THE EFFICIENCY OF CHARCOAL COOLERS FOR HOLDING CREAM ON FARMS.

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INTRODUCTION.

For some considerable time charcoal coolers have been used for the holding of cream on dairy farms in the Wowan district, which is situated south-west of Rockhampton. Investigations were conducted during February and March, 1945, for the purpose of ascertaining the requirements in design and construction, the procedure needed for most efficient operation, and the possibility of extending the area of profitable use of such coolers. As a result of the investigations it has been possible (Few, 1945) to indicate to farmers the range of usefulness of charcoal coolers, details of their design and construction, and particulars regarding their use. The purpose of this paper is to present and discuss the data secured.

SCOPE OF THE INVESTIGATIONS.

The investigations were carried out in three series, dealing respectively with (1) the efficiency of cooling in a standard type of cooler; (2) the effect of a flue vent on the efficiency of cooling; and, (3) check tests on coolers in use on farms.

EFFICIENCY OF COOLING IN A STANDARD-TYPE COOLER.

The observations on cooling in a standard-type cooler were carried out over a 24-hour period in late February. The weather was fine, with the daytime temperatures normal and the night temperatures slightly below the average for late summer. The humidity during the daytime was above the average, because of a fall of two inches of rain two days previously, and consequently the degree of cooling possible under normal conditions of humidity would not be lower than that secured on the testing day.

Technique.

Immediately following the separation of the cream after the morning milking of the herd, a can of cream was placed in the cabinet of the test cooler, and it was held there for 24 hours. A control can of water was held during the same period in the dairy house in which the cream would normally be kept if no charcoal cooler were available. Water was used in the control can because there was insufficient cream for the purpose, but it is considered that the difference in behaviour between cream and water would not be large enough to vitiate the validity of the comparisons made.

Atmospheric shade temperature readings were made in the farmhouse, situated about 50 feet from the cooler, and in the dairy house located about 220 feet from the farmhouse. The thermometers used were checked to read to 1 deg. F. An hygrometer checked to within 1 per cent. was exposed in a shaded position at the farmhouse, and some readings of an hygrometer placed in the cool chamber were also secured. Relative humidity was determined by the use of modern Carrier psychrometric charts.

Discussion of Data.

The data obtained are recorded in Table 1 and are shown in graphical form in Figure 1.

Table 1.

DATA ON THE EFFICIENCY OF COOLING.

Time.	Atmospheric. Shade Temperature.	Atmospheric. Relative Humidity.	Atmospheric. Wet-bulb Temperature.	Dairy Shade Temperature. (Near Can.)	Cooler Cabinet Temperature.	Cream Temperature.	Temperature of Can in Dairy.	Cooler Cabinet Relative Humidity.
	°F.	Per cent.	°F.	°F.	°F.	°F.	°F.	Per cent.
9.00 a.m. ..	81	62	70·8	78	71	85	83	..
9.30 a.m. ..	83	59	71·6	80	71	84	82	..
10.00 a.m. ..	85	56	72·4	84	70	83	82	..
10.30 a.m. ..	86	54	73·0	86	70	82	82	..
11.00 a.m. ..	88	50	73·2	89	70	80	83	84
11.30 a.m. ..	88	48	72·4	91	70	80	83	86
12 noon	89	48	73·2	91	70	79	83	88
12.30 p.m. ..	90	47	73·5	91	73	79	84	..
1.00 p.m. ..	93	48	76·6	91	73	78	84	86
1.30 p.m. ..	92·5	45	75·0	92	73	78	85	88
2.00 p.m. ..	92·5	44	74·3	92	72	78	86	91
2.30 p.m. ..	92	44	74·0	94	72	78	86	90
3.00 p.m. ..	90	44	72·5	90	73	77	87	92
5.30 p.m. ..	89·5	43	71·7	90	70	75	84	96
8.00 p.m. ..	78	64	69·0	79	71	75	82	..
7.00 a.m. ..	70	90	68·0	74	70	74	72·5	80
9.00 a.m. ..	80	75	73·6	85	70	74	74	82

The temperature-time line A in Figure 1 shows the variation in the wet-bulb temperature over the 24-hour period; the highest value is 76.6 deg. F. at 1.00 p.m. and the lowest 68.0 deg. F. at 7.00 a.m. This line represents the maximum degree of cooling theoretically possible by the adiabatic evaporation of water from a wetted surface into the surrounding atmosphere.

