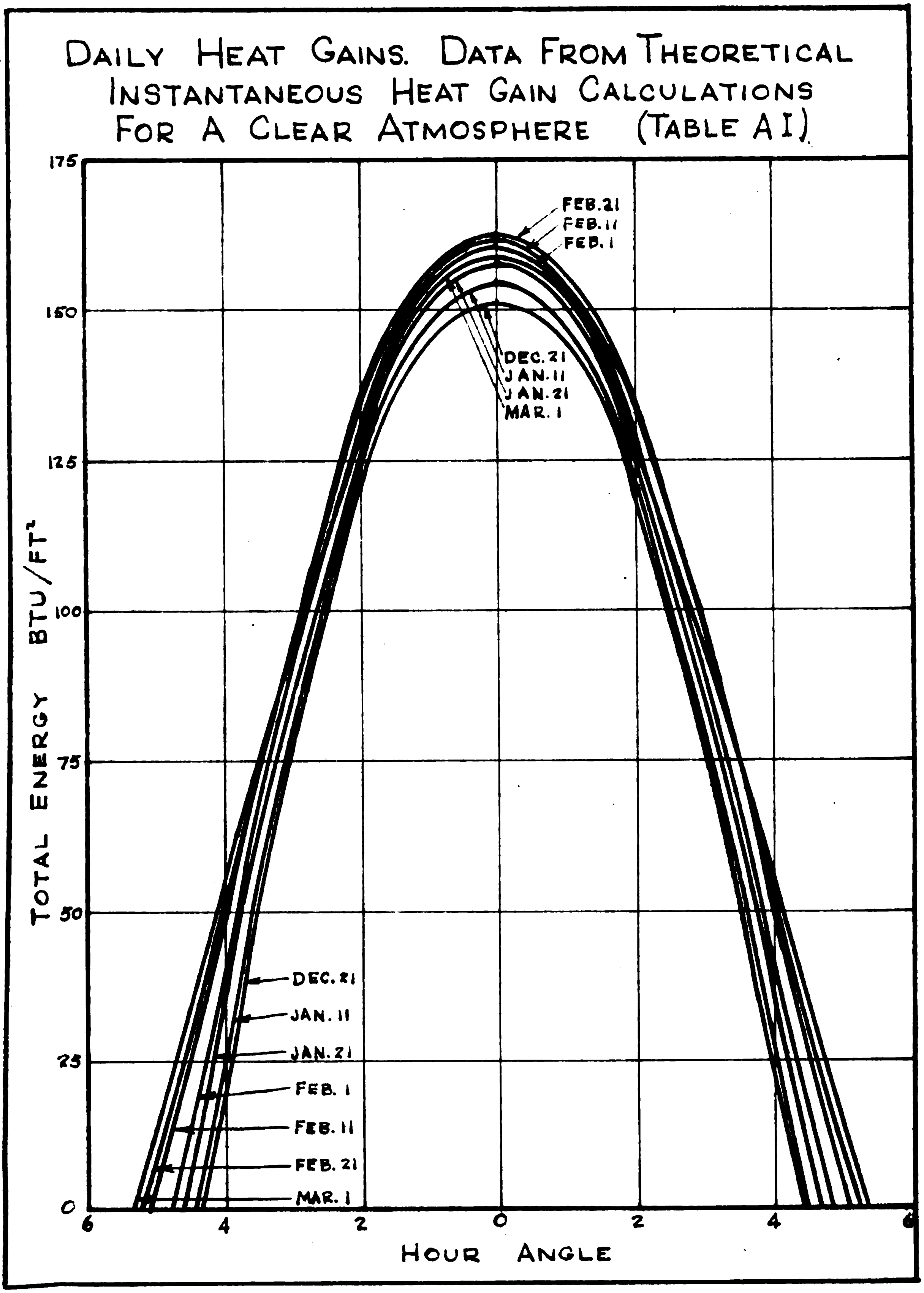

DAILY HEAT GAINS. DATA FROM THEORETICAL INSTANTANEOUS HEAT GAIN CALCULATIONS FOR A CLEAR ATMOSPHERE (TABLE A1)
175
150
125
100
75
50
25
0
TOTAL ENERGY BTU/FT²
FEB. 21
FEB. 11
FEB. 1
DEC. 21
JAN. 11
JAN. 21
MAR. 1
DEC. 21
JAN. 11
JAN. 21
FEB. 1
FEB. 11
FEB. 21
MAR. 1
6
4
2
0
2
4
6
HOUR ANGLE

FIGURE A2

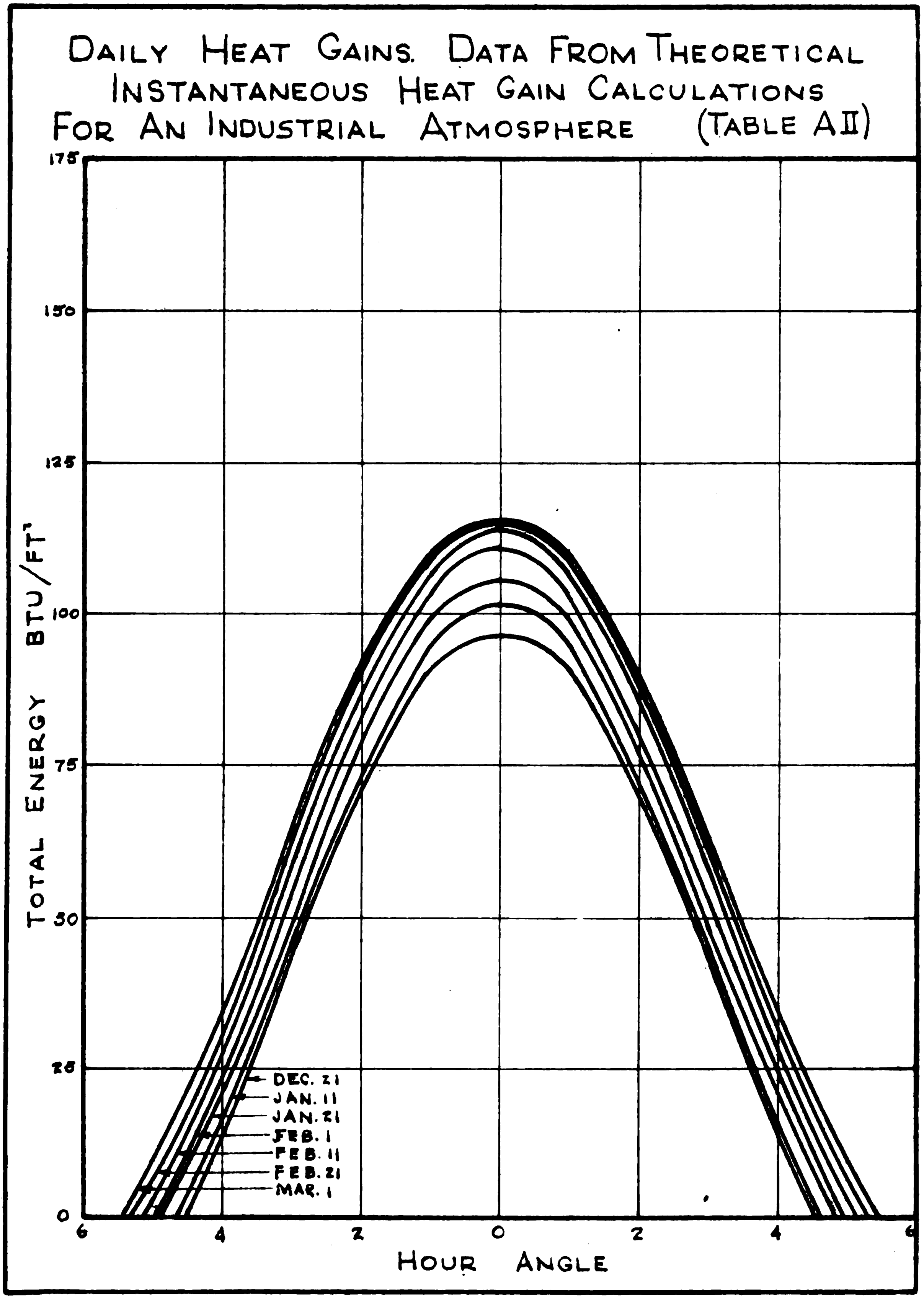
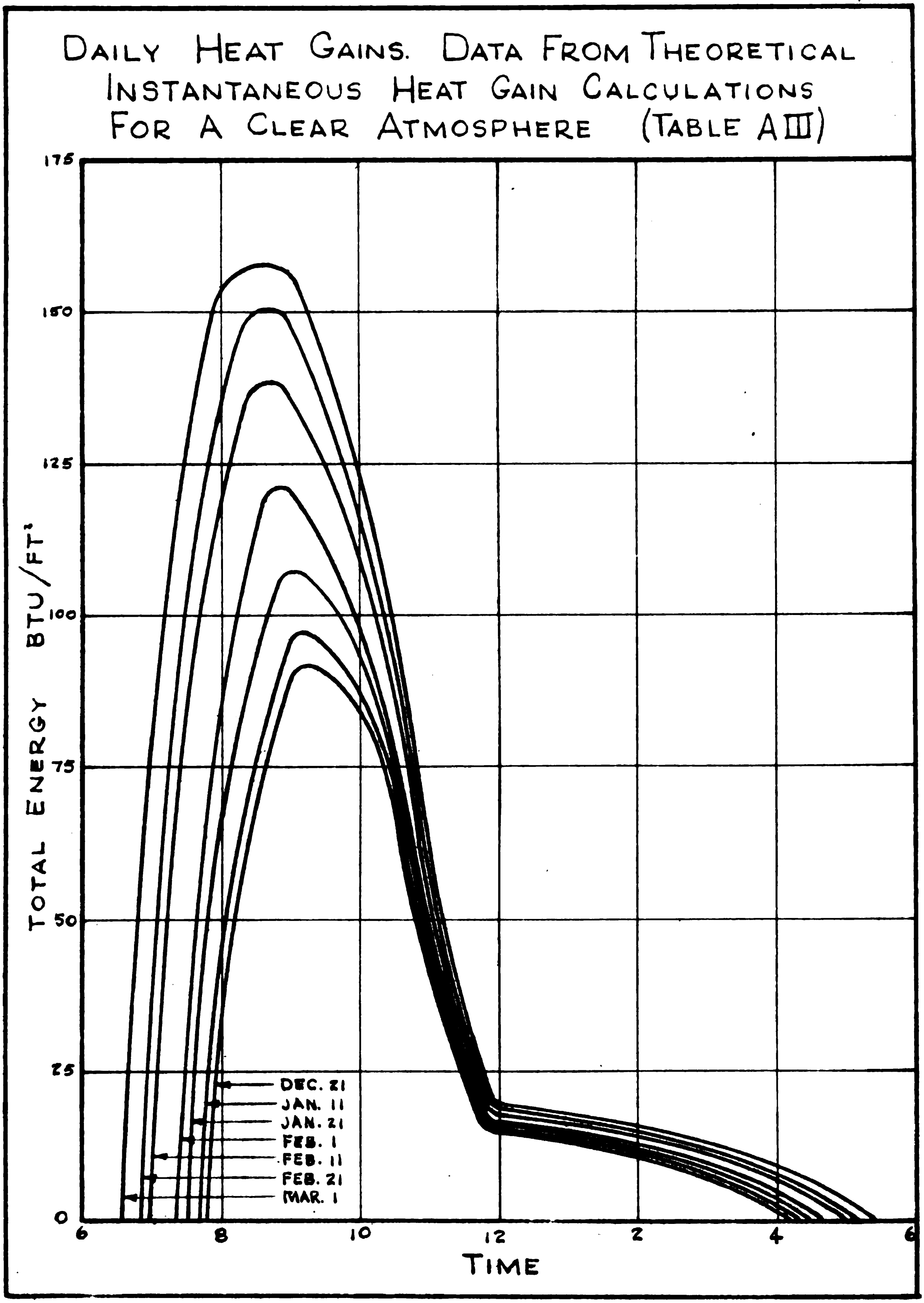

DAILY HEAT GAINS. DATA FROM THEORETICAL INSTANTANEOUS HEAT GAIN CALCULATIONS FOR AN INDUSTRIAL ATMOSPHERE (TABLE AII)
TOTAL ENERGY BTU/FT²
175
150
125
100
75
50
25
0
6
4
2
0
2
4
6
HOUR ANGLE
DEC. 21
JAN. 11
JAN. 21
FEB. 1
FEB. 11
FEB. 21
MAR. 1

FIGURE A3


DAILY HEAT GAINS. DATA FROM THEORETICAL INSTANTANEOUS HEAT GAIN CALCULATIONS FOR A CLEAR ATMOSPHERE (TABLE AIII)
TOTAL ENERGY BTU/FT²
175
150
125
100
75
50
25
0
6
8
10
12
2
4
6
TIME
DEC. 21
JAN. 11
JAN. 21
FEB. 1
FEB. 11
FEB. 21
MAR. 1

# TABLE A IV

## TOTAL DAILY HEAT GAIN COMPUTED FROM AREAS UNDER DAILY HEAT GAIN CURVES (FIGS. A1, A2, & A3)

| DATE | SOUTH FACING INSULATING GLASS WINDOWS | | | | EAST FACING SINGLE GLAZED WINDOWS | |
|---|---|---|---|---|---|---|
| | CLEAR ATMOSPHERE | | INDUSTRIAL ATMOSPHERE | | CLEAR ATMOSPHERE | |
| | AREA UNDER CURVES - IN² | TOTAL HEAT BTU/FT² | AREA UNDER CURVES - IN² | TOTAL HEAT BTU/FT² | AREA UNDER CURVES - IN² | TOTAL HEAT BTU/FT² |
| DEC. 21 | 16.00 | 436 | 9.70 | 264 | 5.44 | 148 |
| JAN. 11 | 16.58 | 452 | 10.25 | 280 | 5.92 | 162 |
| JAN. 21 | 17.42 | 476 | 10.97 | 299 | 6.59 | 180 |
| FEB. 1 | 18.16 | 495 | 11.64 | 316 | 7.52 | 205 |
| FEB. 11 | 19.04 | 520 | 12.37 | 337 | 9.33 | 254 |
| FEB. 21 | 19.37 | 528 | 12.92 | 353 | 10.41 | 284 |
| MAR. 1 | 19.13 | 522 | 13.35 | 364 | 11.74 | 320 |

# Table A V

## Total Daily Heat Gain For Average Day During The Indicated Week

| Week | South facing insulating glass windows | | East facing single glazed windows |
|---|---|---|---|
| | Clear atmosphere total heat BTU/FT² | Industrial atmosphere total heat BTU/FT² | Clear atmosphere total heat BTU/FT² |
| Dec. 10-16 | 438 | 266 | 150 |
| 17-23 | 436 | 264 | 148 |
| 24-31 | 438 | 266 | 150 |
| Jan. 1-7 | 445 | 272 | 155 |
| 8-14 | 452 | 280 | 162 |
| 15-21 | 470 | 290 | 174 |
| 22-28 | 485 | 305 | 190 |
| Jan. 29-Feb. 4 | 495 | 318 | 205 |
| 5-11 | 516 | 333 | 233 |
| 12-18 | 527 | 345 | 262 |
| 19-25 | 528 | 354 | 287 |
| Feb. 26-Mar. 4 | 522 | 364 | 320 |
| 5-11 | 510 | 365 | 348 |
| Total | 6261 | 4025 | 2784 |

Tabulation of results from A.E. 500 special problem. Saia's calculations (35) were made by using the average weekly mean values for solar radiation on a horizontal surface as recorded at East Lansing by the Michigan Hydrologic Research Project from the years 1943 to 1950. These values were multiplied by a ratio of total radiation on a south facing vertical wall to the total radiation on a horizontal surface obtained during the winter of 1945-1946 at the Blue Hill, Massachusetts, Weather Station (11). A transmission value of seventy percent was used for his calculations (38). The results from these calculations are recorded in Table AVI and were taken for the period of the study only.

# TABLE A VI

## HEAT GAINED BY SOLAR RADIATION THROUGH INSULATING GLASS WINDOWS FACING SOUTH CALCULATIONS BY SAIA

| WEEK | WEEKLY TOTAL HEAT GAIN BTU/FT² | AVERAGE DAILY HEAT GAIN BTU/FT² |
|---|---|---|
| DEC. 10-16 | 3390 | 485 |
| 17-23 | 4198 | 600 |
| 24-31 | 3168 | 396 |
| JAN. 1-7 | 3166 | 453 |
| 8-14 | 3516 | 502 |
| 15-21 | 7117 | 1017 |
| 22-28 | 6374 | 910 |
| JAN. 29 - FEB. 4 | 7004 | 1000 |
| 5-11 | 5812 | 830 |
| 12-18 | 5330 | 761 |
| 19-25 | 5051 | 721 |
| FEB. 26 - MAR. 4 | 4993 | 714 |
| 5-11 | 5217 | 745 |
| TOTAL | 64,336 | 9,134 |

Results from the winter of 1953. The equation used for the calculations in this part of the Appendix, $I_V = I_H \text{ (cot a cos D)} \frac{1}{2}(2 - \frac{I_D}{I_H}) + \frac{1}{2} I_H (\frac{I_D}{I_H})$, was developed earlier and the development will not be repeated at this time.

Table AVII was taken from data gathered by the Michigan Hydrologic Research Station and was used with their permission. The values are weekly means and thus these weekly periods were used for the calculation. These data were recorded in units of gram-calories per square centimeter of horizontal surface and were converted to BTU's per square foot of horizontal surface (by multiplying by the factor of 3.68) and were then listed in column 3 of Table AIX.

Values for the solar altitude and solar azimuth, "a" and "D" respectively, are plotted in Figures A4 and A5 for various hour angles through the year. These values were taken at $42^{\circ}$ north latitude which was considered sufficiently accurate for this study. From these two graphs, calculations of the mid-month values of "cot a cos D" were made and these results plotted in Figure A6. This then made it possible to scale these values from the graph for any hour angle and any date with a fair degree of accuracy. This method was used to get the necessary values for column 4 of Table AIX.

The values for the ratio of $I_D$ over $I_H$ of column 5, Table AIX, were obtained from Figure A7. Values to plot these graphs came from data obtained at the Blue Hill, Massachusetts, Weather Station (12) during the period from September, 1945, to March, 1946. Since this was a collection period of only seven months, or one winter, its application to other conditions may be questioned. The use of Figure A7 depended upon the amount of cloudiness recorded in Table AVIII. Cloudiness is measured from 0 to 10 with 10 being a complete cloud cover. The usual range is 0 to 3, clear; 4 to 7, partly cloudy; and 8 to 10, cloudy. Values for the amount of cloudiness were taken from the climatological data of Appendix B for the days of the weekly period and an average value was obtained for the week. These values were recorded in Table AVIII.

Column 6, Table AIX, was obtained mathematically from column 5. Column 6 was so arranged that its value would never be less than 50% of the total solar radiation. This occurred whenever the ratio of $I_D$ over $I_H$ equaled one. When this ratio was equal to one, the values of $I_D$ and $I_H$ would be equal. This might appear to mean that all of the energy was diffuse. This would only be true for an extremely heavy cloud layer, however, since with a light cloud covering such as Cirrostatus, which would still be rated as a cloud covering of 10, a large amount of direct radiant energy will pass through. According to Kimball (22-p653) the ratio of diffuse illumination to total illumination on a horizontal surface at noon in midwinter varies from one-half to one-fifth. Also, over two-fifths of the sun's radiant energy is in the infrared region beyond the visible spectrum (1). This infrared energy is much more penetrating through the atmospheric layers than energy of other wave lengths. It does not seem incorrect then to allow for 50% direct energy when there is a complete cloud covering of average density.

