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Environmental Physiology and Shelter Engineering

With Special Reference to Domestic Animals

LVI. Stable Heat and Moisture Dissipation With Dairy Calves at Temperatures of 50° and 80° F

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Missouri Agricultural Experiment Station and the
United States Department of Agriculture Cooperating

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SUMMARY

Ventilation and air conditions loads which would be attributed to penned dairy calves and their bedded area were determined at 50° and 80° F stable air temperatures. Stable moisture dissipation (latent heat) and stable heat dissipation (latent plus sensible heat) were measured. Both increased with advancing age. The rate of increase was greatest during the first 5 months of age.

Most analyses were made on a per unit body weight basis. Such analyses showed stable heat and stable moisture to increase with age between 6 to 12 weeks of age and thereafter decrease with increasing age until at 55 weeks of age they began approaching constant values. Stable moisture dissipation was nearly twice as great at 80° as at 50° F but stable heat dissipation was nearly the same at both 50° and 80° F. However, at 55 weeks of age, the dissipation rates were nearly the same as were previously determined with mature cows at these two temperatures.

The ratio of latent to total heat (stable moisture to stable heat) averaged 0.37 at 50° F and, after 8 weeks of age, averaged 0.64 at 80° F. These ratios, as well as metabolic heat production[2] measurements of each animal, were used to estimate stable heat and moisture loads of each breed. These estimates are presented in the form of prediction charts for each of the three breeds tested.

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INTRODUCTION

The design of adequate ventilation or air-conditioning systems for animal stables requires knowledge of the heat and moisture they must remove. Primary considerations in such design calculations are: (1) the heat and moisture dissipated by animals, bedded area, and watering devices and (2) the heat and moisture lost or gained by way of walls, ceiling, and floors. The purpose of this report is to present design data concerning the first of these two considerations as they apply to dairy calf housing. The data were obtained under the controlled environmental conditions of the Psychroenergetic Laboratory at the University of Missouri and provide companion data to stable heat and moisture dissipation data previously reported with beef calves.[1]

DEFINITIONS

Terms are defined as follows.

Stable heat refers to the heat dissipated by the animals and their bedded area. It does not include heat from lights, personnel and equipment.

Stable moisture refers only to the moisture dissipated by the animals, their bedded area, and their watering devices.

Animal heat production refers to the heat released through feed utilization and other processes within the animal's body. It was evaluated through the measurement of oxygen consumption with a metabolism apparatus.[2]

Animal vaporization refers to the water vaporized directly from the animal. It was measured with a hygrometric tent.[3]

PROCEDURES

Design of the Experiment

Jersey, Holstein, and Brown Swiss calves were divided into two groups with three calves of each breed within a group. One group was exposed to a constant air temperature of 50° F and the other was exposed to a constant air temperature of 80° F. Duration of the exposure was 11.5 months. A temperature of 50° F was considered representative of the winter temperatures within many of the cattle stables in the northern area of the United States. A temperature of 80° F was considered approximately maximum for near-normal rectal temperatures and growth. The average relative humidity was 65 percent at 50° F and 55 percent at 80° F. More detailed temperature and humidity information is given in the discussion of test room conditions.

The heat and moisture picked up by the ventilation system as well as the heat transferred through walls, ceiling, and floor were determined from continuous records of temperature, dew point, and duct air velocity.

Several other measurements were made periodically by various investigators throughout the tests. Most of these involved the determination of physiological reactions such as: weight gains, growth, feed and water consumption, metabolism, animal vaporization rates, skin and rectal temperatures, pulse and respiration rates, blood volumes, and thyroid activity. A few spot measurements were made of the patterns of temperature, wind velocity, and light intensity within the test rooms. All physiological and other measurements were scheduled for minimum disturbance to the calves and to the ventilation exchange data.

Management Practices

Management practices were like those found on many farms where calves are kept in pens within barns. Wet litter was removed and fresh bedding added daily. Wheat straw and wood shavings were used in a combination which consisted of more than 50 percent straw (See Figure 4). Pens were thoroughly cleaned weekly and pulverized limestone was dusted on the floor. Water was available at all times to each pen.

Milk was fed to the calves for the first 20 weeks of test. The calves were fed grain according to standard practice for the University of Missouri dairy herd. The grain ration was a standard mix for calves and was fortified with a Vitamin D supplement. The calves were provided all the alfalfa hay they chose to eat.

The Calves

All calves used in these tests were brought into the laboratory from farms in the vicinity of the laboratory. Their ages at the beginning of the experiment averaged about 5 weeks. The rates of weight gains were good for all calves. Over the 11.5 month test period the average daily gains were: At 50° F—Holstein

2.00, Jersey 1.29, Brown Swiss 1.90; and at 80° F—Holstein 1.80, Jersey 1.25, Brown Swiss 1.89 pounds per day.[10]

The 80° F Holstein calves were probably under slight stress throughout the experiment as their rectal temperatures were about 0.9° F higher at 80° than at 50° F.[2]

The calves were dehorned during the twelfth week of test.

TABLE 1-AVERAGE WEIGHT (LB./CALF) OF EACH PEN OF CALVES

	Test Room I (50°F)			Test Room II (80° F)		
	Pen 1	Pen 2	Pen 3	Pen 1	Pen 2	Pen 3
Date	Jersey	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein
1956						
Oct. 8	56	107	123	57	111	116
Nov. 1	71	127	158	75	143	145
Dec. 1	120	170	212	110	196	192
1957						
Jan. 1	161	226	287	150	254	249
Feb. 1	206	295	369	196	325	318
Mar. 1	250	366	447	237	393	386
Apr. 1	285	433	503	271	454	449
May 1	331	494	566	308	512	507
June 1	374	559	622	350	574	562
July 1	414	620	676	383	627	604
Aug. 1	448	674	725	423	684	649
Sept. 1	480	726	782	460	738	700

Calf birth dates ranged from Aug. 16, 1956, to Sept. 23, 1956. In Test Room I they were: Brown Swiss - Aug. 16, Aug. 26, and Sept. 9; Holstein - Sept. 1, Sept. 5, and Sept. 13; and Jersey - Sept. 18, Sept. 19, and Sept. 23.
In Test Room II they were: Brown Swiss - Aug. 27, Aug. 31, and Sept. 5; Holstein - Sept. 1, Sept. 14, and Sept. 16; and Jersey - Aug. 28, Sept. 12, and Sept. 23.

Facilities

The Psychroenergetic Laboratory was used as previously described.[1] (See Figure 1.) Raised wooden mangers were placed in the concrete feed mangers for the first four months. Water was available at all times from water tanks in which the water level was maintained by a float-operated water valve. The amount of water drunk in each pen and the time it was drunk were recorded continuously. The temperature of the drinking water ranged from 76° F to 49° F in the 80° F test room and from 75° F to 47° F in the 50° F test room.

The test room temperatures and humidities were maintained through refrigerating and/or heating the air used in ventilation. About 1000 cubic feet of air per minute was circulated through each test room. About 20 percent of this was fresh air which was preconditioned to test room temperatures in the outer work alleys. The remaining 80 percent was recirculated air from the test rooms.