The temperature-time line B shows the temperatures within the cabinet during the 24-hour period. When considered in relation to line A it may be regarded as the efficiency line for the cooler, as it shows the relationship between the actual temperature realized and the existing wet-bulb temperature. In examining the two lines, however, it must be realized that small temperature differences are not significant, due to personal errors in reading the instruments and to the fact that the thermometer error is ± 1 deg. F., and that there is also a possible error of 1 per cent. in humidity values. The temperature remained quite constant within the cabinet till 12.30 p.m., when it suddenly rose 3.0 deg. F. During this time the wet-bulb temperature had gradually risen for the most part until at 12.30 p.m. it was practically the same as the cooler temperature.

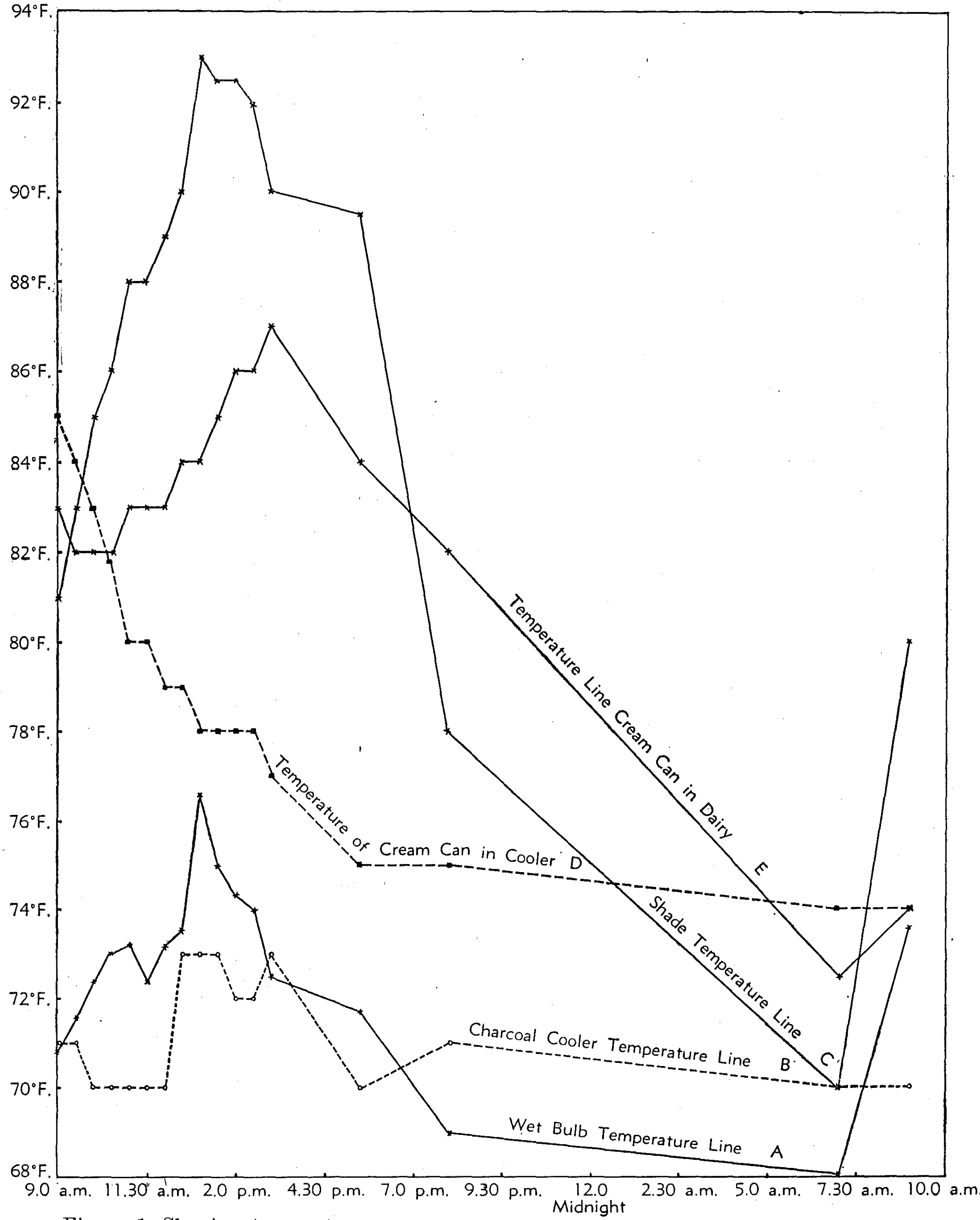

Figure 1. Showing temperature lines relevant to determination of efficiency of cooling.

The practice on the farm on which the work was conducted was to water the charcoal early in the morning and again at midday, and the second watering was given immediately aftr recording the noon readings. During the three hours from 9.00 a.m. to noon the charcoal was relatively dry; its insulating effect is apparent, as the cabinet maintained the wet-bulb temperature corresponding to atmospheric conditions existing at the time of the early morning watering. Between noon and 12.30 p.m., the wet-bulb temperature was slightly over 73.0 deg. F., and this accounts for the sudden rise of 3.0 deg. F. in the cooler temperature following the impairment of the insulating effect of the charcoal by the midday watering. The conclusion to be drawn from the data is that the charcoal has a definite insulating value, enabling the retention of a uniform temperature despite possible fluctuations in wet-bulb readings. As the lowest wet-bulb temperature usually occurs during the night or early in the morning, it is most practicable to water thoroughly at such times and to refrain from further watering during the day. This can be taken as a general rule applicable to the average