Column 7 of Table AIX was obtained as the product of columns 3, 4, and 6. This represents the total amount of direct solar energy perpendicular to a south facing wall.

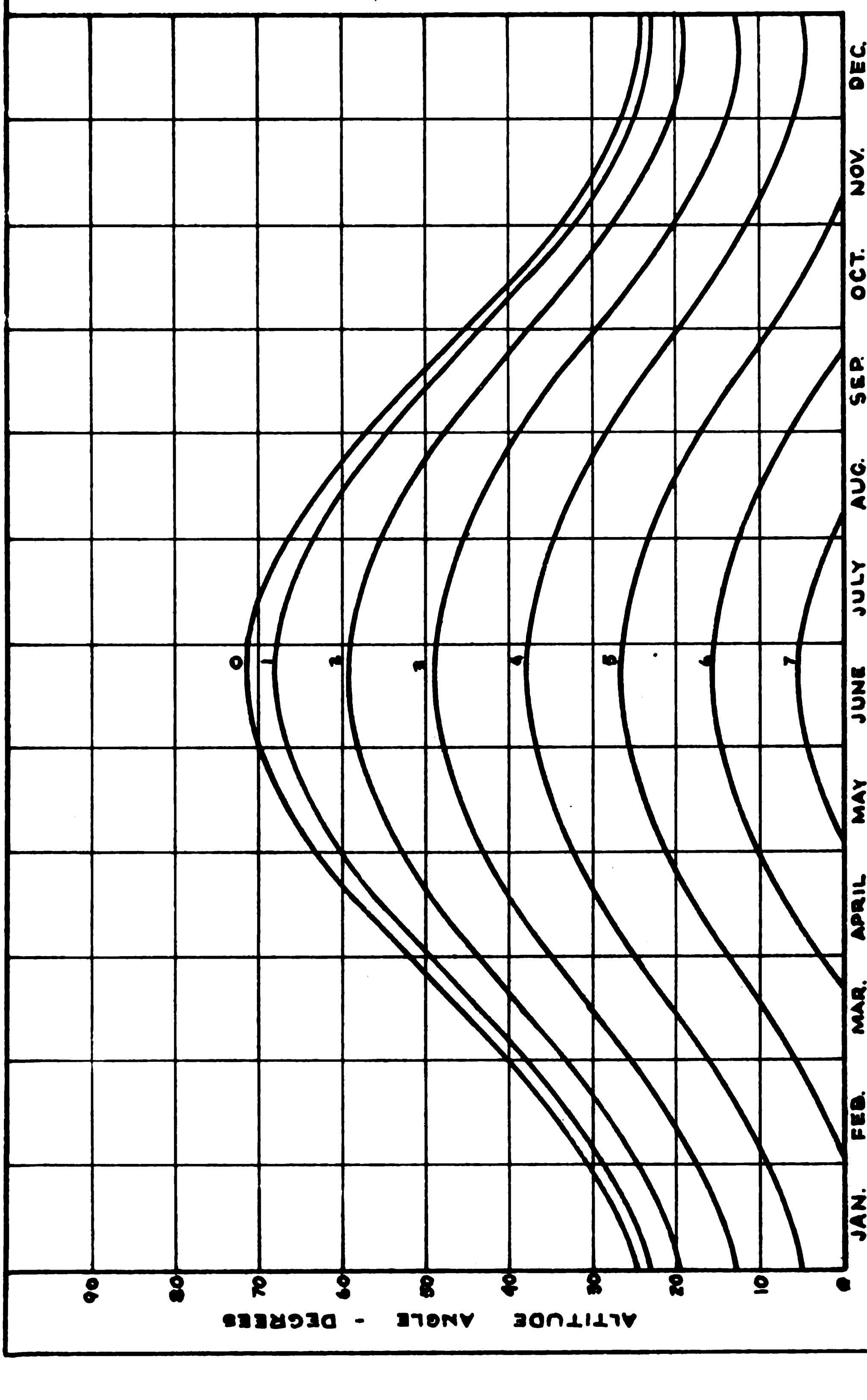
Multiplying the total energy received on a horizontal surface, $I_H$, by the ratio of $I_D$ over $I_H$ gives an answer which is the total amount of diffuse energy received on a horizontal surface from all of the sky. Since a south facing vertical wall is exposed to only one-half of the sky, the diffuse radiation for a horizontal surface was multiplied by one-half to obtain the values for column 8 of Table AIX. It was recognized that normally the southern half of the sky will be brighter than the northern half (24), but it was felt that this was due more to the direct radiation (even when cloudy) than to any appreciable amount of increase in diffuse radiation. This increase has already been accounted for, then, in the preceding paragraph.

Column 9 is the sum of columns 7 and 8 and represents the total amount of radiation or energy expressed in BTU's per square foot impinging upon a south, vertical surface. For the first nine weeks, column 9 was totaled for the day and then multiplied by the transmission percentage of the glass and recorded in column 11. For the last four weeks of the table, column 9 was first multiplied by the transmission percentage and the results were totaled in column 11.

The transmission percentage of column 10 was taken from data compiled by Parmelee (32) for a double glass which resembled the type of insulating glass used in the piggery. The transmission observed on several dates averaged 59.7% for values of the incident angle up to sixty degrees. At about sixty degrees, the transmission dropped off rapidly. This accounts for the use of a transmission value of twenty percent for the early morning and late afternoon hours.

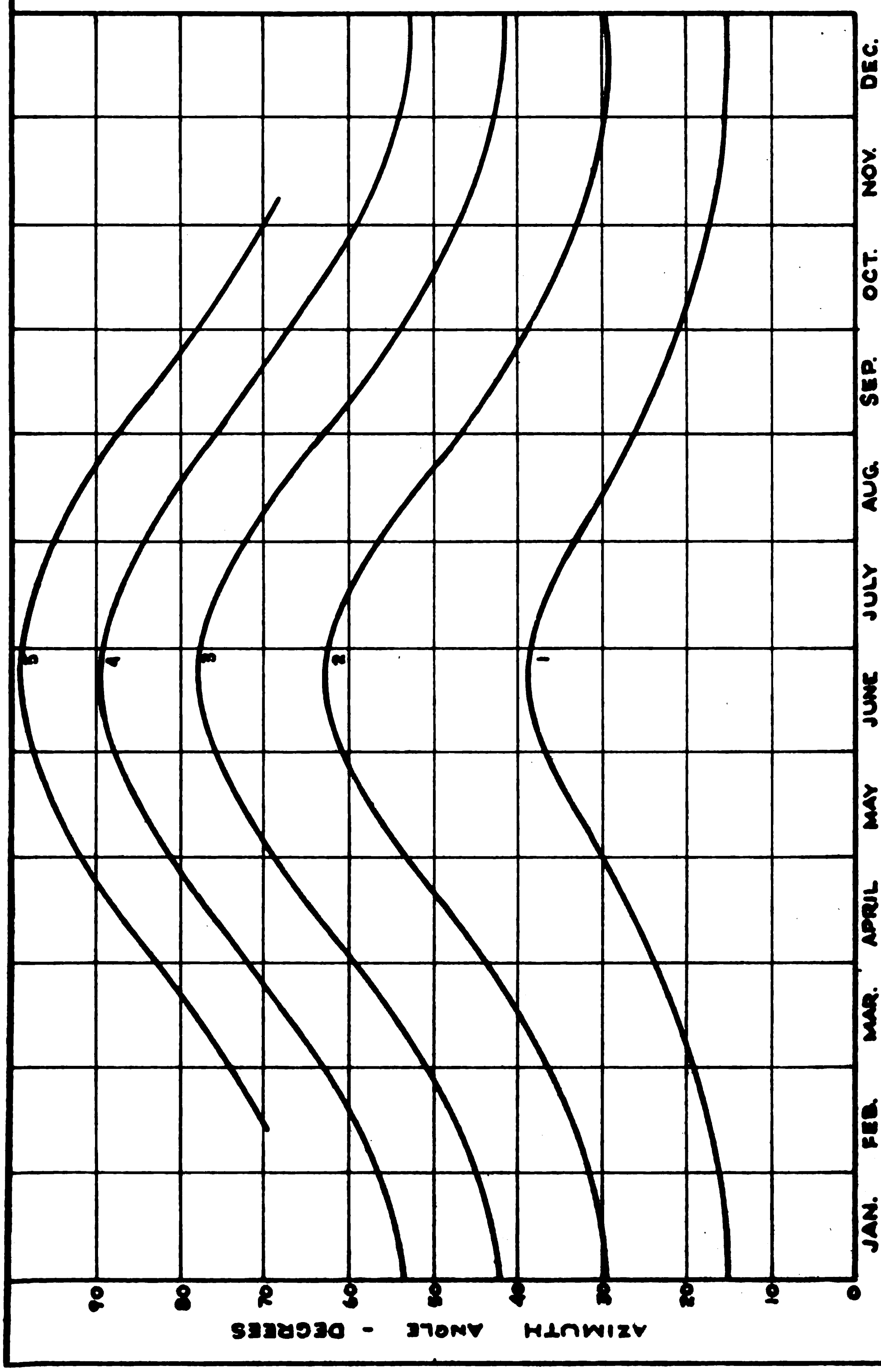
The totals in column 11 represent the total amount of solar energy passing through the south facing insulating glass windows in BTU's per square foot of glass for an average day during the week indicated. These values for the average days were totaled at the bottom of column 11 for the thirteen-week season. Multiplying this total by seven (the number of days in a week) gives the grand total for all of the days of the study.

FIGURE A4



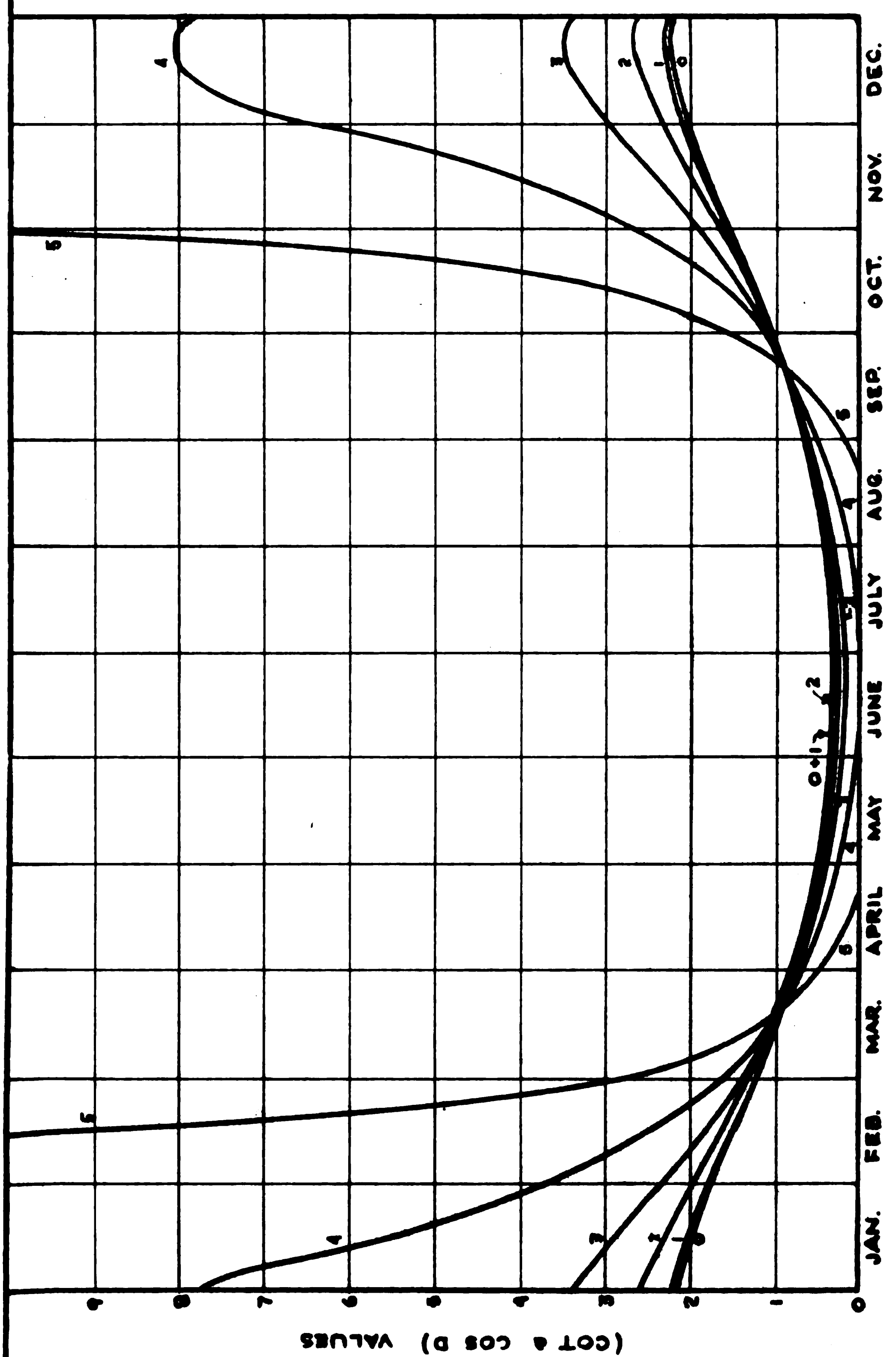

SEASONAL VARIATION OF SOLAR ALTITUDE ANGLE FOR INDICATED HOUR ANGLES

FIGURE A5




SEASONAL VARIATION OF SOLAR AZIMUTH ANGLE FOR INDICATED HOUR ANGLES

FIGURE A6




SEASONAL VARIATION OF COT a COS D FOR INDICATED HOUR ANGLES

# Table A VII

## Weekly Means of Direct and Diffuse Radiation in Gram-Calories per Square Centimeter of Horizontal Surface by Hours

| Hour Angle | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time / Week | 5-6 | 6-7 | 7-8 | 8-9 | 9-10 | 10-11 | 12 Noon | 12-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | Mean Daily Total |
| Dec. 10-16 | | 0.1 | 2.1 | 6.7 | 11.7 | 12.6 | 11.5 | 11.0 | 7.3 | 2.5 | 0.1 | | | 65.6 |
| 17-23 | | 0.1 | 1.9 | 5.0 | 7.7 | 12.0 | 11.2 | 9.4 | 5.1 | 1.7 | T | | | 54.1 |
| 24-31 | | T | 1.7 | 6.4 | 9.5 | 12.2 | 12.3 | 10.7 | 8.2 | 2.5 | 0.1 | | | 63.6 |
| Jan. 1-7 | | 0.2 | 3.0 | 8.0 | 14.1 | 14.3 | 12.3 | 9.4 | 6.6 | 2.7 | 0.3 | | | 70.6 |
| 8-14 | | | 1.7 | 6.1 | 11.1 | 13.1 | 12.9 | 9.9 | 7.0 | 2.7 | 0.2 | | | 63.9 |
| 15-21 | | 0.4 | 4.2 | 9.3 | 17.0 | 19.5 | 16.8 | 10.6 | 7.0 | 4.1 | 0.4 | | | 89.3 |
| 22-28 | | 0.9 | 4.4 | 11.2 | 13.1 | 13.2 | 13.1 | 11.2 | 8.0 | 4.4 | 0.6 | | | 80.1 |
| Jan. 29 - Feb. 4 | | 0.9 | 5.5 | 12.1 | 15.3 | 19.3 | 21.3 | 18.6 | 17.8 | 7.9 | 1.7 | | | 120.4 |
| 5-11 | | 1.2 | 5.5 | 8.8 | 13.8 | 14.7 | 15.1 | 10.4 | 8.7 | 4.5 | 1.0 | | | 83.7 |
| 12-18 | | 1.6 | 6.9 | 12.9 | 20.1 | 24.9 | 27.8 | 22.0 | 16.8 | 9.8 | 3.0 | 0.1 | | 145.9 |
| 19-25 | 0.1 | 4.8 | 14.9 | 21.6 | 26.0 | 28.3 | 27.8 | 24.1 | 20.1 | 12.0 | 4.3 | 0.2 | | 184.2 |
| Feb. 26 - Mar. 4 | 0.3 | 5.3 | 11.4 | 16.9 | 20.3 | 23.7 | 21.4 | 18.2 | 20.7 | 11.9 | 5.1 | 0.4 | | 155.6 |
| 5-11 | 0.6 | 7.0 | 16.3 | 21.2 | 24.8 | 31.2 | 31.5 | 27.3 | 24.0 | 12.7 | 6.0 | 0.8 | | 203.4 |

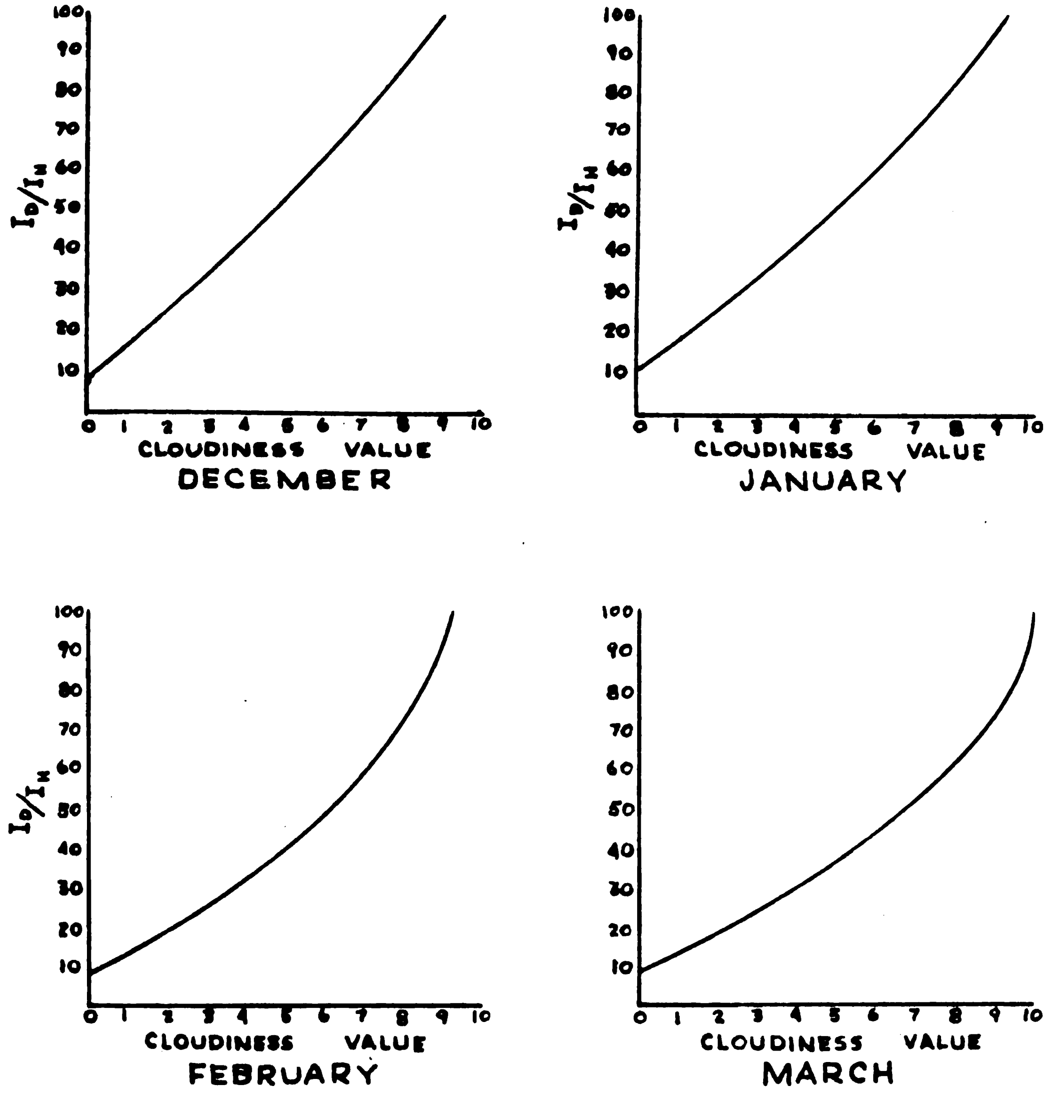
# TABLE A VIII

## DAILY AVERAGE CLOUDINESS COMPUTED FROM LANSING WEATHER BUREAU DATA

| WEEK | DAILY CLOUDINESS VALUES | AVERAGE DAILY CLOUDINESS |
|---|---|---|
| DEC. 10-16 | 10 - 10 - 9 - 10 - 10 - 10 - 0 | 8.4 |
| 17-23 | 7 - 6 - 9 - 10 - 10 - 10 - 10 | 8.9 |
| 24-31 | 10 - 10 - 10 - 3 - 5 - 10 - 10 - 10 | 8.5 |
| JAN. 1-7 | 10 - 10 - 10 - 9 - 9 - 7 - 10 | 9.3 |
| 8-14 | 10 - 10 - 10 - 10 - 9 - 1 - 10 | 8.6 |
| 15-21 | 9 - 6 - 10 - 8 - 10 - 9 - 5 | 8.1 |
| 22-28 | 10 - 10 - 10 - 9 - 8 - 10 - 10 | 9.6 |
| JAN. 29 - FEB. 4 | 9 - 2 - 9 - 4 - 10 - 9 - 9 | 7.4 |
| 5-11 | 10 - 10 - 10 - 9 - 2 - 10 - 10 | 8.7 |
| 12-18 | 10 - 9 - 2 - 8 - 9 - 9 - 7 | 7.7 |
| 19-25 | 7 - 10 - 9 - 4 - 0 - 8 - 8 | 6.6 |
| FEB. 26 - MAR. 4 | 9 - 8 - 9 - 5 - 10 - 10 - 9 | 8.6 |
| 5-11 | 6 - 9 - 9 - 10 - 9 - 10 - 9 | 8.9 |