Instruments

In general the instruments and control devices were the same as used in previous Psychroenergetic Laboratory experiments with mature cattle. The

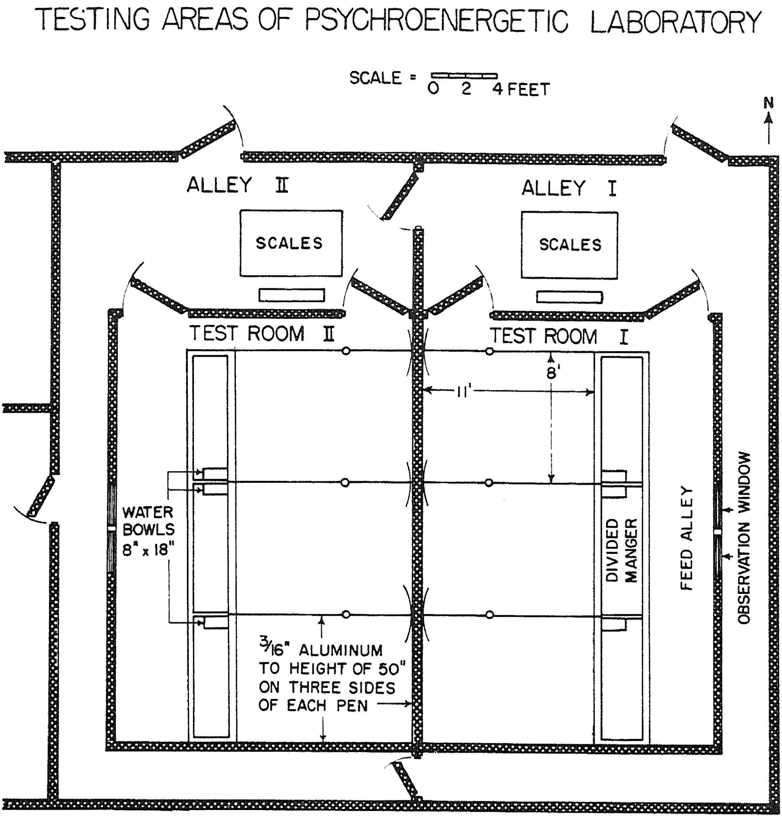

Figure 1—Floor plan of testing areas within the Psychroenergetic Laboratory. Test Room I and Alley I were maintained at 50° F and Test Room II and Alley II at 80° F. The calves were weighed on the alley scales but otherwise remained in the test rooms throughout the tests.

psychrometric properties of both the intake and exhaust air were recorded continuously. Ventilation air temperatures were measured with resistance-type instruments. The moisture content of the air was measured with a lithium-chloride dew-point measuring apparatus, a Foxboro Company "Dewcel." Approximately daily calibration checks of these instruments were made with a sling psychrometer.

Ventilation-duct air velocities were recorded by a recording manometer actuated by a combined-reverse pitot tube in the intake duct. These measurements were checked and average duct velocity traverses were made with a carefully calibrated deflecting-vane-type anemometer, having a probe similar to that of the combined-reverse pitot tube.

Structural heat transfer and storage were estimated from temperatures as detected by 10-junction thermopiles and as recorded by a 16-point recording potentiometer. The pattern of air temperatures among the calves was measured with copper-constantan thermocouples and an automatic-balancing potentiometer.

Test Room Conditions

Exhaust air temperatures and humidities provided the data of test room conditions (Table 2). During the 11.5 months of the 50° F test, the overall average daily temperature was 49.6° F. The weekly average temperature ranged from 49.1° to 50.6° F. In the 80° F test, the overall average temperature was 80.1° F and the weekly average temperatures ranged from 79.6° to 80.9° F. The average relative humidity for the entire period averaged 55 percent in the 50° F room and 65 percent in the 80° F room.

The temperature variation within a day was generally less than 2° F from the average temperature for that day. At no time was this deviation greater than 5° F. The humidity control was not as precise as the temperature control and 5° F variations in dew point were observed within several days throughout the tests.

Air-temperature measurements, made at nine equally-spaced positions and at levels of 15, 30, and 48 inches above the floor within each pen, showed good agreement between exhaust air and pen temperatures. All points were usually within 2° F of the exhaust temperature at any given time. Exceptions to this uniformity of temperatures occurred when measuring temperatures between stanchioned calves. Here the temperatures of the thermocouples were often 2° F higher than might otherwise be measured.

The air temperature within each pen was within 1° F of the temperatures for the other pens in the same test room. Air velocities and light intensities were also found to be uniform among pens. Within each pen, air velocities ranged from 20 to 50 feet per minute with an average value of about 30 feet per minute. Light was provided by six 200-watt incandescent lamps which were automatically switched on at 6 a.m. and off at 6 p.m. A 40-watt light bulb above the middle pen of each room was on at all times. Light intensities with all lights on ranged from 6 to 12-foot candles at positions located 15 inches above the floor within the pens.

Surface temperatures of the bedded area averaged about the same as room air temperatures. Feces, urine or animals lying down caused a localized surface temperature increase of a few degrees. Such localized heating was counteracted by 1° to 2° F lower surface temperatures caused by the evaporation of water from wet spots in the bedded area.

Computations

The method of computing heat and moisture dissipation was also much the same as reported in previous ventilation bulletins of this series.[4, 5] The enthalpy (Btu per pound of dry air) and the humidity ratio (pounds water per pound dry air) of test room intake and exhaust air were determined from psychrometric charts by using the daily average air and dew point temperatures as reference points. The difference in the enthalpy as well as in the humidity ratio between the intake and exhaust air was multiplied by the volume of intake air. Intake air represented the entire air exchange as the test rooms were slightly pressurized.

Volume (Q) of intake air was determined from the following formula:

$$Q \text{ pounds of dry air per hour} = C\left[\frac{D}{(1 + W)v}\right]^{0.5}$$

where D = the differential pressure across an industrial type combined-reverse pitot tube as recorded by a slack-diaphragm type recording draft gage,

W = the humidity ratio of intake air,

v = the specific volume (cubic feet per pound of dry air), and

C = a constant.

The constant, C, represents: (1) a constant for the pitot tube and draft gage; (2) an altitude correction factor; (3) the cross-sectional area of the duct; (4) a correction factor for the errors in the draft gage (when present); (5) and a factor of correlation between the center velocity (at the pitot tube) and the average cross-sectional velocity. Variable factors within this constant were checked about once every two months and necessary corrections were made.

The heat and moisture values which were obtained by this method were further adjusted for heat gains and losses from sources other than those directly related to the animal. The heat added by personnel was calculated by using a coefficient of 720 Btu per man per hour.[6] At 50° F the moisture added by each person was estimated at 0.14 pounds of water per hour. At 80° F a rate of 0.51 pounds of water per hour was used. Adjustments for lights and equipment were made according to their power consumption.