charcoal cooler. In cases where poor design results in relatively inefficient insulation, the temperature may rise during the day, and in such cases watering may be necessary to reduce the cabinet to the existing wet-bulb temperature. The insulating value of a well-constructed cooler is also apparently realized very shortly after watering, as the temperature of 73.0 deg. F. in the cooler was maintained despite the rise in the wet-bulb reading to 76.6 deg. F. at 1.00 p.m. Between 5.30 p.m. and 8.00 p.m. the two lines cross on the graph, showing that, due to a similar insulating effect, the cabinet did not fall to the wet-bulb temperature. From the sanitary viewpoint it is likewise considered inadvisable to open up the cabinet or remove the cream from the cooler overnight. The atmospheric temperature during the night may fall below the evening cooler temperature, but the time lag in cooling a can of cream is so great that the value of removing the cream cans is more apparent than real. During the night of the tests the atmospheric temperature fell to 60.0 deg. F. (as determined by a minimum temperature thermometer), but the control can in the dairy house was down to only 72.5 deg. F. by 7.00 a.m. The atmospheric temperature of 60.0 deg. F. is not recorded on the shade temperature line, as no direct readings were made between 8.00 p.m. and 7.00 a.m.

The temperature-time line C shows the shade temperature at all times when readings were made, and when compared with line B indicates the degree of cooling obtained in the cooler. The maximum difference between atmospheric and cooler temperatures is 20.5 deg. F. at 2.00 p.m. Atmospheric shade temperature readings are of special significance only when taken in conjunction with relative humidities, the wet-bulb temperature being the important value. As a consideration of lines A and B has shown that, allowing for temperature lags due to insulation, wet-bulb temperatures are attained in charcoal coolers, it follows that charcoal coolers will be effective in any locality where the shade temperatures and relative humidity are such that the wet-bulb temperature does not exceed 70.0 deg. F.