FIGURE A7

GRAPHICAL VALUES OF $I_D/I_H$ FOR DIFFERENT CLOUDINESS VALUES FOR FOUR WINTER MONTHS DATA FROM HAND (12)



# APPENDIX B

## LOCAL CLIMATOLOGICAL DATA

The following climatological data were gathered by the Lansing, Michigan, Weather Bureau located at the Capitol City Airport about eight miles from the location of the piggery.

These four tables, representing the winter months of December, January, February, and March, contain the following information for each day:

1. Maximum, minimum, and average temperatures.
2. Departure of temperature from normal.
3. Number of degree days.
4. Total precipitation with an hourly record.
5. Wind directions and velocities.
6. Total and percent sunshine.
7. Amount of cloudiness.

Also of interest is the commentary for the month appearing directly above the hourly precipitation record.

TABLE B I.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

# LOCAL CLIMATOLOGICAL DATA

LANSING, MICHIGAN (Capitol City Airport) DECEMBER, 1952

Latitude 42 ° 47 ′ N. Longitude 84 ° 36 ′ W. Elevation (ground) 859 ft. Eastern Standard time used

| Date | Temperature (°F) Maximum | Minimum | Average | Departure from normal | Degree days (base 65°) | Precipitation Total (Water equivalent) (In.) | Snow, Sleet, Hail (In.) | Snow, Sleet, Hail or Ice on ground at 7:30 am (In.) | Wind Prevailing direction | Average speed (m. p. h.) | Fastest mile Speed (m. p. h.) | Direction | Sunshine Total (hours and minutes) | Percent of possible | Sky cover Sunrise to sunset (tenths) | Midnight to midnight (tenths) | Thunderstorm or distant lightning | Weather restricting visibility to ¼ mile or less | 20 | 21 | 22 | 23 | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | 30 | 18 | 24 | - 7 | 41 | 0.02 | 0.2 | T | S | 12.1 | 17 | S | 0:00 | 0 | 9 | 9 | | | | | | | 1 |
| 2 | 31 | 21 | 26 | - 4 | 39 | 0.25 | 3.1 | 3 | NE | 8.0 | 13 | E | 3:18 | 36 | 8 | 9 | | F | | | | | 2 |
| 3 | 34 | 23 | 29 | - 1 | 36 | 0 | 0 | 3 | E | 10.0 | 17 | NE | 0:26 | 5 | 10 | 10 | | | | | | | 3 |
| 4 | 37 | 26 | 32 | + 2 | 33 | 0.25 | T | 2 | SE | 17.3 | 20 | SE | 0:00 | 0 | 10 | 10 | | | | | | | 4 |
| 5 | 37 | 31 | 34 | + 4 | 31 | 0.14 | 0.5 | T | WSW | 15.9 | 20 | W | 0:00 | 0 | 10 | 10 | | FR | | | | | 5 |
| 6 | 35 | 30 | 33 | + 4 | 32 | T | T | T | WNW | 15.0 | 20 | W | 0:00 | 0 | 10 | 9 | | | | | | | 6 |
| 7 | 48 | 30 | 39 | +10 | 26 | 0 | 0 | T | S | 13.7 | 18 | SE | 8:56 | 97 | 2 | 3 | | | | | | | 7 |
| 8 | 56 | 34 | 45 | +16 | 20 | T | 0 | 0 | S | 14.5 | 23 | S | 0:03 | 1 | 10 | 8 | | | | | | | 8 |
| 9 | 57 | 45 | 51 | +23 | 14 | 0 | 0 | 0 | SSW | 8.8 | 20 | S | 0:34 | 6 | 9 | 8 | | FK | | | | | 9 |
| 10 | 49 | 33 | 41 | +13 | 24 | 0.08 | T | 0 | W | 13.1 | 21 | W | 0:00 | 0 | 10 | 10 | | FKR | | | | | 10 |
| 11 | 34 | 27 | 31 | + 3 | 34 | 0.04 | 0.3 | T | W | 14.6 | 26 | W | 0:00 | 0 | 10 | 10 | | | | | | | 11 |
| 12 | 32 | 23 | 28 | 0 | 37 | 0.06 | 0.7 | 1 | W | 7.8 | 13 | E | 0:22 | 4 | 9 | 9 | | | | | | | 12 |
| 13 | 31 | 24 | 28 | + 1 | 37 | 0.01 | T | T | WNW | 13.4 | 18 | NW | 0:00 | 0 | 10 | 9 | | | | | | | 13 |
| 14 | 27 | 23 | 25 | - 2 | 40 | 0.09 | 0.9 | T | SW | 17.5 | 23 | W | 0:00 | 0 | 10 | 10 | | | | | | | 14 |
| 15 | 35 | 26 | 31 | + 4 | 34 | 0.01 | T | 1 | WSW | 15.0 | 22 | W | 0:37 | 7 | 10 | 7 | | | | | | | 15 |
| 16 | 40 | 25 | 33 | + 6 | 32 | 0 | 0 | T | WSW | 13.0 | 17 | SW | 9:03 | 100 | 0 | 0 | | | | | | | 16 |
| 17 | 40 | 26 | 33 | + 7 | 32 | 0 | 0 | T | W | 8.5 | 15 | W | 1:27 | 16 | 7 | 5 | | FK | | | | | 17 |
| 18 | 30 | 19 | 25 | - 1 | 40 | 0 | 0 | T | NW | 7.5 | 15 | NW | 2:31 | 28 | 6 | 4 | | | | | | | 18 |
| 19 | 32 | 18 | 25 | - 1 | 40 | T | T | T | E | 11.6 | 23 | NE | 0:00 | 0 | 9 | 7 | | | | | | | 19 |
| 20 | 36 | 30 | 33 | + 7 | 32 | 0.59 | T | T | E | 15.9 | 23 | NE | 0:00 | 0 | 10 | 10 | | | | | | | 20 |
| 21 | 36 | 34 | 35 | + 9 | 30 | 0.08 | 0 | 0 | ENE | 4.0 | 8 | N | 0:00 | 0 | 10 | 10 | | FRL | | | | | 21 |
| 22 | 40 | 34 | 37 | +12 | 28 | 0.06 | 0 | 0 | SE | 11.8 | 22 | E | 0:00 | 0 | 10 | 10 | | FL | | | | | 22 |
| 23 | 44 | 37 | 41 | +16 | 24 | 0.11 | 0 | 0 | SE | 13.3 | 12 | SE | 0:00 | 0 | 10 | 10 | | | | | | | 23 |
| 24 | 38 | 32 | 35 | +10 | 30 | T | 0 | 0 | WSW | 18.3 | 17 | W | 0:00 | 0 | 10 | 10 | | | | | | | 24 |
| 25 | 32 | 27 | 30 | + 5 | 35 | 0.03 | T | T | W | 18.3 | 23 | W | 0:00 | 0 | 10 | 10 | | | | | | | 25 |
| 26 | 30 | 24 | 27 | + 2 | 38 | T | T | T | WSW | 18.6 | 26 | W | 0:00 | 0 | 10 | 10 | | | | | | | 26 |
| 27 | 26 | 13 | 20 | - 4 | 45 | T | T | T | NW | 12.9 | 23 | W | 5:53 | 65 | 3 | 4 | | | | | | | 27 |
| 28 | 33 | 13 | 23 | - 1 | 42 | 0 | 0 | T | SSW | 12.8 | 10 | S | 2:46 | 31 | 5 | 3 | | | | | | | 28 |
| 29 | 37 | 27 | 32 | + 8 | 33 | T | T | 0 | SW | 10.0 | 13 | SE | 0:00 | 0 | 10 | 10 | | | | | | | 29 |
| 30 | 34 | 30 | 32 | + 8 | 33 | 0.02 | 0.1 | T | NE | 9.7 | 17 | NE | 0:00 | 0 | 10 | 10 | | F | | | | | 30 |
| 31 | 31 | 27 | 29 | + 5 | 36 | T | T | 0 | NE | 12.5 | 17 | NE | 0:00 | 0 | 10 | 10 | | | | | | | 31 |
| Sum | 1132 | 830 | — | — | — | 1.84 | 5.8 | — | — | 395.4 | — | — | 35:56 | — | 267 | 254 | — | — | | | | | Sum |
| Avg. | 36.5 | 26.8 | — | — | — | — | — | — | — | 12.8 | Fastest | Dir. | Possible | % | 8.6 | 8.2 | — | — | | | | | Avg. |
| | | | | | | | | | | Misc. | 26 | W | 282:13 | 13 | — | — | — | — | | | | | Misc. |

T in columns 7, 8, and 9 indicates amount too small to measure.

**TEMPERATURE: (°F)**
Average monthly 31.7
Departure from normal +4.8
Highest 57 on 9th
Lowest 13 on 27th & 28th
Number of days with —
Max. 32° or below 11
Max. 90° or above 0
Min. 32° or below 25
Min. 0° or below 0

**HEATING DEGREE DAYS (base 65°):**
Total this month 1028
Departure from normal -167
Seasonal total (since July 1) 2578
Seasonal departure from normal -127

**BAROMETRIC PRESSURE (In.)**
Avg. station (elev. 878 feet, m. s. l.) 29.045
Highest sea level 30.46 on 19th
Lowest sea level 29.64 on 10th

**PRECIPITATION: (In.)**
Total for the month 1.84
Departure from normal -0.23
Greatest in 24 hours 0.60 on 20 & 21
Snow, Sleet and Hail —
Total for the month 5.8
Greatest in 24 hours 3.3 on 1st & 2nd
Greatest depth on ground 3 on 2 & 3
Dates of — Hail ——
Sleet 4, 19, 20 Glaze 15, 20, 25

**Symbols used in columns 18-19**
A = Hail
BS = Blowing snow
DL = Distant lightning
D = Dust
E = Sleet
F = Fog
H = Haze
K = Smoke
L = Drizzle
N = Sand
R = Rain
S = Snow
T = Thunderstorm
ZL = Freezing drizzle
ZR = Freezing rain

The month of December was characterized by cloudy skies, above normal temperatures and sub-normal precipitation. Temperatures for the 31-day period averaged almost 5° above normal and was the warmest Dec. since 1941. The total sunshine for the month was abnormally low for Dec., tying the low record for percent of possible sunshine. Only in 1920 and 1935 did so little sunshine occur. While precip. this month was almost 1/4" below normal, rain or snow fell on 24 days. Hazardous driving conditions existed on several occasions. Several personal injury accidents were accredited to 8 separate days of heavy fog.

## HOURLY PRECIPITATION

| Date | A. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | P. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | T | T | .01 | .01 | 1 |
| 2 | .04 | .03 | .05 | .05 | .04 | .01 | T | T | .02 | .01 | T | | | | | | | | | | | | | | 2 |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 4 | | | | | | | | T | T | T | T | | | T | T | .03 | .01 | T | .01 | .05 | .09 | .03 | T | .03 | 4 |
| 5 | .04 | .03 | .01 | .01 | T | | T | T | T | T | T | T | T | T | T | .03 | .01 | T | | T | T | T | T | .01 | 5 |
| 6 | T | T | T | | | | | | | | | | | | | | | | | | | | | | 6 |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | T | 8 |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 10 | T | .06 | T | | | | T | T | .02 | T | | | | | | | | | | | | | | T | 10 |
| 11 | .02 | T | T | .01 | | | T | T | T | | T | T | T | T | T | T | | | | | | | .01 | T | 11 |
| 12 | .01 | .01 | .01 | T | T | T | T | T | T | T | T | | | | | | | | | | .01 | .01 | .01 | T | 12 |
| 13 | T | T | T | T | T | T | T | T | T | T | T | .01 | T | T | T | T | T | T | | | | T | T | T | 13 |
| 14 | T | T | T | T | T | T | T | T | T | T | .02 | .02 | T | T | T | .01 | .01 | T | T | T | T | T | .01 | .02 | 14 |
| 15 | T | T | .01 | T | T | T | T | T | T | | | | | | | | | | | | | | | | 15 |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | 16 |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | | 17 |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | 18 |
| 19 | | | | | | | | | | | | | | | | | | | | | | | T | T | 19 |
| 20 | .01 | .04 | .05 | .02 | .02 | .01 | .02 | .02 | .13 | .08 | .01 | .05 | .01 | .01 | T | T | T | T | T | .03 | .03 | .04 | .01 | | 20 |
| 21 | .02 | .01 | .01 | T | T | .01 | T | T | T | T | T | T | .01 | T | .01 | T | T | .01 | T | T | T | T | T | T | 21 |
| 22 | | | | | T | .01 | .02 | T | .01 | T | T | | T | | | | | | | | T | T | T | .02 | 22 |
| 23 | .05 | .01 | T | T | .01 | .01 | .01 | T | T | T | .01 | T | T | T | T | .01 | T | T | T | T | T | | | T | 23 |
| 24 | | T | T | | | | | | | | | | | T | T | T | T | T | T | | | | | | 24 |
| 25 | | | | T | T | T | T | T | T | .01 | .01 | .01 | T | T | T | T | T | T | T | T | T | T | T | T | 25 |
| 26 | T | T | T | T | T | T | T | T | T | T | T | T | T | T | | | | T | T | T | T | T | T | T | 26 |
| 27 | T | | T | T | T | T | | | | | | | | | | | | | | | | | | | 27 |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | | 28 |
| 29 | | | | | | | | | | | | | | | | | | | | T | T | T | T | T | 29 |
| 30 | .01 | .01 | | | | | | | | | | | | | | | | | | | | | | | 30 |
| 31 | | | | | | | | | | | | T | T | T | T | T | T | | | | | | | | 31 |



WRPC, Kansas City, Mo. -- 1-6-53 -- 325

TABLE B II.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

# LOCAL CLIMATOLOGICAL DATA

LANSING, MICHIGAN (Capitol City Airport) JANUARY, 1953

Latitude 42 ° 47 ' N. Longitude 84 ° 36 ' W. Elevation (ground) 859 ft. Eastern Standard time used