The heat transfer (Btu/hr.) through walls, ceiling, and floor was added (or subtracted if heat was gained) by multiplying the daily average temperature gradient through the walls and ceiling by appropriate coefficients.

Vapor losses or gains through test room surfaces were considered relatively small. No adjustments were made for them in the stable moisture calculations.

RESULTS

Stable Heat and Moisture Data

Results of the 50° and 80° F stable heat and stable moisture computations are shown in Table 2. On a per calf basis, both stable heat and stable moisture dissipation increased rapidly with increasing age until the calves were 5 months of age (when maximum daily weight gains were attained). Thereafter, the rate of increase with age was much slower.

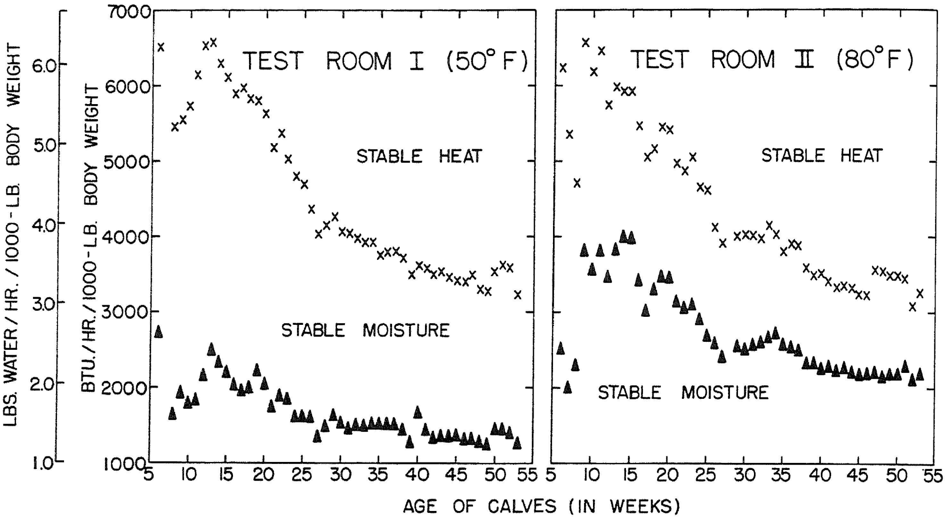

Figure 2—The stable heat (total) and stable moisture (latent heat) dissipated within the 50° and 80° F test rooms. Each datum point represents the weekly average, using the results from daily ventilation exchange calculations (Table 2). These records were obtained with 9 calves in each test room, three each of Jersey, Brown Swiss, and Holstein. Stable moisture may be read on either the heat or the water scale. A value of 1044 Btu/lb. of moisture was used to equate moisture and heat.

For further analysis the dissipation rates were divided by the body weight of the calves (expressed in 1000-pound units) that were represented by the rate. The results were correlated with calf age as shown in Figure 2. On a per unit body weight basis, the rates apparently increased with increasing age within a 6 to 12-week of age period but otherwise decreased with increasing age. Between 12 and 25 weeks of age the rate of decrease was large. Thereafter, the rate of decrease was much less.

It was of interest to note that about the same heat dissipation occurred at 50° as at 80° F whereas previous work with stanchioned cows[7] resulted in slightly greater values at 50° than at 80° F. This comparison also revealed that at 12 weeks of age the 6500 Btu/hr./1000 lb. of body weight value for the calves was about double that expected with cows but that after 55 weeks of age the Btu/hr./1000 lb. of body weight values of the calves were very nearly the same as those of the cows. The stable heat dissipation values for cows were 3400 at 50° F and 3000 at 80° F, compared with a value of about 3300 for calves at these two temperatures.

Contrary to the results with stable heat, the stable moisture dissipation of the calves was nearly twice as great at 80° as at 50° F. This was in agreement with previous results with cows.[7] Again comparing the dairy calf results with previous tests with cows at either 50° or 80° F, the stable moisture dissipation per unit body weight of the calves at 12 weeks of age was nearly twice as great as that of the cows but thereafter decreased until at 45 weeks the calf moisture dissipation rates tended to become constant at values approximating those for cows. Comparisons of stable moisture dissipation rates in pounds of water/hr./1000 lb. of body weight were as follows: For calves after 45 weeks of age, 2.1 at 80° F and 1.3 at 50° F; and for cows 1.8 at 80° F and 1.0 at 50° F. It was expected that penned calves would have higher stable moisture dissipation rates per unit body weight than stanchioned cows due to the probability of a greater wet litter area for calves. Evidently, this is not a major point of difference.

A comparison of the dairy calf stable heat and moisture dissipation rates with those from previous beef calf tests[1] was complicated by extra heat and moisture dissipation that was associated with weekly cleaning during the first 24 weeks of the beef calf experiment. However, the pattern of change with age was the same for both dairy and beef calves. At 80° F, the stable heat dissipation was also the same for both types of calves between the ages of 25 and 35 weeks. Thereafter, (and after 25 weeks of age at 50° F) the dairy calf heat dissipation started becoming the greater until at 55 weeks of age it was about 700 Btu/hr./1000 lb. of body weight greater for the dairy than for the beef calves. Excluding the first 25 weeks of age (when the beef calf pens were cleaned weekly), stable moisture dissipation was generally 0.1 to 0.3 lb. of water/hr./1000 lb. of body weight greater for the dairy than for the beef calves.

The ratio of latent heat (stable moisture dissipation) to total heat (stable heat dissipation) was also similar to those obtained with beef calves[1] and cows.[7] At 50° F the dairy calf ratio was 0.37, irrespective of age. At 80° F the ratio was about 0.42 during the first 8 weeks but thereafter averaged 0.64. For comparison: The beef calf ratios were given as 0.35 to 0.39 at 50° F and 0.67 to 0.71 at 80° F; and the cow ratios were about 0.32 at 50° F and 0.64 at 80° F.

Stable Heat Dissipation and Animal Heat Production

Animal heat production[2] was the major source of heat in the stable heat exchange. From 5 to 15 weeks the ratio of animal heat production to stable heat dissipation was 0.77 at 50° F and 0.71 at 80° F. At 15 weeks the ratios for the respetcive temperature groups sharply increased and remained practically constant throughout the remainder of the tests. The ratios over this 15 to 53-weeks of age period averaged 0.87 at 50° F and 0.93 at 80° F.

To adjust stable heat dissipation (which included 3 breeds) to a particular breed, a comparison of the average animal heat production[2] of each breed with the average for the three breeds was used. Stable heat dissipation on a unit body weight basis was greater for the Jersey than for the Brown Swiss and Holstein calves. After 15 weeks of age the relation of each breed to the average of the three breeds was nearly constant for each temperature. For example: At 50° F, the Jersey values were about 9 percent above, the Holstein 5 percent below, and the Brown Swiss 4 percent below the average for the three breeds; and, at 80° F, the Jersey values were 9 percent above, the Holstein 3 percent below, and the Brown Swiss 6 percent below the average for the three breeds. The relations prior to the 15-week period were not constant but were roughly linear to age with the greatest separation occurring during the first week and thereafter reducing to the relations shown above for the 15 to 53 weeks of age period. During the fifth week of age the relations were: At 50° F—Jersey values 30 percent above, Holstein 11 percent below, and Brown Swiss 19 percent below the average of the three breeds; at 80° F—Jersey values 17 percent above, Holstein 7 percent below, and Brown Swiss 10 percent below the average of the three breeds.