The temperature-time line D shows the progressive cooling of the cream can placed in the cooler at 9.00 a.m. following separation after the morning milking. The most obvious and important feature is the slowness of cooling: at no time during the 24 hours was the cream temperature down to the desired level of 70.0 deg. F. After 11 hours in the cooler the cream temperature fell by 10.0 deg. F., with a further 5.0 deg. F. possible. Thereafter the rate of fall is insignificant, and this occurs when the temperature difference is no greater than 5.0 deg. F. The cream was stirred on each occasion before the temperature was taken, and this would be likely to increase the rate of cooling. Ordinarily the cream is stirred only once or twice during the day to allow any accumulation of gas to escape, and it can be assumed that under such conditions the cream remains at too high a temperature for a lengthy period after first being placed in the cooler cabinet. A suitable method for initial cream cooling is therefore required if cream quality is to be satisfactorily preserved in the cooler.

The temperature-time line E shows the lag in heating of the can stored in the dairy house and also the failure of the can to respond readily to a fall in atmospheric temperature. The line does, however, run roughly parallel with the shade temperature line, the lag in heating and in cooling being apparent. It will be noted that the point at which cooling commences is theoretically impossible, as at that time the shade temperature is actually 3·0 deg. F. above the temperature of the water in the can. This effect is due to evaporative cooling of the water in the can itself, the can being kept with the lid off, following the usual practice with cream on the farm. The relative cooling of the can in the cooler with respect to that in the dairy would thus be greater if cream had been used in the control can, while the early fall in temperature of the can of water follows the fall in the wet-bulb temperature, which becomes quite definite after 1·00 p.m.

A comparison of lines D and E shows clearly the degree of cooling that can be expected by the use of charcoal coolers even if the cream is not cooled before being placed in the cabinet. Over the second day of cream holding, when such is necessary, the value of the cooler would obviously be greater, as little variation in cream temperature would occur after the first 12 to 24 hours of storage.

EFFECT OF A FLUE VENT ON THE EFFICIENCY OF COOLING.

A test was carried out with the main object of determining if the flue vent as ordinarily fitted to charcoal coolers is necessary. The need for such a vent was a matter of doubt, as the cooler air within the chamber is denser than that normally outside, and as a result there would be no tendency for a movement of this air from the cabinet through the flue. It was also commonly suggested that the higher the flue the better the results. This is obviously fallacious, as, even with a furnace chimney, there is an economic height, and a loss in efficiency and draught results if the height is either increased or decreased. Thus, although the necessity for a flue in charcoal coolers was doubted, it was decided that if this deduction was incorrect it should be possible to determine an economic flue height to achieve the maximum degree of cooling in the cabinet.

Technique.

In view of the deductions from the experiment on the efficiency of cooling, the charcoal was watered early in the morning and was not further treated until after the last readings had been taken on the following morning. The cooler employed was the one used in the investigation just reported. The inside cabinet was substantially air-tight except for the two charcoal sides and the flue situated at the top of the back wall of the cabinet. The flue was of galvanized iron, with the joints soldered, and was 20 feet high and 4 inches in diameter. The flue was completely blocked at 7·00 a.m. to prevent any air circulation, and observations were made over the ensuing period of 26 hours.

Table 2.

DATA ON THE EFFECT OF A FLUE VENT ON THE EFFICIENCY OF COOLING.

Time.	Atmospheric.			Cooler Cabinet Temperature.	Cooler Cabinet Relative Humidity.
	Shade Temperature.	Relative Humidity.	Wet-bulb Temperature.		
	°F.	Per cent.	°F.	°F.	Per cent.
7.00 a.m.	70	90	68·0	70	80
9.00 a.m.	80	75	73·6	70	82
12 noon	91	50	75·7	73	over 100
2.00 p.m.	91	45	73·9	74	over 100
5.00 p.m.	86	48	70·8	73	..
9.00 a.m.	82·5	69	74·4	72	..

Discussion of Data.