| Date | Temperature (°F) Maximum | Minimum | Average | Departure from normal | Degree days (base 65°) | Precipitation Total (Water equivalent) (In.) | Snow, Sleet, Hail (In.) | Snow, Sleet, Hail or Ice on ground at 7:30 am (In.) | Wind Prevailing direction | Average speed (m. p. h.) | Fastest mile Speed (m. p. h.) | Direction | Sunshine Total (hours and minutes) | Percent of possible | Sky cover Sunrise to sunset (tenths) | Midnight to midnight (tenths) | Thunderstorm or distant lightning | Weather restricting visibility to ¼ mile or less | | | | | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | 35 | 27 | 31 | + 6 | 34 | 0 | 0 | 0 | SW | 12.0 | 17 | SW | 0:00 | 0 | 10 | 10 | | | | | | | 1 |
| 2 | 33 | 28 | 31 | + 6 | 34 | 0.02 | 0.2 | 0 | SSE | 7.9 | 14 | SE | 0:00 | 0 | 10 | 10 | | | | | | | 2 |
| 3 | 31 | 19 | 25 | 0 | 40 | T | T | T | NNW | 14.8 | 20 | N | 0:00 | 0 | 10 | 10 | | | | | | | 3 |
| 4 | 29 | 16 | 23 | - 2 | 42 | T | T | T | WSW | 10.5 | 17 | S | 0:00 | 0 | 9 | 8 | | | | | | | 4 |
| 5 | 26 | 11 | 19 | - 6 | 46 | 0.07 | 1.0 | T | WNW | 17.3 | 27 | W | 0:33 | 6 | 9 | 9 | | | | | | | 5 |
| 6 | 20 | 6 | 13 | -12 | 52 | 0.05 | 0.8 | 1 | W | 7.3 | 14 | W | 3:20 | 36 | 7 | 8 | | | | | | | 6 |
| 7 | 22 | 3 | 13 | -12 | 52 | T | T | 1 | E | 14.0 | 26 | E | 0:35 | 6 | 10 | 7 | | | | | | | 7 |
| 8 | 27 | 19 | 23 | - 2 | 42 | 0.41 | 1.5 | 1 | ENE | 21.5 | 35 | NE | 0:00 | 0 | 10 | 10 | | | | | | | 8 |
| 9 | 29 | 25 | 27 | + 3 | 38 | 0.03 | T | 3 | NE | 16.4 | 20 | N | 0:00 | 0 | 10 | 10 | | F | | | | | 9 |
| 10 | 33 | 27 | 30 | + 6 | 35 | 0.02 | 0 | 2 | NE | 9.3 | 19 | N | 0:00 | 0 | 10 | 10 | | FZL | | | | | 10 |
| 11 | 33 | 17 | 25 | + 1 | 40 | 0.10 | 1.0 | 2 | NW | 18.6 | 37 | NW | 0:41 | 7 | 10 | 7 | | | | | | | 11 |
| 12 | 37 | 13 | 25 | + 1 | 40 | 0 | 0 | 2 | SSW | 15.5 | 34 | SW | 0:23 | 4 | 9 | 7 | | | | | | | 12 |
| 13 | 42 | 30 | 36 | +12 | 29 | 0 | 0 | 2 | WSW | 8.8 | 15 | SW | 7:27 | 80 | 1 | 3 | | | | | | | 13 |
| 14 | 43 | 30 | 37 | +13 | 28 | 0.02 | 0 | 1 | S | 10.1 | 14 | S | 0:00 | 0 | 10 | 10 | | | | | | | 14 |
| 15 | 56 | 33 | 45 | +21 | 20 | 0.09 | 0 | T | SSW | 17.8 | 35 | SW | 0:10 | 2 | 9 | 10 | | | | | | | 15 |
| 16 | 33 | 18 | 26 | + 2 | 39 | T | T | T | WNW | 15.9 | 37 | W | 3:25 | 36 | 6 | 6 | | | | | | | 16 |
| 17 | 33 | 18 | 26 | + 2 | 39 | 0.29 | T | 0 | NE | 15.8 | 25 | NE | 0:00 | 0 | 10 | 9 | | | | | | | 17 |
| 18 | 33 | 28 | 31 | + 7 | 34 | T | T | T | WSW | 18.6 | 21 | W | 1:37 | 17 | 8 | 9 | | | | | | | 18 |
| 19 | 30 | 25 | 28 | + 4 | 37 | 0.01 | 0.1 | T | NE | 5.8 | 17 | W | 0:00 | 0 | 10 | 10 | | | | | | | 19 |
| 20 | 31 | 21 | 26 | + 2 | 39 | 0 | 0 | T | NE | 7.3 | 16 | NE | 0:32 | 6 | 9 | 6 | | | | | | | 20 |
| 21 | 36 | 25 | 31 | + 8 | 34 | 0 | 0 | T | NE | 5.6 | 8 | N | 5:21 | 56 | 5 | 5 | | | | | | | 21 |
| 22 | 33 | 25 | 29 | + 6 | 36 | T | 0 | T | SSE | 11.5 | 16 | SE | 0:43 | 7 | 10 | 8 | | | | | | | 22 |
| 23 | 36 | 32 | 34 | +11 | 31 | 0.62 | 0 | T | NE | 9.9 | 11 | NE | 0:00 | 0 | 10 | 10 | | | | | | | 23 |
| 24 | 33 | 26 | 30 | + 7 | 35 | 0.16 | 1.5 | 1 | NW | 18.5 | 29 | NW | 0:00 | 0 | 10 | 10 | | | | | | | 24 |
| 25 | 27 | 13 | 20 | - 3 | 45 | T | T | 1 | NW | 17.7 | 35 | NW | 1:02 | 11 | 9 | 7 | | | | | | | 25 |
| 26 | 27 | 5 | 16 | - 7 | 49 | 0 | 0 | 1 | SE | 14.0 | 22 | SE | 3:28 | 35 | 8 | 5 | | | | | | | 26 |
| 27 | 38 | 26 | 32 | + 9 | 33 | 0 | 0 | 1 | SW | 13.3 | 27 | W | 0:00 | 0 | 10 | 10 | | | | | | | 27 |
| 28 | 26 | 21 | 24 | + 1 | 41 | T | T | T | WNW | 18.2 | 26 | W | 0:00 | 0 | 10 | 10 | | | | | | | 28 |
| 29 | 26 | 19 | 23 | 0 | 42 | 0.02 | 0.1 | T | W | 13.4 | 24 | NW | 0:22 | 4 | 9 | 10 | | | | | | | 29 |
| 30 | 35 | 19 | 27 | + 4 | 38 | 0.11 | 1.7 | 2 | ESE | 8.3 | 15 | SE | 7:35 | 77 | 2 | 5 | | | | | | | 30 |
| 31 | 43 | 16 | 30 | + 7 | 35 | T | T | 1 | WNW | 19.2 | 45 | W | 0:30 | 5 | 9 | 8 | | | | | | | 31 |
| Sum | 1016 | 641 | — | — | — | 2.02 | 7.9 | — | — | 415.4 | — | — | 37:44 | — | 269 | 257 | — | — | | | | | Sum |
| Avg. | 32.8 | 20.7 | — | — | — | — | — | — | — | 13.4 | Fastest | Dir. | Possible | % | 8.7 | 8.3 | — | — | | | | | Avg. |
| | | | | | | | | | | Misc. | 45 | W | 293:17 | 13 | — | — | — | — | | | | | Misc. |

T in columns 7, 8, and 9 indicates amount too small to measure.

**TEMPERATURE: (°F)**
Average monthly 26.8
Departure from normal +3.0
Highest 56 on 15th
Lowest 3 on 7th
Number of days with –
Max. 32° or below 13
Max. 90° or above 0
Min. 32° or below 30
Min. 0° or below 0

**HEATING DEGREE DAYS (base 65°):**
Total this month 1179
Departure from normal -139
Seasonal total (since July 1) 3757
Seasonal departure from normal -286

**BAROMETRIC PRESSURE (In.)**
Avg. station (elev. 878 feet, m.s.l.) 28.986
Highest sea level 30.56 on 16th
Lowest sea level 29.44 on 24th

**PRECIPITATION: (In.)**
Total for the month 2.02
Departure from normal +0.15
Greatest in 24 hours 0.78 on 23 & 24
Snow, Sleet and Hail –
Total for the month 7.9
Greatest in 24 hours 1.7 on 30th
Greatest depth on ground 3 on 8,9,10,11,12
Dates of – Hail ---
Sleet 8,9,17,24 Glaze 8,9,10,11,17

**Symbols used in columns 18-19**
A = Hail
BS = Blowing snow
DL = Distant lightning
D = Dust
E = Sleet
F = Fog
H = Haze
K = Smoke
L = Drizzle
N = Sand
R = Rain
S = Snow
T = Thunderstorm
ZL = Freezing drizzle
ZR = Freezing rain

The month of January was characterized by above normal temperatures and precipitation, but below normal snowfall. There have been only four other times since beginning of record that temperatures for the three month period November through January has been warmer than the past three months. The warmest period which occurred during November-January, 1931-32, averaged 8.1° above normal. For the past three months, temperatures averaged 3.3° above normal. Snowfall for the season is 10 inches below normal. Glazing conditions existed several days during the month causing numerous traffic accidents,and 3 deaths on 17th.

## HOURLY PRECIPITATION

| Date | A. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | P. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 2 | | | | | | | | | | | | | | | | | | T | T | T | .01 | .01 | T | T | 2 |
| 3 | T | T | | | | | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | | 3 |
| 4 | | | | | | T | T | T | T | T | T | T | T | T | T | T | T | | T | T | T | T | T | T | 4 |
| 5 | T | T | T | T | T | T | .01 | .01 | .02 | .01 | T | T | T | T | T | T | T | .01 | T | T | T | .01 | T | T | 5 |
| 6 | T | T | T | T | T | T | | | | | | | | | | T | T | .02 | .01 | .01 | .01 | T | T | T | 6 |
| 7 | T | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 8 | | | | T | T | T | | | T | .07 | .05 | .07 | .04 | .04 | .02 | .04 | .02 | .02 | .01 | .01 | .01 | .01 | T | T | 8 |
| 9 | T | T | .01 | T | T | T | T | T | T | T | T | T | T | T | | | | | | | T | .01 | .01 | T | 9 |
| 10 | T | T | T | T | | | | T | .01 | T | T | T | T | | T | T | .01 | T | T | T | T | T | | T | 10 |
| 11 | T | | | | .01 | .01 | T | .02 | .01 | .02 | .03 | T | T | T | T | | | | | | | | | | 11 |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | 12 |
| 13 | | | | | | | | | | | | | | | | | | | | | | | | | 13 |
| 14 | | | | | | | | | | | | | | T | T | .01 | T | | .01 | T | T | | | | 14 |
| 15 | | T | .01 | .01 | .01 | T | | | | | | | | | | | T | .04 | .01 | T | .01 | T | | | 15 |
| 16 | | | T | | | | T | T | T | T | T | T | | | | | | | | | | | | | 16 |
| 17 | | | | | | | | | | | T | .02 | T | T | T | .15 | .08 | .02 | T | T | .02 | T | T | T | 17 |
| 18 | T | T | | | | | | | | | | | | | | | | | | | | | | | 18 |
| 19 | | | | | | | | | | | T | .01 | T | T | T | | | | | | | | | | 19 |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | 20 |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | 21 |
| 22 | | | | | | | | | | | | | | | | | | | | | T | T | T | T | 22 |
| 23 | T | T | | | T | T | T | T | T | T | T | | | | | .01 | .07 | .08 | .08 | .05 | .08 | .08 | .12 | .05 | 23 |
| 24 | .01 | .01 | .03 | .02 | .01 | .02 | .01 | T | .02 | .03 | T | T | T | T | T | T | T | T | | T | T | T | T | T | 24 |
| 25 | T | T | T | | | | T | T | T | T | T | T | T | T | T | T | | | | | | | | | 25 |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | 26 |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | 27 |
| 28 | | | | | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | | | | T | 28 |
| 29 | .01 | T | T | .01 | T | T | T | T | T | T | T | T | T | T | T | T | | | | T | T | T | T | T | 29 |
| 30 | .04 | .02 | .02 | .02 | .01 | T | T | T | | | | | | | | | | | | | | | | | 30 |
| 31 | | | | | | | | | | | | | | | | | | | T | T | T | T | T | T | 31 |

**Effective January 1, 1953 the temperature and precipitation normals used for these reports are derived from the period 1921-1950.**

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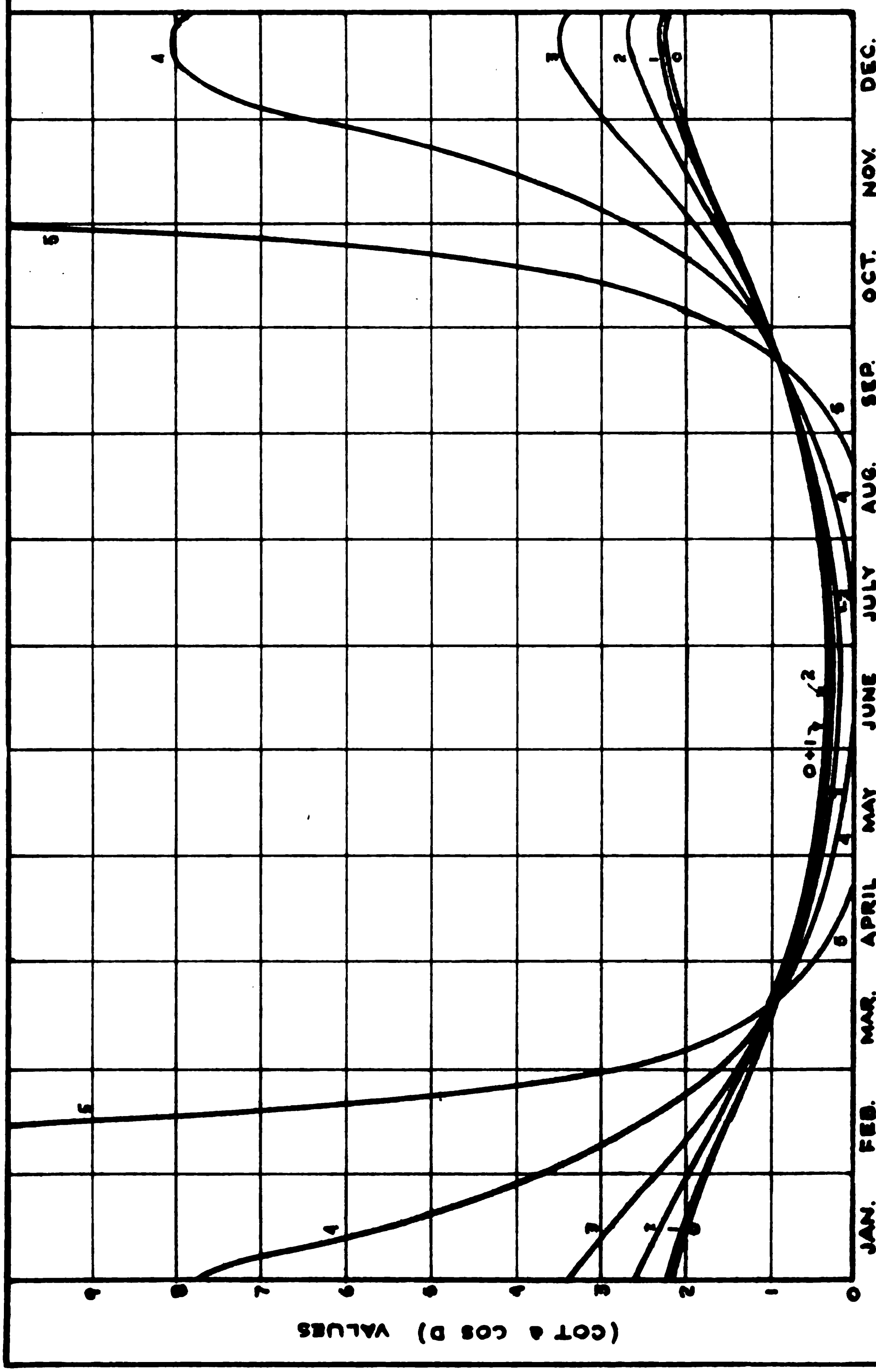
FIGURE A6




Seasonal Variation of Cot a Cos D for Indicated Hour Angles

# Table A VII

## Weekly Means of Direct and Diffuse Radiation in Gram-Calories per Square Centimeter of Horizontal Surface by Hours

| Hour Angle | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Mean Daily Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 5-6 | 6-7 | 7-8 | 8-9 | 9-10 | 10-11 | 12 Noon | 12-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | |
| **Week** | | | | | | | | | | | | | | |
| Dec. 10-16 | | 0.1 | 2.1 | 6.7 | 11.7 | 12.6 | 11.5 | 11.0 | 7.3 | 2.5 | 0.1 | | | 65.6 |
| 17-23 | | 0.1 | 1.9 | 5.0 | 7.7 | 12.0 | 11.2 | 9.4 | 5.1 | 1.7 | T | | | 54.1 |
| 24-31 | | T | 1.7 | 6.4 | 9.5 | 12.2 | 12.3 | 10.7 | 8.2 | 2.5 | 0.1 | | | 63.6 |
| Jan. 1-7 | | 0.2 | 3.0 | 8.0 | 14.1 | 14.3 | 12.3 | 9.4 | 6.6 | 2.7 | 0.3 | | | 70.6 |
| 8-14 | | | 1.7 | 6.1 | 11.1 | 13.1 | 12.9 | 9.9 | 7.0 | 2.7 | 0.2 | | | 63.9 |
| 15-21 | | 0.4 | 4.2 | 9.3 | 17.0 | 19.5 | 16.8 | 10.6 | 7.0 | 4.1 | 0.4 | | | 89.3 |
| 22-28 | | 0.9 | 4.4 | 11.2 | 13.1 | 13.2 | 13.1 | 11.2 | 8.0 | 4.4 | 0.6 | | | 80.1 |
| Jan. 29 - Feb. 4 | | 0.9 | 5.5 | 12.1 | 15.3 | 19.3 | 21.3 | 18.6 | 17.8 | 7.9 | 1.7 | | | 120.4 |
| 5-11 | | 1.2 | 5.5 | 8.8 | 13.8 | 14.7 | 15.1 | 10.4 | 8.7 | 4.5 | 1.0 | | | 83.7 |
| 12-18 | | 1.6 | 6.9 | 12.9 | 20.1 | 24.9 | 27.8 | 22.0 | 16.8 | 9.8 | 3.0 | 0.1 | | 145.9 |
| 19-25 | 0.1 | 4.8 | 14.9 | 21.6 | 26.0 | 28.3 | 27.8 | 24.1 | 20.1 | 12.0 | 4.3 | 0.2 | | 184.2 |
| Feb. 26 - Mar. 4 | 0.3 | 5.3 | 11.4 | 16.9 | 20.3 | 23.7 | 21.4 | 18.2 | 20.7 | 11.9 | 5.1 | 0.4 | | 155.6 |
| 5-11 | 0.6 | 7.0 | 16.3 | 21.2 | 24.8 | 31.2 | 31.5 | 27.3 | 24.0 | 12.7 | 6.0 | 0.8 | | 203.4 |

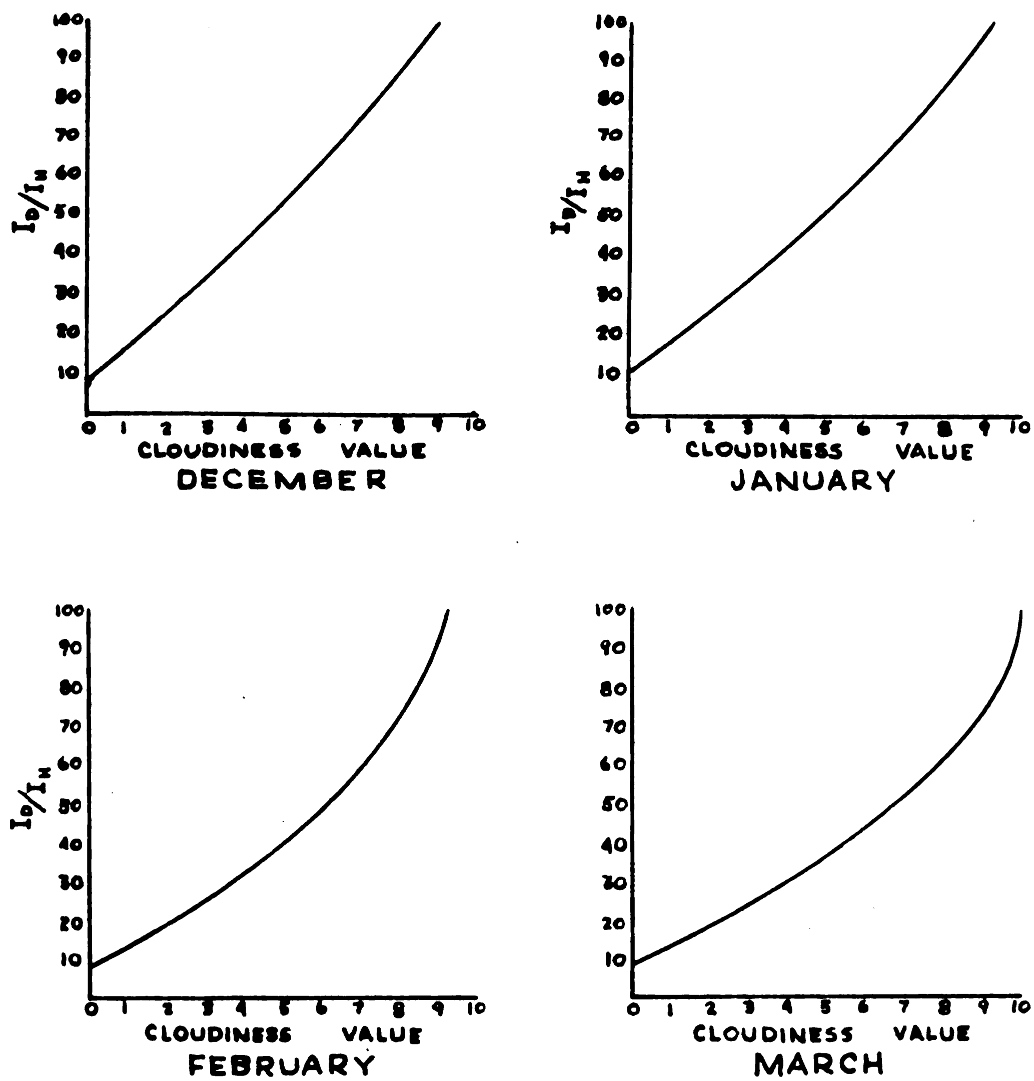
# Table A VIII

## Daily Average Cloudiness Computed From Lansing Weather Bureau Data

| WEEK | DAILY CLOUDINESS VALUES | AVERAGE DAILY CLOUDINESS |
|---|---|---|
| DEC. 10-16 | 10 - 10 - 9 - 10 - 10 - 10 - 0 | 8.4 |
| 17-23 | 7 - 6 - 9 - 10 - 10 - 10 - 10 | 8.9 |
| 24-31 | 10 - 10 - 10 - 3 - 5 - 10 - 10 - 10 | 8.5 |
| JAN. 1-7 | 10 - 10 - 10 - 9 - 9 - 7 - 10 | 9.3 |
| 8-14 | 10 - 10 - 10 - 10 - 9 - 1 - 10 | 8.6 |
| 15-21 | 9 - 6 - 10 - 8 - 10 - 9 - 5 | 8.1 |
| 22-28 | 10 - 10 - 10 - 9 - 8 - 10 - 10 | 9.6 |
| JAN. 29 - FEB. 4 | 9 - 2 - 9 - 4 - 10 - 9 - 9 | 7.4 |
| 5-11 | 10 - 10 - 10 - 9 - 2 - 10 - 10 | 8.7 |
| 12-18 | 10 - 9 - 2 - 8 - 9 - 9 - 7 | 7.7 |
| 19-25 | 7 - 10 - 9 - 4 - 0 - 8 - 8 | 6.6 |
| FEB. 26 - MAR. 4 | 9 - 8 - 9 - 5 - 10 - 10 - 9 | 8.6 |
| 5-11 | 6 - 9 - 9 - 10 - 9 - 10 - 9 | 8.9 |