Stable Moisture Dissipation and Animal Vaporization

Measurements of animal vaporization rate from companion studies[3] provided a means of dividing stable moisture dissipation into a direct and an indirect source with respect to the animal. The primary indirect source was the bedded area as the moisture vaporized from the feed and drinking cups was insignificant. The direct source was animal vaporization. For the entire 11.5-month period the ratio of animal vaporization to stable moisture dissipation averaged 0.55 at 50° F and 0.74 at 80° F. The ratios within a temperature group varied with the age of calves but without a definite pattern. The averages of the ratios within consecutive 12-week periods, beginning at 5 weeks of age, were: 0.55, 0.52, 0.55, and 0.58 at 50° F; and 0.70, 0.68, 0.71, and 0.85 at 80° F. There was marked variation among the animal vaporization data during the last 12 weeks at 80° F. At either temperature, the moisture vaporized from the bedded area was evidently an important factor in stable moisture dissipation.

The direct source, animal vaporization, remains the major source of stable vapor and may be used to show the relative role of each breed in stable moisture dissipation. A comparison of the average animal vaporization per unit body weight of a breed with that of the three breeds showed only small difference among breeds. For the 11.5 month test period the comparison showed that: (1) At 50° F, the Holsteins averaged 6 percent above the Jerseys and the Brown Swiss 3 percent below the average for the three breeds; and (2) at 80° F, each breed averaged within 1 percent of the average for the three breeds. However, variation among the data, from which the averages were obtained, was too great to make the individual breed animal vaporization rates useful in predicting stable moisture dissipation rates of each breed.

Predicted Stable Heat and Moisture Dissipation for Three Breeds of Dairy Calves

The foregoing paragraph indicated that breed animal vaporization rates would be of very limited value for predicting the stable moisture dissipation of a breed. However, the animal heat production of a breed proved useful in ad-

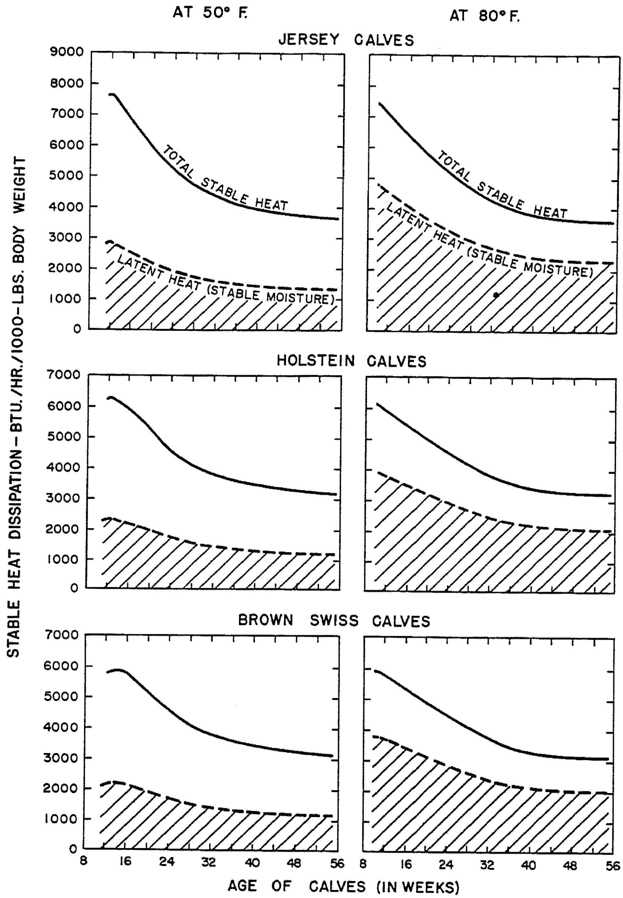

Figure 3—Predicted stable total heat and stable latent heat (stable moisture) dissipation at 50° and 80° F for three breeds of dairy calves and with pens cleaned daily. Total stable heat curves are from test room (3 breeds) ventilation exchange measurements—scaled upward or downward according to breed differences in animal heat production.[2] The ratios of latent to total stable heat (from room ventilation exchange measurements) were applied to the predicted total stable heat curves to obtain the predicted stable moisture curves.

justing the stable heat dissipation data of Figure 2. Figure 3 shows the results of this adjustment for Jersey, Holstein, and Brown Swiss breeds of dairy calves. The latent heat curves of Figure 3 were obtained by applying appropriate latent heat ratios (0.37 for 50° F and 0.64 for 80° F) to the predicted stable heat dissipation curves of each breed. The ratios were those obtained from Figure 2 by dividing the stable heat by the stable moisture dissipation.

No prediction values are given for a period below 10 weeks of age. The dissipation rates, when on a per unit body weight basis, were erratic and it is suggested that predictions for this early period of growth be on a per calf base (Table 2). Thus, from 5 to 10 weeks of age, about 700 Btu/hr./calf might be predicted for stable heat dissipation (with daily cleaning). The laboratory tests showed extreme day-to-day variation with values ranging from 500 to 900 Btu/ hr./calf. Latent heat values were likewise extremely variable, ranging from about 100 to about 500 Btu/hr./calf. At 50° F, 250 would seem to be an appropriate latent heat prediction value during this 5 to 10-weeks of age period. At 80° F, predicted latent heat would increase from 250, at 5 weeks of age, to about 500 Btu/hr./calf at 10 weeks of age.

Litter Production and Bedding Requirements

The weights of the litter (manure) removed and the weights of the bedding materials added (straw, wood shavings, and pulverized limestone) were recorded daily. Since management was similar to that on private farms, it was assumed that these data could be used to estimate litter production and bedding requirements for penned dairy calves. Figure 4 is a summary of the records obtained.

The litter production at 50° F increased nearly linearly from slightly less than 100 lb./week/calf at 5 weeks of age to about 450 lb./week/calf at 38 weeks of age and thereafter through 53 weeks of age remained constant. At 80° F the same results were noted except that litter production increased more rapidly, attaining 550 lb./week/calf at 36 weeks of age. These results compare favorably with previous studies using beef calves.[1] Litter production of the dairy calves was within 50 lb. of that for the beef calves at all ages and both temperatures.

The pattern of change in bedding requirements fas the same as for litter production. At 50° F, the bedding requirement increased from about 30 lb./ week/calf at 5 weeks of age to about 120 lb./week/calf at 37 weeks of age and thereafter remained constant through 53 weeks of age. At 80° F, the same results were noted except that the requirement increased more rapidly up to about 150 lb./week/calf at 38 weeks of age.