The data given in Table 2 show that the cooler cabinet remained at the wet-bulb temperature, except that the insulating effect prevented a rise when the wet-bulb temperature rose, and a fall with the lowering of that reading. Although observations were not continued over a long period or under various atmospheric conditions, it appears reasonable to assume that a direct draught, if such could be produced by a flue, is actually unnecessary to enable cabinet temperatures to be reduced to the wet-bulb reading. A point considered to be of significance is the rise of 3·0 deg. F. in cabinet temperature shown at noon. A breakdown in the insulation value of the charcoal seems the most likely explanation, although this was not as complete as the breakdown in the previous experiment, when the charcoal was thoroughly wetted at the same time. The cabinet humidity was over 100 per cent. at noon, showing that the air within actually contained water droplets in suspension in addition to being saturated with water vapour in the gaseous form. The insulating value of a relatively dry medium would undoubtedly be impaired by the presence of air in such a condition, and this is considered to be the reason for the temperature rise. That it could not be due to lack of insulation of the charcoal itself is shown from the previous experiment, and also from the fact that despite the rise of 3·0 deg. F.

Table 3.

DATA OBTAINED FROM VARIOUS FARM CHARCOAL COOLERS.

Farm.	Date.	Time.	Atmospheric.			Cooler Cabinet.		Remarks.
			Shade Temperature.	Relative Humidity.	Wet-bulb Temperature.	Temperature.	Relative Humidity.	
			°F.	Per Cent.	°F.	°F.	Per Cent.	
W. J. Thomas, Walmul..	27–2–45	10.30 a.m.	89	65	78·9	79	74	Humidity higher than usual due to rain falling on previous day. Flue on cooler 2 in. diam.; 8 ft. high. Charcoal watered immediately after 10.30 a.m. readings. Cooler situated in shed with sloping roof.
		11.00 a.m.	89	61	77·8	78	92	
E. Harris, Wowan ..	27–2–45	12.15 p.m.	93	60	81·3	78	84	Charcoal watered during early part of morning. Flue on cooler 4 in. diam.; 20 ft. high. Cooler situated in open.
		2.30 p.m.	95	54	80·6	77	100	
V. Kearney, Deeford ..	1–3–45	2.55 p.m.	90	50	74·8	86	..	Cooler not used for some time. Flue on cooler 5 in. diam.; 13 ft. high. Cooler situated in shed. Charcoal watered immediately after 2.55 p.m. readings.
		3.10 p.m.	90	50	74·8	75	..	
L. M. Holbing, Deeford..	1–3–45	4.15 p.m.	87·5	54	74·3	72·5	..	Cooler situated in shed. Flue 3 in. diam; 15 ft. high.

in temperature the cabinet is still significantly below the existing wet-bulb temperature. The use of a vent does prevent the air in the cabinet from exceeding 100 per cent. relative humidity, as the figures from the previous experiment indicate. This is true despite the thorough watering of the charcoal at noon, after which time the humidity within the cooler cabinet rose gradually, but did not reach the 100 per cent. level. It can thus be considered sound practice to include a vent in the design of charcoal coolers, not for actual cooling purposes but to avoid excessive humidities likely to impair the insulation of the unit. From the point of view of hygiene it is likewise considered desirable. No flue pipe is really necessary, but the provision of a pipe two or three feet in length is desirable in order that water will not be poured into the cabinet through the vent during charcoal wetting operations.

CHECK TESTS ON FARM COOLERS.

Check tests were made on a number of charcoal coolers in the district, and the results confirm the validity of the general conclusions reached. The cooler used for the experiments so far described was included in these trials, and the data for all coolers are given in Table 3.

Allowing for the insulating effect of the charcoal surrounding the cooler cabinet, the temperatures in all cases are substantially the same as the wet-bulb readings. In the case of the one cooler not being used, the wet-bulb temperature was attained within 15 minutes after thoroughly wetting the charcoal, despite the fact that this involved a reduction of 11 deg. F. in temperature. The location of the coolers is unimportant, since those situated in the open showed the same degree of cooling as the shaded coolers.

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