FIGURE A7

GRAPHICAL VALUES OF $I_D/I_H$ FOR DIFFERENT CLOUDINESS VALUES FOR FOUR WINTER MONTHS DATA FROM HAND (12)



# TABLE A IX

## CALCULATIONS OF SOLAR HEAT GAINS THROUGH INSULATING GLASS WINDOWS FACING SOUTH FOR AVERAGE DAY OF INDICATED WEEK DURING WINTER OF 1953

| (1) WEEK | (2) TIME | (3) TOTAL RADIATION $I_H$ BTU/FT² | (4) COT α COS δ | (5) $I_D/I_H$ | (6) $\frac{1}{2}(2-I_D/I_H)$ | (7) $I_H$ COT α COS δ $\frac{1}{2}(2-I_D/I_H)$ | (8) $\frac{1}{2} I_H (I_D/I_H)$ | (9) TOTAL $I_V$ BTU/FT² | (10) TRANSMISSION | (11) TOTAL DAILY HEAT GAIN BTU/FT² |
|---|---|---|---|---|---|---|---|---|---|---|
| DEC. 10-16 | 7 | 0.4 | - | - | - | - | - | - | | |
| | 8 | 7.7 | 7.9 | 0.90 | 0.55 | 33.5 | 3.5 | 37.0 | | |
| | 9 | 24.6 | 3.3 | 0.90 | 0.55 | 44.6 | 11.1 | 55.7 | | |
| | 10 | 43.1 | 2.5 | 0.90 | 0.55 | 59.4 | 19.4 | 78.8 | | |
| | 11 | 46.4 | 2.2 | 0.90 | 0.55 | 56.1 | 20.8 | 76.9 | | |
| | 12 | 42.3 | 2.15 | 0.90 | 0.55 | 50.0 | 19.0 | 69.0 | | |
| | 1 | 40.5 | 2.2 | 0.90 | 0.55 | 49.0 | 18.2 | 67.2 | | |
| | 2 | 26.8 | 2.5 | 0.90 | 0.55 | 36.8 | 12.0 | 48.8 | | |
| | 3 | 9.2 | 3.3 | 0.90 | 0.55 | 16.7 | 4.1 | 20.8 | | |
| | 4 | 0.4 | 7.9 | 0.90 | 0.55 | 1.7 | 0.2 | 1.9 | | |
| | | | | | | | | 426.1 × | 0.60 = | 256 |
| DEC. 17-23 | 7 | 0.4 | - | - | - | - | - | - | | |
| | 8 | 7.0 | 8.1 | 0.98 | 0.51 | 28.9 | 3.4 | 32.3 | | |
| | 9 | 18.4 | 3.45 | 0.98 | 0.51 | 32.4 | 9.0 | 41.4 | | |
| | 10 | 28.3 | 2.6 | 0.98 | 0.51 | 37.5 | 13.9 | 51.4 | | |
| | 11 | 44.1 | 2.3 | 0.98 | 0.51 | 51.7 | 21.6 | 73.3 | | |
| | 12 | 41.2 | 2.25 | 0.98 | 0.51 | 47.3 | 20.2 | 67.5 | | |
| | 1 | 34.6 | 2.3 | 0.98 | 0.51 | 40.6 | 17.0 | 57.6 | | |
| | 2 | 18.7 | 2.6 | 0.98 | 0.51 | 24.8 | 9.2 | 34.0 | | |
| | 3 | 6.3 | 3.45 | 0.98 | 0.51 | 11.1 | 3.1 | 14.2 | | |
| | 4 | 0 | 8.1 | 0.98 | 0.51 | 0 | 0 | 0 | | |
| | | | | | | | | 371.7 × | 0.60 = | 223 |
| DEC. 24-31 | 7 | 0 | - | - | - | - | - | - | | |
| | 8 | 6.3 | 7.9 | 0.92 | 0.54 | 26.9 | 2.9 | 29.8 | | |
| | 9 | 23.5 | 3.3 | 0.92 | 0.54 | 41.8 | 10.8 | 52.6 | | |
| | 10 | 35.0 | 2.5 | 0.92 | 0.54 | 47.3 | 16.1 | 63.4 | | |
| | 11 | 44.9 | 2.2 | 0.92 | 0.54 | 53.2 | 20.6 | 73.8 | | |
| | 12 | 45.2 | 2.15 | 0.92 | 0.54 | 52.5 | 20.8 | 73.3 | | |
| | 1 | 39.4 | 2.2 | 0.92 | 0.54 | 46.8 | 18.1 | 64.9 | | |
| | 2 | 30.2 | 2.5 | 0.92 | 0.54 | 40.7 | 13.9 | 54.6 | | |
| | 3 | 9.2 | 3.3 | 0.92 | 0.54 | 16.4 | 4.2 | 20.6 | | |
| | 4 | 0.4 | 7.9 | 0.92 | 0.54 | 1.7 | 0.2 | 1.9 | | |
| | | | | | | | | 434.9 × | 0.60 = | 261 |
| JAN. 1-7 | 7 | 0.7 | - | - | - | - | - | - | | |
| | 8 | 11.0 | 7.6 | 1.00 | 0.50 | 41.7 | 5.5 | 47.2 | | |
| | 9 | 29.4 | 3.3 | 1.00 | 0.50 | 48.5 | 14.7 | 63.2 | | |
| | 10 | 51.9 | 2.5 | 1.00 | 0.50 | 64.8 | 25.9 | 90.7 | | |
| | 11 | 52.6 | 2.15 | 1.00 | 0.50 | 56.6 | 26.3 | 82.9 | | |
| | 12 | 45.2 | 2.1 | 1.00 | 0.50 | 47.4 | 22.6 | 70.0 | | |
| | 1 | 34.6 | 2.15 | 1.00 | 0.50 | 37.2 | 17.3 | 54.5 | | |
| | 2 | 24.3 | 2.5 | 1.00 | 0.50 | 30.4 | 12.2 | 42.6 | | |
| | 3 | 9.9 | 3.3 | 1.00 | 0.50 | 16.3 | 5.0 | 21.3 | | |
| | 4 | 1.1 | 7.6 | 1.00 | 0.50 | 4.2 | 0.6 | 4.8 | | |
| | | | | | | | | 477.2 × | 0.60 = | 286 |
| JAN. 8-14 | 7 | 0 | - | - | - | - | - | - | | |
| | 8 | 6.3 | 6.35 | 0.90 | 0.55 | 22.0 | 2.8 | 24.8 | | |
| | 9 | 22.4 | 3.0 | 0.90 | 0.55 | 36.9 | 10.1 | 47.0 | | |
| | 10 | 40.8 | 2.35 | 0.90 | 0.55 | 52.7 | 18.4 | 71.1 | | |
| | 11 | 48.2 | 2.05 | 0.90 | 0.55 | 54.3 | 21.7 | 76.0 | | |
| | 12 | 44.5 | 2.0 | 0.90 | 0.55 | 48.9 | 20.0 | 68.0 | | |
| | 1 | 36.4 | 2.05 | 0.90 | 0.55 | 41.0 | 16.4 | 57.4 | | |
| | 2 | 25.8 | 2.35 | 0.90 | 0.55 | 33.3 | 11.6 | 44.9 | | |
| | 3 | 9.9 | 3.0 | 0.90 | 0.55 | 16.3 | 4.5 | 20.8 | | |
| | 4 | 0.7 | 6.35 | 0.90 | 0.55 | 2.4 | 0.3 | 2.7 | | |
| | | | | | | | | 412.7 × | 0.60 = | 248 |
| JAN. 15-21 | 7 | 1.5 | - | - | - | - | - | - | | |
| | 8 | 16.5 | 5.0 | 0.82 | 0.59 | 45.7 | 6.3 | 52.0 | | |
| | 9 | 34.2 | 2.65 | 0.82 | 0.59 | 53.5 | 14.0 | 67.5 | | |
| | 10 | 62.5 | 2.15 | 0.82 | 0.59 | 79.4 | 25.6 | 105.0 | | |
| | 11 | 71.8 | 1.90 | 0.82 | 0.59 | 80.5 | 29.4 | 109.9 | | |
| | 12 | 61.8 | 1.85 | 0.82 | 0.59 | 67.5 | 25.3 | 92.8 | | |
| | 1 | 39.0 | 1.90 | 0.82 | 0.59 | 43.7 | 16.0 | 59.7 | | |
| | 2 | 25.8 | 2.15 | 0.82 | 0.59 | 32.8 | 10.6 | 43.4 | | |
| | 3 | 15.1 | 2.65 | 0.82 | 0.59 | 24.6 | 6.2 | 30.8 | | |
| | 4 | 1.5 | 5.0 | 0.82 | 0.59 | 4.4 | 0.6 | 5.0 | | |
| | | | | | | | | 566.1 × | 0.60 = | 340 |
| JAN. 22-28 | 7 | 3.3 | - | - | - | - | - | - | | |
| | 8 | 16.2 | 4.0 | 1.00 | 0.50 | 32.4 | 8.1 | 40.5 | | |
| | 9 | 41.2 | 2.4 | 1.00 | 0.50 | 49.4 | 20.6 | 70.0 | | |
| | 10 | 48.2 | 2.0 | 1.00 | 0.50 | 48.2 | 24.1 | 72.3 | | |
| | 11 | 48.6 | 1.8 | 1.00 | 0.50 | 43.7 | 24.3 | 68.0 | | |
| | 12 | 48.2 | 1.75 | 1.00 | 0.50 | 42.2 | 24.1 | 66.3 | | |
| | 1 | 41.2 | 1.8 | 1.00 | 0.50 | 37.1 | 20.6 | 57.7 | | |
| | 2 | 29.4 | 2.0 | 1.00 | 0.50 | 29.4 | 14.7 | 44.1 | | |
| | 3 | 16.2 | 2.4 | 1.00 | 0.50 | 19.4 | 8.1 | 27.5 | | |
| | 4 | 2.2 | 4.0 | 1.00 | 0.50 | 4.4 | 1.1 | 5.5 | | |
| | | | | | | | | 451.9 × | 0.60 = | 271 |
| JAN. 29 TO FEB. 4 | 7 | 3.3 | - | - | - | - | - | - | | |
| | 8 | 20.2 | 3.65 | 0.70 | 0.65 | 48.0 | 7.5 | 55.5 | | |
| | 9 | 44.5 | 2.3 | 0.70 | 0.65 | 66.5 | 15.6 | 82.1 | | |
| | 10 | 56.3 | 1.9 | 0.70 | 0.65 | 69.5 | 19.7 | 89.2 | | |
| | 11 | 71.0 | 1.75 | 0.70 | 0.65 | 80.7 | 24.8 | 105.5 | | |
| | 12 | 78.4 | 1.70 | 0.70 | 0.65 | 86.5 | 27.4 | 113.9 | | |
| | 1 | 68.5 | 1.75 | 0.70 | 0.65 | 77.8 | 24.0 | 101.8 | | |
| | 2 | 65.5 | 1.9 | 0.70 | 0.65 | 80.9 | 22.9 | 103.8 | | |
| | 3 | 29.1 | 2.3 | 0.70 | 0.65 | 43.5 | 10.2 | 53.7 | | |
| | 4 | 6.3 | 3.65 | 0.70 | 0.65 | 14.9 | 2.2 | 17.1 | | |
| | | | | | | | | 722.6 × | 0.60 = | 433 |
| FEB. 5-11 | 7 | 4.4 | - | - | - | - | - | - | | |
| | 8 | 20.2 | 3.0 | 0.86 | 0.57 | 34.6 | 8.7 | 43.3 | | |
| | 9 | 32.4 | 2.05 | 0.86 | 0.57 | 37.9 | 13.9 | 51.8 | | |
| | 10 | 50.7 | 1.75 | 0.86 | 0.57 | 50.6 | 21.8 | 72.4 | | |
| | 11 | 54.1 | 1.65 | 0.86 | 0.57 | 50.9 | 23.2 | 74.1 | | |
| | 12 | 55.1 | 1.6 | 0.86 | 0.57 | 50.3 | 23.7 | 74.0 | | |
| | 1 | 38.2 | 1.65 | 0.86 | 0.57 | 35.9 | 16.4 | 52.3 | | |
| | 2 | 32.0 | 1.75 | 0.86 | 0.57 | 31.9 | 13.7 | 45.6 | | |
| | 3 | 16.5 | 2.05 | 0.86 | 0.57 | 19.3 | 7.1 | 26.4 | | |
| | 4 | 3.7 | 3.0 | 0.86 | 0.57 | 6.3 | 1.6 | 7.9 | | |
| | | | | | | | | 447.8 × | 0.60. = | 269 |
| FEB 12-18 | 7 | 5.9 | 9.1 | 0.68 | 0.66 | 35.4 | 2.0 | 37.4 | 0.20 | 7.5 |
| | 8 | 25.4 | 2.35 | 0.68 | 0.66 | 39.4 | 8.6 | 48.0 | 0.60 | 28.8 |
| | 9 | 47.5 | 1.75 | 0.68 | 0.66 | 54.9 | 16.1 | 71.0 | 0.60 | 42.6 |
| | 10 | 74.0 | 1.55 | 0.68 | 0.66 | 75.6 | 25.1 | 100.7 | 0.60 | 60.5 |
| | 11 | 91.8 | 1.48 | 0.68 | 0.66 | 89.6 | 31.2 | 120.8 | 0.60 | 72.4 |
| | 12 | 102.0 | 1.45 | 0.68 | 0.66 | 97.6 | 34.6 | 132.2 | 0.60 | 79.4 |
| | 1 | 81.0 | 1.48 | 0.68 | 0.66 | 79.1 | 27.5 | 106.6 | 0.60 | 64.0 |
| | 2 | 61.8 | 1.55 | 0.68 | 0.66 | 63.2 | 21.0 | 89.2 | 0.60 | 50.5 |
| | 3 | 36.0 | 1.75 | 0.68 | 0.66 | 41.5 | 12.2 | 53.7 | 0.60 | 32.3 |
| | 4 | 11.0 | 2.35 | 0.68 | 0.66 | 17.1 | 3.7 | 20.8 | 0.60 | 12.5 |
| | 5 | 0.4 | 9.1 | 0.68 | 0.66 | 2.4 | 0.1 | 2.5 | 0.20 | 0.5 |
| | | | | | | | | | | 451.0 |
| FEB. 19-25 | 7 | 17.7 | 5.0 | 0.56 | 0.72 | 63.8 | 5.0 | 68.8 | 0.20 | 13.8 |
| | 8 | 64.5 | 1.90 | 0.56 | 0.72 | 74.5 | 15.2 | 89.7 | 0.60 | 53.8 |
| | 9 | 79.5 | 1.45 | 0.56 | 0.72 | 83.0 | 22.2 | 105.2 | 0.60 | 63.2 |
| | 10 | 95.6 | 1.35 | 0.56 | 0.72 | 93.0 | 26.8 | 119.8 | 0.60 | 71.8 |
| | 11 | 104.0 | 1.3 | 0.56 | 0.72 | 97.4 | 29.1 | 126.5 | 0.60 | 76.0 |
| | 12 | 102.3 | 1.3 | 0.56 | 0.72 | 95.7 | 28.6 | 124.3 | 0.60 | 74.6 |
| | 1 | 88.7 | 1.3 | 0.56 | 0.72 | 83.0 | 24.8 | 107.8 | 0.60 | 64.6 |
| | 2 | 73.9 | 1.35 | 0.56 | 0.72 | 71.8 | 20.7 | 92.5 | 0.60 | 55.5 |
| | 3 | 44.1 | 1.45 | 0.56 | 0.72 | 46.0 | 12.3 | 58.3 | 0.60 | 35.0 |
| | 4 | 15.8 | 1.9 | 0.56 | 0.72 | 21.6 | 4.4 | 26.0 | 0.60 | 15.6 |
| | 5 | 0.7 | 5.0 | 0.56 | 0.72 | 2.5 | 0.2 | 2.7 | 0.20 | 0.6 |
| | | | | | | | | | | 524.5 |
| FEB. 26 TO MAR. 4 | 7 | 19.5 | 3.2 | 0.76 | 0.62 | 38.7 | 7.4 | 46.1 | 0.20 | 9.2 |
| | 8 | 41.9 | 1.6 | 0.76 | 0.62 | 41.5 | 15.9 | 57.4 | 0.60 | 34.4 |
| | 9 | 62.2 | 1.35 | 0.76 | 0.62 | 52.1 | 23.6 | 75.7 | 0.60 | 45.4 |
| | 10 | 74.7 | 1.23 | 0.76 | 0.62 | 57.0 | 28.4 | 85.4 | 0.60 | 51.2 |
| | 11 | 87.2 | 1.20 | 0.76 | 0.62 | 64.8 | 33.1 | 97.9 | 0.60 | 58.7 |
| | 12 | 78.8 | 1.2 | 0.76 | 0.62 | 58.6 | 30.0 | 88.6 | 0.60 | 53.2 |
| | 1 | 67.0 | 1.2 | 0.76 | 0.62 | 49.8 | 25.4 | 75.2 | 0.60 | 45.1 |
| | 2 | 76.0 | 1.23 | 0.76 | 0.62 | 58.1 | 28.9 | 87.0 | 0.60 | 52.2 |
| | 3 | 43.8 | 1.35 | 0.76 | 0.62 | 36.6 | 16.7 | 53.3 | 0.60 | 32.0 |
| | 4 | 18.8 | 1.6 | 0.76 | 0.62 | 18.7 | 7.1 | 25.8 | 0.60 | 15.5 |
| | 5 | 1.5 | 3.2 | 0.76 | 0.62 | 3.0 | 0.6 | 3.6 | 0.20 | 0.7 |
| | | | | | | | | | | 397.6 |
| MAR. 5-11 | 7 | 25.8 | 1.8 | 0.72 | 0.64 | 29.7 | 9.3 | 39.0 | 0.20 | 7.8 |
| | 8 | 60.0 | 1.3 | 0.72 | 0.64 | 49.9 | 21.6 | 71.5 | 0.60 | 42.8 |
| | 9 | 78.0 | 1.18 | 0.72 | 0.64 | 58.9 | 28.1 | 87.0 | 0.60 | 52.2 |
| | 10 | 91.2 | 1.1 | 0.72 | 0.64 | 64.2 | 32.8 | 97.0 | 0.60 | 58.2 |
| | 11 | 114.8 | 1.08 | 0.72 | 0.64 | 79.3 | 41.3 | 120.6 | 0.60 | 72.4 |
| | 12 | 116.0 | 1.08 | 0.72 | 0.64 | 80.2 | 41.7 | 121.9 | 0.60 | 73.0 |
| | 1 | 100.4 | 1.08 | 0.72 | 0.64 | 69.5 | 36.2 | 105.7 | 0.60 | 63.4 |
| | 2 | 88.3 | 1.1 | 0.72 | 0.64 | 62.1 | 31.8 | 93.9 | 0.60 | 56.3 |
| | 3 | 46.7 | 1.18 | 0.72 | 0.64 | 35.2 | 16.8 | 52.0 | 0.60 | 31.2 |
| | 4 | 22.0 | 1.3 | 0.72 | 0.64 | 18.3 | 7.9 | 26.2 | 0.60 | 15.7 |
| | 5 | 3.0 | 1.8 | 0.72 | 0.64 | 3.5 | 1.0 | 4.5 | 0.20 | 0.9 |
| | | | | | | | | | | 473.9 |
| | | | | | | | | SEASON TOTAL = | | 4,434 |

# APPENDIX B

## LOCAL CLIMATOLOGICAL DATA

The following climatological data were gathered by the Lansing, Michigan, Weather Bureau located at the Capitol City Airport about eight miles from the location of the piggery.