Aside from general information for planning farm operations, the most significant result is the greater (up to 25 percent greater) litter production and bedding requirement at 80° than at 50° F. Increased water consumption at 80° F was considered the major contributing factor for this difference.

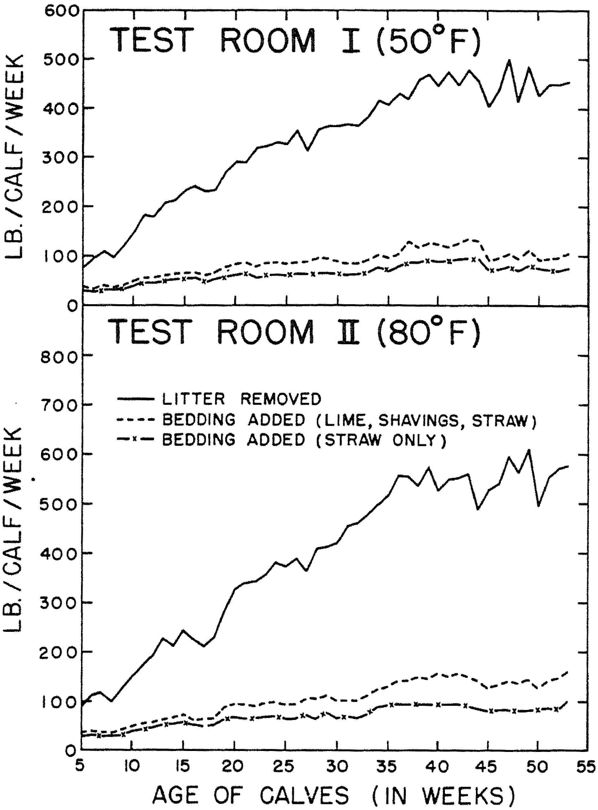

Figure 4—Litter production and bedding requirements for dairy calves of various ages. The data represent weekly averages of daily measurements within the Psychroenergetic Laboratory during the 50° and 80° F dairy calf growth tests. Wet litter was removed daily and the pens thoroughly cleaned weekly.

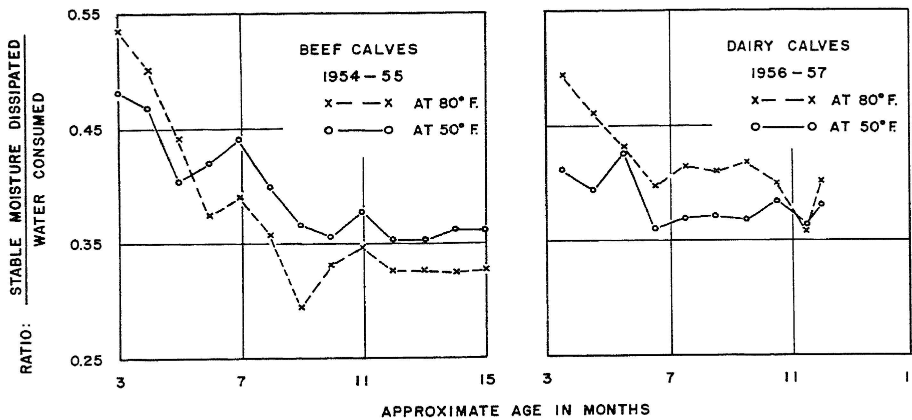

Figure 5—The change in the ratio, stable moisture dissipation divided by water consumption,[9, 10] with advancing calf age. Monthly averages from the beef and dairy calf studies were used. The calf pens were cleaned weekly until the beef calves were 5 months of age. Thereafter, as during the entire test for the dairy calves, the pens were cleaned daily.

Relation of Stable Moisture Dissipation and Water Consumption

Previous studies with lactating cattle[8] have established a correlation between stable moisture dissipation and animal water consumption. The ratio of one to the other increased with increasing temperature but the scatter of data was too great to make this analysis of practical use in predicting stable moisture dissipation. Figure 5 shows results of the calculation of these ratios for the dairy calf experiment and for the previous year's beef calf experiment. With dairy calves, the ratios were greater at 80° than at 50° F but the beef calf ratios were less at 80° than at 50° F except for the first 5 months of age when the beef calf pen were cleaned only once a week. Evidently with calves in pens, as these animals were, water consumption would not be satisfactory for predicting stable moisture dissipation at various temperatures.

TABLE 2-STABLE HEAT (BTU/HR./CALF) AND MOISTURE (LBS./HR./CALF) DISSIPATION RATES WITH CORRESPONDING AIR AND DEW POINT TEMPERATURES (^{0} F)

	Test Room I (50°F)				Test Room II (80°F)			
Date	Heat	Moisture	Temp.	Dew Point	Heat	Moisture	Temp.	Dew Point
1956								
Oct. 8	---	---	49.4	---	---	---	79.8	41
9	---	---	49.3	---	---	---	78.8	39
10	---	---	50.3	---	696	.333	79.6	50
11	---	---	51.7	---	716	.347	78.2	56
12	---	---	49.2	---	809	.341	79.6	63
13	---	---	49.2	---	652	.283	80.4	58
14	---	---	49.2	---	668	.232	80.6	60
15	825	.299	49.9	42	768	.225	77.4	66
16	891	.417	50.5	42	758	.354	79.2	62
17	839	.379	49.2	39	528	.182	80.0	60
18	649	.252	50.2	39	588	.197	80.6	60
19	541	.188	50.4	39	---	---	80.6	61
20	558	.194	50.5	40	584	.243	80.4	61
21	---	---	50.6	---	627	.280	80.4	60
22	---	---	50.3	---	616	.228	80.4	62
23	---	---	50.0	---	602	.263	80.4	63
24	---	---	50.0	---	691	.346	80.2	59
25	---	---	50.2	---	---	---	80.2	---
26	---	---	50.5	---	629	.205	79.8	63
27	---	---	50.6	---	602	.185	80.0	66
28	---	---	50.6	---	512	.130	80.4	67
29	688	.197	50.7	41	658	.336	80.2	60
30	---	---	50.5	---	---	---	80.6	---
31	---	---	50.6	---	---	---	80.4	---
Nov. 1	---	---	49.3	---	---	---	80.4	---
2	---	---	49.1	---	---	---	80.4	---
3	---	---	49.2	---	---	---	80.4	---
4	---	---	50.5	---	---	---	80.6	---
5	---	---	50.6	---	---	---	80.4	---
6	695	.181	49.0	40	921	.576	80.0	58
7	836	.282	48.4	38	857	.476	79.7	60
8	834	.318	50.2	41	807	.439	80.2	60
9	662	.230	50.4	40	874	.481	80.8	62
10	764	.226	50.3	40	894	.475	80.8	62
11	769	.260	50.4	40	851	.456	80.8	62
12	788	.234	50.2	40	849	.436	79.8	60
13	807	.235	50.4	40	865	.438	80.6	63
14	806	.243	50.3	40	848	.485	80.6	63
15	851	.259	50.1	40	890	.481	79.6	61
16	816	.226	50.3	40	---	---	79.6	61
17	916	.274	50.5	40	874	.512	80.2	61
18	833	.305	50.7	40	942	.549	80.6	62
19	969	.275	50.4	39	957	.513	80.8	61
20	997	.286	50.2	40	943	.509	80.0	64
21	976	.268	50.1	40	975	.528	78.6	63
22	915	.254	50.2	39	948	.537	79.4	64
23	952	.269	49.9	38	938	.528	79.2	64
24	1023	.292	50.0	39	996	.585	80.6	63
25	1007	.287	50.3	39	977	.554	81.0	65

TABLE 2-CONTINUED

Date	Test Room I (50°F)				Test Room II (80°F)			
	Heat	Moisture	Temp.	Dew Point	Heat	Moisture	Temp.	Dew Point
26	1088	.329	49.9	39	957	.587	79.4	54
27	1103	.344	50.0	38	855	.464	80.4	61
28	1114	.336	48.7	36	957	.539	80.0	59
29	1082	.333	49.1	37	976	.525	80.0	64
30	1092	.325	49.7	37	---	---	80.8	63
Dec. 1	1167	.383	49.7	38	942	.562	80.2	64
2	1119	.402	51.2	40	964	.594	81.0	63
3	1130	.373	49.8	38	984	.585	80.2	61
4	1166	.372	49.4	38	933	.607	80.6	63
5	1153	.387	49.2	38	1055	.610	80.2	63
6	1125	.392	48.7	38	967	.578	80.0	61
7	---	---	49.4	39	969	.573	79.8	65
8	1352	.594	49.1	39	1023	.622	80.2	67
9	1382	.583	49.5	39	1042	.641	80.4	66
10	1320	.521	49.7	38	955	.602	79.8	62
11	1262	.470	49.1	38	1174	.640	79.6	61
12	1209	.414	49.1	38	1020	.616	79.6	62
13	1163	.403	49.2	39	1023	.640	79.7	61
14	1199	.409	49.4	39	---	---	80.4	63
15	1283	.457	49.7	40	1359	.943	80.6	63
16	1299	.471	50.1	40	1516	1.078	80.6	65
17	1271	.444	49.7	39	1271	.781	80.2	63
18	1312	.429	49.8	39	1134	.709	80.0	63
19	1303	.435	49.6	39	1123	.704	79.7	62
20	1458	.486	49.6	39	1261	.798	79.6	62
21	1018	.383	50.2	41	1363	.928	79.8	63
22	1291	.454	50.8	41	1184	.823	81.2	63
23	1295	.438	49.2	39	1219	.731	79.7	61
24	1336	.452	48.4	38	1168	.710	79.6	57
25	1413	.484	49.3	39	1241	.739	79.4	61
26	1377	.471	49.5	39	1258	.810	80.4	63
27	1232	.438	49.4	38	1113	.671	79.4	61
28	1275	.411	49.4	37	1087	.642	79.2	60
29	1269	.360	49.1	36	1116	.630	79.4	60
30	1268	.386	49.2	36	1120	.650	80.0	61
31	1393	.419	49.5	37	1205	.673	79.8	60
1957								
Jan. 1	1412	.463	49.0	38	1167	.680	79.8	61
2	1365	.424	49.3	38	1156	.727	80.6	63
3	1418	.418	49.1	38	1176	.665	79.4	60
4	---	---	49.2	37	1242	.686	79.6	63
5	---	---	49.3	39	1209	.733	80.2	62
6	---	---	50.3	40	1185	.707	80.2	61
7	---	---	49.8	40	1256	.753	80.2	61
8	1436	.444	49.0	38	1167	.669	79.2	60
9	1434	.422	48.5	37	1214	.676	79.6	61
10	1454	.494	48.5	38	1179	.646	80.0	65
11	1495	.519	49.3	38	---	---	79.7	52
12	1482	.486	49.4	37	1313	.927	80.2	48
13	1493	.497	48.7	36	1299	.865	79.7	52
14	1532	.499	49.5	37	1362	.786	79.9	61
15	1567	.533	49.3	37	1378	.819	79.8	61

TABLE 2-CONTINUED

	Test Room I (50°F)				Test Room II (80°F)			
Date	Heat	Moisture	Temp.	Dew Point	Heat	Moisture	Temp.	Dew Point
16	1515	.550	49.1	37	1351	.807	79.6	63
17	1546	.581	49.0	38	1417	.838	79.8	63
18	---	---	50.4	39	1405	.863	80.2	63
19	1548	.584	50.2	40	1342	.876	80.1	61
20	1574	.627	51.0	42	1394	.873	80.8	64
21	1585	.567	49.5	39	1581	.897	79.6	64
22	1595	.563	49.5	37	1350	.825	81.1	65
23	1591	.561	50.1	36	1378	.835	79.7	63
24	1574	.529	48.4	37	1430	.909	79.4	57
25	1527	.480	48.7	37	---	---	79.7	61
26	1642	.571	49.0	38	1496	.931	80.4	62
27	1590	.515	49.1	37	1455	.911	80.6	62
28	1490	.503	49.0	37	1498	.914	80.4	63
29	1439	.460	49.0	37	1434	.892	79.8	61
30	1469	.453	49.4	38	---	---	80.6	---
31	1546	.490	49.1	38	1286	.716	80.2	63
Feb. 1	---	---	49.3	38	1428	0.857	79.8	59
2	1594	.514	50.4	41	1398	.865	81.0	60
3	1657	.540	50.3	40	1379	.824	79.8	59
4	1687	.565	49.1	38	1437	.846	80.2	61
5	1772	.598	50.0	39	1434	.818	80.0	63
6	1584	.545	49.9	39	1472	.845	80.6	64
7	1641	.531	49.6	38	1368	.828	79.7	60
8	1657	.549	49.8	39	---	---	80.8	62
9	1731	.595	48.5	39	1480	.938	78.2	56
10	1650	.539	49.6	40	1470	.946	79.6	53
11	1684	.551	50.0	39	1453	.905	80.4	54
12	1808	.647	49.5	39	1509	.909	80.8	61
13	1635	.580	49.3	38	1639	.993	82.0	59
14	1621	.566	49.2	37	1630	.910	80.0	57
15	---	---	49.2	37	1667	.924	79.8	60
16	1548	.552	49.7	37	1512	.878	80.6	60
17	1618	.572	49.2	38	1629	.944	81.5	63
18	1603	.526	49.1	37	1537	.897	80.4	58
19	1688	.576	49.1	38	1535	.897	80.6	60
20	1726	.532	49.7	37	1510	.872	80.2	63
21	1630	.511	49.2	38	1542	.943	80.8	61
22	1636	.517	49.6	38	---	---	80.3	63
23	1620	.520	50.3	40	1529	.945	81.5	64
24	1615	.522	50.3	40	1477	.866	81.1	66
25	1747	.543	49.9	39	1630	.865	79.3	65
26	1676	.551	49.4	39	1602	.930	79.5	62
27	1661	.549	49.3	39	1591	.889	78.6	61
28	1658	.541	49.4	39	1553	.864	78.2	60
Mar. 1	---	---	49.3	39	1486	.892	78.8	58
2	1663	.524	49.0	38	1597	.849	77.9	57
3	---	.598	50.2	39	---	.868	78.4	57
4	---	.550	49.4	37	---	.791	78.2	60
5	---	.594	49.3	39	---	.815	79.7	61
6	---	.555	49.2	38	---	.957	79.8	62
7	---	---	49.4	---	---	---	80.0	---
8	1453	.538	56.8	48	---	---	80.6	62