These four tables, representing the winter months of December, January, February, and March, contain the following information for each day:

1. Maximum, minimum, and average temperatures.
2. Departure of temperature from normal.
3. Number of degree days.
4. Total precipitation with an hourly record.
5. Wind directions and velocities.
6. Total and percent sunshine.
7. Amount of cloudiness.

Also of interest is the commentary for the month appearing directly above the hourly precipitation record.

TABLE B I.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

# LOCAL CLIMATOLOGICAL DATA

LANSING, MICHIGAN (Capitol City Airport) DECEMBER, 1952

**Latitude** 42 ° 47 ′ N. **Longitude** 84 ° 36 ′ W. **Elevation (ground)** 859 ft. Eastern **Standard time used**

| Date | Temperature (°F) Maximum | Minimum | Average | Departure from normal | Degree days (base 65°) | Precipitation Total (Water equivalent) (In.) | Snow, Sleet, Hail (In.) | Snow, Sleet, Hail or Ice on ground at 7:30 am (In.) | Wind Prevailing direction | Average speed (m. p. h.) | Fastest mile Speed (m. p. h.) | Direction | Sunshine Total (hours and minutes) | Percent of possible | Sky cover Sunrise to sunset (tenths) | Midnight to midnight (tenths) | Thunderstorm or distant lightning | Weather restricting visibility to ¼ mile or less | | | | | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | 30 | 18 | 24 | - 7 | 41 | 0.02 | 0.2 | T | S | 12.1 | 17 | S | 0:00 | 0 | 9 | 9 | | | | | | | 1 |
| 2 | 31 | 21 | 26 | - 4 | 39 | 0.25 | 3.1 | 3 | NE | 8.0 | 13 | E | 3:18 | 36 | 8 | 9 | | F | | | | | 2 |
| 3 | 34 | 23 | 29 | - 1 | 36 | 0 | 0 | 3 | E | 10.0 | 17 | NE | 0:26 | 5 | 10 | 10 | | | | | | | 3 |
| 4 | 37 | 26 | 32 | + 2 | 33 | 0.25 | T | 2 | SE | 17.3 | 20 | SE | 0:00 | 0 | 10 | 10 | | | | | | | 4 |
| 5 | 37 | 31 | 34 | + 4 | 31 | 0.14 | 0.5 | T | WSW | 15.9 | 20 | W | 0:00 | 0 | 10 | 10 | | FR | | | | | 5 |
| 6 | 35 | 30 | 33 | + 4 | 32 | T | T | T | WNW | 15.0 | 20 | W | 0:00 | 0 | 10 | 9 | | | | | | | 6 |
| 7 | 48 | 30 | 39 | +10 | 26 | 0 | 0 | T | S | 13.7 | 18 | SE | 8:56 | 97 | 2 | 3 | | | | | | | 7 |
| 8 | 56 | 34 | 45 | +16 | 20 | T | 0 | 0 | S | 14.5 | 23 | S | 0:03 | 1 | 10 | 8 | | | | | | | 8 |
| 9 | 57 | 45 | 51 | +23 | 14 | 0 | 0 | 0 | SSW | 8.8 | 20 | S | 0:34 | 6 | 9 | 8 | | FK | | | | | 9 |
| 10 | 49 | 33 | 41 | +13 | 24 | 0.08 | T | 0 | W | 13.1 | 21 | W | 0:00 | 0 | 10 | 10 | | FKR | | | | | 10 |
| 11 | 34 | 27 | 31 | + 3 | 34 | 0.04 | 0.3 | T | W | 14.6 | 26 | W | 0:00 | 0 | 10 | 10 | | | | | | | 11 |
| 12 | 32 | 23 | 28 | 0 | 37 | 0.06 | 0.7 | 1 | W | 7.8 | 13 | E | 0:22 | 4 | 9 | 9 | | | | | | | 12 |
| 13 | 31 | 24 | 28 | + 1 | 37 | 0.01 | T | T | WNW | 13.4 | 18 | NW | 0:00 | 0 | 10 | 9 | | | | | | | 13 |
| 14 | 27 | 23 | 25 | - 2 | 40 | 0.09 | 0.9 | T | SW | 17.5 | 23 | W | 0:00 | 0 | 10 | 10 | | | | | | | 14 |
| 15 | 35 | 26 | 31 | + 4 | 34 | 0.01 | T | 1 | WSW | 15.0 | 22 | W | 0:37 | 7 | 10 | 7 | | | | | | | 15 |
| 16 | 40 | 25 | 33 | + 6 | 32 | 0 | 0 | T | WSW | 13.0 | 17 | SW | 9:03 | 100 | 0 | 0 | | | | | | | 16 |
| 17 | 40 | 26 | 33 | + 7 | 32 | 0 | 0 | T | W | 8.5 | 15 | W | 1:27 | 18 | 7 | 5 | | FK | | | | | 17 |
| 18 | 30 | 19 | 25 | - 1 | 40 | 0 | 0 | T | NW | 7.5 | 15 | NW | 2:31 | 28 | 6 | 4 | | | | | | | 18 |
| 19 | 32 | 18 | 25 | - 1 | 40 | T | T | T | E | 11.6 | 23 | NE | 0:00 | 0 | 9 | 7 | | | | | | | 19 |
| 20 | 36 | 30 | 33 | + 7 | 32 | 0.59 | T | T | E | 15.9 | 23 | NE | 0:00 | 0 | 10 | 10 | | | | | | | 20 |
| 21 | 36 | 34 | 35 | + 9 | 30 | 0.08 | 0 | 0 | ENE | 4.0 | 8 | N | 0:00 | 0 | 10 | 10 | | FRL | | | | | 21 |
| 22 | 40 | 34 | 37 | +12 | 28 | 0.06 | 0 | 0 | SE | 11.8 | 22 | E | 0:00 | 0 | 10 | 10 | | FL | | | | | 22 |
| 23 | 44 | 37 | 41 | +16 | 24 | 0.11 | 0 | 0 | SE | 13.3 | 12 | SE | 0:00 | 0 | 10 | 10 | | | | | | | 23 |
| 24 | 38 | 32 | 35 | +10 | 30 | T | 0 | 0 | WSW | 18.3 | 17 | W | 0:00 | 0 | 10 | 10 | | | | | | | 24 |
| 25 | 32 | 27 | 30 | + 5 | 35 | 0.03 | T | T | W | 18.3 | 23 | W | 0:00 | 0 | 10 | 10 | | | | | | | 25 |
| 26 | 30 | 24 | 27 | + 2 | 38 | T | T | T | WSW | 18.6 | 26 | W | 0:00 | 0 | 10 | 10 | | | | | | | 26 |
| 27 | 26 | 13 | 20 | - 4 | 45 | T | T | T | NW | 12.9 | 23 | W | 5:53 | 65 | 3 | 4 | | | | | | | 27 |
| 28 | 33 | 13 | 23 | - 1 | 42 | 0 | 0 | T | SSW | 12.8 | 10 | S | 2:46 | 31 | 5 | 3 | | | | | | | 28 |
| 29 | 37 | 27 | 32 | + 8 | 33 | T | T | 0 | SW | 10.0 | 13 | SE | 0:00 | 0 | 10 | 10 | | | | | | | 29 |
| 30 | 34 | 30 | 32 | + 8 | 33 | 0.02 | 0.1 | T | NE | 9.7 | 17 | NE | 0:00 | 0 | 10 | 10 | | F | | | | | 30 |
| 31 | 31 | 27 | 29 | + 5 | 36 | T | T | 0 | NE | 12.5 | 17 | NE | 0:00 | 0 | 10 | 10 | | | | | | | 31 |
| Sum | 1132 | 830 | — | — | — | 1.84 | 5.8 | — | — | 395.4 | — | — | 35:56 | — | 267 | 254 | — | — | | | | | Sum |
| Avg. | 36.5 | 26.8 | — | — | — | — | — | — | — | 12.8 | Fastest | Dir. | Possible | % | 8.6 | 8.2 | — | — | | | | | Avg. |
| Misc. | | | | | | | | | | Misc. | 26 | W | 282:13 | 13 | — | — | — | — | | | | | Misc. |

T in columns 7, 8, and 9 indicates amount too small to measure.

**TEMPERATURE: (°F)**
Average monthly 31.7
Departure from normal +4.8
Highest 57 on 9th
Lowest 13 on 27th & 28th
Number of days with —
Max. 32° or below 11
Max. 90° or above 0
Min. 32° or below 25
Min. 0° or below 0

**HEATING DEGREE DAYS (base 65°):**
Total this month 1028
Departure from normal -167
Seasonal total (since July 1) 2578
Seasonal departure from normal -127

**BAROMETRIC PRESSURE (In.)**
Avg. station (elev. 878 feet, m. s. l.) 29.045
Highest sea level 30.46 on 19th
Lowest sea level 29.64 on 10th

**PRECIPITATION: (In.)**
Total for the month 1.84
Departure from normal -0.23
Greatest in 24 hours 0.60 on 20 & 21
Snow, Sleet and Hail —
Total for the month 5.8
Greatest in 24 hours 3.3 on 1st & 2nd
Greatest depth on ground 3 on 2 & 3
Dates of — Hail ----
Sleet 4, 19, 20 Glaze 15, 20, 25

**Symbols used in columns 18-19**
A = Hail
BS = Blowing snow
DL = Distant lightning
D = Dust
E = Sleet
F = Fog
H = Haze
K = Smoke
L = Drizzle
N = Sand
R = Rain
S = Snow
T = Thunderstorm
ZL = Freezing drizzle
ZR = Freezing rain

The month of December was characterized by cloudy skies, above normal temperatures and sub-normal precipitation. Temperatures for the 31-day period averaged almost 5° above normal and was the warmest Dec. since 1941. The total sunshine for the month was abnormally low for Dec., tying the low record for percent of possible sunshine. Only in 1920 and 1935 did so little sunshine occur. While precip. this month was almost 1/4" below normal, rain or snow fell on 24 days. Hazardous driving conditions existed on several occasions. Several personal injury accidents were accredited to 8 separate days of heavy fog.

## HOURLY PRECIPITATION

| Date | A. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | P. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | T | T | .01 | .01 | 1 |
| 2 | .04 | .03 | .05 | .05 | .04 | .01 | T | T | .02 | .01 | T | | | | | | | | | | | | | | 2 |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 4 | | | | | | | | T | T | T | T | | | T | T | .03 | .01 | T | .01 | .05 | .09 | .03 | T | .03 | 4 |
| 5 | .04 | .03 | .01 | .01 | T | | T | T | T | T | T | T | T | T | T | .03 | .01 | T | | T | T | T | T | .01 | 5 |
| 6 | T | T | T | | | | | | | | | | | | | | | | | | | | | | 6 |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | T | 8 |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 10 | T | .06 | T | | | | T | T | .02 | T | | | | | | | | | | | | | | T | 10 |
| 11 | .02 | T | T | .01 | | | T | T | T | | T | T | T | T | T | T | | | | | | | .01 | T | 11 |
| 12 | .01 | .01 | .01 | T | T | T | T | T | T | T | T | | | | | | | | | | .01 | .01 | .01 | T | 12 |
| 13 | T | T | T | T | T | T | T | T | T | T | T | .01 | T | T | T | T | T | T | | | | T | T | T | 13 |
| 14 | T | T | T | T | T | T | T | T | T | T | .02 | .02 | T | T | T | .01 | .01 | T | T | T | T | T | .01 | .02 | 14 |
| 15 | T | T | .01 | T | T | T | T | T | T | | | | | | | | | | | | | | | | 15 |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | 16 |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | | 17 |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | 18 |
| 19 | | | | | | | | | | | | | | | | | | | | | | | T | T | 19 |
| 20 | .01 | .04 | .05 | .02 | .02 | .01 | .02 | .02 | .13 | .08 | .01 | .05 | .01 | .01 | T | T | T | T | T | .03 | .03 | .04 | .01 | | 20 |
| 21 | .02 | .01 | .01 | T | T | .01 | T | T | T | T | T | T | .01 | T | .01 | T | T | .01 | T | T | T | T | T | T | 21 |
| 22 | | | | | T | .01 | .02 | T | .01 | T | T | | T | | | | | | | | T | T | T | .02 | 22 |
| 23 | .05 | .01 | T | T | .01 | .01 | .01 | T | T | T | .01 | T | T | T | T | .01 | T | T | T | T | T | | | T | 23 |
| 24 | | T | T | | | | | | | | | | | T | T | T | T | T | T | | | | | | 24 |
| 25 | | | | T | T | T | T | T | T | .01 | .01 | .01 | T | T | T | T | T | T | T | T | T | T | T | T | 25 |
| 26 | T | T | T | T | T | T | T | T | T | T | T | T | T | T | | | | T | T | T | T | T | T | T | 26 |
| 27 | T | | T | T | T | T | | | | | | | | | | | | | | | | | | | 27 |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | | 28 |
| 29 | | | | | | | | | | | | | | | | | | | | T | T | T | T | T | 29 |
| 30 | .01 | .01 | | | | | | | | | | | | | | | | | | | | | | | 30 |
| 31 | | | | | | | | | | | | T | T | T | T | T | T | | | | | | | | 31 |

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WRPC, Kansas City, Mo. -- 1-6-53 -- 325

TABLE B II.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

# LOCAL CLIMATOLOGICAL DATA

LANSING, MICHIGAN (Capitol City Airport) JANUARY, 1953

Latitude 42 ° 47 ' N. Longitude 84 ° 36 ' W. Elevation (ground) 859 ft. Eastern Standard time used

| Date | Temperature (°F) Maximum | Minimum | Average | Departure from normal | Degree days (base 65°) | Precipitation Total (Water equivalent) (In.) | Snow, Sleet, Hail (In.) | Snow, Sleet, Hail or Ice on ground at 7:30 am (In.) | Wind Prevailing direction | Average speed (m. p. h.) | Fastest mile Speed (m. p. h.) | Direction | Sunshine Total (hours and minutes) | Percent of possible | Sky cover Sunrise to sunset (tenths) | Midnight to midnight (tenths) | Thunderstorm or distant lightning | Weather restricting visibility to ¼ mile or less | | | | | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | 35 | 27 | 31 | + 6 | 34 | 0 | 0 | 0 | SW | 12.0 | 17 | SW | 0:00 | 0 | 10 | 10 | | | | | | | 1 |
| 2 | 33 | 28 | 31 | + 6 | 34 | 0.02 | 0.2 | 0 | SSE | 7.9 | 14 | SE | 0:00 | 0 | 10 | 10 | | | | | | | 2 |
| 3 | 31 | 19 | 25 | 0 | 40 | T | T | T | NNW | 14.8 | 20 | N | 0:00 | 0 | 10 | 10 | | | | | | | 3 |
| 4 | 29 | 16 | 23 | - 2 | 42 | T | T | T | WSW | 10.5 | 17 | S | 0:00 | 0 | 9 | 8 | | | | | | | 4 |
| 5 | 26 | 11 | 19 | - 6 | 46 | 0.07 | 1.0 | T | WNW | 17.3 | 27 | W | 0:33 | 6 | 9 | 9 | | | | | | | 5 |
| 6 | 20 | 6 | 13 | -12 | 52 | 0.05 | 0.8 | 1 | W | 7.3 | 14 | W | 3:20 | 33 | 7 | 8 | | | | | | | 6 |
| 7 | 22 | 3 | 13 | -12 | 52 | T | T | 1 | E | 14.0 | 26 | E | 0:35 | 6 | 10 | 7 | | | | | | | 7 |
| 8 | 27 | 19 | 23 | - 2 | 42 | 0.41 | 1.5 | 1 | ENE | 21.5 | 35 | NE | 0:00 | 0 | 10 | 10 | | | | | | | 8 |
| 9 | 29 | 25 | 27 | + 3 | 38 | 0.03 | T | 3 | NE | 16.4 | 20 | N | 0:00 | 0 | 10 | 10 | | F | | | | | 9 |
| 10 | 33 | 27 | 30 | + 6 | 35 | 0.02 | 0 | 2 | NE | 9.3 | 19 | N | 0:00 | 0 | 10 | 10 | | FZL | | | | | 10 |
| 11 | 33 | 17 | 25 | + 1 | 40 | 0.10 | 1.0 | 2 | NW | 18.6 | 37 | NW | 0:41 | 7 | 10 | 7 | | | | | | | 11 |
| 12 | 37 | 13 | 25 | + 1 | 40 | 0 | 0 | 2 | SSW | 15.5 | 34 | SW | 0:23 | 4 | 9 | 7 | | | | | | | 12 |
| 13 | 42 | 30 | 36 | +12 | 29 | 0 | 0 | 2 | WSW | 8.8 | 15 | SW | 7:27 | 80 | 1 | 3 | | | | | | | 13 |
| 14 | 43 | 30 | 37 | +13 | 28 | 0.02 | 0 | 1 | S | 10.1 | 14 | S | 0:00 | 0 | 10 | 10 | | | | | | | 14 |
| 15 | 56 | 33 | 45 | +21 | 20 | 0.09 | 0 | T | SSW | 17.8 | 35 | SW | 0:10 | 2 | 9 | 10 | | | | | | | 15 |
| 16 | 33 | 18 | 26 | + 2 | 39 | T | T | T | WNW | 15.9 | 37 | W | 3:25 | 36 | 6 | 6 | | | | | | | 16 |
| 17 | 33 | 18 | 26 | + 2 | 39 | 0.29 | T | 0 | NE | 15.8 | 25 | NE | 0:00 | 0 | 10 | 9 | | | | | | | 17 |
| 18 | 33 | 28 | 31 | + 7 | 34 | T | T | T | WSW | 18.6 | 21 | W | 1:37 | 17 | 8 | 9 | | | | | | | 18 |
| 19 | 30 | 25 | 28 | + 4 | 37 | 0.01 | 0.1 | T | NE | 5.8 | 17 | W | 0:00 | 0 | 10 | 10 | | | | | | | 19 |
| 20 | 31 | 21 | 26 | + 2 | 39 | 0 | 0 | T | NE | 7.9 | 16 | NE | 0:32 | 6 | 9 | 6 | | | | | | | 20 |
| 21 | 36 | 25 | 31 | + 8 | 34 | 0 | 0 | T | NE | 5.6 | 8 | N | 5:21 | 56 | 5 | 5 | | | | | | | 21 |
| 22 | 33 | 25 | 29 | + 6 | 36 | T | 0 | T | SSE | 11.5 | 16 | SE | 0:43 | 7 | 10 | 8 | | | | | | | 22 |
| 23 | 36 | 32 | 34 | +11 | 31 | 0.62 | 0 | T | NE | 9.9 | 11 | NE | 0:00 | 0 | 10 | 10 | | | | | | | 23 |
| 24 | 33 | 26 | 30 | + 7 | 35 | 0.16 | 1.5 | 1 | NW | 18.5 | 29 | NW | 0:00 | 0 | 10 | 10 | | | | | | | 24 |
| 25 | 27 | 13 | 20 | - 3 | 45 | T | T | 1 | NW | 17.7 | 35 | NW | 1:02 | 11 | 9 | 7 | | | | | | | 25 |
| 26 | 27 | 5 | 16 | - 7 | 49 | 0 | 0 | 1 | SE | 14.0 | 22 | SE | 3:28 | 35 | 8 | 5 | | | | | | | 26 |
| 27 | 38 | 26 | 32 | + 9 | 33 | 0 | 0 | 1 | SW | 13.3 | 27 | W | 0:00 | 0 | 10 | 10 | | | | | | | 27 |
| 28 | 26 | 21 | 24 | + 1 | 41 | T | T | T | WNW | 18.2 | 26 | W | 0:00 | 0 | 10 | 10 | | | | | | | 28 |
| 29 | 28 | 19 | 23 | 0 | 42 | 0.02 | 0.1 | T | W | 13.4 | 24 | NW | 0:22 | 4 | 9 | 10 | | | | | | | 29 |
| 30 | 35 | 19 | 27 | + 4 | 38 | 0.11 | 1.7 | 2 | ESE | 8.3 | 15 | SE | 7:35 | 77 | 2 | 5 | | | | | | | 30 |
| 31 | 43 | 16 | 30 | + 7 | 35 | T | T | 1 | WNW | 19.2 | 45 | W | 0:30 | 5 | 9 | 8 | | | | | | | 31 |
| Sum | 1016 | 641 | — | — | — | 2.02 | 7.9 | — | — | 415.4 | — | — | 37:44 | — | 269 | 257 | — | — | | | | | Sum |
| Avg. | 32.8 | 20.7 | — | — | — | — | — | — | — | 13.4 | Fastest | Dir. | Possible | % | 8.7 | 8.3 | — | — | | | | | Avg. |
| | | | | | | | | | | Misc. | 45 | W | 293:17 | 13 | — | — | — | — | | | | | Misc. |