TABLE 2-CONTINUED

	Test Room I (50°F)				Test Room II (80°F)			
Date	Heat	Moisture	Temp.	Dew Point	Heat	Moisture	Temp.	Dew Point
9	1692	.623	50.6	39	1390	.862	80.0	61
10	1692	.561	49.8	38	1512	.944	79.8	61
11	1719	.605	49.5	39	1609	1.007	79.8	61
12	1696	.570	49.2	38	1504	.909	79.8	60
13	1595	.502	49.2	37	1419	.805	80.2	60
14	1505	.521	49.4	38	1291	.699	80.6	60
15	---	---	49.1	36	1364	.784	80.7	60
16	1390	.408	49.4	37	1410	.826	80.0	60
17	1518	.525	49.9	39	1381	.860	80.4	61
18	1594	.536	49.7	39	---	---	80.6	---
19	---	---	49.2	---	---	---	80.2	---
20	1665	.572	49.4	39	---	---	80.6	---
21	1660	.572	49.7	40	---	---	80.6	---
22	---	---	49.5	---	---	---	80.5	---
23	---	---	50.3	---	---	---	79.2	---
24	---	---	50.2	---	---	---	79.4	---
25	1783	.624	49.6	39	1456	.837	80.6	62
26	1692	.623	49.5	39	1573	.982	79.7	61
27	1705	.609	49.2	38	1557	.955	80.3	61
28	1662	.635	49.7	39	1558	1.005	80.2	62
29	1855	.653	49.6	38	---	---	79.8	---
30	1798	.708	49.7	38	---	---	79.4	---
31	1614	.602	50.3	38	---	---	80.0	---
Apr.1	1750	.637	50.3	39	---	---	79.8	---
2	1604	.532	49.5	38	1545	.972	80.3	62
3	1682	.557	49.4	38	1649	.964	80.3	62
4	1655	.593	49.2	39	1621	.958	80.1	62
5	---	---	49.1	38	1658	.932	79.6	60
6	1737	.638	49.3	39	1616	.978	79.6	61
7	1787	.691	49.7	40	1590	.965	80.0	61
8	1754	.636	49.2	38	1589	.972	79.9	61
9	1753	.632	49.2	38	1612	1.006	79.7	61
10	1757	.577	49.4	36	1711	1.015	79.4	61
11	1731	.611	49.3	37	1696	1.055	79.8	61
12	1752	.586	49.5	37	---	---	79.9	60
13	---	---	49.2	---	---	---	79.7	---
14	---	---	49.3	---	---	---	80.4	---
15	1824	.688	51.0	41	1677	1.025	79.7	61
16	1728	.615	49.7	39	1732	1.048	79.6	61
17	1811	.637	49.8	39	1606	1.071	79.4	61
18	1711	.617	49.6	40	1658	1.060	79.2	61
19	1782	.652	49.5	39	---	---	79.4	61
20	1767	.629	49.5	39	1669	1.019	79.2	61
21	1777	.644	49.5	39	1715	1.056	79.5	62
22	1755	.643	50.2	40	1801	1.081	79.7	63
23	1791	.658	49.8	39	1794	1.085	79.5	63
24	1826	.633	49.4	37	1697	1.058	79.0	63
25	1827	.666	49.3	38	1763	1.098	79.7	64
26	---	---	49.7	39	1770	1.093	79.8	64
27	---	---	48.9	38	1857	1.130	79.4	63
28	1799	.669	48.7	38	1901	1.185	79.4	63

TABLE 2-CONTINUED

Date	Test Room I (50°F) Heat	Moisture	Temp.	Dew Point	Test Room II (80°F) Heat	Moisture	Temp.	Dew Point
29	1888	.690	49.3	38	1757	1.117	81.2	63
30	1802	.684	49.2	38	1794	1.165	80.9	63
May 1	1827	.705	49.5	38	1910	1.276	80.8	63
2	1943	.713	49.3	38	1810	1.168	80.6	63
3	1792	.654	49.1	37	---	---	80.5	61
4	1876	.722	48.8	37	1726	1.128	80.6	61
5	1830	.622	48.5	35	1709	1.079	80.6	61
6	1889	.710	49.6	36	1832	1.188	80.6	61
7	1999	.782	49.0	38	1665	1.068	80.7	61
8	1687	.599	49.0	37	1644	1.101	80.1	61
9	1775	.680	49.7	39	1732	1.160	80.0	63
10	---	---	50.9	41	1723	1.093	79.7	62
11	1736	.692	50.6	40	1718	1.103	79.7	61
12	1828	.704	50.4	40	1835	1.128	79.5	62
13	1907	.711	49.5	39	1849	1.178	79.9	63
14	1785	.654	49.2	38	1782	1.151	80.1	63
15	1820	.695	49.5	39	1806	1.142	80.0	62
16	1877	.712	49.7	39	1794	1.111	80.6	62
17	1867	.705	49.8	39	---	---	80.0	63
18	1978	.802	50.2	40	1880	1.117	80.4	62
19	1914	.738	49.9	39	1918	1.136	80.2	62
20	1940	.752	51.1	41	1829	1.127	81.2	63
21	1942	.750	49.6	39	1880	1.145	80.3	62
22	1940	.713	49.3	39	1951	1.219	81.4	63
23	2046	.746	49.8	40	1830	1.189	81.2	62
24	---	---	49.6	40	1814	1.115	81.6	62
25	1851	.698	49.7	40	1974	1.172	81.3	63
26	1880	.703	49.8	41	1819	1.020	79.0	62
27	1954	.735	49.1	39	1678	1.064	81.5	61
28	1941	.695	49.4	38	1757	1.080	80.9	62
29	1956	.710	49.7	39	1821	1.188	80.8	63
30	1942	.721	50.3	40	1779	1.052	79.1	62
31	1971	.743	50.9	41	---	---	80.7	63
June 1	1968	.721	49.5	40	1769	1.054	79.6	62
2	1766	.653	49.4	39	1835	1.140	80.6	62
3	1876	.677	49.7	40	1855	1.168	80.8	62
4	1856	.705	50.2	40	1682	1.056	81.0	63
5	1938	.671	49.3	38	1701	1.093	80.5	63
6	1913	.690	49.6	40	1795	1.162	80.2	63
7	---	---	49.2	38	1771	1.142	80.6	63
8	1720	.561	49.4	38	1762	1.112	79.7	63
9	1814	.564	49.5	38	1735	1.085	79.6	63
10	1910	.674	50.4	40	1796	1.146	80.3	64
11	2050	.729	49.5	40	1856	1.088	79.5	65
12	2150	.822	49.3	40	1754	1.034	80.6	64
13	1984	.962	50.5	43	1837	1.169	80.6	64
14	2157	.907	49.0	40	---	---	80.1	65
15	2204	.953	49.3	41	1796	1.099	79.7	64
16	2303	1.004	49.1	42	1765	1.105	80.0	64
17	1995	.770	49.7	40	1885	1.171	79.4	63
18	2100	.809	49.2	39	1837	1.172	79.8	62

TABLE 2-CONTINUED

	Test Room I (50°F)				Test Room II (80°F)			
Date	Heat	Moisture	Temp.	Dew Point	Heat	Moisture	Temp.	Dew Point
19	2048	.741	49.0	39	1787	1.133	80.1	61
20	2072	.760	49.5	39	1812	1.162	80.0	62
21	---	---	50.0	40	1718	1.106	80.5	63
22	1749	.739	50.0	40	1731	1.101	79.8	62
23	1977	.745	48.9	39	1725	1.102	80.2	61
24	2001	.732	49.1	39	1828	1.146	81.1	61
25	1953	.698	49.1	38	1787	1.144	81.1	62
26	1965	.720	49.8	39	1856	1.182	81.0	63
27	2084	.743	49.9	40	1844	1.180	81.1	63
28	2006	.779	49.6	40	---	---	80.6	62
29	1935	.698	49.0	39	1643	1.047	80.1	62
30	1946	.699	49.4	39	1691	1.105	80.4	63
July 1	2133	.781	49.2	39	1820	1.212	80.6	63
2	1994	.701	49.1	39	1846	1.201	80.7	63
3	2041	.752	49.9	39	1706	1.085	81.5	64
4	2031	.744	49.6	39	1916	1.211	79.7	61
5	---	---	49.5	38	1903	1.215	80.4	60
6	1988	.729	49.2	38	1760	1.112	80.1	60
7	2056	.758	50.2	39	1836	1.227	80.8	62
8	2082	.777	49.8	39	1825	1.155	80.5	61
9	2065	.812	49.4	40	1960	1.264	80.6	62
10	1989	.737	49.3	39	1851	1.181	80.9	61
11	2030	.765	50.0	40	1811	1.181	80.8	62
12	2046	.778	50.3	40	---	---	80.3	62
13	2021	.760	49.3	39	1795	1.126	79.9	62
14	1998	.723	49.6	39	1835	1.125	79.6	62
15	1985	.701	49.7	39	1784	1.135	80.3	62
16	1978	.739	49.4	39	1937	1.236	79.8	62
17	2076	.802	49.9	39	1805	1.165	81.0	63
18	2094	.792	49.4	39	1892	1.208	80.6	62
19	---	---	49.7	39	1876	1.241	80.3	62
20	2159	.840	49.6	40	1746	1.118	80.1	61
21	1992	.764	49.4	39	1781	1.149	80.4	61
22	1945	.729	49.7	39	1816	1.119	80.7	62
23	2018	.721	49.5	38	1913	1.273	80.2	61
24	2050	.748	49.3	39	1974	1.276	79.8	61
25	2057	.747	49.2	38	1754	1.143	80.5	60
26	2037	.729	49.5	39	---	---	80.2	62
27	2220	.840	50.3	40	---	---	80.4	62
28	2139	.804	50.6	41	---	---	81.0	64
29	2175	.812	50.0	39	1869	1.164	80.5	63
30	2311	.851	49.9	39	2110	1.259	81.2	63
31	2128	.771	49.5	39	2102	1.193	81.0	63
Aug. 1	2114	.771	49.4	39	2068	1.185	80.9	64
2	---	---	49.8	39	2255	1.323	80.6	65
3	2056	.746	49.0	38	2071	1.223	80.4	63
4	2183	.755	48.6	38	2059	1.319	81.2	62
5	1921	.732	49.2	38	2242	1.320	81.1	62
6	2132	.780	49.6	39	2029	1.153	80.7	61
7	1982	.704	49.4	39	2043	1.182	81.2	62
8	2064	.733	49.7	39	2184	1.301	81.0	63

TABLE 2-CONTINUED

Date	Test Room I (50°F)				Test Room II (80°F)			
	Heat	Moisture	Temp.	Dew Point	Heat	Moisture	Temp.	Dew Point
9	2068	.759	50.6	41	---	---	80.6	64
10	2196	.800	49.3	39	2101	1.188	80.4	63
11	2148	.813	50.8	41	2132	1.187	80.8	64
12	2244	.834	49.7	39	2187	1.306	81.4	64
13	2157	.781	49.8	39	2080	1.236	81.2	63
14	2099	.722	49.5	39	2168	1.372	81.3	65
15	1999	.691	49.3	40	2153	1.254	80.6	64
16	---	---	49.5	41	2217	1.304	80.9	64
17	1993	.694	49.3	41	1979	1.142	80.4	62
18	2135	.836	49.3	41	---	---	80.0	62
19	2241	.821	49.3	41	2305	1.351	79.2	63
20	2263	.904	50.2	42	2165	1.251	79.8	62
21	2233	.940	50.9	42	2046	1.236	80.0	62
22	2375	.884	50.0	41	2119	1.328	80.0	62
23	2510	.943	49.7	41	---	---	79.8	63
24	---	---	49.4	---	---	---	79.7	---
25	---	---	49.5	---	---	---	80.4	---
26	2466	.915	49.9	40	2170	1.433	80.0	64
27	2335	.806	49.7	39	1999	1.255	79.6	64
28	---	---	49.6	36	---	---	79.6	63
29	2390	.928	49.5	41	2248	1.369	80.5	64
30	---	---	49.6	41	2249	1.379	80.3	65
31	2522	1.014	49.2	41	2390	1.466	80.2	66
Sept.1	2363	.908	49.4	41	2084	1.375	79.9	65
2	2456	.955	48.8	40	---	---	---	---
3	2401	.896	49.4	41	2035	1.296	79.6	62
4	2396	.902	50.1	42	1823	1.156	79.7	62
5	2393	.887	50.2	41	---	---	81.2	---
6	2506	.890	49.8	40	---	---	79.5	63
7	2615	.964	49.3	40	2018	1.307	79.7	62
8	2329	.821	49.6	39	2129	1.432	79.7	63
9	---	---	50.7	---	---	---	79.7	---
10	2254	.813	48.8	38	2048	1.367	80.0	64
11	2262	.863	50.5	40	2055	1.346	79.7	64
12	2243	.810	49.5	39	2276	1.457	79.6	65
13	---	---	49.1	39	2219	1.408	80.0	64
14	2187	.790	50.3	40	2206	1.334	80.6	65
15	2208	.806	49.4	39	2188	1.395	79.9	65

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