T in columns 7, 8, and 9 indicates amount too small to measure.

**TEMPERATURE: (°F)**
Average monthly 26.8
Departure from normal +3.0
Highest 56 on 15th
Lowest 3 on 7th
Number of days with —
Max. 32° or below 13
Max. 90° or above 0
Min. 32° or below 30
Min. 0° or below 0

**HEATING DEGREE DAYS (base 65°):**
Total this month 1179
Departure from normal -139
Seasonal total (since July 1) 3757
Seasonal departure from normal -266

**BAROMETRIC PRESSURE (In.)**
Avg. station (elev. 878 feet, m. s. l.) 28.986
Highest sea level 30.56 on 16th
Lowest sea level 29.44 on 24th

**PRECIPITATION: (In.)**
Total for the month 2.02
Departure from normal +0.15
Greatest in 24 hours 0.78 on 23 & 24
Snow, Sleet and Hail —
Total for the month 7.9
Greatest in 24 hours 1.7 on 30th
Greatest depth on ground 3 on 8,9,10,11,12
Dates of — Hail ---
Sleet 8,9,17,24 Glaze 8,9,10,11,17

**Symbols used in columns 18-19**
A = Hail
BS = Blowing snow
DL = Distant lightning
D = Dust
E = Sleet
F = Fog
H = Haze
K = Smoke
L = Drizzle
N = Sand
R = Rain
S = Snow
T = Thunderstorm
ZL = Freezing drizzle
ZR = Freezing rain

The month of January was characterized by above normal temperatures and precipitation, but below normal snowfall. There have been only four other times since beginning of record that temperatures for the three month period November through January has been warmer than the past three months. The warmest period which occurred during November-January, 1931-32, averaged 8.1° above normal. For the past three months, temperatures averaged 3.3° above normal. Snowfall for the season is 10 inches below normal. Glazing conditions existed several days during the month causing numerous traffic accidents,and 3 deaths on 17th.

## HOURLY PRECIPITATION

| Date | A. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | P. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 2 | | | | | | | | | | | | | | | | | | T | T | T | .01 | .01 | T | T | 2 |
| 3 | T | T | | | | | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | | 3 |
| 4 | | | | | | T | T | T | T | T | T | T | T | T | T | T | T | | T | T | T | T | T | T | 4 |
| 5 | T | T | T | T | T | T | .01 | .01 | .02 | .01 | T | T | T | T | T | T | T | .01 | T | T | T | .01 | T | T | 5 |
| 6 | T | T | T | T | T | T | | | | | | | | | | T | T | .02 | .01 | .01 | .01 | T | T | T | 6 |
| 7 | T | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 8 | | | | T | T | T | | | T | .07 | .05 | .07 | .04 | .04 | .02 | .04 | .02 | .02 | .01 | .01 | .01 | .01 | T | T | 8 |
| 9 | T | T | .01 | T | T | T | T | T | T | T | T | T | T | T | | | | | | | T | .01 | .01 | T | 9 |
| 10 | T | T | T | T | | | | T | .01 | T | T | T | T | | T | T | .01 | T | T | T | T | T | | T | 10 |
| 11 | T | | | | .01 | .01 | T | .02 | .01 | .02 | .03 | T | T | T | T | | | | | | | | | | 11 |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | 12 |
| 13 | | | | | | | | | | | | | | | | | | | | | | | | | 13 |
| 14 | | | | | | | | | | | | | | T | T | .01 | T | | .01 | T | T | | | | 14 |
| 15 | | T | .01 | .01 | .01 | T | | | | | | | | | | | T | .04 | .01 | T | .01 | T | | | 15 |
| 16 | | | T | | | | T | T | T | T | T | T | | | | | | | | | | | | | 16 |
| 17 | | | | | | | | | | | T | .02 | T | T | T | .15 | .06 | .02 | T | T | .02 | T | T | T | 17 |
| 18 | T | T | | | | | | | | | | | | | | | | | | | | | | | 18 |
| 19 | | | | | | | | | | | T | .01 | T | T | T | | | | | | | | | | 19 |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | 20 |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | 21 |
| 22 | | | | | | | | | | | | | | | | | | | | | T | T | T | T | 22 |
| 23 | T | T | | | T | T | T | T | T | T | T | | | | | .01 | .07 | .08 | .08 | .05 | .08 | .08 | .12 | .05 | 23 |
| 24 | .01 | .01 | .03 | .02 | .01 | .02 | .01 | T | .02 | .03 | T | T | T | T | T | T | T | T | | T | T | T | T | T | 24 |
| 25 | T | T | T | | | | T | T | T | T | T | T | T | T | T | T | | | | | | | | | 25 |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | 26 |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | 27 |
| 28 | | | | | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | | | | T | 28 |
| 29 | .01 | T | T | .01 | T | T | T | T | T | T | T | T | T | T | T | T | | | | T | T | T | T | T | 29 |
| 30 | .04 | .02 | .02 | .02 | .01 | T | T | T | | | | | | | | | | | | | | | | | 30 |
| 31 | | | | | | | | | | | | | | | | | | | T | T | T | T | T | T | 31 |

**Effective January 1, 1953 the temperature and precipitation normals used for these reports are derived from the period 1921-1950.**

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WRPC, Kansas City, Mo. -- 2-5-53 -- 325

TABLE B III.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

# LOCAL CLIMATOLOGICAL DATA

LANSING, MICHIGAN (Capitol City Airport) FEBRUARY, 1953

Latitude 42 ° 47′ N. Longitude 84 ° 36 ′ W. Elevation (ground) 859 ft. Eastern Standard time used

| Date | Temperature (°F) Maximum | Minimum | Average | Departure from normal | Degree days (base 65°) | Precipitation Total (Water equivalent) (In.) | Snow, Sleet, Hail (In.) | Snow, Sleet, Hail or Ice on ground at 7:30 am (In.) | Wind Prevailing direction | Average speed (m. p. h.) | Fastest mile Speed (m. p. h.) | Fastest mile Direction | Sunshine Total (hours and minutes) | Percent of possible | Sky cover Sunrise to sunset (tenths) | Midnight to midnight (tenths) | Thunderstorm or distant lightning | Weather restricting visibility to ½ mile or less | RED CEDAR RIVER AT EAST LANSING | | | | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | 17 | 4 | 11 | -13 | 54 | T | T | T | NW | 11.4 | 33 | NW | 6:55 | 69 | 4 | 4 | | | 2.0 | | | | 1 |
| 2 | 29 | 12 | 21 | - 3 | 44 | T | T | T | SE | 12.8 | 20 | SE | 0:00 | 0 | 10 | 10 | | | 1.7 | | | | 2 |
| 3 | 26 | 19 | 23 | - 1 | 42 | T | T | T | NW | 6.6 | 16 | W | 1:12 | 12 | 9 | 8 | | | 1.5 | | | | 3 |
| 4 | 35 | 17 | 26 | + 2 | 39 | T | T | T | SSW | 8.9 | 13 | S | 1:37 | 16 | 9 | 8 | | | 1.6 | | | | 4 |
| 5 | 43 | 32 | 38 | +14 | 27 | 0.02 | 0 | T | S | 19.3 | 35 | SE | 0:00 | 0 | 10 | 10 | | | 1.6 | | | | 5 |
| 6 | 44 | 31 | 38 | +14 | 27 | 0.11 | T | 0 | WSW | 26.1 | 38 | SE | 0:00 | 0 | 10 | 10 | | | 1.6 | | | | 6 |
| 7 | 35 | 32 | 34 | +10 | 31 | 0.01 | 0.1 | T | WSW | 13.9 | 17 | W | 0:00 | 0 | 10 | 10 | | | 1.6 | | | | 7 |
| 8 | 33 | 20 | 27 | + 3 | 38 | 0.02 | 0.3 | T | WNW | 10.9 | 20 | W | 1:30 | 15 | 9 | 7 | | | 1.6 | | | | 8 |
| 9 | 31 | 16 | 24 | 0 | 41 | 0 | 0 | T | W | 7.9 | 15 | NW | 9:55 | 96 | 2 | 1 | | | 1.5 | | | | 9 |
| 10 | 33 | 25 | 29 | + 5 | 36 | 0.01 | 0.1 | T | E | 15.1 | 24 | SE | 0:00 | 0 | 10 | 10 | | | 1.5 | | | | 10 |
| 11 | 38 | 29 | 34 | +10 | 31 | 0.06 | 0.1 | T | SE | 18.8 | 30 | SE | 0:00 | 0 | 10 | 10 | | | 1.5 | | | | 11 |
| 12 | 35 | 29 | 32 | + 8 | 33 | 0.02 | 0.2 | 0 | WNW | 15.8 | 31 | NW | 0:00 | 0 | 10 | 10 | | | 1.5 | | | | 12 |
| 13 | 32 | 26 | 29 | + 5 | 36 | 0.04 | 0.4 | T | W | 16.3 | 23 | W | 1:15 | 12 | 9 | 8 | | | 1.5 | | | | 13 |
| 14 | 45 | 28 | 37 | +13 | 28 | T | T | T | SSW | 16.0 | 25 | S | 8:53 | 85 | 2 | 4 | | | 1.5 | | | | 14 |
| 15 | 32 | 17 | 25 | + 1 | 40 | 0.01 | 0.1 | 0 | WNW | 18.1 | 34 | W | 1:43 | 16 | 8 | 7 | | | 1.5 | | | | 15 |
| 16 | 21 | 13 | 17 | - 7 | 48 | T | T | T | WNW | 9.8 | 26 | W | 1:30 | 14 | 9 | 7 | | | 1.5 | | | | 16 |
| 17 | 26 | 15 | 21 | - 3 | 44 | T | T | T | W | 14.9 | 25 | W | 0:58 | 9 | 9 | 7 | | | 1.5 | | | | 17 |
| 18 | 43 | 10 | 27 | + 3 | 38 | T | T | 0 | WSW | 14.2 | 26 | S | 4:13 | 39 | 7 | 8 | | | 1.5 | | | | 18 |
| 19 | 48 | 24 | 36 | +11 | 29 | 0 | 0 | 0 | E | 10.0 | 17 | E | 2:21 | 22 | 7 | 6 | | | 1.5 | | | | 19 |
| 20 | 55 | 40 | 48 | +23 | 17 | 0.43 | 0 | 0 | SSE | 20.7 | 35 | S | 0:00 | 0 | 10 | 9 | T | | 1.7 | | | | 20 |
| 21 | 50 | 17 | 34 | + 9 | 31 | 0.01 | T | T | WSW | 29.2 | 34 | W | 0:00 | 0 | 9 | 9 | | BS | 2.0 | | | | 21 |
| 22 | 29 | 9 | 19 | - 6 | 46 | 0.01 | 0.1 | T | W | 16.0 | 25 | W | 5:18 | 49 | 4 | 6 | | | 2.9 | | | | 22 |
| 23 | 44 | 27 | 36 | +11 | 29 | 0 | 0 | T | W | 12.7 | 18 | W | 10:56 | 100 | 0 | 1 | | | 2.3 | | | | 23 |
| 24 | 42 | 31 | 37 | +12 | 28 | 0 | 0 | 0 | W | 12.8 | 18 | W | 2:13 | 20 | 8 | 7 | | | 2.0 | | | | 24 |
| 25 | 39 | 24 | 32 | + 6 | 33 | T | 0 | 0 | SW | 10.1 | 17 | SW | 2:22 | 21 | 8 | 7 | | | 1.9 | | | | 25 |
| 26 | 43 | 32 | 38 | +12 | 27 | 0.18 | 0.2 | T | WSW | 22.5 | 30 | SW | 3:28 | 31 | 9 | 10 | | | 1.9 | | | | 26 |
| 27 | 40 | 25 | 33 | + 7 | 32 | 0.08 | 0.6 | T | W | 21.4 | 45 | W | 2:09 | 19 | 8 | 9 | | S | 1.8 | | | | 27 |
| 28 | 35 | 18 | 27 | + 1 | 38 | 0.02 | 0.2 | T | WNW | 19.1 | 43 | NW | 1:35 | 14 | 9 | 7 | | | 1.7 | | | | 28 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | 29 |
| 30 | | | | | | | | | | | | | | | | | | | | | | | 30 |
| 31 | | | | | | | | | | | | | | | | | | | | | | | 31 |
| Sum | 1023 | 622 | — | — | — | 1.03 | 2.4 | — | — | 431.3 | — | — | 70:03 | — | 219 | 210 | — | — | 47.9 | | | | Sum |
| Avg. | 36.5 | 22.2 | — | — | — | — | — | — | — | 15.4 | Fastest | Dir. | Possible | % | 7.8 | 7.5 | — | — | 1.7 | | | | Avg. |
| | | | | | | | | | | Misc. | 45 | W | 295:38 | 24 | — | — | — | — | | | | | Misc. |

T in columns 7, 8, and 9 indicates amount too small to measure.

**TEMPERATURE: (°F)**

| | |
|---|---|
| Average monthly | 29.4 |
| Departure from normal | +5.2 |
| Highest 55° on | 20th |
| Lowest 4° on | 1st |
| Number of days with — | |
| Max. 32° or below | 9 |
| Max. 90° or above | 0 |
| Min. 32° or below | 27 |
| Min. 0° or below | 0 |

**HEATING DEGREE DAYS (base 65°):**

| | |
|---|---|
| Total this month | 987 |
| Departure from normal | -212 |
| Seasonal total (since July 1) | 4744 |
| Seasonal departure from normal | -478 |

**BAROMETRIC PRESSURE (In.)**

| | | | |
|---|---|---|---|
| Avg. station (elev. 878 feet, m. s. l.) | | | 29.010 |
| Highest sea level | 30.65 | on | 10th |
| Lowest sea level | 29.33 | on | 28th |

**PRECIPITATION: (In.)**

| | | | |
|---|---|---|---|
| Total for the month | | | 1.03 |
| Departure from normal | | | -.78 |
| Greatest in 24 hours | 0.43 | on | 20th |
| Snow, Sleet and Hail — | | | |
| Total for the month | | | 2.4 |
| Greatest in 24 hours | 0.7 | on | 27 & 28 |
| Greatest depth on ground | T | on | 1st 1/ |
| Dates of — Hail | | | — |
| Sleet 11th | Glaze 11th, 12th | | |

1/ and other dates

**Symbols used in columns 18-19**

A = Hail; BS = Blowing snow; DL = Distant lightning; D = Dust; E = Sleet; F = Fog; H = Haze; K = Smoke; L = Drizzle; N = Sand; R = Rain; S = Snow; T = Thunderstorm; ZL = Freezing drizzle; ZR = Freezing rain

Temperatures for the fourth month in a row averaged well above normal. This was the warmest February since 1938 and the fifth warmest February since 1900. Total snowfall for the month was unusual in that there have been only two other such February's with less than 2.4 inches of snow. The amount of snowfall so far this season totals 17.0 inches which is 17.8 inches below the seasonal normal.

## HOURLY PRECIPITATION

| Date | A. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | P. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | T | T | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 2 | | | | | | | | | T | T | T | T | T | T | T | T | T | | | | | | | | 2 |
| 3 | | | | | | | | | T | T | T | | | | | | | | | | | | | | 3 |
| 4 | | | | | | | | | | | | T | | | | | | | | | | | | | 4 |
| 5 | | | | | | | | | | | | | T | T | T | | | | | 0.01 | T | 0.01 | T | T | 5 |
| 6 | 0.06 | 0.02 | | 0.01 | 0.02 | | | | | | T | T | T | T | | | | | | | | | | | 6 |
| 7 | T | 0.01 | T | | T | T | T | T | | | T | T | T | T | T | T | T | T | | T | T | | | | 7 |
| 8 | | | | T | 0.01 | T | T | 0.01 | T | T | T | | | | | | | | | | | | | | 8 |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 10 | | | | | | | | | | 0.01 | T | | | T | T | T | | | T | | | | | | 10 |
| 11 | | | | 0.02 | 0.01 | T | T | T | T | 0.01 | T | T | T | T | T | 0.02 | T | T | T | T | T | T | T | T | 11 |
| 12 | | | | | | | | | T | 0.02 | T | T | T | T | T | T | | T | | T | T | T | T | T | 12 |
| 13 | T | 0.01 | 0.02 | 0.01 | T | T | T | T | T | T | T | T | T | T | | | | | | | | | | | 13 |
| 14 | | | | | | | | | | | | | | | | | | | | T | T | T | T | | 14 |
| 15 | | | | | | | | | T | T | T | | | | T | T | T | T | T | | 0.01 | T | T | T | 15 |
| 16 | T | | | | | | | | | | | | | | | | | | | | | | | | 16 |
| 17 | | | | T | T | T | T | T | T | T | T | T | T | T | | T | T | T | | | | | | | 17 |
| 18 | | | | | | | | | | T | T | | | | | | | | | | | | | | 18 |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | | 19 |
| 20 | | | | | | | | T | T | 0.01 | 0.02 | 0.06 | 0.01 | T | | | T | T | T | 0.22 | 0.02 | 0.08 | 0.01 | T | 20 |
| 21 | T | T | T | | | T | T | T | T | T | T | T | T | T | T | T | T | T | T | T | 0.01 | T | T | T | 21 |
| 22 | 0.01 | T | T | T | T | T | T | | | | | | | | | | | | | | | | | | 22 |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | 23 |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | 24 |
| 25 | | | | | | | | | | | | | | | | | | | | | T | T | T | T | 25 |
| 26 | T | 0.02 | 0.02 | T | 0.01 | T | T | T | | | | | | | | | | T | 0.01 | T | 0.01 | 0.05 | 0.04 | 0.02 | 26 |
| 27 | T | T | 0.02 | 0.03 | T | | | | | | T | 0.02 | T | 0.01 | T | T | | T | T | T | T | T | T | T | 27 |
| 28 | 0.01 | T | T | T | T | | | | | | T | T | T | | 0.01 | T | T | | | | | | | | 28 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | | 29 |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | 30 |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | 31 |

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WRPC, Kansas City, Mo. — 3-6-53 — 325

TABLE B IV.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

# LOCAL CLIMATOLOGICAL DATA

LANSING, MICHIGAN (Capitol City Airport) MARCH, 1953

Latitude 42 ° 47 ′ N. Longitude 84 ° 36 ′ W. Elevation (ground) 859 ft. Eastern Standard time used

| Date | Temperature (°F) Maximum | Minimum | Average | Departure from normal | Degree days (base 65°) | Precipitation Total (Water equivalent) (In.) | Snow, Sleet, Hail (In.) | Snow, Sleet, Hail or Ice on ground at 7:30 AM (In.) | Wind Prevailing direction | Average speed (m. p. h.) | Fastest mile Speed (m. p. h.) | Direction | Sunshine Total (hours and minutes) | Percent of possible | Sky cover Sunrise to sunset (tenths) | Midnight to midnight (tenths) | Thunderstorm or distant lightning | Weather restricting visibility to ¼ mile or less | RED CEDAR RIVER AT EAST LANSING | GRAND RIVER AT LANSING | | | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | 27 | 14 | 21 | - 6 | 44 | T | T | T | ENE | 17.0 | 27 | N | 8:18 | 74 | 5 | 5 | | | 1.7 | 3.2 | | | 1 |
| 2 | 29 | 17 | 23 | - 4 | 42 | T | T | T | E | 27.3 | 45 | E | 0:00 | 0 | 10 | 10 | | | 1.9 | 3.1 | | | 2 |
| 3 | 37 | 28 | 33 | + 5 | 32 | 0.88 | T | T | SE | 14.3 | 29 | NE | 0:00 | 0 | 10 | 10 | | | 1.9 | 2.7 | | | 3 |
| 4 | 33 | 22 | 28 | 0 | 37 | 0.09 | 1.5 | T | WSW | 21.3 | 32 | W | 0:28 | 4 | 9 | 10 | | | 3.6 | 4.6 | | | 4 |
| 5 | 28 | 17 | 22 | - 7 | 43 | 0.02 | 0.3 | 1 | W | 21.5 | 32 | W | 4:07 | 36 | 6 | 5 | | | 4.8 | 5.5 | | | 5 |
| 6 | 27 | 14 | 21 | - 8 | 44 | T | T | 1 | W | 14.3 | 36 | W | 2:20 | 20 | 9 | 7 | | | 4.0 | 5.5 | | | 6 |
| 7 | 23 | 9 | 16 | -14 | 49 | T | T | T | W | 5.9 | 10 | W | 3:34 | 31 | 9 | 6 | | | 3.3 | 4.6 | | | 7 |
| 8 | 28 | 12 | 20 | -10 | 45 | 0.02 | 0.5 | T | WSW | 8.9 | 18 | W | 0:34 | 5 | 10 | 7 | | | 2.6 | 4.1 | | | 8 |
| 9 | 38 | 17 | 28 | - 2 | 37 | T | T | T | WSW | 9.0 | 15 | SW | 2:07 | 18 | 9 | 7 | | | 2.4 | 4.1 | | | 9 |
| 10 | 40 | 32 | 36 | + 5 | 29 | 0 | 0 | T | SE | 13.0 | 26 | SE | 1:10 | 10 | 10 | 9 | | | 2.2 | 4.2 | | | 10 |
| 11 | 55 | 31 | 43 | +12 | 22 | T | 0 | 0 | SSE | 13.3 | 17 | SE | 2:46 | 24 | 9 | 8 | | | 2.0 | 3.8 | | | 11 |
| 12 | 60 | 42 | 51 | +19 | 14 | 0.22 | 0 | 0 | SSE | 11.2 | 19 | SE | 3:14 | 28 | 10 | 10 | | | 2.0 | 3.7 | | | 12 |
| 13 | 51 | 33 | 42 | +10 | 23 | 0.01 | 0 | 0 | WNW | 13.4 | 21 | W | 0:00 | 0 | 10 | 10 | | F | 2.4 | 4.1 | | | 13 |
| 14 | 42 | 32 | 37 | + 4 | 28 | 0.20 | 0 | 0 | E | 16.0 | 34 | E | 0:15 | 2 | 10 | 10 | | | 2.6 | 4.2 | | | 14 |
| 15 | 49 | 34 | 42 | + 9 | 23 | 0.29 | T | 0 | WSW | 17.4 | 29 | E | 0:00 | 0 | 10 | 10 | T | F | 3.1 | 4.5 | | | 15 |
| 16 | 36 | 32 | 34 | 0 | 31 | T | T | 0 | W | 18.5 | 32 | W | 0:25 | 3 | 10 | 10 | | | 3.7 | 5.0 | | | 16 |
| 17 | 54 | 31 | 43 | + 9 | 22 | T | T | T | ESE | 10.1 | 18 | SE | 11:15 | 94 | 1 | 4 | | | 3.6 | 5.1 | | | 17 |
| 18 | 53 | 34 | 44 | +10 | 21 | 0.25 | 0 | 0 | SSE | 13.5 | 43 | NW | 0:18 | 2 | 10 | 9 | | | 3.2 | 4.8 | | | 18 |
| 19 | 40 | 30 | 35 | 0 | 30 | 0.05 | 0.2 | T | WNW | 17.7 | 28 | W | 1:46 | 15 | 9 | 6 | | | 3.2 | 4.8 | | | 19 |
| 20 | 49 | 25 | 37 | + 2 | 28 | 0 | 0 | 0 | SE | 8.3 | 17 | SE | 11:38 | 96 | 5 | 5 | | | 3.2 | 4.8 | | | 20 |
| 21 | 68 | 37 | 53 | +18 | 12 | T | 0 | 0 | SE | 20.2 | 32 | SE | 9:37 | 79 | 4 | 5 | | | 2.9 | 4.3 | | | 21 |
| 22 | 55 | 48 | 52 | +16 | 13 | 0.12 | 0 | 0 | SSE | 17.0 | 32 | SE | 0:00 | 0 | 10 | 9 | | | 2.8 | 4.0 | | | 22 |
| 23 | 58 | 45 | 52 | +16 | 13 | 0.02 | 0 | 0 | SW | 19.3 | 57 | SE | 8:04 | 66 | 7 | 8 | | | 2.8 | 4.6 | | | 23 |
| 24 | 53 | 32 | 43 | + 6 | 22 | 0.01 | 0 | 0 | W | 12.1 | 27 | W | 5:38 | 46 | 7 | 8 | | | 2.8 | 4.5 | | | 24 |
| 25 | 39 | 30 | 35 | - 2 | 30 | T | T | T | NW | 9.3 | 18 | NW | 0:40 | 5 | 10 | 10 | | | 2.8 | 4.4 | | | 25 |
| 26 | 46 | 30 | 38 | + 1 | 27 | 0.02 | T | T | NW | 19.6 | 37 | W | 4:28 | 36 | 8 | 9 | | | 2.8 | 4.3 | | | 26 |
| 27 | 53 | 35 | 44 | + 6 | 21 | 0 | 0 | 0 | WNW | 17.8 | 36 | W | 4:55 | 39 | 8 | 7 | | | 2.7 | 3.6 | | | 27 |
| 28 | 40 | 33 | 37 | - 1 | 28 | 0.01 | T | 0 | WNW | 20.5 | 35 | W | 0:19 | 3 | 9 | 8 | | | 2.5 | 3.6 | | | 28 |
| 29 | 40 | 34 | 37 | - 1 | 28 | T | T | 0 | NNW | 15.4 | 22 | N | 0:46 | 6 | 10 | 9 | | | 2.4 | 4.5 | | | 29 |
| 30 | 42 | 31 | 37 | - 2 | 28 | 0 | 0 | 0 | E | 7.3 | 17 | E | 5:13 | 41 | 9 | 9 | | | 2.2 | 3.8 | | | 30 |
| 31 | 51 | 29 | 40 | + 1 | 25 | 0.08 | 0 | 0 | E | 9.3 | 18 | E | 1:01 | 8 | 10 | 9 | | | 2.1 | 3.4 | | | 31 |
| Sum | 1342 | 890 | — | — | — | 2.29 | 2.5 | — | | 459.7 | — | — | 94:56 | — | 263 | 249 | — | — | | | | | Sum |
| Avg. | 43.3 | 28.7 | | | | | | | | 14.8 | Fastest | Dir. | Possible | % | 8.5 | 8.0 | | | | | | | Avg. |
| | | | | | | | | | | Misc. | 57 | SE | 370:08 | 26 | — | — | — | — | | | | | Misc. |

T in columns 7, 8, and 9 indicates amount too small to measure.

**TEMPERATURE: (°F)**
Average monthly 36.0
Departure from normal +2.8
Highest 68 on 21st
Lowest 9 on 7th
Number of days with –
Max. 32° or below 6
Max. 90° or above 0
Min. 32° or below 21
Min. 0° or below 0

**HEATING DEGREE DAYS (base 65°):**
Total this month 891
Departure from normal -147
Seasonal total (since July 1) 5635
Seasonal departure from normal -625

**BAROMETRIC PRESSURE (In.)**
Avg. station (elev. 878 feet, m. s. l.) 29.050
Highest sea level 30.59 on 7th
Lowest sea level 29.20 on 3rd

**PRECIPITATION: (In.)**
Total for the month 2.29
Departure from normal -0.28
Greatest in 24 hours 0.90 on 3 & 4
Snow, Sleet and Hail –
Total for the month 2.5
Greatest in 24 hours 1.8 on 4 & 5
Greatest depth on ground 2 on 5th
Dates of – Hail —
Sleet — Glaze 3 & 4

**Symbols used in columns 18-19**
A = Hail
BS = Blowing snow
DL = Distant lightning
D = Dust
E = Sleet
F = Fog
H = Haze
K = Smoke
L = Drizzle
N = Sand
R = Rain
S = Snow
T = Thunderstorm
ZL = Freezing drizzle
ZR = Freezing rain

For the fifth consecutive month, temperatures averaged above normal for the 31-day period making it the warmest March since 1946. Temperatures during the last half of the month averaged ten degrees warmer than the first fifteen days of March. Snowfall for the season through the end of March totaled 19.5 inches, second only for the least snowfall to the season of 1905-06, when only 17.7 inches of snow accumulated. At this time last year, the Lansing area had received 77.3 inches of snow! No serious storms occurred in the area throughout March.

## HOURLY PRECIPITATION

| Date | A. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | P. M. Hour ending at 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | T | T | | | | | | | | | | | | | | | | | | | | | | 1 |
| 2 | | | | | | | | | | | | | | | | | | | T | | | | | | 2 |
| 3 | | | T | T | T | | T | T | T | T | T | T | T | T | T | .10 | .14 | .21 | .06 | .08 | .12 | .02 | .01 | .14 | 3 |
| 4 | .01 | .01 | | | | | | | | | | T | T | T | | | T | T | T | T | T | .02 | .01 | .04 | 4 |
| 5 | .01 | | | T | T | T | T | T | T | .01 | T | T | T | T | | | | | | | | | | | 5 |
| 6 | | | | | | | | | | | | T | T | T | T | T | T | T | T | T | | | | | 6 |
| 7 | | | | | | | | | | | | | | | | | | | | | T | T | T | T | 7 |
| 8 | | | | | | | | | T | T | T | T | T | T | .01 | T | T | T | T | T | T | .01 | T | T | 8 |
| 9 | | | | | | | | | | | T | T | | | | | | | | | | | | | 9 |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | 10 |
| 11 | | | | | | | | | | | | | | | | | | | | | | T | T | T | 11 |
| 12 | T | T | T | T | T | | | | | | | | | | | | T | .03 | .07 | .05 | .03 | .02 | .01 | .01 | 12 |
| 13 | .01 | T | | | | T | T | T | | | | | | | | | | | | | | | | | 13 |
| 14 | | | | | | | | | | | | | | | | T | .05 | .04 | .04 | .06 | .01 | T | | | 14 |
| 15 | | .06 | .19 | .01 | | | | T | .02 | T | T | | | | | T | T | .01 | T | | T | T | | T | 15 |
| 16 | T | T | T | T | | | | | | | | | | | | | | | | | | | | | 16 |
| 17 | | | | | T | T | T | | | | | | | | | | | | | | | | | | 17 |
| 18 | | | | | | | | | | | T | | | T | .01 | | .03 | .02 | .02 | .17 | T | T | | | 18 |
| 19 | | | | T | .01 | .03 | .01 | | | | | | | | | | | | | | | | | | 19 |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | 20 |
| 21 | | | | | | | T | | | | | | | | | | | | | | | | | | 21 |
| 22 | | | | | | T | .02 | | T | T | T | .03 | T | T | | | .02 | .01 | .02 | T | .02 | T | | | 22 |
| 23 | T | T | | | T | T | .01 | .01 | | | | | | | | | | | | | | | | | 23 |
| 24 | T | | | | | T | .01 | | | | T | | | T | | | | | | | | | | | 24 |
| 25 | | | T | T | T | T | T | T | T | T | | | | T | | | T | T | T | T | T | T | T | T | 25 |
| 26 | .01 | T | T | T | T | T | | | | | | | | | | | | T | | .01 | T | T | T | | 26 |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | 27 |
| 28 | | | | | | | | | T | T | T | T | T | | T | T | T | T | T | T | .01 | T | T | T | 28 |
| 29 | T | T | T | | | | T | T | T | T | T | | | | | | | | | | | | | | 29 |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | 30 |
| 31 | | | | | | | | | | | | | | | | | | T | .01 | .01 | T | .01 | .01 | .04 | 31 |

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W.R.P.C., Kansas City, Mo. -- 4-7-53 -- 325

# GLOSSARY

## DEFINITIONS OF TERMS RELATING TO SOLAR ENERGY

Air Mass--a number representing the ratio of the relative length of the path at sea level of solar rays through the atmosphere as compared with the extent of the path when the sun is in the zenith, or approximately the secant of the sun's zenith distance.

Atmospheric Transmittance--the direct normal solar radiation at the earth's surface divided by the solar constant.

British Thermal Unit--heat required to raise one pound of water at its temperature of maximum density one degree Fahrenheit. This equals 252 gram-calories.

Diffuse Sky Radiation-(energy)--the scattered solar radiation (energy) received by the earth from the atmosphere as distinguished from the radiation incident in direct sunlight.

Direct Solar Radiation-(energy)--the energy received directly from the sun. Its spectral distribution is characterized by a maximum intensity in the blue-green portion of the spectrum at about one-half micron and hence often is called shortwave radiation to distinguish it from the predominantly longer wave terrestial radiation. As received at the earth, the spectral distribution is characterized by numerous intense telluric adsorption lines and bands. The most important are produced by oxygen, ozone, carbon dioxide and water.

Equinox--the moment (occurring twice each year) when the sun in its apparent annual motion among the fixed stars crosses the celestial equator. So called because then the night is equal to the day, each being twelve hours long over the whole earth. The Autumnal Equinox occurs on or about September 22 when the sun is traveling southward. The Vernal Equinox occurs on or about March 21, when the sun is moving northward.

Gram-Calorie--the amount of heat required to raise the temperature of one gram of water at 15 degrees centigrade one degree centigrade. This is not to be confused with the large calorie which has a value one thousand times as great.

Hour Angle--the angle between the sun and the meridian of the zenith. Usually expressed in hours and fractions of an hour. For example, the hour angle at 7:35 A.M. solar time is 4:25 (12-7:35 is equal to 4:25).

Incidence Angle--the angle between the direction of the sun's rays and a perpendicular to the surface being considered.

Mean Solar Distance--mean distance of the earth from the sun; an arithmetical mean between its greatest and least distances.

Normal Incidence Radiation--as used in this paper, solar energy received at normal incidence denotes the impingement of solar energy on a flat surface at a right angle to the sun's rays.

Overhang--an architectural devise, such as a roof extension, placed over a window or vertical wall surface, to intercept the sun's rays from above.

Percentage of Possible Sunshine--percentage of the time that the sun casts a well defined shadow when the sun is above the true horizon.

Profile Angle--the angle through which a horizontal plane must be rotated about a horizontal axis located in the plane of the window or wall in order to include the position of the sun.

Solar Altitude--angular elevation of the sun above the true horizon.

Solar Azimuth--the angular direction of the sun with respect to true south. True south, rather than true north is used because southern orientation is the more important in northern latitudes.

Solar Constant--the rate at which solar radiant energy is received outside the atmosphere on a surface normal to the incident radiation at the earth's mean distance from the sun. The value of 1.94 gram-calories per square centimeter per minute as determined by the astrophysical observatory of the Smithsonian Institute is used throughout this paper.

Solar Declination--the angle distance of the sun north or south of the celestial equator. The solar declination in the northern hemisphere at the time of the equinoxes is zero degrees. At the summer and winter solstices the solar declination is plus 23 degrees, 27 minutes and minus 23 degrees, 27 minutes respectively.

Solar Time--the hours of the day as reckoned by the appar ent position of the sun. Solar noon is that instant on any day at which the sun reaches its maximum altitude for that day.

Solstices--points on the apparent path of the sun midway between the equinoxes when the sun attains its greatest north and south declinations. The summer solstice or the sun's most northern point on its travel path occurs about June 21. The winter solstice or the sun's most southern point on the circle occurs about December 22.

Telluric Adsorption--the adsorption of solar radiation which is caused by the constituents of the earthly atmosphere.

Total Incident Solar Radiation--direct plus diffuse solar radiation measured perpendicular to the plane of a window or wall.

Transmission Factor--the ratio of transmitted solar energy to total incident solar radiation.

Transmitted Solar Energy--that portion of the total incident solar radiation which passes directly through glass as radiation and which has the same wave length spectrum as the total incident radiation.

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